DI Ivan Redi

Transdisciplinary design collaboration

Enabling Innovation in Architectural Practice through Transdisciplinary Collaboration over the Internet

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STATUTORY DECLARATION

I declare that I have authored this thesis independently, that I have not used other than the declared sources / resources, and that I have explicitly marked all material which has been quoted either literally or by content from the used sources.

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CONTENTS

Abstract

This dissertation contains information on new approaches to creative transdisciplinary design collaboration in complex, knowledge-based networked environments – most notably in architectural praxis, and the novel software instruments that make such approaches possible.

Recently, design procedures have changed because of a significant rise in the amount of data. Consequently, knowledge-based environments have manifested in social phenomena like the Open Source movement, the bottom-up approach, the transparency of multiple-authorship, user-driven innovations and the "form follows feedback" principle. This development has called for novel software instruments that enable designers to harness the vast complexity of collaborative networked settings without losing their own point of view.

The focus of the thesis is on one such instrument called A.N.D.I. – A New Digital Instrument for creative networked collaboration, which we introduced in 2004. This software tool enables improved management of emerging relational networks by enabling productive interaction within our practice, ORTLOS. These interactions include online expert communities from various domains ("connected intelligence") that are committed to a specific project goal despite the possibility of an uncertain outcome.

Here, we will use a practice-oriented approach rather than a theoretical one. The methods and strategies associated with trans-disciplinary collaboration are universally applicable. In other words, architecture is not the only discipline that will benefit from these methods.

Keywords: knowledge enabled design, user-driven innovation, transdisciplinary environment, collaborative platform, complexity in organizations, distributed collaboration, connected intelligence, performative design, action design.

Preface

Architects have been always generalists. Experts of overview, holders of bigger picture, operators of knowledge and information flows for the whole building process, mediators who are spanning the bridges between different areas and different disciplines. An architect is a designer, a technician, an artist, an environmentalist, a material specialist, a manager, a philosopher, a researcher, a writer, a graphic expert, a computer scientist, sometimes even a psychoanalyst, among other professions - all in one person. But this is of course a myth. However, after a long period of ever-increasing specialization in the last century, there is a need for more relational knowledge. The author in his professional practice has been exposed to inquiries about particular specializations of his architectural studio: housing, commercial, retail, office, institutional, infrastructural or industrial buildings. In some cases, entering certain architectural design competitions is only possible with the proof of already realized projects in that particular field.. So the question is how to solve a dilemma of being a new renaissance man of the 21st century, specialized in many areas, considering the building industry and beyond. One possible answer would be to team-up with other experts.

The work presented in this thesis is the result of a vision to conceive and create a collaboration environment on the Internet, where the project partners from different disciplines could creatively and simultaneously work together on innovative architectural and urbanistic tasks. The community that has grown around the A.N.D.I. project (A New Digital Instrument) since 2001, when A.N.D.I. was launched, and following project “City Upgrade”, includes professionals from various fields, such as architects, engineers, philosophers, media artists, writers, sociologists, urban planners, IT experts and programmers, composers, curators, photographers, politicians, and some others. While A.N.D.I. was launched as a funded research project with a clear research plan, many of its most important features were not planned but instead developed organically through the creative collaborative process. A.N.D.I. emerged through countless hours of workshops, discussions, sub-projects, and public presentations, all of which involved extensive collaboration. Intended as a tool to facilitate the collaborative process, where the project's goal is not initially clear, and creativity needs freedom to fully unfold, A.N.D.I. was in fact itself developed as part of just such a creative collaborative process.

Conducted in the spirit of practice-based research in architecture[1], which calls for a close integration of theoretical approaches in practical implementation by discovery of theory through the analysis of data and the experience gained thorough the research process, the journey of A.N.D.I.'s development exemplifies an open-ended design-driven research strategy. This PhD-thesis documents and reflects on this journey. It illustrates the ideas behind the A.N.D.I.'s development, on the one hand relating conceptual breakthroughs in the software design to the dynamics of the discussion, and on the other hand reflecting on the importance of certain features of A.N.D.I. on how their implementation took place within the Case Study "City Upgrade".

By giving this account of the development, the thesis is consistent with the tradition of research by design. It evaluates and discusses a research process both in terms of its successes and failures and thereby aims to contribute to the knowledge not only about the research objective, but also about the nature of design processes in general.

The thesis starts with an introduction chapter about critical discourse and identifying research problems, followed by a definition of terms and objectives. It describes how the main terms of the thesis are commonly defined and provides context for thinking about these terms in the architectural practice. The third part of the introduction chapter introduces the claim that the change of architectural practice leads to innovation in architectural design.

Based on this, in the second chapter the objectives, goals, research methodology and A.N.D.I. mission statement, the basis for the initial

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[1] Memorandum by RIBA Research Committee - http://www.architecture.com/Files/RIBAProfessionalServices/ResearchAndDevelopment/WhatisArchitecturalResearch.pdf

research application, are explained. Along with this description, the formation of the team is described: who was invited to do what and why. This chapter explains the requirements and preconditions needed to enable innovation in architectural practice from the transdisciplinary design collaboration point of view by introducing of several established theories. The questionnaire for the participants involved in the Case Study “City Upgrade” has been included, with questions about the working process and experience with A.N.D.I. system.

The third chapter describes the main components of A.N.D.I. in terms of their conceptual purpose and their development over the course of the project. This chapter starts with Infospace, which is conceptually the backbone of A.N.D.I. system. It describes the methodology of envisioned theories with subsequent implementations of concepts that address collaborative design environment. It describes the nature of the discussions we had based on A.N.D.I. system components and tools to support transdisciplinary design process. Using the terms introduced in the first chapter and by concrete implementation of User Interface, this chapter includes an analysis of the changes due to transdisciplinary processes, when collective intelligence can be said to have led to an improvement or when a new solution emerged.

The fourth chapter chronicles the “City Upgrade” case study. Starting with a synopsis of the A.N.D.I. system as it was implemented at the beginning of the project and how it was adapted during its course, the chapter also presents the main design results of the project and the collaborative process how they came about. The chapter also provides a quantitative overview of the processes, including how many people were involved and how much use they each made of the system. The behavioral patterns of participants within the system will be analyzed as an important insight considering the proof of concept. This report underlines the claim that the methods and strategies previously explained are of universal nature. The main advantages of the A.N.D.I. system are also highlighted.

The fifth chapter presents a summary of the project's experiences, results, and conclusions and interpretations. Specifically, we discuss which features and types of collaborative interactions were most successful or most innovative and what future work could build on these findings.

The project years, 2004-2008, which included research and development of project A.N.D.I., as well as the subsequent research project ,"City Upgrade," have been supported by: Stadt Graz Kultur / Stadt Graz Wirtschaft & Tourismus / Stadt Graz Wissenschaft & Forschung / Zukunftsfond Steiermark / Das Land Steiermark Kultur / steirischer herbst / bm:ukk .KUNST Republik Österreich / FORUM STADTPARK / MedienKunstLabor im Kunsthaus Graz / KulturKontaktAustria / Creative Industries Styria / Kammer der Architekten und Ingenieurkonsulenten für Steiermark und Kärnten.

1. Introduction

"Architecture as spatial design has to adapt to the new spatial understanding. The telematic media ultimately force a new dynamic concept of space onto architecture. This concept of space is characterized by immateriality and nonlocality." Peter Weibel

Much research in recent years has focused on design collaboration in architectural practice and education. It is generally accepted that the architect relays on other experts (consultants) from the building industry.

Given the importance of this relationship, a critical question in our current era of technological progress is how an application of computer technology can improve information, communication, creation and data exchange in architectural design processes. Although it has been suggested that knowledge from disciplines not directly associated with building industry influences architectural design on many levels (e.g. philosophy, sociology, art, politics, economy, etc.), there are unsolved questions as to how to implement this knowledge in creative ways and how to enable the emergence of innovation within such a collaborative environment. In the past, many metaphors from Computer Science have been introduced in digital architectural practice, especially in regard to protocols and organizational structures of creative process - i.e. Algorithmic Architecture - but those are almost entirely focused on the role of the architect in the creative design process and not on the relationship of an architect to other stakeholders from different disciplines or on the the interconnectivity among the stakeholders involved into creative design collaboration.

This chapter starts with critical discourse to define the problem at hand by illustrating the issues connected to the information transmission within the information network. It then explains the evolution of the creative process from simple participation to "collective intelligence", by establishing collaborative work as social space (based on transparency and openness), and therefore making it significant for architectural research.

By rethinking of architectural practice, the basis and reasoning for discussion in this thesis will be established. The approach we have used in this chapter is to establish the terminology for theoretical context for the suggested work. Transdisciplinarity, networked practice, collective intelligence, and emergence of new ideas, are the basic ingredients for discussion about the complexity in collaborative environments, which should build the framework for the argument in this thesis.

The central term for this thesis is transdisciplinarity (see 1.2.1.). This terminology is not intended to mean the "putting together of things" by combining different disciplines but to expand the architectural discussion from its focus on form and function of objects (object-oriented geometries) to relational system-oriented approach. "Transdisciplinarity" emphasizes architectural creative practice more than the product itself and assumes that change in collaborative practice will lead to change in actual output.

1.1. Critical discourse

This thesis investigates the new approaches to creative transdisciplinary design collaboration in complex, knowledge-based networked environments – most notably in architectural practice, and the novel software instruments that make such approaches possible. It argues that the creative transdisciplinary collaboration in architectural practice that occurs over the Internet should enable innovation of the future designs procedures. These procedures should then facilitate emergence of novel working methods and strategies, which are a departure point for novel design in architecture. However, the scope of this work focuses on identified lack of strategies, methods, and most importantly tools for implementation of transdisciplinary approach in architectural practice conducted on the Internet.

The work presented here builds upon a practice-based methodology, setting up a discourse focused on collaborative technology-based design processes and outcomes. Through practice-based research, this thesis aims to establish a more effective model for dealing with implementation of a holistic transdisciplinary approach in the very first phase of architectural projects. The understanding of this process in a creative idea-finding collaboration of multiple disciplines differs from old dualistic models, which considered architect-consultants relationship processes in a linear manner. The model outlined here sees the creative transdisciplinary design collaboration as a creation process that redefines the architectural practice by going beyond the single discipline to enable innovation within the framework of information network.

1.1.1. Problem: Many problems today need more then one kind of knowledge to solve them

It is frequently noted that the context of applications and the requirements for innovation that arise from these applications are themselves increasingly complex, demanding collaboration across different knowledge domains. In the technical report "Radical innovation: crossing knowledge boundaries with interdisciplinary teams" Blackwell et al argue that innovation arises from positive effects that result when stepping across the social boundaries by which we structure knowledge. Further, solving many of today's problems requires more than one kind of knowledge, so interdisciplinary innovation is an essential tool[2]. The researchers claim that interdisciplinary innovation is largely about team-work, where members of the team bring different skills and perspectives (Blackwell et al 2009). Nowotny states that transdisciplinarity entails contributing "to a joint problem solving that is more than just juxtaposition; more than just laying one discipline along side another" (Nowotny 2007).

In the context of open source, open innovation and user-driven innovation, collaboration in multi-disciplinary environments is a new

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[2] Blackwell A, Wilson L., Street A., Boulton, Knell J., *Radical innovation: crossing knowledge boundaries with interdisciplinary teams* (Technical Report: University of Cambridge, November 2009)

approach encompassing the specifics of the other terms. In 2006, Chesbrough published "Open Innovation: Researching a New Paradigm," where open innovation is included along with three other factors: "internationalization," "knowledge economy as an economy of learning," and "multidisciplinary ways of approaching research and problem resolution." The central principle of open innovation according to the Dutch Science and Technology Policy Council[3] is the shift to multi-disciplinary knowledge collaboration, where combined knowledge is needed to deal with complexity of today's problems[4]:

> "The shift from closed to open, collaborative, innovative processes means assembling various types of knowledge to form chains and networks. This not only involves technical and social-scientific knowledge but also and primarily the experiential knowledge of end users. Therefore the innovation will have greater relevance to services, experiences, and users than to products alone."

There is an emergent belief that multi-disciplinary knowledge increases the likelihood of new solutions to the problem or to achieving commercialization of opportunities. Multi-disciplinary collaboration is thought to therefore excel innovation in an enterprise. This acceleration requires more then the simple combination of professional skills to carry out routine business. Incremental innovation exploits existing technology and it is characterized by low uncertainty. It focuses on cost or feature improvements in existing processes, products, or services. On the other hand, radical innovation explores new technology, with high uncertainty. It focuses on products, processes, or services with unprecedented performance features. End-results of radical innovations create dramatic changes that transforms existing markets or industries, or create new ones.

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[3] AWT werkprogramma 2005: groslijst van mogelijke onderwerpen, www.awt.nl/uploads/files/groslijst2005.pdf (last accessed Juni 2010)

[4] When dealing with an enormous amount of data (in a so called Petabyte Age), the classical approach to science, i.e. hypothesis, model, test – becomes obsolete. According to Chris Anderson, editor-in-chief of the "Wired Magazine": "We can analyze data without having hypotheses of what this data is supposed to show. In this way patterns can be found in a domain where science and common sense fail. We can make discoveries for which it is not important what they mean but how they are networked with each other. The available quantity of data including the tools to deal with the figures offer a new way of understanding the world. The connection replaces the cause" (Anderson, 2008).

1.1.2. Problem: People with different training have difficulty communicating and they are trying to achieve different things.

In both contexts - professional problem-solving and the open-ended academic research - innovations arise in ways that cannot be anticipated at the outset of a new interdisciplinary enterprise, whether that enterprise is the assembly of a commercial team or the start of a research project. Blackwell et al found that the definition of a problem in disciplinary terms immediately excludes insights of other disciplines. While it is clear that there are many components of innovation, encompassing both creativity and exploitation, as argued by Blackwell et al, it is also clear that "there are many targets for innovative activity in different sectors, encompassing the development of products or services for commercial exploitation of new ideas, technologies and processes, curiosity-driven academic research, problem solving of various scope, and the creation of social value through specific intervention." (Blackwell et al 2009) These researchers found that disciplines have a tendency to define and establish ownership of their own particular kinds of constraint, just as they own their specific methods and explanatory frameworks.

It is important to recognize that these different sectors do not simply have different pieces of knowledge, or even different languages in which knowledge is expressed. Rather, they have different types of knowledge - the knowledge that is valued, bounded, and whose boundaries are crossed, in one sector is not necessarily even recognized as being knowledge when viewed from another sector. The ways in which disciplinary practices shape our thinking is, in all likelihood, quite underestimated. It is through these particular 'frames of reference' (Goodman 1978) that we structure and make sense of the world as professional practitioners. These differing perspectives are not necessarily commensurable with one another. We have investigated patterns of boundary-crossing behavior. However, the crossings are experienced in relation to boundaries that not all participants may perceive, being boundaries around objects that in themselves we might not all recognize (Leitner and Wilson 2007).

In an article on the importance and challenges of transferring knowledge across disciplines when science and technology are becoming increasingly specialized, Kostoff outlines a method for facilitating interdisciplinary research (Kostoff 1999). Kostoff argues that research should combine interdisciplinary workshops along with the assessment of linked literature. Workshops would involve experts from different disciplines and would focus on specific central themes to provide a common thread from which innovative thought might arise. Examining relationships between linked or overlapping literature would enable researchers to see when a discovery in one field might be applied to another.

1.1.3. Review of literature on transdisciplinarity and innovation. Problem: insufficient implementation examples in architectural practice

The notion of interdisciplinarity has circulated as long as disciplines have existed and has gained increased significance in research policy at several points throughout the twentieth century (Jantsch 1972, Klein 1996, Klein 1999, Klein 2004, Tress, Barbel, and Fry 2004). In the literature reviews, the focus tends to be on innovation, and differences between interdisciplinarity and other forms of collaborative research are rarely explained. There are publications that consider how the innovation and new practice can emerge from transdisciplinary approach, but there are only few in the context of architecture, urban design, and art. Doucet et al focused on transdisciplinary knowledge production in Architecture and Urbanism[5]. They claim that, "in contrast with interdisciplinary knowledge, which is primarily located in scholarly environments, transdisciplinary knowledge production entails a fusion of academic and non-academic knowledge, theory and practice, discipline and profession". With other words, they treat the theory and practice as two different disciplines and

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[5] Isabelle Doucet ed., *Transdisciplinary Knowledge Production in Architecture and Urbanism Towards Hybrid Modes of Inquiry. [in eng]. Urban and Landscape Perspectives.* (Dordrecht u.a.: Springer, 2011)

ground enough to call for transdisciplinarity. Therefore, they assume that "architecture (and urbanism), operating as both a discipline and a profession, seems to form a particularly receptive ground for transdisciplinary research." Although this specificity has not yet been fully developed, the researchers fail to present a single example of transdisciplinary design collaboration practice beyond the academic context.

Attempts to define the methodological characteristics of interdisciplinary research in the literature often involve a focus on the distinction between multi- and inter- disciplinarity, as representing a distinction between "juxtaposition" and" integration" respectively (Rhoten 2007). However, there is a lack of discussion about what integration might consist of in terms of actual disciplinary transformations, how individual researchers might go about identifying and combining these different knowledge types, and what value this notion of integration might have for those researchers. Many of the critiques of interdisciplinarity referred to here focus on the way in which it substitutes for critical reflection and stands for innovation, without the presence of any in-depth analysis into how and why it might instigate these creative processes.

An interesting interpretation of transdisciplinarity can be found in a book about transdisciplinary digital art by Randy *et al.*. In their Introduction, the authors treat the artists as experts who are capable of cross-disciplinary activity. This tendency suggests that the artist in Digital Art must be an engineer as well, so as to be capable of successfully transporting his own ideas to other disciplines.

> "Interdisciplinarity implies a certain level of detachment across the mediums: the artist, the engineer, the musician and the dancer may collaborate with each other but in much interdisciplinary work there is a sense that they are separate entities performing their own expert functions without more thorough knowledge of the other's technical or artistic processes. Transdisciplinarity implies a level of direct connection and cross-over between mediums: the artist also becomes the engineer, the engineer becomes the artist, and when they collaborate they actually

> have enough expertise in the other's field to be able to address concerns across the mediums and even across disciplines."[6]

As an example for modern interdisciplinary approach Randy et al quote the project "Variations V" by John Cage in which the composer, the film artists Nam June Paik and the choreographer Merce Cunningham worked in relative isolation, only meeting for the final performances. However, Randy et al fail to show how the transdisciplinary approach would differ from this example in artistic practice. Neither the editors nor the authors of the articles in the book present any Case Study or discuss which methods, instruments, and strategies could be applied in transdisciplinary collaborative practice.

While the theoretical models of multidisciplinarity, interdisciplinarity, and transdisciplinarity are subject to the above criticisms in that they tend to be directive without specifying how collaborations might occur, some examples of empirical research into interdisciplinary research methodologies can be found in the fields of science, technology, and management studies. These examples often consist of the kind of 'problem solving' contexts for which a 'management model' of combining and ordering different knowledge types might be valuable. Lakhani et al. conclude that, "openness and access to information about problems between fields thus appears to be important for scientific progress and is systematically achieved through problem broadcasting and openness." (Lakhani et al. 2007)

However, Barry et al.'s notion[7] of 'invention' points to the possibility that critical reflection in interdisciplinary projects may be observable in form of ontological shifts of understanding. In their usage, the difference between invention and innovation appears to lie in the value of the former and does not depend on pre-specified outcomes. It might thus be compared to what Strathern has called the 'research mode' of knowledge

[6] Adams, Randy, Steve Gibson, and Stefan Müller Arisona. *Transdisciplinary Digital Art : Sound, Vision and the New Screen : Digital Art Weeks and Interactive Futures 2006/2007*, (Zurich, Switzerland and Victoria, Bc, Canada, Selected Papers. Communications in Computer and Information Science,. Berlin: Springer, 2008)

[7] Barry, A., Born, G., and G. Weszkalnys, *Logics of Interdisciplinarity* (Economy and Society, 37(1), 2008) 20-49.

production, where every question generates new questions, rather than particular solutions being anticipated as endpoints.

1.1.4. Problem: implementation of knowledge from different disciplines in creative process and how to enable the emergence of innovation within collaborative environment.

It is important to stress that while the importance of creativity to the innovative process is often emphasized in business management literature (e.g. De Meyer and Garg 2005), the notion of creativity is rarely explored in depth. In this literature, creativity is often assumed to be the trigger for innovation. That is, innovation is the successful implementation of alternative or creative thinking of managed diversity in organizations. Thus, creativity exists in these models in a linear relationship with innovation. However, this conception of the creative process may be too restrictive. In a cross-cultural study of creativity and innovation, Tim Ingold argues that creativity does not entail the realization of a pre-formed concept but is a process 'generative of form rather than merely the revelation of pre-existing design' (Hallam and Ingold 2007). The distinction is an important one and may have important implications for policy. Specifically, if a creative process is generative of form, then how might unforeseen consequences be planned for and incorporated in policy? The great majority of interdisciplinary innovations are associated with teamwork, in which members of the team bring different types of knowledge with them.

The literature review pointed to numerous attempts to identify the differences between multi- and inter-disciplinarity and highlighted an emerging consensus concerning the meanings of these terms across the academic literature (e.g. Klein 1996, Latucca 2001, Miller 1982, Rossini and Porter 1985, e.g. Tress, Barbel, and Fry 2004, Wickson, Carew, and Russell 2006). However, when it comes to collaboration between academic researchers from different disciplines and non-academic participants who work together towards a common goal, the question is how to achieve the breakdown of epistemological barriers ,not only at the level of disciplines but also at the level of institutions.

Computer-supported collaboration involves many different modes of communication in social-technical context. Fischer defines two different types of design communities: *communities of practice* and *communities of interest*[8]. To address the communication challenges between diverse design communities, a common ground and shared understanding in the context of complex design tasks needs to be established. According to Fischer, there is no media-independent communication and interaction -- "that tools, materials, and social arrangements are always involved in some way in these activities". (Fisher & Ostwald, 2005)

Summarizing the critical discourse in this section the defined research topics for this thesis and the connected research are following:

- Formation of random views in one information network
- Semantic structuring and clustering of provided data input
- Manipulation of information structures within collaborative environment
- Problem analyses of transdisciplinary data structures
- Demonstration of the provided requirements and the defined Case Study "City Upgrade" by implementation of A.N.D.I. system.

1.2. Contextual Terminology

The contexts provided by the world of the 21st century require that our societies rethink and reinvent learning, teaching, working, and collaboration. A first basic challenge insouciantly addressed by prior research and practice is that almost all of the significant problems of tomorrow will be systemic problems, which cannot be addressed by any one specialty. The claim here is that these problems require

[8] G. Fischer & J. Ostwald, *Knowledge Communication In Design Communities*, In R. Bromme, F. Hesse, & H. Spada (Eds.), (Barriers and Biases in Computer-Mediated Knowledge Communication, Springer, New York, NY: 2005) 213 - 242

transdisciplinary collaboration that focuses on opportunities for knowledge workers to work in teams, communities, and organizations that encompass multiple ways of knowing and collaborating. Many real-world problems have become too complex to solve for a single expert out of one discipline. The knowledge relevant to solve complex problems is increasingly distributed among many people requiring *socio-technical environments*[9] that bring together people with different, complementary, and often-controversial points of view to form a community. Despite these widely accepted attributes, contemporary higher education is primarily characterized by receiving knowledge out of one single department (usually synonymous with one single discipline), therefore forming specialists with depth in uni-disciplinary knowledge and discipline-dependent characteristics.

1.2.1. Transdisciplinary Innovation

Transdisciplinary collaboration is a group process between individuals educated and knowledgeable in different disciplines (such as: computer scientists, biologists, designers of new media, urban planners, etc.). In exploring these collaborations, researchers and educators use the terms multidisciplinarity, interdisciplinarity, and transdisciplinarity, often without clearly distinguishing among them, though these terms are well defined and distinguished by e.g. Klein[10], Roseneld[11] and Nicolescu[12]. In short,

- multidisciplinarity means that several disciplines are being involved either in a sequential or juxtaposed mode;

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[9] E. Mumford, *A Socio-Technical Approach to Systems Design* (Requirements Engineering, 5(2), 2000) 59-77

[10] J. T. Klein, A Platform for a Shared Discourse of Interdisciplinary Education (Journal of Social Science Education, Volume 5, Number 2, September 2006) 10-18

[11] P. L. Rosenfield, *The potential of transdisciplinary research for sustaining and extending likages between the health and social sciences* (Social Sciences and Medicine, 35: 134357, 1992)

[12] B. Nicolescu, *The transdisciplinary evolution of learning* (http://www.unesco.org/education/educprog/lwf/dl/nicolescu_f.pdf, 1999)

- interdisciplinarity implies integration or blending of knowledge from different disciplines;
- transdisciplinarity places the highest demand on the objective to form new knowledge from available unidisciplinary awareness.

In common contemporary architectural practice, collaboration between architect and various experts, all connected to the building industry, occurs as consulting to achieve pre-defined tasks based on requirements provided by the client. If we understand transdisciplinarity on this instrumental level, then transdisciplinarity is nothing new. According to Mittelstraß, this interpretation of transdisciplinarity would be an extension of interdisciplinarity[13]. He sees the transdisciplinarity as a research principle only if it is active wherever "a definition of problems and their solutions is not possible within a given field or discipline." Mittelstraß claims that research changes, the scientific system must change, and that transdisciplinarity could evoke this change.

Therefore, transdisciplinarity in architectural practice that requires the creation of new organizational frameworks for knowledge from separate disciplines demands collaboration from professionals and experts from those disciplines. Nicolescu describes the need for a transdisciplinary approach, saying it is necessary because of its goal "which cannot be accomplished in the framework of disciplinary research."[14] Although all three approaches extend beyond disciplinary boundaries, it is important to distinguish between different goals. According to Nicolescu, the goal of transdisciplinarity is "the understanding of the present world, of which one of the imperatives is the unity of knowledge." By going beyond the transferring knowledge from one discipline to another, where the knowledge still remains within the framework of single disciplines,

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[13] J. Mittelstraß, *New Structures in Science* (http://xserve02.mpiwg-berlin.mpg.de/ringberg/Talks/mittels%20-%20CHECKOUT/Mittelstrass.html)

[14] B. Nicolescu, *The Transdisciplinary Evolution of the University Condition for Sustainable Development* (Universities' Responsabilities to Society. International Congress. International Association of Universities, Chulalongkorn University, Bangkok, Thailand, November 12-14, 1997. [Online] http://nicol.club.fr/ciret/bulletin/b12/b12c8.htm)

"transdisciplinarity concerns that which is at once between the disciplines, across the different disciplines, and beyond all discipline. Its goal is the understanding of the present world, of which one of the imperatives is the unity of knowledge." (Nicolescu 1997)

> "Transdisciplinary research is needed when knowledge about a societally relevant problem field is uncertain, when the concrete nature of problems is disputed, and when there is a great deal at stake for those concerned by problems and involved in dealing with them." (Hirsch Hadorn et al., 2008)[15]

The change of the operational framework, in this case, for the design process within architectural practice, will change the practice itself. Nowonty et al.[16] claim that this change of common practice is a creative act.

> "Trans-disciplinarity, by which is meant the mobilization of a range of theoretical perspectives and practical methodologies to solve problems, but, unlike inter- or multi-disciplinarity, it is not necessarily derived from pre-existing disciplines, nor does it always contribute to the formation of new disciplines. The creative act lies just as much in the capacity to mobilize and manage these perspectives and methodologies, their 'external' orchestration, as in the development of new theories or conceptualizations, or the refinement of research methods, the 'internal' dynamics of scientific creativity." (Nowonty et al. 2003, p. 186)

Comprehending the interconnectivity of stakeholders involved into collaboration as a potential characteristic of the creative process, the thesis re-introduces a new layer, which emphasizes an original volition of project partners from the same professional domain. The interconnection between architect and the partners from various domains are blended into one creative flow. The working environment for such collaboration is an Information Network. The epistemological gap between all partners involved in the collaborative design process can disappear only if such network is accessible and manipulable by all. There are different types of networks: technological networks, social networks, biological networks, etc. [17]The networks of information are networks consisting of items of data

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15 Hirsch H., G., Hoffmann-Riem, H., Biber-Klemm, S., Grossenbacher-Mansuy, W., Joye, D., Pohl, C.V. Weismann & E. Zemp (EDs.), *Handbook of transdisciplinary research* (Heidelberg: Springer, 2008) p431.

16 Nowotny, H., Scott, P. and Gibbons, M., *INTRODUCTION: 'Mode 2' Revisited: The New Production of Knowledge* (Minerva 41, 2003) 179–194.

17 Mark Newman, *Networks: An Introduction* (OUP Oxford, 2010)

linked together in some way. In addition, there are some networks that could be considered information networks, but which also have social aspects to them. The information networks are for example world wide web in general, citation networks, peer-to-peer networks, recommender networks, but also the social-networking websites, networks of weblogs and online journals. The network's model introduced here takes into account all of the examples mentioned above, although the major focus is on knowledge and data sharing to support the collaboration over the Internet. Through the recognition of the interconnection of all participants involved in creative collaboration, the thesis develops a critical framework and reconsiders technology-based architectural practice, proposing an informational network and model of networked collaboration termed the Infospace. This model suggests an information network as an environment for knowledge management in which the technology within the architectural practice is an enabling application. It is argued that the Infospace provides the needed infrastructure for facilitating the multi-agent platform for exchange of knowledge and data of higher entropy[18] involving many stake-holders from different disciplines. It follows the central paradigm of classical information theory defined by Shannon of the transmission of information over a noisy channel. Thereafter, the collection and storage of data is not as important as the quantification of information. Shannon states in his "noisy-channel coding theorem" that reliable communication is possible over noisy channels, provided that the rate of communication is below the channel capacity of appropriate encoding and decoding system (Shannon, 1948). This idea could be an underlying metaphor for the system presented here – a digital platform named A.N.D.I. - A New Digital Instrument for creative transdisciplinary collaboration. This platform reintroduces an immaterial abstract dimension to the architectural practice, by invoking the uncertain events and unforeseen results as a core of creative process. The platform facilitates the creative processes and therefore can be described as an

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[18] C.E. Shannon, *A Mathematical Theory of Communication* (Bell System Technical Journal, vol. 27, July, October, 1948) 379–423, 623-656,

"innovation ecosystem", for which the flow of technology and information among people and enterprises is key to an innovative process. It contains the interaction between the actors who are needed to turn an idea into a design concept within the collaborative practice.

1.2.2. Networked design practice

Collaboration in architectural practice over the Internet has not focused entirely on technological aspects of Internet as an infrastructure needed to facilitate the networked design practice. However, a network design practice[19] has underlined an abstract organizational model, as it describes only the relationship between things (objects or information), which can be applied to the organization of anything from friendships, to biological systems, stock markets, flue epidemics, or global warming. One thing the author would like to convey through this thesis is a sense of where the networked design practice comes from, how it fits into larger schemes of product development of any kind (considering even a spatial production as a product in architectural terms), and what it can tell us about the world itself. Actually, there is far more to say about these matters than can be included and addressed here, as there are years worth of literature on the topic. Furthermore, the work presented here will convey the point that the connected age cannot be understood by forcing it to fit with a particular model of the world, nor can it be understood by any one discipline in isolation.

Once, networks were considered *objects of rigid structure* their *properties* being *fixed in time* (Watts, 2003; Barabási, 2003). Real networks, however, consist of separate components that, for example, generate power, send data, or make decisions. Therefore, network *diagrams* for presentational purposes - produced to represent a certain state of the system – could be confused with graphs explaining the topology of

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[19] Networked design practice should be positioned as an intersection of design, social space, and range of complex relational information models, to create new opportunities for collaborative practice as a new field – enabling platform – for transdisciplinary "connected intelligence". Developing new forms of architectural practice could be a departure point towards a new architecture.

networks as dynamic structure. However, through their activities and decision-making processes, networks function as *dynamic objects,* which *evolve and change in time*. The new approach to networks, as claimed by Duncan Watts[20], "must bring together the relevant ideas and the people who understand them from all disciplines. The networked practice must become a manifestation of its own subject matter, a network of collaborators collectively solving problems that cannot be solved by any single individual or even any single discipline."(Watts, 2003) Watts explains that, "understanding networks in this more universal fashion, however, is an extremely difficult task. Not only are networks inherently complicated, but they also require different kinds of specialized knowledge that are usually segregated according to academic specialty and even discipline." The languages "used" in the various disciplines are diverse, and scientists and researchers often have difficulties communicating, even if they work on similar problems, especially if their approaches differ.

Why are networks interesting for architectural practice, and how can their implication help in describing the architecture of complex relationships within real and virtual environments of today? It has been observed that networks grown under different conditions to meet markedly different needs turn out to be almost identical in their structure (Surowiecki, 2004) (Buchanan, 2002). A new theoretical perspective on networks helps to answer this question and enables researchers in almost every area of science to begin tackling some of the most challenging and important problems (Barabási, 2003) (Strogatz, 2003). "For centuries, scientists have been taking nature apart and analyzing its pieces in ever-increasing detail. It is necessary to point out that this process of 'reduction' can take understanding only so far." (Buchanan, 2003). Furthermore, Surowiescki (2004) argued that the organizational patterns that make the collective function can not be unfolded by any individual. At present, most issues and difficulties derive from unraveling the elaborated ways of how these complex networks are organized. Johnson claims that: "in an abstract

[20] Duncan J. Watts, Six Degrees, The Science of a Connected Age (New York: W. W. Norton & Company, 2003)

sense, any collection of interacting parts – from atoms and molecules to bacteria, pedestrians, traders on a stock market floor, and even nations – represent a kind of complex network with certain laws" (Johnson, 2001).

Why are, thus, *complex connected systems* difficult to comprehend and why are they complex? How can individual and collective behavior complement each other? Could the answer for these questions be that for parts that make up a whole there is no easy way to be summed up? At this point, the key seems to be interaction. Through interaction, even the simplest parts can collectively achieve an outstanding behavior. The next section explains the interaction as phenomena of collective intelligence.

1.2.3. Collective Intelligence

Many aspects of designing with multiple participants from various disciplines have previously been addressed with approaches like participatory design, multidisciplinary design, co-operative design, and concurrent engineering. According to Achten, a precise definition and focus area of collaborative design is still missing.[21] However, the nature of collaborative design can be discussed by contrasting a number of aspects. For instance some researchers are eager to distinguish between cooperative versus collaborative design[22]. In cooperative design, actors are solving and later integrating partial solutions of the whole design. In collaborative design, the participants are not bound to solve a particular problem but are encouraged to engage in solving design problems from other participants or to contribute to their design work as well. Research findings by Maver and Petric are showing that such approaches of mutual information exchange and engagement in tackling all design aspects tend to be beneficial for all participants.

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[21] Achten, H.H., *Requirements for Collaborative Design in Architecture*, in Timmermans, H.J.P. and de Vries, B.(eds.) (Sixth Design and Decision Support Systems in Architecture and Urban Planning - Part one: Architecture Proceedings Avegoor, the Netherlands: 2002) 1-13.

[22] Maver, T. and J. Petric, *Media in Mediation – Prospects for Computer Assisted Design Participation*, in Stellingwerff, M. and J. Verbeke (eds.) (Accolade – Architecture. Collaboration. Design, Delft University Press, Delft: 2001) 121-134.

When a group of individuals collaborate or compete with each other, intelligence or behavior that otherwise didn't exist suddenly emerges; this is commonly known as collective intelligence. Scientists from the fields of sociology, mass behavior, and computer science have made important contributions to this field. In Computer Science, phenomena of collective intelligence have been applied to tasks of making recommendations, searching and ranking, optimization, document filtering, modeling with decision trees, etc. Numerous accounts described in this thesis suggest collective intelligence as a model for gaining knowledge within the creative design collaboration. Understanding of Collective Knowledge as distributed, complementary and interlinked knowledge - each stakeholder holds one part of the puzzle - is helpful for handling transdisciplinary collaborative environments. Collective Knowledge or Collective Intelligence emerges from collaboration and group interaction of individuals during the decision making process. Prepositions for establishing of collective intelligence within a design project includes willingness and openness of involved actors for sharing ideas and knowledge in interactive connected environment. In creative collaborative environments, self-organization and unpredictability of outcomes are further key features. Those approaches are appropriate for ill-defined problems, very common in architecture, and other creative disciplines, which can be only solved by devising an original solution, which *emerges* from the proceedings described as collective intelligence.

1.2.4. Emergence and non-linearity

By the definition: "emergence is a function of the nature of recursive causation in complex systems (recursive logic was introduced as a core paradigmatic feature of complexity)."[23] The concept of emergence describes the properties, behaviors, and structure that occur at higher levels of a system, which are not present or predictable at lower levels. In biological, physical, and social systems, there is the potential for something

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[23] Penny Sweetser, *Emergence in games* (Boston: Cengage Learning, 2005)

needs to be created from simple entities interacting with their local environment and with each other. When these entities come together to form the whole, the whole is not merely a collection of these entities, it is something else entirely (Sweetser, 2005). Emergent events are products of unpredictable combinations and re-combinations among interdependent agents (Kauffman, 1995). When sets of agents, introduced and coordinated by constraints, visions and rules, begin to "resonate in sync" with one another a creative event can occur. Project coordinators or project initiators in complex organizations focuses more on creating conditions that enable emergence of distributed contributions, than to directing collaborators' behaviors. Project initiators accomplish this by setting up the structures, organizational patterns, enabling rules, and motivation to foster interactive forces of creative spirit. It could be assumed that this creative spirit could unfold within "collective intelligence", in situations where new and unexpected ideas are able to emerge and unfold.

The success of the gradual procedure is justified by stating that many systems are roughly linear. In physics, a linear system is, although simplified, is a system in which the whole is equal to the sum of all its parts and in which the sum of many causes induces a corresponding number of effects. Scientific analysis in particular relies on the feature of linearity, i.e. that the comprehension of the parts of a complex system allows conclusions about the comprehension of the whole. The ability to segment a linear system, without destroying it, is expressed in mathematical methods that describe the system. Linear Mathematics is very convenient in this case because its complexity can be segmented into simple terms as well.

Though linear approaches to thinking have been successful for over three hundred years, they often fail to consider that real systems almost always contain non-linear elements. In cases where non-linearity is critical to a system, it becomes impossible to proceed analytically because the whole is bigger than the sum of its parts then. Nonlinear systems can evince a comprehensive and complex repertoire of behavior; they can become chaotic, for example. In general, a non-linear system has to be viewed in its totality, which practically means that numerous restrictions, constraints, and starting conditions have to be considered.

There are many examples of the holistic nature of non-linear systems. Parts of these systems are self-organizing phenomena, like chemical mixtures ,which together cultivate forms and pulsating color patterns. The non-linearity of physical systems imparts an incredible ability to do something unexpected with an almost lifelike quality. They can behave cooperatively, adapt spontaneously to their environment, or simply organize themselves into coherent structures with clearly recognizable identities. Dealing intensively with non-linear systems causes a remarkable shift of emphasis away from inherent mass – dead matter, which reacts upon animated forces – towards systems that evince spontaneous and surprising elements.

1.2.5. Open Innovation in collaborative environment

The Collaboration 2.0 applied in the Enterprise 2.0 suggests that the way we innovate and create new designs is undergoing a fundamental change.[24] According to Thomas Kuhn (see 2.1.1), we are witnessing a “paradigm shift” in organizational behavior, especially when one single discipline is not in control of the innovation process. For instance, architects must generate their own ideas and then develop them, communicate them to others, market them, publish them, service them, in many cases finance them, and support them on their own. At the same time, they need to be a part of socio-political discourse, pay attention to environmental issues, and follow the development of the newest technologies. With rising complexity of requirements, these tasks becomes almost impossible. Chesbrough calls attempts to innovate in such environments “Closed Innovation.” According to Chesbrough, Closed Innovation in architectural practice will mean, architects hire the best people to work for them, so that the smartest people come up with new

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[24] Chesbrough, Henry William. *Open Innovation : The New Imperative for Creating and Profiting from Technology.* (Boston, Mass.: Harvard Business School ; Maidenhead : McGraw-Hill, 2003)

innovative designs. They innovate themselves and get their innovations to the market first, giving them an advantage in a world-wide competition. The size of architectural studios and the amount of investment in R&D are also associated with level of success. Intellectual property by my strictly controlled so that competition does not profit from stolen ideas Chesbrough, 2003). For most of the twentieth century, this paradigm worked well. However, the research by Chesbrough shows that "the companies that originally funded the breakthrough did not profit from its investment in the R&D that led to breakthrough". For Chesbrough the Closed Innovation is no longer sustainable. Instead he introduces a concept of "Open Innovation". "Open Innovation is a paradigm that assumes that firms can and should use external ideas as well as internal ideas, as the firms look to advance their technology" (Chesbrough, 2003)

Closed Innovation Principles	Open Innovation Principles
The smart people in our field work for us.	Not all the smart people work for us. We need to work with smart people inside and outside our company.
To profit from R&D, we must discover it, develop it, and ship it ourselves.	External R&D can create significant value; internal R&D is needed to claim some portion of that value.
If we discover it ourselves, we will get it to market first.	We don't have to originate the research to profit from it.
The company that gets an innovation to market first will win.	Building a better business model is better that getting to market first.
If we create the most and the best ideas in the industry, we will win.	If we make the best use of internal and external ideas, we will win.
We should control our IP, so that our competitors don't profit from our ideas.	We should profit from others' use of our IP, and we should buy others' IP whenever it advances our own business model.

Table 1: Contrasting principles of closed and open innovation (Source: Chesbrough, 2003)

The drivers for a new kind of enterprise according to Coleman are: overwhelming amount of information available, user created content, expertise discovery from cross organizational teams with interactions based on relationship and not on transaction. These are the same ingredients of Open Innovation defined by Chesbrough. Open Innovation can be understood as the exploration strategy of various internal and external sources to gain innovation, the integration of this exploration within enterprise, and the exploitation of these opportunities through multiple channels. Methods to achieve Open Innovation include: collaborative product design and development, customer immersion and innovation networks. A network of contributors in the design process are motivated through the form of an incentive[25]. Innovation networks rely on stakeholders to develop solutions to identified problems within the development process, as opposed to new products inventions. However, the Open Innovation concept[26] fails to prove methods for implementation in productive environments because of the increased complexity of controlling innovation and regulation of how contributors affect the project. Furthermore, the means and instruments are missing to properly identify and incorporate external innovation[27].

The question is how is Open Innovation applicable in collaborative environment? What type of collaborative environment is needed to foster the unusual levels of innovation? It has been observed that the level of innovation rises with the number of people thinking about certain problems, as well the number of people looking at the problems outside of their domain of expertise and their communication across the disciplines[28]. Innovation is result of human creative thinking, but also of productive thinking, otherwise the creative process stays trapped in brainstorming of different ideas. The systematic search for innovation

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[25] “An incentive is something that motivates an individual to perform an action. The study of incentive structures is central to the study of all economic activity (both in terms of individual decision-making and in terms of co-operation and competition within a larger institutional structure). Economic analysis, then, of the differences between societies (and between different organizations within a society) largely amounts to characterizing the differences in incentive structures faced by individuals involved in these collective efforts. Ultimately, incentives aim to provide value for money and contribute to organizational success.” (Wikipedia, accessed March 2013)

[26] Parallels and comparisons to Open Source model are somehow misleading because of different understanding of IP rights and patent issues.

[27] Schutte, Corne and Marais, Stephan, *The Development of Open Innovation Models to Assist the Innovation Process* (University of Stellenbosch, South Africa: 2010) West, J., Gallagher, S., *Challenges of open innovation: The paradox of firm investment in open-source software* (R and D Management 36 (3): 2006), p319

[28] Siegfried Geiger and Wolfgang Heyn, *Innovation* (Management Enzyklopädie, Verlag Moderne Industrie, München 1970) p557

practiced until now can be achieved through following methods: function-product-matrix (defining of functions for a certain product), pattern planning assistance through technical evaluation of relevant numbers, analysis of future requirements, and others (Geiger and Heyn, 1970). However, to enable implementation of Open Innovation paradigm within transdisciplinary collaborative setting, a careful examination on user context in agent-based environment is needed. The definition of user context and methods of agent-based applications provide specific and precise details about how team members contribute to a team as a whole, how team members communicate with one another and how groups within teams communicate with one another (internal and external).

1.3. Rethinking the Architectural Practice - Thesis: the change of architectural practice leads to innovation in architectural design.

The architectural practice, both as profession and as discipline, deals with a broad range of disciplinary and practical forms of knowledge. This knowledge can be scientific, non-scientific or fuzzy (fuzzy in sense of not being possible to make clear categorization), since the architectural design is a balance between arts and science. Acting as a discipline as much as a profession (theory and practice) and having to deal with different kinds of disciplinary and non-disciplinary knowledge suggests that multi-disciplinarity is embedded in architecture. Originally, an architect was a person who designed buildings. However, the buildings are just one (physical) form of *the space*, to which architectural expertise could be applied. Simply put, the space design goes far beyond that of the building design. The design of spaces and the production of space could be manifested in form of a building space as an output -- physical enclosure inhabited and used by humans. For the understanding of the space production it is important to says that the space[29] can be seen and explained differently through different disciplines (for example arts, philosophy, science etc.) Also, various typologies of the space these domains could be traced: e.g. physical space, virtual space, social space, political space and so forth.

1.3.1. Topic: Lack of tools for transdisciplinary collaboration in old model of collaborative practice

The critical discourse identifies a significant lack in practical applications of methods, strategies, and tools for the creative collaboration in architectural design. It emphases that although philosophical discussions of technology already provide meaningful solutions for how the creative collaboration could be enhanced through the tools, architectural applications appear to ignore them and therefor remain on the level of data sharing and file exchange. The thesis first revisits the old models of collaborative practice in architecture, to highlight their particular lack in practical applications for complex tasks involving many stake-holders, which produced ambivalent concepts and design outcomes in the architectural practice.

1.3.2. Topic: Social Space - Confusing "design of space" with "design of buildings" in context of critique, empowerment, and dissent (according to Henri Lefebvre)

Henry Lefebvre considers the production of the space as the reproduction of social relations of production.[30] Lefebvre points out that there are different modes of production of space from natural space ("absolute space") to more complex spatialities whose significance is socially produced (i.e. social space). Lefebvre introduces a three-part dialectic model between everyday spatial practice, presentation of space,

[29] "**space**, a boundless, three-dimensional extent in which objects and events occur and have relative position and direction." ("space." Encyclopædia Britannica. Encyclopædia Britannica Online. Encyclopædia Britannica Inc., 2012. Web. 13 Apr. 2012.)

[30] Henri Lefebvre, *The Production of Space* (Wiley-Blackwell, 1991)

and the spatial imaginary or representation of space.(Lefebre, 1991) The "*pratique spatiale*" unites the production and reproduction of the space, especially within the places of social interaction. Such cohesion leads to competence for each participant of spatial production and introduce a certain performance for the whole. These observations suggest that the collaborative work, as a form of social interaction with particular collective aim, is a production of space and therefor of interest for architectural practice. Furthermore, the environment for collaborative work is a space itself, which could be then designed thereafter. It follows that the collaborative practice is not only a production of spaces, but it is a *space itself*, which is of particular interest for this thesis.

There is some ambiguity when discussing the tools in architectural practice. Digital tools could also enable the structural use of new, non-linear, computational design methods and rapid prototyping.[31] In this thesis, digital tools are considering the applications for creative collaboration, where the content and the output is not an object but the information. Information Architecture[32] deals with designing of such tools. More precisely it is meant the information architecture of the collaborative environments, the design that stands for underlaying structures for different collaborative tools to be implemented. The term 'information architecture' was introduced without a proper definition. In this thesis, we are borrowing the description by Richard Wurman, to describe top view on creation of environments where the information is the essential building block. Wurman uses architect[33] as "in the creating of systemic, structural, and orderly principles to make something work — the

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31 See Manuel De Landa, "Material Complexity", in Neil Leach, David Turnbull, and Chris Williams, eds., *Digital Tectonics* (Chichester: Wiley-Academy, 2004), p 14-22

32 "Information Architect: 1) the individual who organizes the patterns inherent in data, making the complex clear; 2) a person who creates the structure or map of information that allows others to find their personal paths to knowledge; 3) the emerging 21st century professional occupation addressing the needs of the age focused upon clarity, human understanding and the science of the organization of information." (Wurman, 1996)

33 Wurman, Richard Saul, and Peter Bradford. *Information Architects* (New York: Graphis ; London : HI Marketing [distributor]: 1997)

thoughtful making of either artifact, or idea, or policy that informs" (Wurman, 1997). From the IT domain, there are different meanings for information architecture, e.g. by Rosenfeld and Morville,[34] who are talking about the structural design of shared information environments and emerging effort of collaborative practice by communities to bring principles of design and architecture to the digital landscape (Rosenfeld and Morville, 1998). This description from Computer Science is very close to something, which can be a metaphor for architectural practice,[35] though it is clear if it derives from the idea of traditional architectural practice, where the bricks have been exchanged with bits.[36] Nevertheless, the common ground between traditional architectural practice and implementation of information architecture are the instructions on proceedings, meaning how the design process has been conceived, planned and executed. In other words an algorithm,[37] a procedure for addressing a problem in a finite number of steps using logical operations, can be used to create design for actual physical space and as a methodology for interactive social space of creative collaboration.

1.3.3. Topic: the Algorithm - Instruction of proceedings, how the design process has been conceived, planned and executed.

The Algorithm, as a backbone of any software development project, needs some explanations for introduction in architecture. Kostas Terzidis in "Algorithmic Architecture" establishes the relation between the examination of possibilities of design offered by the computer and more

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34 Rosenfeld, Louis, and Peter Morville. *Information Architecture for the World Wide Web*. (Cambridge: O'Reilly, 1998.)

35 The author uses these definitions to distinguish the architectural practice of designing the buildings from the architectural practice of designing the collaborative environments.

36 For discussions about these probable developments, see Mitchell, 1996, Mitchell, 1998, Schmitt, 1996.

37 "**algorithm**, systematic procedure that produces—in a finite number of steps—the answer to a question or the solution of a problem." ("algorithm." Encyclopædia Britannica. Encyclopædia Britannica Online. Encyclopædia Britannica Inc., 2012. Web. 19 Mai. 2012.)

general philosophical questioning on the design process.[38] Terzidis claims that design is not in the strict sense an invention, the creation of something absolutely new, but it should rather be considered as the result of an unveiling or a rediscovery process (Terzidis, 2006). Computational tools are based on algorithms, but many architects according to Terzidis are using tools in description of digital practice as formal phenomena. The term' tools' is often used to describe interaction of designer with computer. However, "designers are frequently amazed by processes performed by algorithmic procedures, of which they have no control or knowledge." (Terzidis, 2006, p.148). For one this has to do with authorship and ownership of design process. The architect feels in charge for the final design, even if this process is influenced by expertise of others. And secondly, the architect is very determined about the output of design process. Mario Carpo explains that current understanding of digital design[39] doesn't involve user-generated content nor that architectural design process is open to other disciplines outside the architectural domain, except for consulting purposes. "Architects that by choice or by necessity intervene in someone else's digital design environments are to some extent only secondary authors - end users and not designers" (Carpo, 2011, p126). Carpo thus concludes that the process of architectural design, and the architect's role as an author, may radically change through digital paradigm shift. Nevertheless, if the digital tools and Algorithmic Architecture propose a "paradigm shift", which paradigm exactly is shifting?

Peter Weibel explains that the major problem of false understanding the Algorithmic Design in architecture is due to the false understanding of the algorithm itself.[40] 'Algorithm' means a set of operational instructions in finite steps, but it does not imply a predefined

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[38] Terzidis, Kostas. *Algorithmic Architecture*. (1st ed. ed. Amsterdam; London: Architectural Press, 2006.)

[39] Carpo, Mario. *The Alphabet and the Algorithm, Writing Architecture*. (Cambridge, Mass.: MIT Press, 2011.)

[40] Peter Weibel, *Algorithmus und Kreativität,* In W. Berka, E. Brix, C. Smekal (Eds.), (Woher kommt das Neue?, Bohlau, Wien: 2003) 85-97

solution. For the Architecture, Weibel proposes a model where an event-based world or artificial world is created as context controlled data field. The variables of the data field can be independent agents (software or persons) that develop own agenda and therefore mimic a real-life situation (Weibel, 2003), which means two things. Firstly, the future building is its own morphogenesis, in other words the building can change its own form and appearance without intervention by architects - it creates itself. Secondly, an algorithm will replace the architect as a creator. More precisely, the creative work of architect shifts from creation to interpretation, focused to discover unknown not to purposely design. Weibel sees the Algorithmic Architecture as a control mechanism for the genesis principles of the building form and preceding design decisions. Architecture, seen as complex, adaptive, dynamic System, happens within the Algorithm. The architect no longer designs the buildings. Instead, he designs designs algorithms, procedures, instructions, and strategies for the architecture. According to Weibel, the architect of the future deals with "data and information transfers" instead with movement of bricks and concrete (Weibel, 2003). Since the algorithm can have multiple inputs, it is being fed not only with specific architectural knowledge, but it is expanding itself for multiuser input. Therefore, this thinking refers to the change of architectural practice, and it does not suggest that architecture stops being architecture and become something else. More importantly, it advocates the rethinking of architectural design process in a more organizational way similar to development of software products.

The logic of selection argued by Weibel is a good example of how the set of design practices and conventions is now encoded in the software itself. The result is a new form of control over design process. Although computer software somehow "neutralizes" the model of authorship, there is authorship as selection and interpretation: an author puts together an object from elements that he himself did not create. The creative energy of the author goes into selection and sequencing of elements rather then into original design. It seems that this method in digital media means a closed loop between the interconnected authors feedings the system, since they can make selection only based on information already available in the system.

1.3.4. Topic: Comprehensive Designer - the specialist in an emerging synthesis of artist, inventor, mechanic, objective economist and evolutionary strategist (according to Fuller)

Algorithmic instructions as planning methods lead to process orientated Architecture, or at least to the idea that Architecture is a process or data-based application within specific operating systems. Weibel claims that therefore innovation happens as a change in condition of design proceedings, and algorithms influence these changes (Weibel, 2003). Furthermore, the creator himself (architect, artist, musician, author), who interprets the products of the algorithm, is a part of that algorithm. That means that not only the architectural output, but also the creative design process, according to Weibel, will significantly change. It is argued that the creativity means algorithmic planning, which incorporates *the unknown*, the events beyond the subjective horizon of a single person. Since such systems operate through the problem-solving interpretations and not genesis, the creativity it is not matter of creation, but the interpretation. It becomes obvious that one single person as designer, the creator, is not a sound concept anymore. This shift occurs because of the overwhelming number of operations and possibilities . A single human mind cannot make rational, advantageous choices in these circumstances. The concept of algorithmic architecture allows multiple authors (agents) within the design process. Or with other words algorithmic architecture allows their organization. The creative process of interpretation and subsequent design decisions necessitates the collaborative interconnection of several experts and thus multiple authorship. Instead of a single person knowing many things, we have situation many persons know many things. This *collective intelligence*[41] substitutes so-called "Comprehensive Designer". Buckminster Fuller coined this term in

[41] The term "collective intelligence" will be explained in the next chapter "Contextual Terminology."

"Comprehensive Designing."[42] He describes the designer as "the specialist in comprehensive design in an emerging synthesis of artist, inventor, mechanic, objective economist and evolutionary strategist." (Fuller, 1963) Fuller trusts the Comprehensive Designer with tasks to synthesize the social, political, economic, technological, and environmental as single entity into design for globalized world. After 40 years now we know that this is impossible task, but Fuller pawned the way for ideas of interconnecting different domains to solve global problems of today's society. Buckminster Fuller foreseen that the "innovation" in the architectural practice is a paradigm switch in the domain of collaborative design methods, as well the strategies for comprehensive inclusion of different disciplines.

However, instead of one supreme Designer representing all the various disciplines in one person this thesis goes one step further and proposes to acknowledge interconnection of experts from various domains. This condition opens up the filed of operation and demands the transparency in working proceedings. In this context, to seek an interrupted flow means applying the algorithm-based digital tool in the designing process, through which the transparent medium produces, an event state in the stakeholder's experience. The aim of an application of transparency is immediacy producing new knowledge for the user involved in the design process. As this knowledge is gained through an collaborative experience, it can be defined as a creative layer of technologically-mediated experience. To open up the process of the collaboration between more authors and to establish a system that facilitates knowledge exchange, the argument in this chapter looks as well at the conception of "openness" and "responsiveness" in context of creative collaboration. It is argued that openness can be viewed as an architectural concept and responsiveness as a technological concept and proposes a revision to produce a new framework for technology based architectural production.

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[42] R. Buckminster Fuller, Ideas and Integrities: A Spontaneous Autobiographical Disclosure (First Edition 1963, New Edition 2010, Lars Müller Publishers) pp. 232-33.

1.3.5. Topic: Openness of architectural concept and responsiveness of technology, as immediacy for producing new knowledge.

An open and responsive working environment for knowledge sharing and production includes the concept of *transparency*. According to Rowe and Slutzky, transparency can be "literal and phenomenal."[43] The phenomenal transparency and immateriality describe structure as a form and not as the physical shape of the object. The transparency of the structure is read as an open system of relationships on various layers (semantic, syntactic, physical, emotional, etc.) The notion of openness is taken from Umberto Eco's investigation of participatory art.[44] By revisiting Eco's original concept of semiotic openness, the emphasis lies on the significance of the concept of "meaning creation". From this, a re-evaluation of openness for digital technology-based design process provides a solution for technology driven applications such collaborative platforms. Umberto Eco claims in his book "Opera aperta" that open artwork is an abstract hypothetical model, for which it is not much of importance how the problems have been solved, but rather how the problematic questions have been stated. He also distinguishes between "Meaning" and "Information" – information as a possibility to inform, as a virtually possible structure. As an instrument to apply his theory, he uses the book "Finnegan Wake" by James Joyce. He argues that this masterpiece of modern literature is unreadable just because it can be read in so many ways. It is clear to him that the reader does not have to understand every sentence or word of the text, since the strength of this text is in its permanent ambiguity and mixture of many possible meanings, which are free to be chosen, but from a non-predefined choice, or are filter-dominated. In Joyce's work there is no hierarchy of values, but constant juxtaposition. The book does not end, since it did not start in any particular way; it does not tell the story it is a story for itself. This method

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[43] Colin Rowe, Robert Slutzky, *Transparent: Literal and Phenomenal* (3. erw. Auflage, Basel, Birkhäuser: 1989) 21-41

[44] Umberto Eco, *Das offene Kunstwerk* (8. Aufl., Suhrkamp, Frankfurt am Main: 1998)

embraces an unexpected result as well, since no option has been removed. As a result "Finnegans Wake" introduces procedures and methods of "algorithmic design" by reflecting the computational forms of thinking into forms of language and semantic relationships.

Eco has anticipated that the "artist-artwork-spectator" triangle (or analogy in architecture: designer-design-user) can be seen as an algorithmic flow in which the quality of the artistic creation (or design) is immediately manifested through the openness and responsiveness of the system. Comprehending the design experience as an algorithmic-flow phenomenon, next section introduces the terminology and the concepts of multiple authorships, where the stakeholders from different disciplines are interacting as content creators, and explains the context of possible technological environment, which enables such content's creation.

2. Research outline and methodology

This investigation builds upon a practice-based methodology, setting up a discourse focused on technology-based design processes and outcomes. Through practice-based research this thesis aims to develop a more effective model for transdisciplinary creative collaboration applied through the development of new architectural projects especially on urban planning scale. This research applies an interdisciplinary investigation which uses accounts from the fields of philosophy, design and art theory, computer science, network science, information theory, looking for emerging concepts or approaches which, through a re-conceptualization, may serve to produce contemporary solutions to technology-based architectural practice. The examination builds a body of evidence through a review of literature within these relevant fields, bibliographic and archival research of digital media, analysis of technology-based practice, critical reflections on contemporary architectural and design practices, and collaborative work with scientists, programmers and other participants of the A.N.D.I. Project in recent years in what is termed an *evolutionary collective creative process*[45](Fischer and Nakakoji, 1997). The evidence-based research also profits from concept-based investigations (for example the concept of algorithmic design or the concept of transparency), in a transdisciplinary context, generating new insights of specific conceptions. Through the critical discourse of architectural practice based on advanced computer technology, this thesis suggests solutions for applications through this proposed new model. By applying the *Infospace* model, the practice-based work of the research will attempt to present a sophisticated outcome, which proves to be an innovative solution to the identified lack in architectural practice.

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[45] G. Fischer and K. Nakakoji, *Computational Environments Supporting Creativity in the Context of Lifelong Learning and Design* (Special Issue of the International Journal "Knowledge-Based Systems," Elsevier Science B.V., Oxford, UK, 10, 1997) p21

2.1. Theories: Actor-network theory, Connectivism, Activity theory. Complexity theory & Design Methods

To deal with complexity in organizations, for example the environments for creative collaboration, understanding of complexity theory is necessary. By the definition: "Complexity Theory envisions adaptive systems as neural-like interactive networks of agents and seeks to understand the dynamics of network behaviors."[46] New behaviors emerge seemingly unbidden and cannot typically be traced to simple input events such as mutations. Complex systems behave in quite complicated ways because of the nature of interdependent interactions, and they thrive from cooperation more than competition. According to Marion, complex systems are probably best described as information processing systems because of their dual ability to store, yet dynamically process and change, knowledge.

2.1.1. Complexity paradigm (difference between chaos and complexity)

Beside the implication in the domains of biology and physics, complex theory can be applied to the social sciences and to the architecture as well. It is possible for the theories from biology to be adopted to explain social interaction. According to philosopher Thomas Kuhn, science undergoes recurrent "paradigm shifts,"[47] or sudden changes in perspectives regarding natural behaviors. "Paradigm shifts produce dramatically new ways of understanding present reality; they allow us to 'see' new realities that, in retrospect, were there all along but were ignored or were unseen. Paradigm shifts generate completely new sets of hypothesis about the human environments and often require new analytical tools to convey the studies of those ideas."(Kuhn, 1962) So why

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[46] Russ Marion, *Complexity in Organizations: A Paradigm Shift*, in Chaos, Nonlinearity, Complexity, ed. A. Sengupta (Berlin: Springer-Verlag, 2006),

[47] Thomas Kuhn, *The Structure of Scientific Revolutions* (Chicago: University of Chicago Press, 1962)

is "paradigm shift" of interest when we talk about complexity of transdisciplinary collaborative environments in architectural practice? First there is, as mentioned in section 1.2, the claim by Carpo that implementation of digital tools in architectural design practice propose a "paradigm shift"(Carpo, 2011). Second the amount of data we are dealing with today is according to Watts overwhelming for any profession, so there is a "paradigm shift" in scientific approach and practice needed (Watts, 2003). And finally, as claimed in this thesis, the introduction of transdisciplinary approach in design collaboration, impose new sets of hypothesis about architectural practice as complex collaborative environment. In this context especially are interesting the complex relationships of stakeholders from different disciplines among themselves.[48]

The "complexity paradigm" is part of chaos theory since it shares the uncertainty and nonlinearity of chaos. According to Marion: "a major difference between chaos and complexity (aside from complexity being less dynamic) is the fact that complex systems (and the agents that comprise them) are adaptive: they 'intelligently' change their behavior and structure to adapt to environmental contingencies." Complex systems rely on chaos to conduct *dynamicism*. Complex systems implement change during the information processing by creation of unpredictable results. On the other hand, they have to establish sufficient stability in order that change and new information can be used and developed further on. This ambiguous state is defined as "edge of chaos,"[49] where optimal fitness of the system[50] is introduced. At this state complex systems can process, modify, and store information, by minimizing the possibility of destructive change.

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48 The findings considering these questions will be discussed in Chapter 4 sections 4.4 and 4.5

49 Chris Langston, *Studying artificial Life with cellular automata*, Physica 1986

50 Stuart Kauffman, *At home in the universe: The search for the laws of self-organization and complexity* (New York: Oxford University Press, 1996)

The application of complexity theory to complex organizations allows us "to understand organizational behavior in new ways, to redefine the role of leadership, and to envision new ways to organize, coordinate, and motivate workflows" (Kuhn, 1962). This complexity changes the way we understand organizations. According to Kuhn, the complexity theory "alters our core paradigmatic focus." Based on technological advanced of today we can advocate a change in collaborative design process too. In history, whenever something new emerged it was an event mostly connected to changed production methods and usage of new technologies. Thus, to establish the transdisciplinary design collaboration as a valid method (if this can be argued "paradigm shift" in current architectural practice), we need to understand the essence of change in a creative process.

2.1.2. Observer effect / Essence of change / Point of view

In ancient Greece there were many disputes about the nature of change. Some philosophers like Heraclitus thought that everything flows and nothing can escape from change. In contrast, Parmenides thought that everything is what it ought to be, and therefore could not become something that it is not. 5 B.C. he offered a new hypothesis, namely that all matter consists of minute, indestructible units he called atoms. The atoms themselves have remained invariable because they have had fixed attributes, such as size and form, but could move freely and could connect with one another building microscopic bodies that seem to be variable. All changes in the world were simply explained through new connections between atoms in empty space.

In his book "Principia,"[51] Isaac Newton introduced his famous laws of motion. Like the Greek atomists, Newton described matter as passive and inertial. Newton's mechanics presented a clear connection between cause and effect, and the mechanical representation required that matter

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[51] *Philosophiae Naturalis Principia Mathematica*, also often translated as *Principia Mathematica* or simply *Principia*, is the main work of Sir Isaac Newton. The Latin title translated means "Mathematical Principles of Natural Philosophy".

oriented itself strictly according to the mathematical laws. The lore which describes the universe as consisting of inertial matter which is closed in into a kind of deterministic giant clockwork has pervaded in many fields of human research. In the beginning it was the Theory of Relativity, which questioned Newton's presumptions about time and space.

Quantum Theory has fundamentally changed our perception of matter. The expansion of the quantum theory, the quantum field theory, has even gone a step further: It creates a picture in which the solid matter simply resolves itself and is being replaced by motionless impulses and oscillations of invisible field energy. All this has peaked in the so-called Superstring Theory which tries to combine space, time, and matter, and tries to build them from the oscillations of submicroscopic ties of invisible strings which inhabit a ten dimensional imagined universe. Quantum mechanics allows for the reconciliation of seemingly contradictory observations for a single atom atom. It is not about imagining atoms, electrons, etc. as small "things" that can exist on their own. The theory is to be viewed as a summarizing procedure of these observations in an integrative and logic system – a mathematical algorithm. Niels Bohr, one of the founders of quantum mechanics, states the following: "Physics is not about what the world is like, but rather what we can say about it."[52] Quantum mechanics, whose core is the Heisenberg uncertainty principle. says that all things that are measurable underlie coincidental fluctuations - they are inherent in the effect of nature on an atom level. An element of unpredictability is therefore an essential component of nature.

By following the understanding of change mentioned above, one may conclude that the rigid determinism of Newton's clockwork-like universe, inspired by Greek Atomists, is resolved into nothing and is being replaced by a world in which the future is open and matter brakes open its rigid barriers and becomes the creative element itself. Matter has lost its position and has been replaced by concepts of organization, complexity, and information.

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[52] Paul McEvoy, *Niels Bohr: Reflections on Subject and Object* (2001) p. 291

For some time, it has been assumed that determinism and predictability belong together, but the crucial point of a *chaotic process* is that predictions of failure emerge with time. In this case, physicians speak of a “hidden degree of freedom”.[53] The Heisenberg uncertainty principle is commonly being mistaken for the so-called “observer effect”.[54] The uncertainty principle describes in fact how precisely we can measure the position and impulse of a particle – if we increase the precision of measuring one quantity we will loose the precision at measuring another one. This principle obviously deals with measuring, not with observation. In science and in languages in general the term “observation effect” refers to change as an act of observation of a phenomenon. This means that if we observe something the observed will change. For an electron to be “seen”, for example, the electron needs to interact with a proton first, and this interaction would then cause the change of it. In sociology, this effect refers to the action of a person when he or she is being observed, i.e. how people change behavior when their activities or actions are being observed.

For creative design collaboration change is essential. It is unachievable to foretell what the next creative step of a participating designer will be[55], but through observing his actions and interactions with other users it is possible to define his/hers mental point of view (personal approach, view to design topic) in all likelihood. This *Point of View* is the condition, which defines the intelligent methods for the decision support to extend the possibilities of creative actions within a dynamic reconfiguration of creative collaboration. If we would map this approach to the creative design, it could be generally claimed that: the design is unpredictable process in flow of information within constant change under observation by the humans involved from their own point of view. Ideally, the advance technological environment would help us to

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[53] http://en.wikipedia.org/wiki/Quantum_decoherence

[54] B.D'Espagnat, P.Eberhard, W.Schommers, *Quantum Theory and Pictures of Reality* (Springer-Verlag, 1989)

[55] By using the analogy based on the uncertainty principle, one can tell that if we would measure creativity or creative actions we would lose out on another accuracy on the other side, or we would limit the possibilities of the following step.

understand and describe this framework to meaningfully interact within the same. However, to tame the complexity of such processes, novel strategies, methods, models and tools have to be introduced, which requires an understanding of the complexity of practice-based design enterprises themselves.

2.2. Objectives and goals of research

A.N.D.I. (A New Digital Instrument) has been imagined as a collaborative design platform. It has been developed as an instrument, an open source project, with objective to develop a run-time environment with the focus on the development of applications for networked international and transdisciplinary production in the creative sphere of architecture design and urban planning. A.N.D.I. has two basic aspects. On the one hand, it is a database driven collaborative environment and on the other hand it will enable the development of future software and tools for networked creative collaboration. The objective and vision of the project is to bring transdisciplinary project partners together and create a virtual working space for the projects in their first creative conceptual phase.

Essentially, A.N.D.I. is a system development project including the usual phases, from the collection of requirements, research, conceptual design of the prototype to the implementation of the A.N.D.I. engine, testing and optimizing the prototype and the establishment of a dissemination and exploitation strategy. In addition to these “standard” tasks A.N.D.I. comprises test projects (the Case Studies) to give input about the system specification and exploitation opportunities, since many important parameters defining the system performance can be and should be evaluated for system development. The main task and the information flow between these tasks are shown in the following Figure 1.

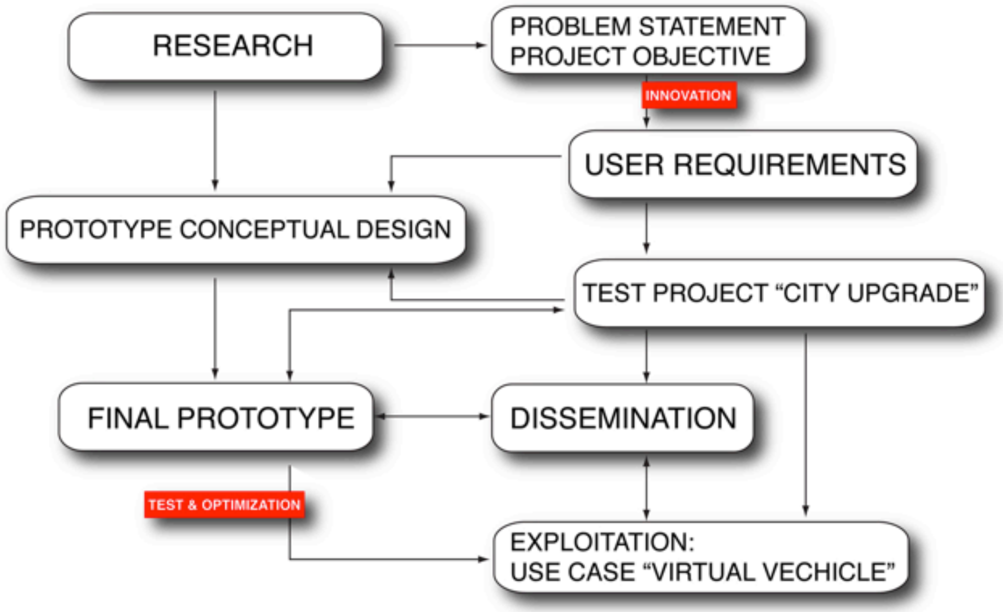

Fig. 1: Project tasks and the information flow between these tasks for A.N.D.I. project

The project's aim has been defined to cross the existing borders in collaborative environments where ideas and creations through intensive work done by stakeholders involved in design process meet with state-of-the-art Information and Communication Technologies (ICT). In such a setting, ICT is used beyond data and information processing to enable idea sharing, creativeness, and interaction. The process is very complex in a sense that it integrates multiple aspects of the problem, including heterogeneous data formats, idea representation and communication, creative design process support, interaction and collaboration support, automatic mapping of the problem aspects onto users' input, identification of value-creation networks within the process, and mechanisms for successful dissemination of the design outcome. Hence, the conceptual design and development of such a platform requires a unique combination of specific knowledge and experience to successfully conduct integral research and development in the fields of software development and transdisciplinary collaborative practice in architecture.

The intention was to create a tool for an interconnected, distributed, and multi-perspective authorship, which allows new creative output and innovation in architectural design practice. The first necessary steps in this direction have been the following two:

- improved communication between user and developer
- generation of complex system of parametrical procedural decisions.

This collaborative environment as already mentioned is envisioned as an operating system, an instrument to work transdisciplinary and internationally in a particular from at the very beginning of the design to increase the creative dimension of the project and gain innovation in design. In addition, this collaborative environment should provide an optimal use of time and work resources of complex collaborative setting. Furthermore, it should prevent the loss of information by allowing that the project partners can work parallel and from all over the world on the same problems and share the same infrastructure.

The project partners can work independently from one specific place as soon as they are connected to the Internet. The working within environment should be possible through a common web browser, independent of the operating system (Windows, Linux, Apple) or software configuration of the user's machine, under the circumstance that the Java console is working and the needed browser plug-ins are installed. In the sense of open source software,[56] the users could even extend the features of the platform and add their modules for specific tasks. Such collaborative environment should enable innovation and a new generation of architectural and urban concepts concerning:

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[56] According to Eric S. Raymond there are two models of gaining the knowledge when we try to understand a certain system, which he explains in his book "The Cathedral & the Bazaar." Open source and free software models made it possible for a still growing world-wide community not only to understand the code of the first Linux version provided by Linus Torvalds, but also to contribute and participate in such an engaged way which no company in the world could afford, making Linux to one of the top operating systems besides Microsoft (which Raymond considers as the cathedral) and Apple OS X (which is based on Linux). From the technological point of view A.N.D.I. is an open source project, but also from the point of view of conception it is strongly committed to open source ideas. The lack of the commitment to the project and common goal, as well as the misunderstandings within collaborative praxis can be fatal for the projects described in this dissertation.

- transdisciplinary authorship,
- creative input,
- unexpected output.

Following the collaborative strategies in terms of user-context and agent-based collaborative applications the interaction between all involved stakeholders (specialists and users) should be established. Therefore, the collaborative environment needs to support processes that allow the collection of input from various sources and an open environment where everybody involved can access and understand the development of the solution. For A.N.D.I., as an engine for facilitating "bottom-up" distributed creative collaborative processes, collaborative design methods should be implemented on three levels:

- the level of implementation
- the level of interface and process design and
- the process of working collaboratively on a creative task

2.3. Formation of the transdisciplinary collaborative teams - workshops, events.

A.N.D.I. project has been in development since 2001. After three years of theoretical research, conceptional phase and one year of programming, the project "City Upgrade" emerged: H*igh Spirited Networked City* in 2005 was the first case study for testing and debugging it. The projects A.N.D.I. and City Upgrade go hand in hand in their development. Therefore, in the research framework of this thesis, the author will not distinguish between the formation of the A.N.D.I. and City Upgrade transdisciplinary team. Work presented here focused on the overlap and mutual interference of those two projects. Initial programming phase of A.N.D.I. has ended in 2005 and from thereon the further improvements have been done based on experience gained through the Case Study "City Upgrade".

The main challenge at the initial phase of the project was to introduce to all involved stakeholders completely new working methodology and a new Interface Design based on a synchronic working process. Many users involved in A.N.D.I. and City Upgrade project were familiar with their own tools, but when it came to collaboration with other professions, especially at the creative stage of a project with unknown end-results, it was crucial to generally understand the different working approaches in collaborative environment such as A.N.D.I..

During the first period of time from November 2004 to October 2005, various strategies of reconsidering the collaborative environment as to be able to adapt ”intelligently”, i.e. self-regulative and self-optimizing, to new working methods were discussed and investigated in a collaborative environment of a transdisciplinary team. A heterogeneous group of professionals from diverse disciplines (architects, city planners, media artists and theorists, philosophers, regional politicians) was invited to share their knowledge and contribute their input. All project participants were encouraged to “keep walls low enough” so that the sharing of intellectual property and ideas which today is more and more necessary to do innovation[57], would be possible.

[57] Thomas L. Friedman, *The World Is Flat: A Brief History of the Twenty-First Century* (New York: Farrar, Straus and Giroux, 2005) 217. See also Henry W. Chesbrough, Open Innovation: The New Imperative for Creating and Profiting from Technology (Boston: Harvard Business School Press, 2003)

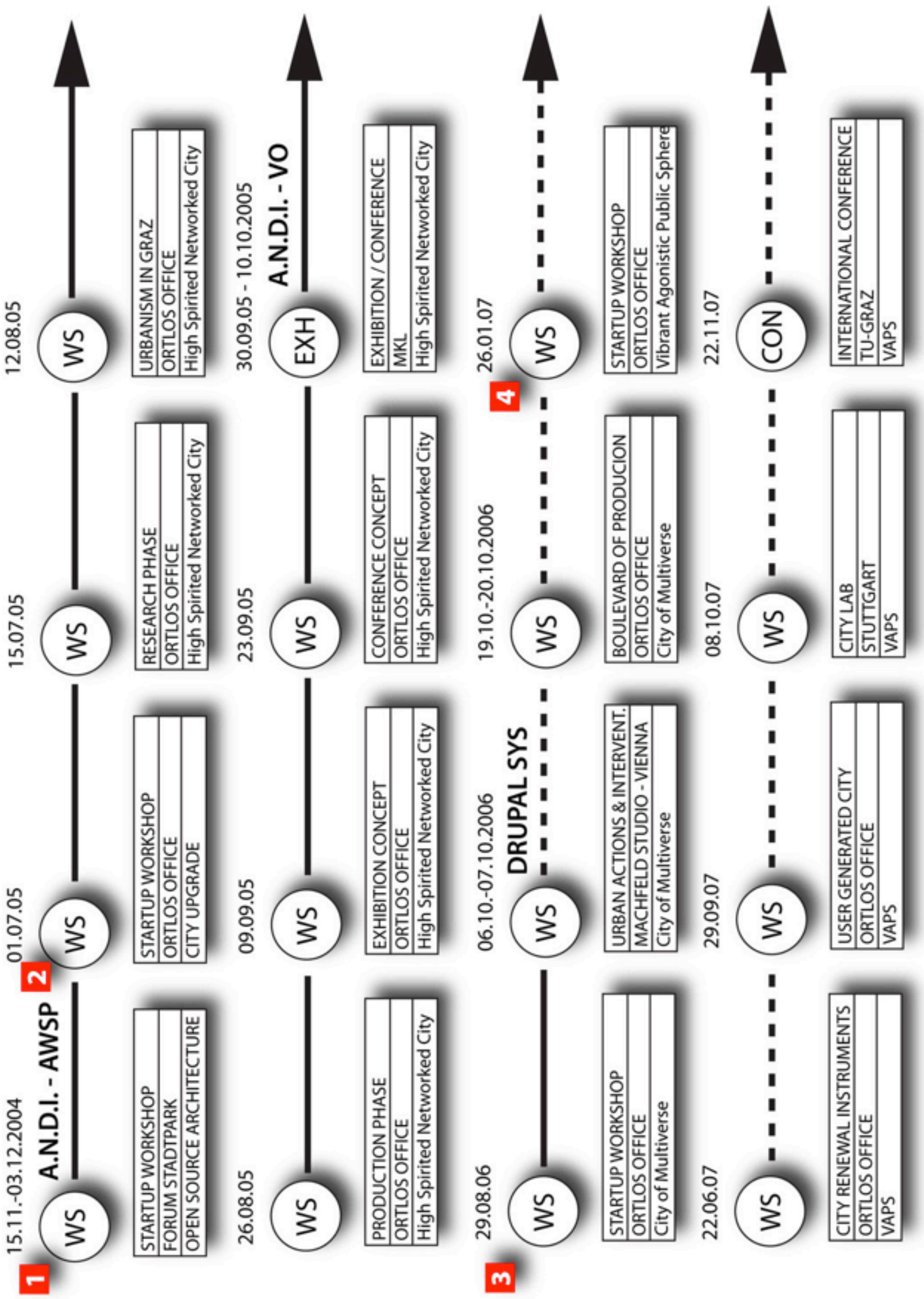

Fig. 2 hows the project timeline for "City Upgrade", defining type of event, topic, place and sub-project name. The A.N.D.I. system was used from 15.11.2004 until 06.10.2006. Collaboration was mainly tracked and analyzed in 2005.

According to Pynadath[58], for teams to work together successfully, it is imperative that the team coordinators or project initiators make sure that commitment of stakeholder and trust into project's goals is forged in a

58 D.V. Pynadath, PsychSim: Modeling theory of mind with decision-theoretic agent, IJCAT 05, 1181-1186

deliberate and explicit way. It is, therefore, the transdisciplinary team coordinator's responsibility to exhibit behaviors that engender and reinforce trust, including making social conversation, showing enthusiasm and responsiveness in team interactions, demonstrating a predictable and consistent communication and providing substantial and timely responses to inquiries. The first step in understanding why a virtual team is not performing well is to understand that there are different types of potential conflicts. The "human factor" plays important role in terms of communication and it could invoke problem situations based on: "lack of clear agreements, personality style differences, different observations/ perceptions, different interpretations/language, different feelings, different needs/outcomes, different cultures, different genders, urgency and stakes" (Pynadath, 2005).

Pynadth finds out that it is difficult to model a system by holding both the societal view and the individual agent view, since "the societal view involves the careful design of agent-to-agent interactions so that an individual agent's choices influence and are influenced by the choices made by others within the society. On the other hand, the agent view involves modeling only an individual agent's decision-making processes that sometimes follow intuition and bounded rationality" (Pynadath, 2005). A difficulty in modeling theories about agent and society exists in quantitative or qualitative modeling of uncertainty and preference. In the case of quantitative modeling, the traditional models like game theory and decision theory have their own limitations. Game theory[59] typically relies on concepts of equilibrium that people rarely achieve in an unstructured social setting, and decision theory typically relies on assumptions of rationality that people constantly violate.

Again, all of these issues have been a product of still relying on using collaborative methods and experience connected to the traditional collaboration practice in architecture. Therefore, some additional investment was necessary to overcome the current “mind-set” of the users. Consequently, most of the problems had a psychological nature, not showing the failure of the novel system, but showing high threshold in acceptance of the novel system. In the course of A.N.D.I. project it was also proven that many problems had arisen within the collaboration between architects (team members who are educated architects), since it was feared that other designers may interfere with their own design or even worse, use somebody else’s ideas and present them as their own. There is, of course, still a need for us to “re-tool” and “re-engineer” ourselves to cope with this new, transdisciplinary approach towards innovation.

The following sections show all involved participants. Their role within the project was based on their profession, which is stated bellow. Some participants had provided only an input to the project during the

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[59] “Game theory is a branch of applied mathematics that is used in the social sciences (most notably economics), biology, engineering, political science, international relations, computer science, and philosophy. Game theory attempts to mathematically capture behavior in strategic situations, in which an individual's success in making choices depends on the choices of others. While initially developed to analyze competitions in which one individual does better at another's expense (zero sum games), it has been expanded to treat a wide class of interactions, which are classified according to several criteria. Today, game theory is a sort of umbrella or unified field theory for the rational side of social science, where social is interpreted broadly, to include human as well as non-human players (computers, animals, plants)”(Aumann, 1987).
“Traditional applications of game theory attempt to find equilibrium in these games. In an equilibrium, each player of the game has adopted a strategy that they are unlikely to change. Many equilibrium concepts have been developed (most famously the Nash equilibrium) in an attempt to capture this idea. These equilibrium concepts are motivated differently depending on the field of application, although they often overlap or coincide. This methodology is not without criticism, and debates continue over the appropriateness of particular equilibrium concepts, the appropriateness of equilibrium altogether, and the usefulness of mathematical models more generally.” (Wikipedia, April 2009)

workshops and conferences that have been organized on various occasions. More precise timeline will be described in the chapter about the Case Study "City Upgrade". From the beginning of the project Ortlos' team members had the leading role and have been in charge of all organizational and managerial issues.

2.3.1. 2004/2005, Start-up Workshop & 1st Project year: "City Upgrade – High Spirited Networked City"

- Architects: ORTLOS Space Engineering - Ivan Redi, Andrea Redi, Vincent Cellier, Kira Kirsch / SPLITTERWERK Architekten - Mark Blaschitz, Hannes Freiszmuth, Edith Hemmrich [A] / WSKKFV – Elisabeth Oswald, Carola Peschl [A]
- Programmers: Aleksandar Stoiljkovic, Nebojsa Dinic - ORTLOS doo [SRB] /
- Philosopher: Georg Flachbart - mind(21)factory [D] /
- Urbanist: Institut für Städtebau - Grigor Doytchinov [A]
- Media artist: Martin Krusche, NetzLiterat [A] /
- Politics: Christian Buchmann - Grazer Kulturstadtrat [A]
- Input: TU Graz Institut für Architektur und Medien - Urs Hirschberg [A] / ETH Zürich Institut für Städtebau - Kerstin Höger, Maia Engeli [CH] / reMI, Michael Pinter, Renate Oblak, Media Artist [A, NL ,D] / SU.N spaceunit.network – Andreas Mayer, [A,I] / Srdjan Jovanovic Weiss, Architect [USA]

2.3.2. 2006, second project year: additional to 2005 "core team": City Upgrade - City of the Multiverse"

- Media artists: MACHFELD - aka Sabine Maier & Michael Mastrototaro [A]
- Architects: OSA - Anke Strittmatter [D] / JVC Architecture - Vincent Cellier [F]
- Technology experts: Visenso - Martin Zimmermann [D]

2.3.3. 2007, 3rd Project year: "City Upgrade – Vibrant Agonistic Public Spheres"

- Architects: ORTLOS space engineering - Ivan Redi, Andrea Redi, Gudrun Jöller, Florian Absenger, Marko Russo, [A]
- Philosopher: Georg Flachbart - mind(21)factory [D]

- Urbanist: Grigor Doytchinov - TU Graz, Institut für Städtebau [A]
- Computer Science: Sven Havemann - TU Graz Institut für Computergrafik und Wissensvisualisierung [A] / Manfred Bogen und Gerold Wesche - Fraunhofer Institut Intelligente Analyse und Informationssysteme [D]
- Photographer: Emil Gruber [A]
- Input: Charlotte Pöchhacker, Artimage [A] / Archi-Tectonics – Winka Dubbeldam [USA] / Schauspielhaus Graz - Jaschka Lämmert [A] / Tanaka Business School ThinkPlayDo Group at the Imperial College London - Nick Leon [GB] / University of Westminster Political Theory at the Centre for the Study of Democracy - Chantal Mouffe [GB] / Creative Industries Styria - Eberhard Schrempf [A] / ZKM Center for Art and Media Karlsruhe – Peter Weibel [D]

2.3.4. 2008, 4th Project year: "City Upgrade -"Sensitive Space 7/24", 11th Architecture Biennale 2008, Venice

- Architects: ORTLOS space engineering - Ivan Redi, Andrea Redi, Gudrun Jöller, Florian Absenger, Marko Russo, Stefan Schmol, Georg Kettele [A]
- Composer: Beat Furrer [A]
- Curator: Charlotte Pöchacker - Artimage [A]
- Philosopher: Georg Flachbart - mind(21)factory [D]
- Photographer: Emil Gruber [A]
- Computer Science: Sven Havemann - TU Graz Institut für Computergrafik und Wissensvisualisierung [A] / Frank Kappe - TU Graz Institut für Informationssysteme und Computer Medien [A]

2.3.5. Balanced team members' roles and their importance

The following table visualizes the numbers of team members mentioned above through years 2005 to 2008. Further it categorizes the team members in regard of their profession and thereafter their role in the project. Interesting observation as shown by Table 2 has been that in the beginning, in 2005, architects were the dominating profession with 46% of participants. After 2 years in 2007, the expertise has been more balanced in terms of team members, with the number of architects decreasing to 17%. At the time the first serious project spin-off emerged, “City Lab”[60], and was ready for realization, the concept “Boulevard of Production” as the lead idea became important for the project “City Upgrade”. This outcome shows clearly that A.N.D.I. works better as collaborative environment within a transdisciplinary environment, including the experts from different disciplines, but not as an instrument for the collaboration between architects mainly, or any other single discipline.

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60 **City Lab** – http://www.ortlos.org - is a large-scale instrument of the beyond-the-desktop-era 3D ambient computing for creative networked collaboration. This mixed-reality based space module is highly flexible due to its innovative user-responsive IT components, intelligent control mechanisms, and a novel workflow. Enriched by mobile and virtual elements, a broad spectrum of so-called on-demand spatial settings could be possible inside City Lab, thus enabling different kinds of SMEs to substantially improve their innovative performance in prototyping and developing new products or product ideas and, eo ipso, their overall competitiveness in the context of the globalized economy.
City Lab's genuine field of application is the **Knowledge and Imagination Economy**. We assume that in the near future this economy will be playing a leading role in Europe and that it will require new socio-spatial environments that are able to offer optimal working conditions to support a work style characterized by increased mobility, high levels of creativity and powerful 3D simulation capacity.
The preferred locations for City Lab’s implementation are: empty shops at the street level within existing buildings in urban inner-city areas. Many examples for a "dying street", a street that lost its previous function, can be found in every medium-sized European city (therefore the name of the installation is **City Lab**). The aim is to upgrade those inner-city areas by means of *production instead of consumption*, the latter has been the usual, mostly unsuccessful practice urban development practice until now.

Profession	2005	2006	2007	2008
Architect	6	3	2	1
Computer Scientist	2	1	2	2
Philosopher	1	1	3	1
Urban planner	1	1	1	0
Writer	1	1	0	0
Politician	1	0	1	0
Media artist	1	1	0	0
Economist	0	0	1	0
Photographer	0	0	1	1
Curator	0	0	1	1
Composer	0	0	0	1
TOTAL PARTICIPANTS (TEAMS)	13	8	12	7

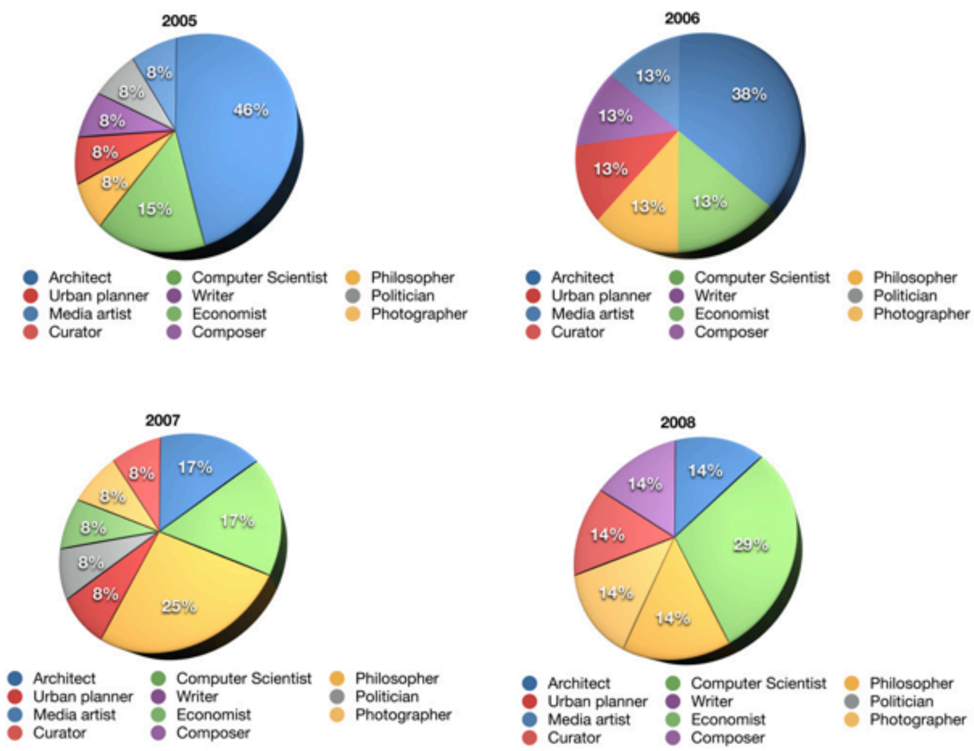

Table 2: shows participants' profession percentages through project years 2005-2008. The diagram shows more that balanced team formation in terms of included disciplines and their roles in later years, compared to the initial situation with concurrent expertise and overlapping roles. The impact of such team formations and balance between participants from different disciplines will be discussed in more detail later in the chapter 4 about Case Study "City Upgrade".

Today, the architect's job of envisioning the future needs of users is not an easy task. To name one example the global demand for sustainability challenges numerous current issues such as the effects of climate change, natural resource over-consumption, greenhouse gas emissions, transport, economic regeneration, etc. Therefore, the development of new strategies, technologies, processes and innovative practices with respect to collaborative performance including stakeholders from different disciplines is crucial. The complexity of given situation requires innovation within the architectural practice and this thesis proposes as solution the transdisciplinary design collaborative environment, where new ideas and designs emerge by implantation of novel networked collaborative methods and tools. In research and development initiatives for the next 25 years Dawood et al see the *knowledge management*[61] of intelligent information systems in the first initiation phase of design process as high priority[62]. Thereafter, the communication, concurrency, and collaboration will change toward: web-based collaboration, mobile technologies, stakeholder interaction, data exchange and common standards, design reuse, enterprise function. The idea here is to support the collaborative design process by collaborative design environment in a virtual value chain with no time, distance, or organizational boundaries. Next chapter describes conceptual and technological aspects, methods and strategies of such an environment applied to the author's architectural practice.

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[61] "Knowledge management (KM) comprises a range of strategies and practices used in an organization to identify, create, represent, distribute, and enable adoption of insights and experiences. Such insights and experiences comprise knowledge, either embodied in individuals or embedded in organizations as processes or practices." Nonaka Ikujiro, *The knowledge creating company* (Harvard Business Review 69, 1991) 96–104.

[62] Nashwan Dawood, R. Marasini and John Dean, V*R-Roadmap: A vision for 2003 in the built environments*, in Virtual Futures for Design, Construction & Procurement, Ed. Peter Brandon and Tuba Kocatürk (Oxford: Blackwell Publishing, 2008), 269

3. A.N.D.I. - Collaborative Environment for Transdisciplinary Design

This chapter explains in most parts the development of software project A.N.D.I., which is conceived as an instrument for creative transdisciplinary collaboration. However, the major focus here is not about software development only, but rather the description of strategies, methods and proceedings of how change and emergence take place in design process implemented through the software.

The discourse in this thesis is based on architectural research through practice. This chapter provides the background of previous and current research activity, highlighting the architectural practice of the author. The particular project “A New Digital Instrument for networked creative collaboration in architecture” (A.N.D.I.) will be discussed to contextualize the practice-based methodologies used in the discourse and also to display a research continuum and development of concepts of a platform, which should enable innovation in architectural practice. The A.N.D.I. Mission statement will be described, as the basis for the initial research, as well the system components, their functionality and as well user interface in particular will be explained.

Complex architectural and urban tasks require more knowledge than any single person can possess, and the knowledge relevant to a problem is often distributed and controversial. In our post-industrial society, new and complex urban systems are emerging through infrastructural and digital media as a result of a globalized economy and intensified exchange patterns. Orientation towards trans-local and networked environments forces us to think and work in a different way, and to produce novel (architectural and urban) solutions. As mentioned in previous chapter (sections 1.2 and 1.4) the claim is that the “innovation” in the architectural practice is a paradigm switch in the domain of collaborative design methods within the transdisciplinary setting (see section 1.3.1). Therefore, the collaborative design environment will be explained first in some detail, as a departure point for enabling innovation in architectural practice.

3.1. Collaborative Design Environment

Collaboration technologies are beginning to support what we could call "on-demand collaboration," where one can move fluidly and naturally from solo work to teamwork (asynchronously or in real time with team members or partners in other organizations). On-demand collaboration could be seen as a subset of the "human-based computing trend" in that the ultimate goal of the software is to support people in their computer-mediated interactions. As it became evident that working with external entities across the supply chain or with the customer base was of value to the organization, secure sites, called extranets, were developed that aggregated information for the group of internal and external participants on a project team. The latest developments are Wiki and CMS-based team spaces. These platforms were designed to make it relatively easy for participants to access and modify shared material, and since many of them are offered as a service, the users often did not need IT involvement to get them up and running.

There are a large number of online social network and community tools available now (e.g. Google Sites and Groups, Wikipedia, Leverage Software, Smallworldlabs, CollectiveX and many others), which can be used for creative collaboration. Many of Web 2.0[63] companies embrace the principles of transparency, ease-of-use, agile programming, little or no training required, and customer involvement. The types of tools offered by these applications provide variety of functions such as: user profiles, expertise discovery, brainstorming, blogs, wikis, multimedia file sharing, discussion forums, integrated calendar management, rating and ranking of content, group and role administration, community activity reporting, etc. Therefore, in most cases, these services can be used as collaborative platforms as well.

The new way of Internet-based collaboration, so called Collaboration 2.0,[64] has many of the same characteristics of Web 2.0 including: ease of use, transparency, interactivity and participation, the ability to create mash-ups of data or functions from several sources. As we moved to a knowledge-based economy with multi-national organizations, it became an imperative to work closely with others we may never meet face to face. The challenges many have taken up are those of: developing the same capacity, creativity, and competence to work efficiently and effectively with our virtual colleagues across the boundaries of time, space, culture and the same complex challenges inherent in working with other human beings in the ever-changing external and internal collaborative

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[63] During the development of the A.N.D.I. project (since 2001) new technology of social software has emerged. The so-called Web 2.0 and Collaboration 2.0 are web-based software systems that allow users to interact and share data. Many of these applications share characteristics like open APIs, service oriented design, and the ability to upload data and media. There is the assumption that by using these tools they create actual communities or “on-line communities” to describe the resulting social structures. Since it is still not quite clear what Web 2.0 actually is, either technological or social change of how people around the world interact today, it is not possible for me to use this terminology within my scientific work or as reference to the A.N.D.I. system. However, it is a fact that those social technologies are used in organizations, mostly in network-orientated ones, for the creation of knowledge that is carried out through collaboration. Some companies, such as Dessault, have realized the importance of social software and develop their future products in these directions in which they make less and less distinctions between “social” and “collaborative” technologies.

[64] The main difference between Web 2.0 and Collaboration 2.0 within an enterprise can be described as: where Web 2.0 is a consumer occurrence, Collaboration 2.0 is applying these methodologies and technologies in a more productive and managed way for particular users. See also Table 2 (Coleman et al, 2008) for analogy considering Enterprise itself, where the new ways of collaboration should be implemented.

environment. That fact of organizational life has driven us to the new frontiers of implementing Collaboration 2.0 into new way of enterprises (according to *Coleman et al* so called Enterprise 2.0). The following table shows differences considering enterprises at the moment and expected in the future.

Enterprise 1.0	Enterprise 2.0	Drivers
Static content and web pages, focus on content	Dynamic content, focus on interaction	Consumer Web 2.0 and social networking tools
Messages pushed by e-Mail	Information pulled through RSS feeds	Users want to personalize their information
Content produced, and edited according to policy	Content from blogs, wikis, and other participatory sites	User created content
Asynchronous interactions (e-mail)	Synchronous interactions (IM, Chat and SMS)	Net Generation, growing up with computers
IT imposed control of technology	Individuals use new technologies and create content	Situational applications, and IT backlog
Search and Browse for information	Publish and subscribe to information feeds	Overwhelming amount of information available
Transactional oriented interactions	Relationship oriented interactions	Expertise discovery, cross organizational teams
One application for everyone	Individual and niche applications	IT backlog and situational applications

Table 3: The following table shows the comparison of Enterprise 1.0 and 2.0 characteristics and drivers (Source: Coleman et al, 2008).

3.1.1. Complexity in collaborative environments

Recently, many scientists have applied discoveries from biology, such as the complex organization of ant colonies or bird flocking, as models for complex social structures of interaction. These theories would perfectly fit into Marion's ideas about dynamic, self-organizing, organically growing organizations. However, can those mechanisms of "collective intelligence" be applied to social systems and can be those used in creative collaborative design practice? There are several possible answers.[65] According to Lichtenstein et al the activities of firms are far more complex than are the activities of ants and birds, and such complexity may be dependent on intelligent interventions. Second, organizational behaviors often depend on not just adaptability, but creative adaptability, and

[65] Benyamin Lichtenstein, *Four degrees of emergence: A typology of complexity and its implication for management* (University of Syracuse, 2003)

leadership may help enable this. Third, humans are free-will agents; their work behaviors are not controlled by genetic dispositions, and thus humans require the organizing and coordinating actions of managers to accomplish the sort of motivation that ants and birds accomplish instinctively.

The scientific method is build up upon hypotheses, which can be tested. The models are systems of a vision, which are then tested, and the experiments then confirm or disprove of the theoretical model. Scientists have been claiming that correlation is not the cause, and that no cognition can be gained through the relation between two objects (because the relation may be a random one). On the contrary, first one has to understand the mechanism behind it, which connects the two variables. It is possible to connect the data sets if the models are available. The data without its models is only information noise. However, at the point when mathematical progression developed, we moved from the data folder to data libraries until the analogical possibilities came to an end. Ludwig Wittgenstein pointed the fundamental problems of every hierarchical classification system in the 1950's out; he proved this problematic nature through his example of family likeness in "Philosophische Untersuchungen" (Wittgenstein, 1953). The philosopher Michel Foucault criticized in his work "The Order of Things" (Foucault, 1974) the dubious nature of any categorization system as well, because they underlie a ligation of place and time.

The current understanding of organizations embraces Newtonian arguments that our collaborative practice is defined by functional relationship among variables. Causal, coordinated, and planed structures could enable the controlling of events in the future through the adjustments of input variables and complex events. Complexity theory changes this perception of organizational structures. Marion claims that it is premised on different assumptions: "outcomes derive from recursive interactions among numerous events (variables) and mechanisms (defined as an account of the behavior and interrelationship)."[66]

Creative processes in architectural production, as claimed here, do not build upon persistent relationship among variables, nor are their outcomes sequences of consecutive events, although day-to-day practice may suggest different. Especially in a transdisciplinary environment, which this thesis is advocating here, a creative event can be described as nonlinear function of complex, neural-like interactions. When stakeholders interact within collaborative organizations, they will adapt their structures and behaviors to accommodate one another. Within interacting network, agents and ideas combine and recombine unpredictably such that new structures or knowledge emerge from the dynamic process. Therefore, predicting outcomes should not be the focus, but rather the description of strategies of how change and emergence take place. These mechanisms deny prediction of an output and disobey explanation by establishing new working tools, which should enable complex behaviors that supporting organizations for knowledge production and innovation.

3.1.1.1. New paradigms of organizational behavior in complex collaborative environments

In the past, before the "digital" was introduced in architecture, the architectural production was based on linear process logic[67]. Current development of architecture - in digital information age - is challenging this thinking[68] and practice. New working methods focus on interactive, rather than on sequential causality. Further, often there is no proportional relationship between the behavioral patterns and the extent of emerging

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[66] Russ Marion, *Complexity in Organizations: A Paradigm Shift*, in Chaos, Nonlinearity, Complexity, ed. A. Sengupta (Berlin: Springer-Verlag, 2006) 248-271.

[67] Mario Carpo calls this "Albertian Paradigm": "Alberti's definition of architecture as an authorial, allographic, notational art held sway until very recently, and defines many if not all of the architectural principles that the digital turn is now unmaking." (Carpo, 2011, p44)

[68] Carpo implies that open-endedness, variability, interactivity, and participation are technological quintessence of the digital age. (Carpo, 2011, p126)

events. This of course increases the complexity of collaborative environments and organizations. A new set of rules and tool need to be introduced, which support unexpected, unpredicted and emergent innovation. According to Marion: "complex organizations do not engage in planning in the traditional sense, rather they engage in non-determinate visioning and mission-setting to foster emergent innovations."(Marion, 2006) Complex multi-perspective and interactive dynamics are the key driving forces in an organization. The interactivity during the creative process can happen on any level of non-hierarchical knowledge-based environments.

	Currently dominant paradigm of organizational behavior	Complexity theory perspective of organizational behavior
Core paradigmatic focus	Top-down, convergent on leadership	Bottom-up, convergent on interactive dynamics
The function of organization	Organizations enable humans to efficiently produce useful outcomes on a large scale	Organizations enable humans to effectively create knowledge that can produce useful outcomes on a large scale
Structural requirements	Bureaucracy or commitment based unites	Bottom-up, complex organization
Causation	a) Linear, process theory b) Epistemology based on variables c) Leaders are casual stimulants	a) Nonlinear, recursive theory b) Epistemology based on mechanisms and variables c) Interaction worldview
Causal implication	a) Outcomes are planned b) Leaders are casual stimulants	a) Outcomes are emergent surprises b) Leadership is an outcome
Motivation	Motivation by central structures (CEO's, bureaucratic rules, etc)	Motivation by interactive dynamics
Vision	Unity of vision	Heterogeneous and indeterminate visions
Definition of leadership	Leaders are individuals who create organizational energy through charisma, intelligence, interpersonal consideration, inspiration…	Leadership is energy that emerges across the organization under given enabling conditions

Table 4: Old versus new paradigms of organizational behavior (Marion, 2006): "Table contrasts differences between the current worldview of organizational theory (beliefs, perceptions, accepted values and definitions, etc.) and the worldview offered by complexity theory. The differences are not simply matters of style; they get at the very heart of how we think about organization and leadership."

By comparing two different perspectives on organizational behaviors (as shown in Table 4), Marion argues that the complex organizations that enable and produce knowledge, may implement innovation much more robustly than do centralized, top-down structures.

> "This perspective de-emphasizes the centrality of authority and emphasizes instead the core importance of effective network dynamics. It shifts the traditional perspective of organizations from top-down or centralized coordination to informal interaction among organizational agents at all hierarchical levels. Leadership's role becomes less to plan and coordinate and more to foster conditions that enable emergence and embedded coordination and motivation. This perspective does not deny

> authority, rather it adds a focus on informal networked interactions within organizations. Complexity theory suggests yet another control mechanism, one in which coordination is built into network dynamics rather than implemented by managers via bureaucratic rules or by co-opting meaning. This represents a dramatic departure from the traditional assumption (in both bureaucracy and management of meaning) that coordination is the responsibility of leaders within a context of top-down authority. Rather, coordination is embedded into the structure and activities of the complex organization. Such coordination strategies enable maximum flexibility and the capacity to respond effectively to highly volatile environments — a strategy that is ideal in knowledge-based economies." (Marion, 2006)

Naturally in networked collaboration as the complex organization the conflicting constraints are much more complex than those experienced by direct collaboration. Considering the interdependency and coordination issues among stakeholders there is a need for an *enabling organization*, which is required to define action boundaries without limiting creativity. Enabling rules and balancing participant's interests differ from traditional structures of carefully rationalized procedures. Otherwise it has been observed that inappropriate vision and not clearly defined mission can obstruct innovation in complex organizations. Since in some cases it is not made a differentiation between collective vision and project mission. According to Mumford et al. in practice the project mission is product, or solution, during the vision is a projection of the future, and there remains a need for methods, which can distinguish between the process, which enables innovation and simple fulfilling the predefined tasks.[69]

> "Complex vision envisions an indeterminate future, or a future that is unconstrained by current beliefs or understanding. For example, a vision that anticipates future creativity (an activity) is indeterminate because it does not anticipate a definable outcome; a vision that projects the future state of an existing technology is a determinate vision. This enables innovation (which by definition cannot be preordained) and creative knowledge growth while the latter simply unfolds what is already known." (Marion, 2006)

And yet, the project mission have to have clear objectives, since "they provide a structure for addressing problems, they provide a framework for idea development that does not unduly restrict the

[69] Mumford, M.D. et al, *Creating the conditions for success: Best practice in leading for innovation*, 2005

autonomy and potential unique contributions of team members, and they provide a framework for sense-making" (Mumford et al., 2005). The objectives should be set, however they should not predefine the creative outcomes, since the innovation is an event that diverges from current understanding. As Popper stated: "we cannot anticipate today what we shall know only tomorrow."[70]

3.1.1.2. Bottom up versus top down

In a top-down practice a project leader is responsible for following functions: motivation, coordination, and productivity; from the point of view of organizational structures advocated in this thesis (bottom-up), they are built in to the interactive framework. Marion describes motivation as: "function of networks of interdependent relationships in which individuals are responsible to each other for productivity." That means that stakeholders influence one another to produce meaningful results. Enabling rules that allow interdependent actions also enhances performance. In that sense stakeholders (individuals or groups) can be motivated by enabling environment to enforce each other, rather than just supporting the efforts to provide solutions to a given problem. Complex organizations emphasize heterogeneous vision. Marion argues that: "heterogeneous visions interact interdependently across a network of sometime conflicting, sometime congruous visions." Such interactions pressure agents to elaborate their visions and to form vision alliances. Networks of interacting stakeholders adapt and change as organizational knowledge and environmental contexts change and develop. Compared to top-down strategies, networked, heterogeneous collaborative environments are dynamic, self-organizing, organically growing. (Marion, 2006)

The next section introduces to reader the analysis of user context in collaborative environment and requirements for agent-based collaborative application. It offers general methods for using the described theoretical

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[70] Karl Popper, *The poverty of historicism* (London: Routledge, 1986)

framework for transdisciplinary design collaboration, based on the objectives for the A.N.D.I. project.

3.1.2. User context in collaborative environment

The investigation of existing collaborative environments available on the market showed that most of them are focused mainly on the organizational level of co-working. The main conception of those applications is to keep project data at the same central place on the Internet, so that all planers and consultants (so called sub-planners) can have access to reduce the loss of information, and to guarantee that the whole team is up-to-date. Existing Engineering Data Management-Systems or Product Data Management Networks are mainly developed to reduce building costs, to make facility management more efficient, and to optimize the time of planning and production, thus only economical aspects have been considered. In short, the scope and main usage of these online platforms are for project management, (like for example buzzsaw.com or conject.com, etc.), project co-ordination and administration (like procoon.com), or knowledge exchange platforms (such as Wikipedia).

Nevertheless, the specific user-context of creative design environments especially in regard of appropriate interface has been not acknowledged. The articulation of the User Interface of collaborative environment stayed within practical conception of data exchange (upload/ download/edit) and versioning control (CVS / SVN), and it was not applied to diverse aspects of creative collaboration. Furthermore, Baldwin found [71] that "calling up all the parties to attend meetings for virtual design works is difficult due to lack of interest . Designers find this task too time-consuming and complicated, particularly when faced with the normal time-scales permitted within the tendering process." (Baldwin, 2006) This has consequence that early in a project, many professional and non-professional stakeholders do not provide well-informed input to the

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[71] Baldwin et al, *Planning and scheduling in a virtual prototyping environment*, 2006

design. The reason for that is lack of proper Applications and Interfaces. Baldwin argues that and this is one of key reasons for development of a collaborative platform that support transdisciplinary creative collaboration:

> "The user interfaces that exist today do not facilitate this input, which leads to a long design process and the discovery of design criteria and stakeholder requirements sequentially. Better user interfaces that focus on engaging groups of stakeholders from many different backgrounds could help to achieve a more effective and efficient early project design phase". (Baldwin, 2006)

Baldwin argues that design in architecture is an activity that is social and professional, characterized by a specific *design collaboration context*. However, in his findings the available collaborative tools are not adapted to this context. Indeed, the collaborative and distributed design requires a cognitive synchronization based on 'unplanned' activities that he qualifies as 'implicit' activities. In collaborative design process, no matter if the common goal is to produce a document, a product or a building, Baldwin founds out that "autonomous actors, belonging to one or more entities, realize these activities with varied and complementary competences."(Baldwin, 2006) To be more effective, collaborative design environments need to be able to understand changes in the context of the user and to deliver the right information at the right time on an as-needed basis. Aziz points out that the context awareness needs to be integrated in collaborative environment[72], otherwise the users would be less aware of input by others, which would make the collaboration less efficient:

> "The integration of context awareness and web services into virtual applications offers considerable potential for enhancing their versatility and ensuring that end-users are provided with access to context-specific data, information and services. The context parameters that need to be incorporated can be defined by the project team based on the requirements of each project. These will include some of the user-context parameters as well (e.g. role, discipline, interests, preferences, etc.)."(Aziz, 2003)

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[72] Zeeshan Aziz, *"Semantic web based services for intelligent mobile construction collaboration"*, ITcon 9 (Special Issue: Mobile Computing in Construction, 2003) 367-379

The discussion about user-context parameters suggests that we are dealing here with users' *multiple points of view*, such that reasoning can be undertaken based on the interpreted context and intelligent action taken. In such environments, users (agents) will have the ability to learn the rules and regulations for participation through interaction with other users.

3.1.3. Agent-based collaborative applications

User organization in collaborative environment can be understood from two perspectives: organization as a process and organization as an entity. That is, organization is considered both as the process of organizing a set of individuals, or as an entity in itself, with its own requirements and objectives. The notion of user-based, or in Computer Science agent-based,[73] environment can consider simulating the actions and interactions of autonomous agents (individuals or groups) with a perspective to estimating their affect on the system holistically. On the other hand a software agent, which we use here as metaphor, is according to Wooldridge and Jennings "a self-contained program capable of controlling its own decision making and acting, based on its perception of its environment, in pursuit of one or more objectives". Their definition of agents contemplates four main attributes that determinate agenthood[74]:

- "Autonomy: The ability to function largely independent of human intervention
- Social ability: The ability to interact 'intelligently' and constructively with other agents and/or humans
- Responsiveness: The ability to perceive the environment and respond in a timely fashion to events occurring in it
- Pro-activeness: The ability to take the initiative whenever the situation demands" (Wooldridge and Jennings, 1995)

Agents are operating in open, complex, dynamic, and distributed environments. Agents interact with other agents, which may include both

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73 Agent can be a human user, but also a computer program. See http://en.wikipedia.org/wiki/Agent-based_model and http://en.wikipedia.org/wiki/Intelligent_agent.

74 Wooldrige and Jannings, *"Intelligent agents: Theory and practice"* (The Knowledge Engineering Review 10/2: 1995) 115

people and software. This exploits aspects of the emerging visions of the collaborative design environment in which agents come together to deliver unite results. A collaborative platform supports such working methods by implication of self-organization to handle dynamism in contemporary open computing environments. Those self-organizing systems function without central management, where complex collective behavior emerges from actor's mutual interactions. Within such a system agents modify system's structure and functionality to adapt to changes in requirements and the environment based on previous experience. Therefore, new theories of emergence[75] are being developed[76] based on inspiration from natural or social systems. For the decision making process within agent-based collaborative applications it is important to capture human notions such as trust, reputation, dependence, obligations, permissions, norms, institutions and other social structures in electronic form (Ashri et al., 2006). Especially in online applications there is a need to properly structure preferences [77] of collaborative environment such: roles, powers, rights and obligations to other agents, to handle security and trust aspects. (Garcia-Camino, 2006)

Furthermore, communication technologies and techniques between agents are important for the self-organized interaction. Luck found out that [78] there is a need for agent-based environments where the self- and bottom-up organization is possible, where coordination of decisions, emergent cooperation and distributed planning are achievable:

> "There is a need for mechanisms that allow agents to coordinate their actions automatically without the need for top-down supervision in many applications. Important step is to develop a wide range of different types of coordination and cooperation mechanisms, such as: coordination protocols (which structure interactions to reach decisions);

[75] See section 1.3.4

[76] Ashri et al, *"Using electronic institutions to secure grid environments"*, Proceedings of the Tenth International Workshop CIA 2006 on Cooperative Information Agents (University of Edinburgh, 2006), 461-475

[77] Garcia-Carmino, *"A rule-based approach to norm-oriented programming of electronic institutions"* (ACM SIGecom Exchange 5/5, 2006) 33-40

[78] Luck et al, *Agent Technology: Computing as Interaction* (A Roadmap for Agent Based Computing, University of Southampton, 2005)

> emergent cooperation (which can arise without any explicit communication between agents); coordination media (or distributed data stores that enable asynchronous communication of goals, objectives or other useful data); and distributed planning (which takes into account possible and likely actions of agents in the domain)." (Luck, 2005)

Although a lot off agent-based collaborative applications have been envisioned, developed, prototyped and evaluated, no one has yet built a robust and fully functional multi-agent system that has been successfully deployed in architectural practice [79]. According to Tah currently, "there is a lack of sophisticated software tools, techniques and methodologies to support the specification, development, integration and management of agent systems compared to more mature technologies" (Tah, 2005)..Furthermore, Tah noted that there is a need for further work on knowledge gaining in multi-agent contexts. He puts particular emphasis on the gap in comprehending and tracing the results of knowledge production for users in dynamic way, and using such knowledge meaningful across different systems.

> "There is still a lack of mechanisms for explaining and tracing the reasoning behind results and outputs produced by agent-based applications. Mechanisms need to be developed that allow users to trace how particular outputs have been produced in order to inspire future projects and reuse already gained experience in more dynamic interactive way. Further challenge is to bridge the semantic gaps between multiple systems, e.g. to realize scalable and practically usable ontologies between systems using different ontologies."(Tah, 2005)

Building upon Tah's findings, it can be said that particularly in architectural design collaboration, there is a need for a model of digital representation that can provide the basis of a common language that can be understood by multiple agents from various disciplines. The model itself needs to be defined at a level of information resolution that allows for computational interpretation and reasoning.

Tah's findings are particularly important to the thesis as they comprehend a need for non-linear systems, which are able to cope with complex collaborative design environments in intelligent and responsive manner. Tah points out that there is a need for systems that "can process

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[79] Joseph Tah, *Towards an agent-based construction supply network modeling and simulation platform* (Automation in Construction 14/3, 2005) 353-359.

incomplete, uncertain and ambiguous information, and can learn and adapt to environments that require interoperating with other intelligent, adaptive complex systems. The ability to cope with uncertainty is a fundamental characteristic of knowledge systems designed to address real world problems" (Tah, 2005). According to him the next generation of virtual collaboration platforms will need to draw heavily on agent-based and emerging technology. The nature of complexity, mentioned in previous chapter, characterizes creative design projects as complex adaptive systems that depend on multi-agent systems' solutions. The interaction between multiple agents in the system results in an emergent behavior of the overall system. Tah claims that: "it has been widely acknowledged that the agent-based approach provides a metaphor and framework for channeling problem- solving approaches from diverse disciplines into the design of software systems capable of handling complexity." (Tah, 2005) However, according to Tah the implementation in architectural practice is far from perfect and in many cases inadequate.

The collaborative environment and the research project A.N.D.I. is an attempt to summarize the requirements and current issues suggested for agent-based collaborative application described in this section (Baldwin described ill-defined interfaces, Luck observed a need for bottom-up distributed collaborative environments, Tah identified a lack of sophisticated software tools, techniques and methodologies). The next section deals with initial methods and conceptual strategies of possible implementation for such agent-based environment.

3.2. Infospace- Intelligent Information System

This section deals with Infospace, which is conceptually the backbone of A.N.D.I. system. It describes the theories, methods and model, that were envisioned in subsequent implementations of concepts described earlier. Further, this chapter describes the main components of A.N.D.I. in terms of their conceptual purpose, but also in terms of their development over the course of the project. It describes the nature of the discussions that went on, based on these components and User Interface. Using the terms introduced in chapter one, it analyzes which of these changes were due to transdisciplinary processes, when collective intelligence can be said to have led to an improvement or when a new solution emerged.

The procedure "Action Design" and method "Diffuse Design Theory" explain the strategies for building of an international, transdisciplinary forum and work environment for an open community that builds upon the expertise and inspirations of "collective intelligences" to enhance the creative, design processes in a direct, interactive and intuitive manner without imposing restrictions on them. The idea here was that the development and use of A.N.D.I. system should create novel work practices that make the allocation of resources more efficient by sharing the infrastructure and workplace equipment. By making the conception design of architectural projects transparent the involved project partners could build upon each actor's ideas and expertise. As mentioned in previous chapter the fostering of novel usage of information and communication technologies across disciplines should build the basis for innovation in transdisciplinary design collaboration.

A.N.D.I. connects teams of experts with teams of project partners - consisting of members from areas as diverse as architecture, interface design, net art, human computer interaction, social sciences, with the aim to collaborate in architectural and urban design projects, and to develop and use open working systems. Within the context of transdisciplinary teams within the extended enterprise,[80] collaborative design, and data management processes have become crucial for faster, better product development from the early phases of a project on. In this context, the

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[80] "An Extended Enterprise could be defined as self-organizing network of companies that combine their economic output or collaborate to provide products and services offerings to the market. The firms in the extended enterprise normally operate independently, and are connected through some collaborative platform. Each firm is a flexible unit, and connected together the EE could also manage bigger projects" (Wikipedia, April 2009).

heterogeneity and diversity of software used by the actors within a project, the data exchanges and the management between the different partners and through different activities, the need to create supporting "*collaborative platforms*"[81] has increased. The role of such platforms is to enable the interoperability and associability of different data that is to be created and managed.

When considering data management systems, these aspects are characterized by the fact that the created, exchanged, and the integrated data must all contain exactly the same semantic objects. Because the number of attributes attached to the product also increases with the evolution of data management requirements, data exchange and management between partners need more complete interfaces. As a consequence, there is also an increased need to provide control over the processed data through these systems. Data management systems and collaborative environments are facing two major issues:

- the need to be able to semantically parse data this issue relies on the capability to define and extract the collaborative and semantic objects so that they can be exploited by partners and activities which need them;
- the need to be able to contextualize data; this issue relies on the capability to determine the context in which data has to be processed.

[81] "Collaboration platform supports people in their cooperative work, which involves organizational, technical and social issues. As standard applications or services are considered: e-mailing, instant messaging, file sharing, video conferencing, document management, tasks and workflows management, blogging, etc." (Wikipedia, April 2009).

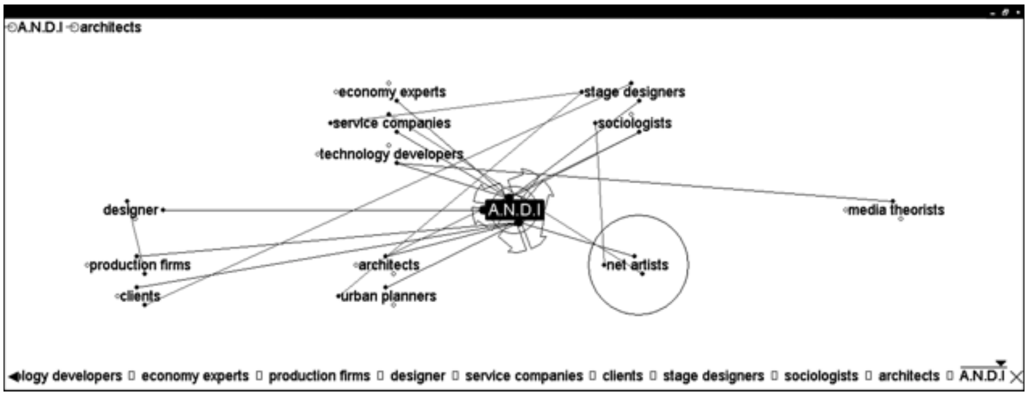

Fig. 3: Collective intelligence of interconnected actors involved within A.N.D.I. project

3.2.1. Infospace description

Infospace is a core application of A.N.D.I. system and has been conceived as Intelligent Information System (IIS)[82]. The IIS is not passive environment (collecting information, processing and presenting it in a structured way as a classic information system does) but also open and interactive (it is an integral part of a collaborative environment, it reasons about behavior, communicates and collaborates, has a purpose and a mission, etc.). Infospace setting is expected to provide open platform for heterogeneous and transdisciplinary work. As a result of the approach, it has been envisioned a universal, transparent, and pervasive IT platform for the development of collaborative applications. Such approach facilitate several aspects: technology, business, social and design aspect.

The Technology aspect is increasingly correlated to the following aspects: the discovery of knowledge from large data collections; providing cooperative support to users in complex query formulation and refinement; access, retrieval, storage and management of large collections of (multimedia) data and knowledge; information integration from multiple heterogeneous data and knowledge sources; behavior and information unity in virtual systems, and reasoning about information

[82] "IIS represent the next generation of information systems embodying knowledge that allows them to exhibit intelligent behavior, cooperate with users and other systems in problem solving, discovery, access, retrieval and manipulation of a wide variety of multimedia data and knowledge, and reason under uncertainty." Journal of Intelligent Information Systems: Integrating Artificial Intelligence and Database technologies, Mission and Scope, http://www.isse.gmu.edu/JIIS/JIIS_Folder/Mission.Scope.html (accessed Sept. 2003.)

under uncertain conditions. Keeping the impact of the collaborative network in mind the emerging need for new tools and techniques for the management of these dynamic and evolving information spaces existing on a global scale over the Internet becomes evident.

The Business and Social aspect of the IIS has evolved due to the global acceptance of the Internet, from very limited impact (when computing centers were used for IT support according to the big enterprises' needs only) to an increasingly high one (e-government, e-communities, e-business, e-learning, etc.). Consequently, IIS is required not only to automate information processing, storage and distribution, but also to reason about issues like knowledge sharing,[83] value creation, and social impact.[84]

The Design aspect of IIS includes interoperability, platform independence, reusability, concurrency and abstraction. This aspect has been in the focus of research within the IT community for a long time,[85] and has resulted in emerging technologies such as Model Driven Architecture.[86] Our belief is that the design aspect will benefit the most from the proposed approach by adopting mechanisms from other aspects as design components (for example, applying auctions and value-based formal business models to the collaboration of software components and platforms) while "borrowing" well-known proven design practices to other aspects in return as well.

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83 McIlraith, S.A., Son, T.C., Zeng, H. "Semantic Web Services", IEEE Intelligent Systems (March/April 2001), 46-53.

84 Miranda, S.M., Saunders, C.S., "The Social Construction of Meaning: An Alternative Perspective On Information Sharing", Information Systems Research Vol. 14, No. 1, (March 2003).

85 Borghoff, U.M., Schlichter, J.H., Computer-Supported Cooperative Work: Introduction to Distributed Applications (Springer, 2000).

86 OMG Model Driven Architecture, http://www.omg.org/mda/. Fan, M., Stallaert, J., Whinston, A.B., "The Adoption and Design Methodologies of Component-Based Enterprise Systems," European Journal of Information Systems, 9 (1), 2000, 25-35.

A.N.D.I. Infospace is the modular system of applications and tools supporting the creative collaborative work through the network. With these tools, the following should be made possible:

- Finding ideas for projects that are not yet defined but are currently in a creation and initialization phase (e.g. research, various experiments, and tryouts). The users can add and propose the project ideas or even develop own applications within exiting container templates.
- Projects that are in a basic creative pre-design phase (e.g. architectural studies, competitions, etc.). The system should be supportive for the various types of users with various levels of user skills (even if we consider only the advanced ones), which means that the tools are more generic to use or to program.
- A Design laboratory with mostly experimental architecture and urban design projects. This laboratory like environment can be extended by additional functional modules, developed by users, which basically are not meant to be an integral part of the system, but to expand existing system and add new functionalities.

Most parts of the applications should be server-side run so that the following two goals can be achieved: the client is relieved because it can be run on not as performable computers (e.g. laptop or even some other mobile device); and a common operating system is used (OS non-dependable), which means that a minimum of software is needed - in most cases only an Internet browser with Java support. With other words the user can work from stations where he/she has limited rights for installing the software (Internet cafes, etc.). In some cases, for example, very complex and demanding applications, some additional software has to be downloaded for the usage first. This also considers the necessary plug-ins especially for 3D and 2D graphic applications. The technical engine behind the Infospace should be understandable, open source, and easy to extend with new application modules.

3.2.2. Action Design

To establish operation mechanisms within Infospace based on manipulation of information and data, a novel definition of working procedures has to be defined. The Infospace working procedures coined as "*Action Design*" has been inspired by Action Painting – "a style of abstract painting that uses techniques such as the dribbling or splashing of paint to achieve a spontaneous effect." In used metaphor of Action Painting the canvas is the framework in which the artist operates. The action of painting becomes a creative moment of the artist, focused and intense - the canvas becomes the record of the event. It is mainly associated with several artists of Abstract Expressionism, including Willem De Kooning, Franz Kline and Jackson Pollock.[87] The action design metaphor used here is based on Pollock's action painting technique. Focusing on creative action is only possible if the user is not distracted by a limitation of the User Interfaces or constantly switching between various programs during the work. The working instruments (in case of action painting) such as paint brush, color, and canvas represent artist's interface toward medium, and are not priority of the creative process. They are blend out in way that artist if fully focused on the work itself and he is not struggling with the limitations of particular tools or interfaces.

Infospace facilitates Action Design through on the visualization of the **hypersurface matrix**, which defines new paradigms for architecture, urban planning, product creation and other kind of networked collaboration. 'Hyper' denotes the reconfiguration of humanity through technology and 'surface' the temporal plane onto which these changes are mapped. *Hypersurface* is not simply a concept, but rather an *event* (Tschumi, 1990),[88] a dynamic data set continually reformatted by users' inputs. The meaning lies in this state of flux, in the topological flow of data

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[87] http://www.artlex.com/ArtLex/a/actionpainting.html

[88] "Tschumi has argued that there is no fixed relationship between architectural form and the events that take place within it. The ethical and political imperatives that inform his work emphasize the establishment of a proactive architecture which non-hierarchically engages balances of power through programmatic and spatial devices." (Wikipedia, April 2010)

that emerges as an augmented matrix. This work does not capture or represent traditional forms of project management processes. Instead, it introduces its own system of thoughts, which is created by the input of each user, out of own data nodes in real-time during creative interaction.

Action oriented working method to produce knowledge and information within the system rather then importing the data has been defined as "action design". Since the Infospace has been considered as empty in the beginning, and there are no possibilities to directly or indirectly import data into the system, the critical mass of usable knowledge emerges through the user's action with time: the creation of nodes and their interconnection. During its use and through the collaboration the system learns about various user actions and can propose possible connected branches, which are not recognized by the user at first. A collaborative input over network is described by the design graph and is manipulated just in time (live)[89].

3.2.3. Diffuse Density Theory

The Action Design working procedures within Infospace are based on so called "Diffuse Density Theory"[90]. The traditional Euclidian coordinate system has X-, Y- and Z-axes. The **diffuse coordinate system** (DCS) is based on the **single node,** which represents the center of the specific *node cloud*[91]. Apart of the Euclidian space that is 3-dimensionsional, this Infospace is endlessly n-dimensional and therefore non-dimensional. It is not defined by the coordinates but by the density of

[89] The input can be: text, images/stills, video clips (footage), audio sequences, MIDI signals which are then synthesized. Considering the input from various media sources and mixing those together there are comparable software products on the market, such as Touch Designer, Processing, PD, MAX/MSP/Jitter, etc. The main difference is that A.N.D.I. Infospace is an on-line system which focuses on creative, simultaneous, transdisciplinary work, non-presentational but actual collaborative working within system, and not so much on the particular content itself.

[90] This is a non-existing term invented by the author. In this section it will be pointed the meaning of this theory, when we talk about diffuse information and dense information, connected to importance of information within certain system.

[91] Node Cloud means the current presentation of the nodes on the work panel defined by system's parameters (Current Node, Deepness, Sensitivity).

the information. Each node has its properties, which are defining the content of the node.

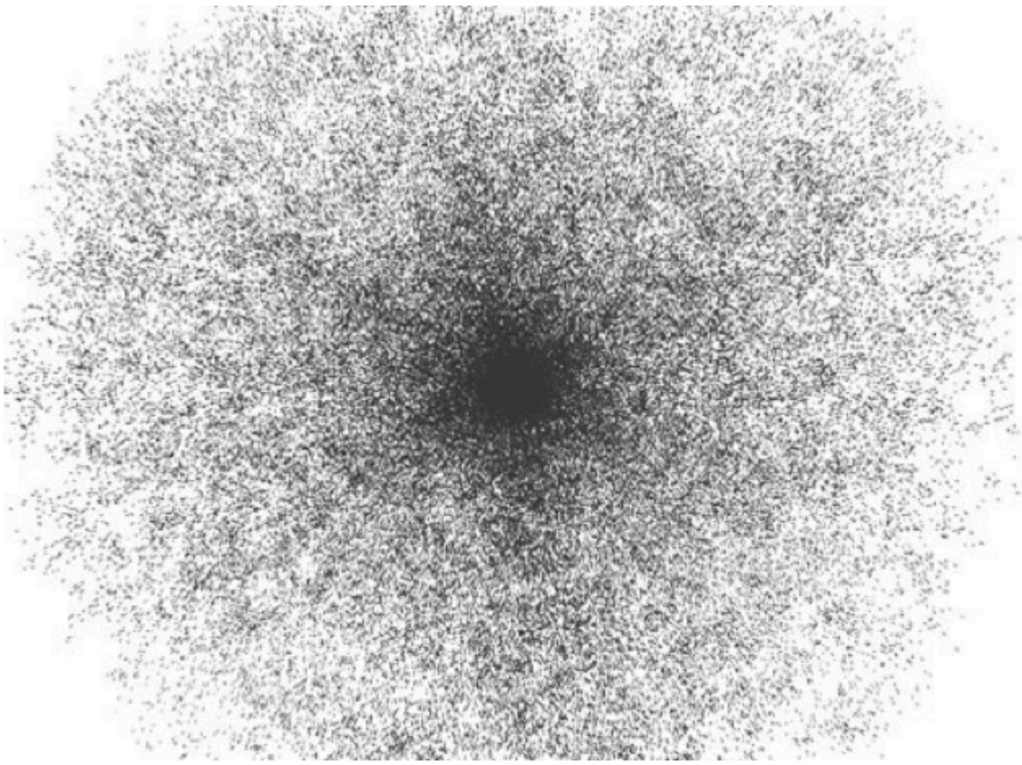

Fig. 4: Image is showing the density of the Information around the specific node.

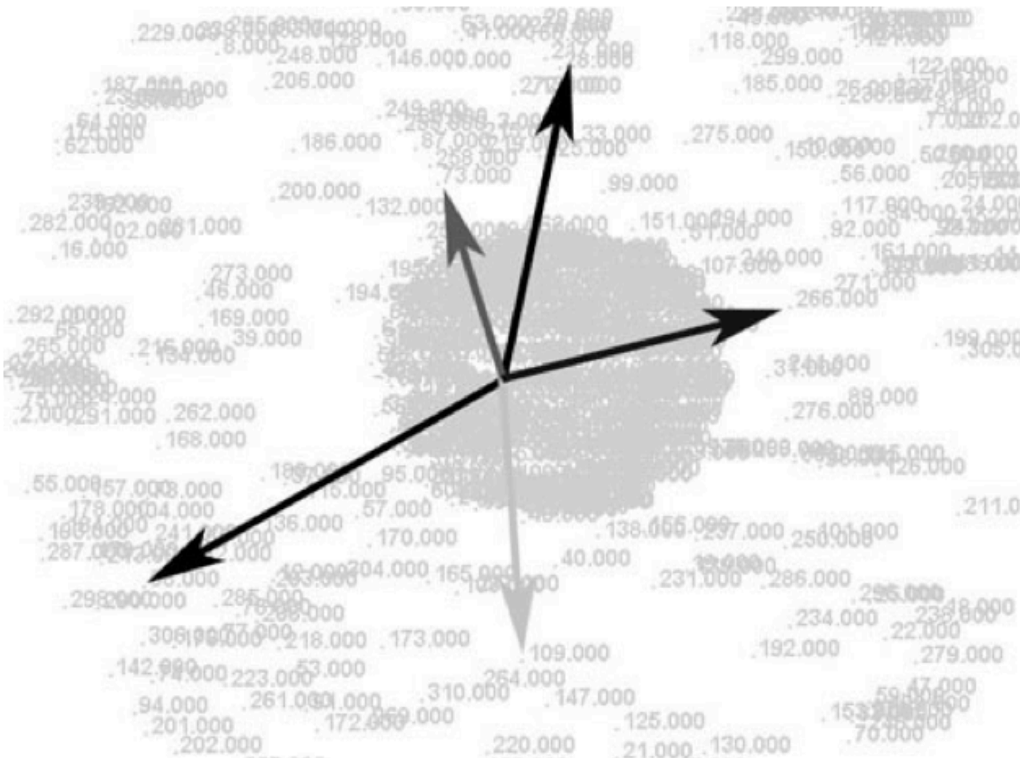

Fig. 5 Vector-orientated directional value from 1 for current node toward theoretical 0 for irrelevant information.

In the literature diffuse coordinate system describes a natural framework based on diffusion processes for the multi-scale analysis of high-dimensional data sets. “Dimensionality reduction algorithms try to discover the true dimension of a data set. The diffusion process scheme enables the description of the networks structures of such sets by utilizing the paradigm according to which a global description of a system can be derived by the aggregation of local transitions and changes” (Maimon et al, 2008). This scheme also supports the parameterization of a data set when there is a directional relationship e.g. between two nodes within similarity matrix is available.

The *Diffuse Density System* is based on the single node of the **information vector**, as well as the **relative distance**. Since the vector can have any possible angle absolute to the certain reference coordinates we can assume endless numbers of directions. Therefore we can speak of *diffuse information source*. The relative distance is connected to the fuzzy logic of information relationships: value 1 has the node itself described as **clear condition**, and all other relationships to other nodes are between 1 and 0. The lower the value, the less important the information is assumed to be, which is described as a **blurry condition**. The information vector has direction, or in other words it gives information on how one looks at a certain solution of a problem from the current node. Point-of-View consists of many directions at a certain time, and it can be changed within the creative process. For every creative process, the directions will be defined separately.

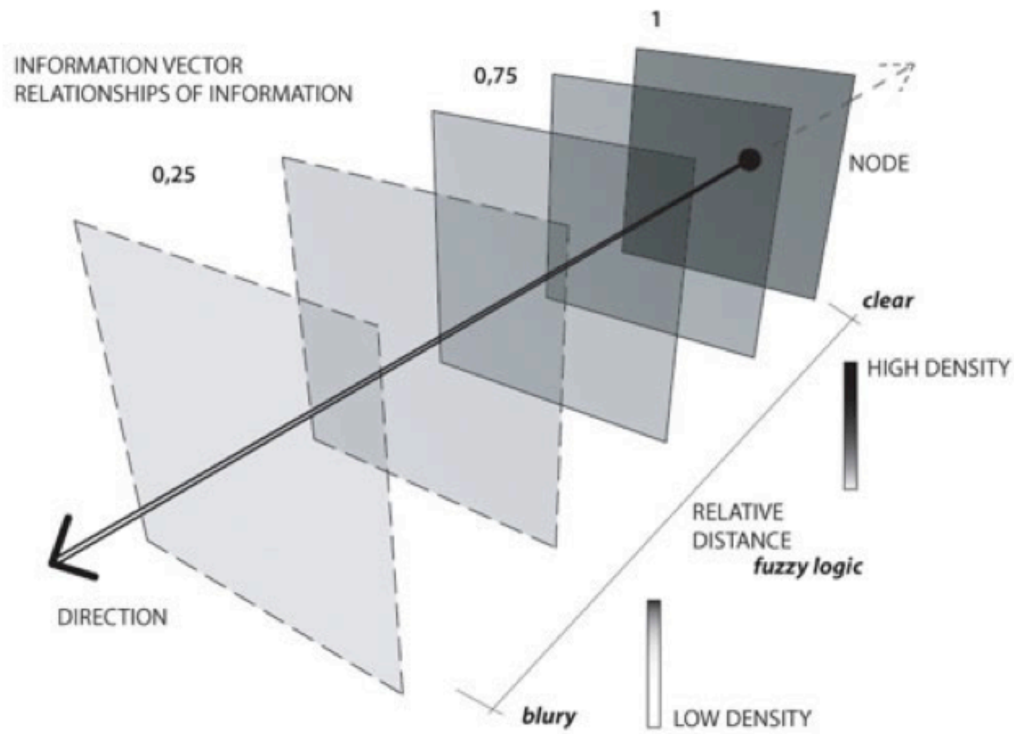

Fig. 6: Information vector and relationships of information based on information density. Sensitivity of the connection from 1 for current node and 0 for irrelevant information.

This connection extends the basic initial relationship and inherits its properties – the system reorganizes and adjusts to the user's interests by changing these connections during the work phase. The main regulators are: **Distance**, **Density** (value: >0 and <1), and **Direction**. The information closer to the source node is clearer and has high density, with the information of lesser value more dispersed. The density of quality information is low. It resembles the user's position in a real world situation.

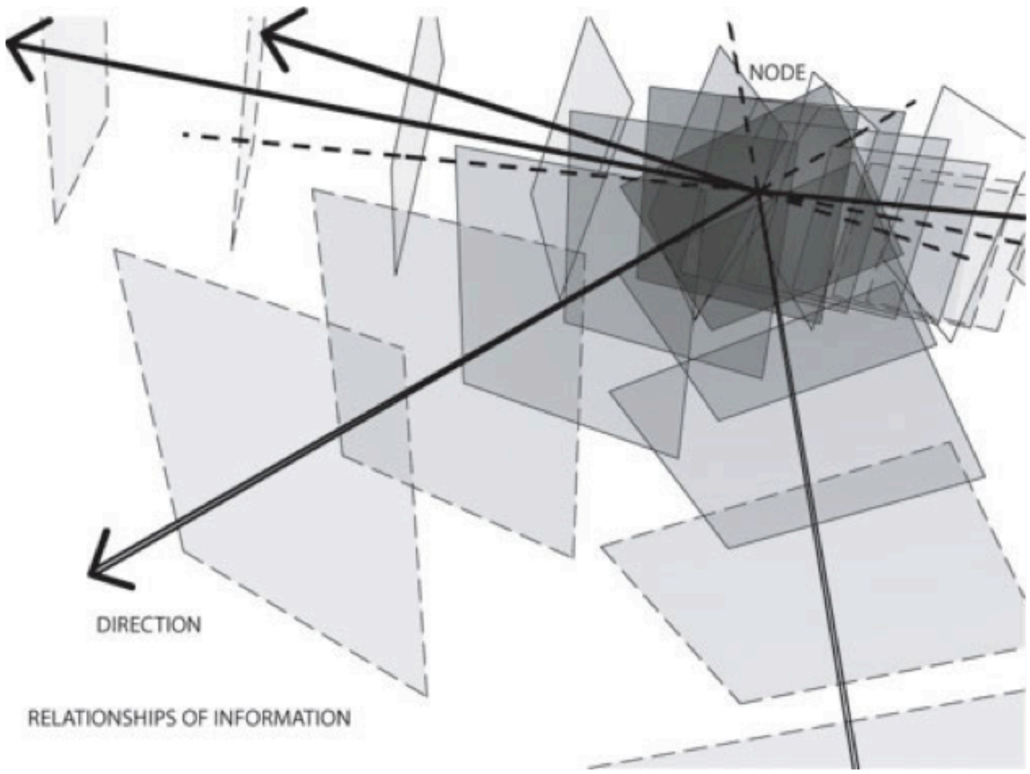

Fig. 7: The node is the smallest part of the ***Networked Sequencer****, and it can be seen as one neuron - a basic element of the neural network. Its properties also include the functions for the relationships of the information. Every node is constantly at the center of the system and its axes are building an endless spatial construct. The figure "Relationships of Information" shows the* ***node cloud****, which is the high-density information condition for more nodes around one node. The node clouds cannot directly interact with each other, since they are representations of the relevant node groups. The node clouds are not stable and are changing all the time according to the representation of the actual direction (Point-Of-View), since the dependencies of the node relationships are permanently changing with the project's progress.*

The consistent knowledge-based system of Infospace is imagined as a multi-agent environment, as an example for the "active design" with users (agents), which includes all the information about and links to the data that is needed for the work. The matrix of *Diffuse Density System* can also be seen as an *endless plateau*, with the primary function of representing knowledge links. This is a network of **connected events**. One event is a certain condition of the connected nodes and the state of their relationship. Selected events and its content (data) are defining Infospace and its result can be transferred through the specific interface by invoking an "event".

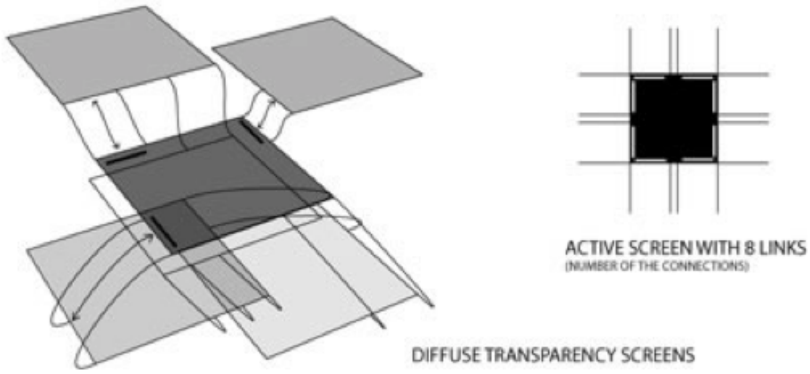

*Fig. 8: Diffuse transparency screens are the actual working field of the single user. The graphical representation for dealing with data would be **active screens**. It is an Interface Design of the "endless table", where the information, or rather the connections to the physical files are presented "just-in-time". Active screens have two modes of implementation: a zoom-in and a zoom-out mode.*

The organization of the design framework, as a support for the "active design", is based on the hierarchy of three categories (top to bottom):

- **Event** - Events are the temporary system conditions, which are happening through the modifications done by the user through various synthesized processes. The relationships of the nodes and their interaction define an event. The conditions of the events are based on the various outputs from the sequence synthesizer. These outputs are event results. An event is a result of the creative process of one collaborative session. The event conditions are the highest organizational level.
- **Synthesizer** - The synthesizer is a processor for the sequences. Sequences brought together and filtered are defining one synthesizer's input. They are application modules created or customized by the user, and can be defined by the system's supplied visual tools for modeling synthesizer behavior. One sequence is a group of nodes, no matter if those are connected in any form (e.g. node cloud). The node grouping is a necessary prerequisite for the nodes to be used by the synthesizer (filter for grouping and handling nodes). Events are the output of the synthesizer. The filtering options are system constraints for defining the criteria by which relevant data should be exported.

- **Node** - Node is a system's atom and represents one file (MIME) type with connection to the actual physical files. The user creates the original node.. Under certain event conditions it is possible that the system generates the new node connections and relationships. One node can contain several documents of the same MIME type.

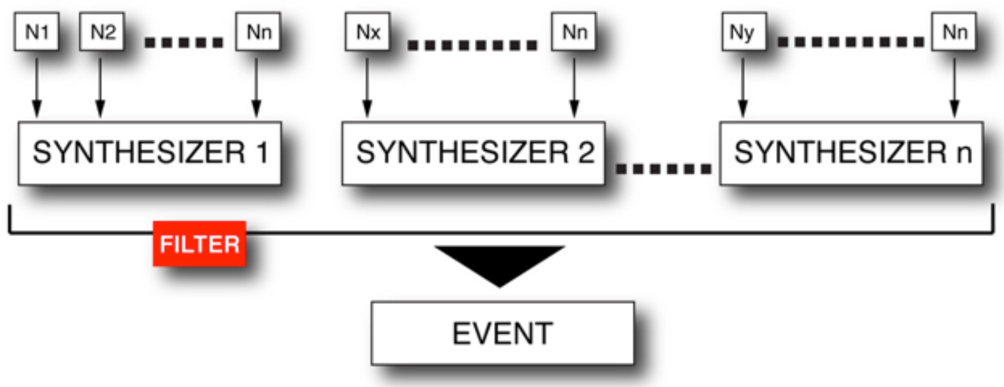

Fig. 9: Diagram shows design framework for active design

3.2.4. Infospace knowledge-based system structure

By definition the transdisciplinary design collaboration requires a high level of human expertise, and therefore involves employment of methods for defining the knowledge-based system structure[92]. The theory explained in the previous section needs formal description by knowledge structure, which is visualized as knowledge diagram. Such diagram brings the knowledge elements in a semantic relationship. Moreover, it represents a basis for navigation within Infospace. The knowledge elements in this diagram are represented as nodes (information container) and the links between them are showing relationships. The relationships are explaining what and how nodes are connected as well which type of relationship has been concerned. As can be accessed directly on explicit knowledge, this is not possible with tacit knowledge. Tacit knowledge is dependent on the specific experience of one expert. This type of

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92 E. Feigenbaum, P. McCorduck, *The fifth generation* (1st ed. Reading, MA: Addison-Wesley, 1983)

knowledge is very complex to be transmitted to the other stakeholders involved in the design process. Therefore, it is important to describe knowledge-based system through relationship model besides the content production within the nodes.

Knowledge-based system structure configures itself through learning from the user's actions of one collaborative group where the system recognizes the possible connections to any input existing within the system. Actions are depended on users' interests in specific directions. The system can not produce content; in other words, it can not create new nodes by itself, but it can monitor actions within the creative process and propose the overlooked nodes that may be of interest through additional branching. According to Aziz, to effectively share knowledge the adaptation and enablement of specific factors and technologies to design is inevitable: "Applications that are context-sensitive and can recognize what the user is aiming to do. They should thence be able to provide appropriate guidance, menus and make available the relevant information" (Aziz, 2003).

The following diagram shows the relationship model for such approach. Since we are sometimes dealing with a very intuitive logic, for example the design process as such, system intelligence develops its "logic" from analyses of the relationships, and not from understanding the content of the elements that establish those relationships. This formulation allows for creative actors to be subjective, based upon their field and background.

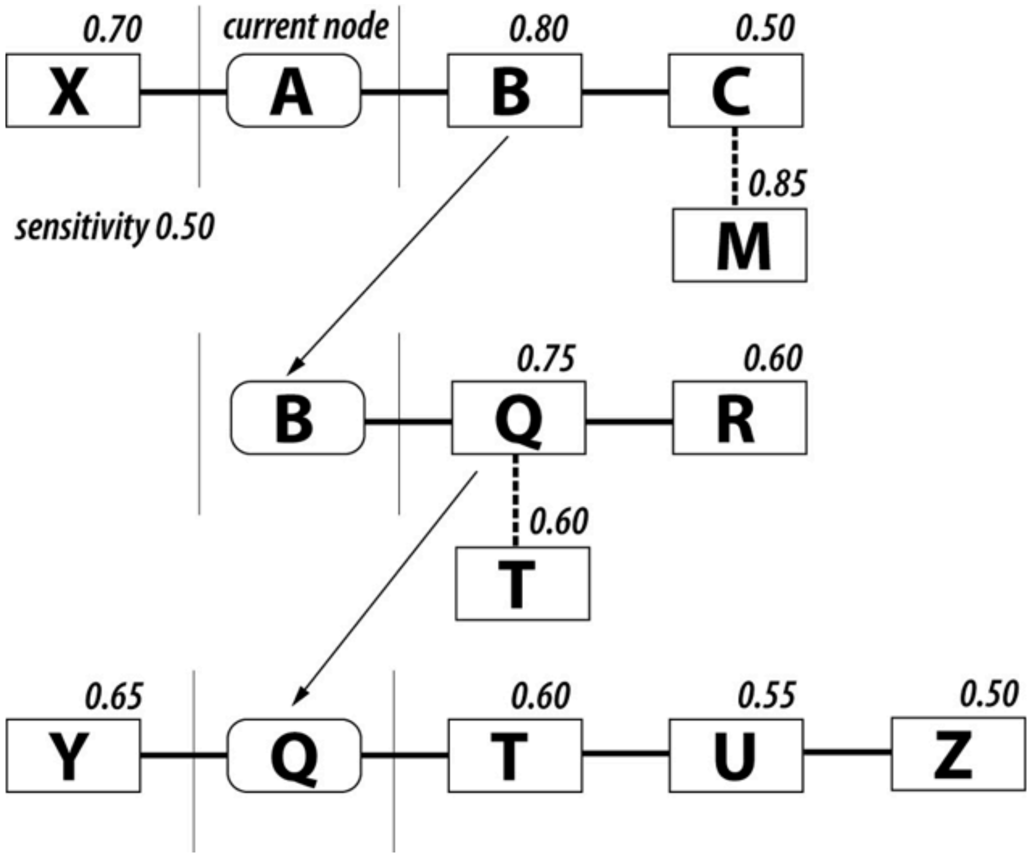

*Fig. 10: Relationship model for directional network of A.N.D.I. Infospace System. It is showing the principle of **directed graph** with selected "current node" in the first row, with weighted connections from 1 to 0, depending on importance of information directly connected to the current node (in this case Node A). The **sensitivity** parameter set with 0.5 filters out all nodes connected to node A or any other node set thereafter as current with less weight then 0.5. The parameter **deepness** describes the out degree of nodes (in range from 1 to 0) not directly connected to the current node but to one of the nodes on one direction (as shown for node M in the first row, or node T in the second row). By choosing another node as current, e.g. Node B in the second row, the diagram reconfigures itself based on new conditions. In many cases the previous current node is not showing any more. The third row of the this figure shows a case where the node T is shown since it is directly connected to the node Q which then becomes the current node.*

For this relationship model the semantic content of the node is not as important as the relative behavior from one node to the other ones. The system provides user with the relationships from one Point-of-View (direction), proposals for possible relationships made by other users of the creative group, information of all similar working groups, and their relationships within the system. The knowledge-based system structure can be described through following important features:

- User inputs are within the nodes, as output of built-in tools, or as uploaded binary data. The system monitors the collaborative actions, as well as, the spontaneous actions done by a single user. The additional relationships (beside the manually created relationships by the user) and the calculated processes by the system should have descriptive meaning (in the manner of Meta language), as well as, the impact of the cascading change proposals on all relationships (these proposals are to be reconsidered by the users and acceptation happens through the usage). With every input impulse (action) the system learns.

- Every user has his/her own “point of view”. This is a way or direction through which each user of the connected environment “looks” at a certain topic, but still considers a common goal/ product.
- On the global level the processing of sequences (the group of nodes) through the synthesizer leads to a common description of the collaborative creative process, which we call event.
- Meta language, which is a communication option, explains the method of referring to nodes and their documents, by creating relationships, but also re-working, interpreting, or manually forcing the connections of nodes. Semantic connections can be used as an additional way of establishing proposed relationships.
- By bringing the new node into an existing direction or into a new direction, the node’s meaning, and its impact will be calculated. This introduces a new alphabet of visual descriptive language, since the keywords should not be used (no matter what language the users agree on for communicational purposes).
- The interaction within the system is based on two parameters, which are also used as navigational parameters, namely **system sensitivity** and **system deepness**. The less sensitive setting will reveal more nodes connected to the current node from one point of view (direction), and higher deepness shows additional branching to the nodes within this direction (those do not have necessarily direct connection to the current node).

- The learning system is split up into the user's Point-of-View, the nodes processed through the synthesizer, creative events, and the experience of all creative processes existing in the system. Thus, the new recombination nodes will be created. This increases the possibilities for new ideas and solutions to emerge within the system.
- Learning will be established through the users' reaction on those proposals (neural networks train the system by defining the creative process to get relationship proposals for users). Two of the input parameters are the users' point of view and the current node. To define the best and optimized behavior the system runs through more neural networks. With the deployment of the system new learning concepts will be introduced.
- The criteria to evaluate events (in a system with unknown results) are: the system learns what the creative process procedure has been about (usage of synthesizer for getting events) by working out the concrete Point-of-View. The learning input is the documentation of events, as the description of a creative process from the initiating requirements to the system's outputs.

3.3. System Components of A.N.D.I.

System components of collaborative platform A.N.D.I. has been developed as model for application of previously described methodology. The theoretical investigations on collaborative environments found their implementation in series of instruments and tools needed for collaborative design within transdisciplinary framework. The system of the A.N.D.I. Infospace constitutes four main components: 1. design visualization tools, 2. internal visualization of the collaborative work, 3. ideas generator (brainstorming tool), 4. linger plateaus (chat/communication tool). These components are interlinked together and each component communicates to each other to produce a coherent knowledge-based system of Infospace.

3.3.1. Design Visualization Tools

Design visualization tools are visually described design processes. These tools modules, applet containers as representational models of data, are created, added, and edited by the users during the creative process of collaboration in a networked environment. Tools are provided for geographically dislocated design participants, thus they can work on specific ideas at the same time by sharing the same media. This media is not restricted to the user group and software product, but is a common tool for all team members. The applications are running server-side, so the clients can work with common Internet browsers, from any computer. The design framework is a visual support for the networked "active design". The tools in this section are more manipulative than executive, providing information on how to manipulate the connections (links) to the data rather than providing information on how to manipulate physical data itself through the system.

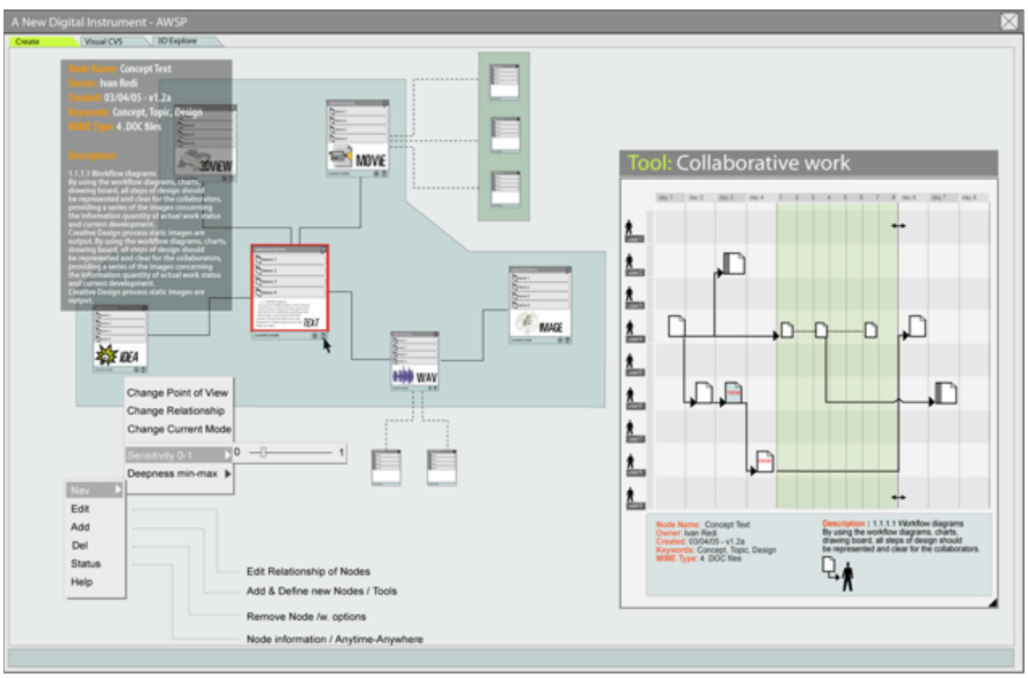

Fig. 11: Overview representation of design framework GUI

The contents of the node (the node is the smallest part of the system) are the actual links to the documents. Since one node can contain more connected documents, the content is split up into several sections. These are files of the same MIME type[93] (one or more documents), with a strong definition from the code dictionary. An empty node cannot exist within the system. A node cannot be deleted if it contains a document. The deletion causes its removal from the active screen, but not from the database. Initial relationship from node to node, if possible, is proposed by the system itself. It is a simple connection. Being of initial relation value of the new node it has minimum sensitivity to the current node cloud. Node clouds represent high density (high sensitivity) information. This is the connection of highly related nodes, and it has temporary duration. This condition is a system output and it is not in direct interaction with the user. The node clouds are based on the Diffuse Density System (see explanation in previous section).

Synthesizers are application modules, mostly applets. They are filtering and processing several sequences. Sequences are groups of nodes of various MIME types (small nodes networks), which can be synthesized together into one event through specific methods. They are filters for grouping and handling nodes. The filters are project constraints that describe the relevance of the processed information. Events are the output of the synthesizers. The Event is a description for one creative process. Modified and initiated by one user or more users. The relationships of the nodes and their interaction define an event. The conditions of the events are based on the various outputs from the sequence synthesizer. The event conditions are the highest organizational level. There are digital and analog events. Digital events are products of Infospace computed design processes through its core parts or by additionally developed applications. Analog events are digital inputs with "analog" origins (e.g. digitalized sketches or architectural models, etc.).

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[93] "An Internet media type, originally called a MIME type after MIME and sometimes a Content-type after the name of a header in several protocols whose value is such a type, is a two-part identifier for file formats on the Internet" (Wikipedia, April 2009).

3.3.2. Internal Visualization of the Collaborative Work

In the case of creative multiple authorships it is important to track every significant input of each user, as well as, to keep a clear project overview of every design step. Ideally this is the part of the new working methods A.N.D.I. should prolong in terms of the network collaboration. During this part the work process and its state will be visualized. Every participant has the potential to see his or her particular inputs, also in the context of the whole process.

By using workflow diagrams, charts, and a drawing board, all steps of design should be represented and made clear for the users providing a series of images concerning the information quantity of the actual work status and the current development. So-called "visual reports" are the output of the creative design collaboration process.[94] The visual reports about the workflow with a zoom aspect ratio and point of interest (option to choose a certain process or node cloud) are the actual tool.

The internal relationship of the connected co-workers presents the final state of the collaboration within the project. It also shows, at any moment, the certain input of a specific project partner and the relationship of his/her input to the general work. This data output should be visual protocols, in which they should be logged by the author's name, his/her content, and time of change. These diagrams make it visible how the authors' inputs are connected to each other throughout the whole design process. It is a visual tool for organizing and visualizing project documents based on one document's relationship to another. Because it is based on this information it is possible to go back and forth in the working process. The last work session will be saved at the log-out and used as departure point for the next login of the same user.

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[94] Report diagrams are visual representations of the collaborative work – visual CVS and user involvement in the work (workflow). They are generated as reports by the system and have limited interaction with the user. This shows the work history of creating and using the specific node by the users, which are represented through different colors. The activation of reporting tools is enabled from the filter panel.

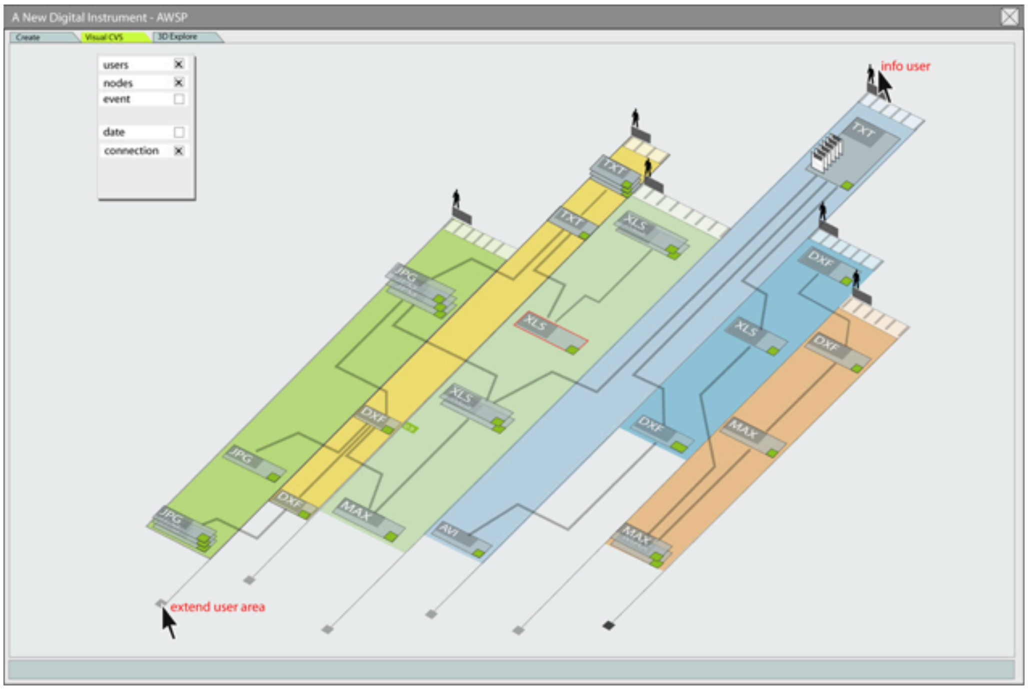

Fig. 12: Report diagram based on flexible stripes - The report diagram is organized in parallel, colored stripes defining the user's domain. Each created node will be displayed in the respective owner's area. Thus, this representation allows it to be seen who did what at a glance. The surface of the stripe is manually extendable by dragging an anchor, which is located at the bottom of the stripe. Information about user status is available by clicking on the icon in the header part of each domain.

The day timeline (on the left) works as a statistic graphic report showing the amount of files created each day. Clicking and dragging an anchor located at the bottom-right of each node allows to open the node sub-domain and to see how related documents are linked together.

Fig. 13: Timeline diagram with content stripes. Timeline shows the state of the diagram when the date button is turned on. Each node is displayed on the diagram at a precise position following its date and hour of creation. Each stripe possesses its own hour timeline, visible at the top of it. By extending the user's area, nodes automatically move to their right positions according to the hour of creation.

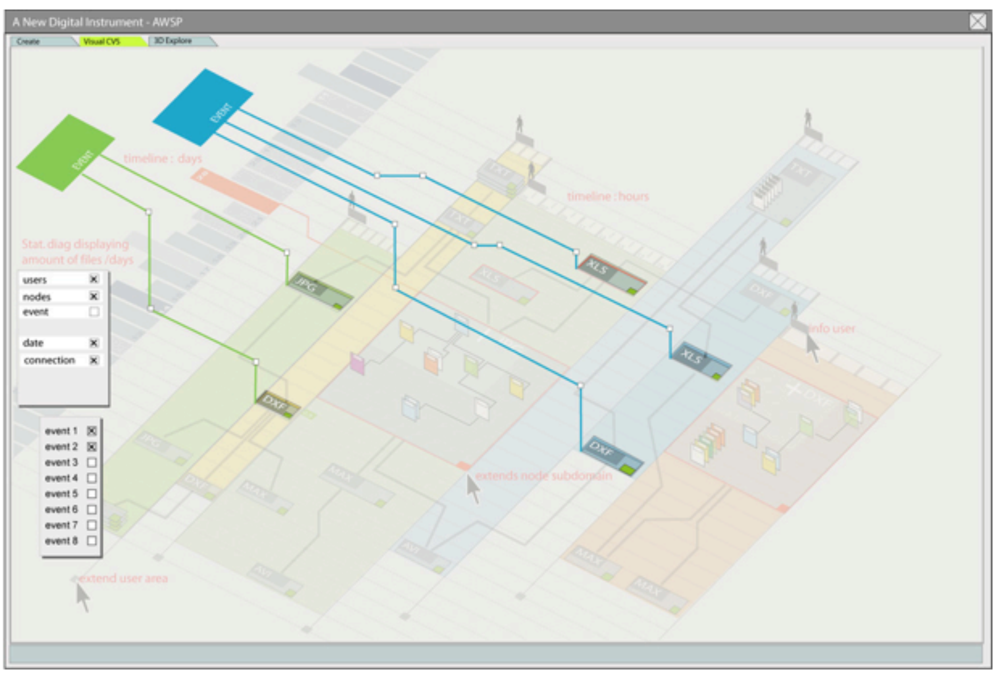

Fig. 14: Event diagram - the workflow on the generation of events is based on user involvement and/or tools usage. A panel allows only display of selected events.

3.3.3. Ideas Generator

Ideas Generator is a tool for brainstorming, mind mapping, and a "think tank" white-board for exchanging ideas. Considering the engine behind this tool, it has been proposed as a neural network. During the interactive use, the user adds events in a "quick-write-mode", with no need for an exact definition of all parameters; this can be done later in a review mode. The event listener is a module that listens to the events of the user. It triggers and creates their relationships after the event, meaning that the system should recognize and recommend the best connection between the events.

Ideas Generator has three modes: Quick Write – entering of new ideas (all input is dashed); Review Mode – editing ideas and creating connections; Event Mode – brainstorming in collaboration with other users.

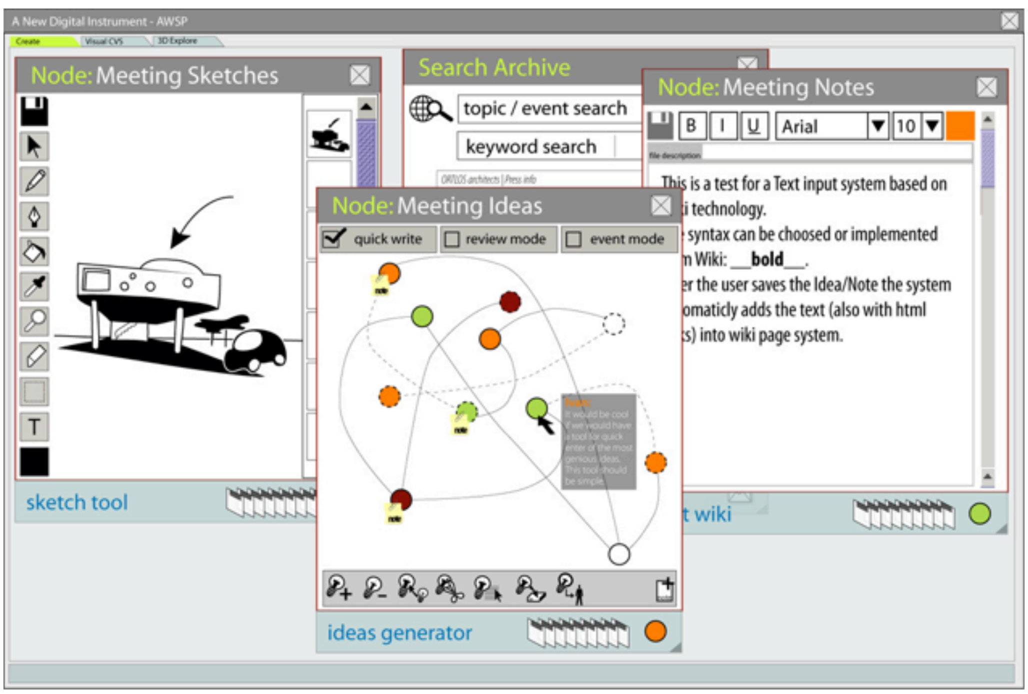

Fig. 15: Basic tools for creating new nodes - Ideas Generator in front

3.3.4. Linger Plateaus

Linger plateaus are "Interactive surfaces" - an instant messaging system for user communication. It is a network of the connected events, which is represented as links on one "plateau". It is a user interface for producing events with various file type content, and it works as a common virtual user's table to spread out all information and data needed for the birth of ideas. An avatar should represent each user.

This tool based on JOGL technology shows who is online and the current status of the user. Users specify their status by selecting from the list on the top of the panel. User search is available as well, one can search for other users through the other user's name and interests described as the user's point-of-view. User's last input to the group or to another user in private is displayed in another user's view as a speech bubble. If one user wants to see all of the correspondences with another user, he/she needs to click on the related user's plane and the plane will be rotated and outspread to display the perspective (2D view). Linger plateaus is equipped with a single line input box at the bottom of it. The box can be used to enter, and send a message. Each user item is displayed on a separate plane. In case some users are in the same session, their items share the same plane. The view can be rotated with the zoom function. Each contact person has a unique color (only if online), which serves as an identifier within the whole system. Each user can predefine which users from the "contact list" will be displayed on the plateaus.

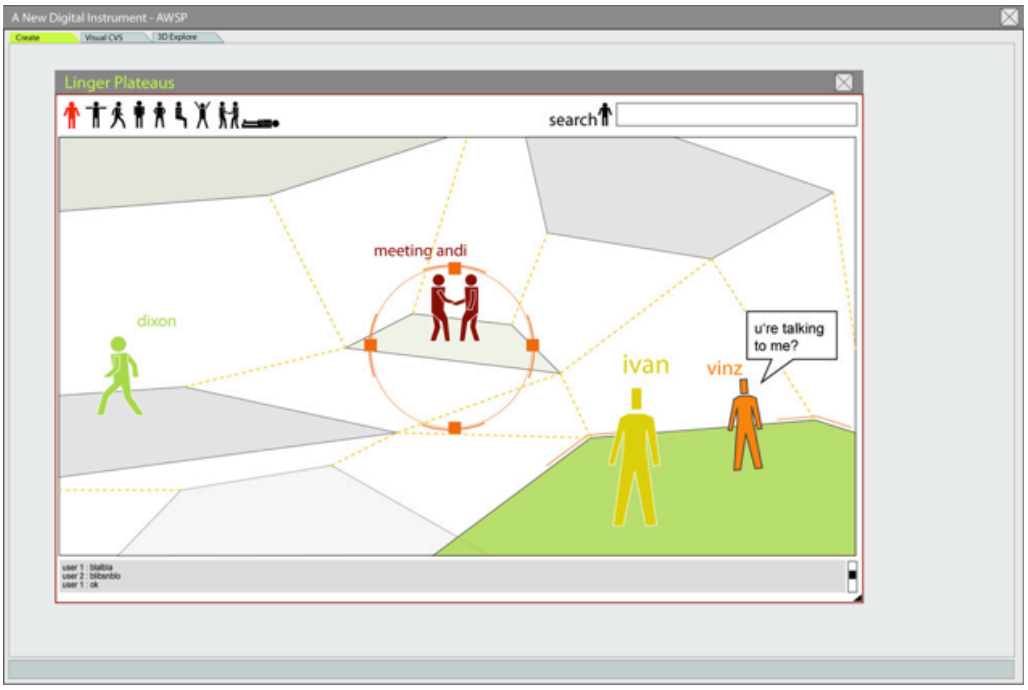

Fig. 16: Linger Plateau for instant messaging.

3.3.5. Other tools

Beside basic tools, the user can additionally write own tools and implement them into the system (applet synthesizers). There are template containers in ASWP code, which can be used for any kind of additional plug-in. For example later added "**sketch tool**" serves for quick, synchronal exchange purposes of visual ideas. Each sketch can be saved in the gallery. Export is conducted in form of a vector or pixel graphic. Import of any other node of the system should be possible as underlay background to be sketched over. Search system and archive by topic (event) search or by keyword. The user is given a possibility to search for events, nodes and documents based on the current work and point-of-view. This way the system presents intelligence in recognizing the topic and previous work from the whole system that is of interest to the current work. With a strong reporting tool support, the system is able to bring visual representation of related experience from previous projects. Text input is based on Java wiki technology. One node can have more then one text document.

3.4. User Interface for transdisciplinary collaboration environment

The concept for the interface is based on neural networks[95] to perform an automatic analysis and categorization of the semantic contents of the documents. The graphical output of this analysis, is a 2D map of nodes in which each node or node cloud occupies a space proportional to their component's frequency. The more frequent patterns occupy a greater area at the expense of the less relevant ones. The semantic map is an interface that evaluates and visualizes semantic links between individual nodes on the A.N.D.I. database. Interactive visualization provides an overview of the context and "links" between the relevant documents. The top level map shows the node which is **"current node"**, with other relevant nodes connected to it and spread in a way to show the value of the relationship. After making the other node current, the system "reconfigures" itself, based on the relationships to the new actual node. With time the system "learns" which relationships are important for a single user and/or for the whole team and which are not.

In some suggestive schemes, as for example Kohonen SOM, the top level is like a set of tiles where the different domains adopt polygonal shapes from parallel sides. Each domain has an associated word or phrase that defines the category. If one clicks on a particular domain, a second screen opens up containing another similar map that is then restricted to the sub-domains of this domain. We can repeat the process until we reach a level on which the individual documents that belong to that specific sub-domain appear as traditional listing. Examples of potential categories are: entertainment > music > jazz > Miles Davis. But in reality this system is based on commonly used terms or social agreements without including un-sharp (blurry) descriptions and fuzziness. In the creative process

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95 The features of self organizing maps are based on dimensionality reduction, i.e. a higher dimensional feature space is mapped into a lower dimension. This neural net implements a consultation module for an N-dimension map. "n-D" refers to the cluster space - during training, clusters are allowed to form a vector direction rather than a 2D- map. The algorithm takes an N-dimensional set of nodes as input and trains a neural network that finally converges to produce a 2D map – a screen interface.

different interpretations of the same thing have to be allowed! This does not make the category of the single element important, or what it is and where it comes from, but how contents relate to each other. In our system one can claim that Miles Davis is a pop musician. However, more interesting is that he uses his improvisations by relating to his own spatial configuration.

The user adjusts the node cloud through working on Infospace. By defining and changing the directions and working on nodes in one node cloud the system learns about the users' preferences and interests. By removing one node from the current cloud (dragging it out) the node automatically gets less value then that of the current node cloud. This way ,the direction set will be modified. The user can also drag in the node that will appear out of his node cloud as a proposal by the system or by the co-workers. By brining the nodes from outside into the cloud either a new direction will be created, or it can be placed on the exiting direction where the current status of direction's value will be assigned to it.

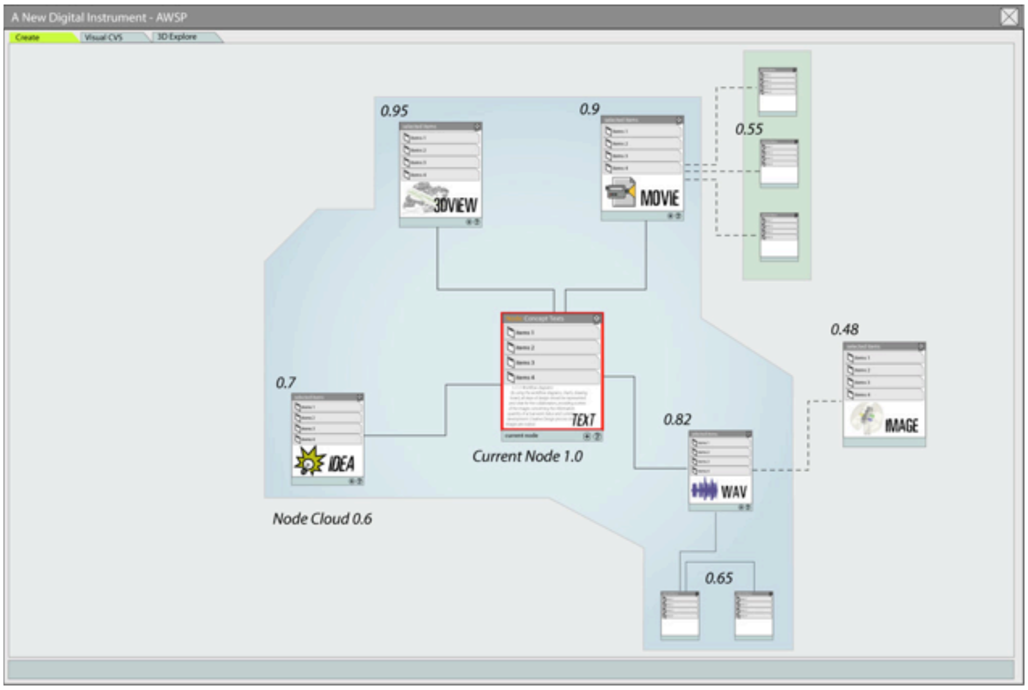

Fig. 17: 2D representation of nodes with icons suggesting the MIME type of each node.The current node has a red frame around it, the selected node a blue one. This exemplifies a zoom-out condition. The small preview of each node with max 4 document icons can be shown. Documents with a greater number of content links are grouped in clusters (node clouds). The node cloud is defined by the value of system sensitivity.

Navigation appears through one click on an empty field. Then the following options are available: changing *Point of View* – filtering of represented directions; adding new directions to current point-of-view; changing *Current Node* (the node has to be pre-selected – white frame); changing *System Sensitivity* (slider 1 – 0), with value 1 only the current node will be shown - all values under 0.5 have to be explicitly approved by the user; changing *System Deepness* min-max; ADD – adding and defining a new node by default or custom, or by using the system tools: e.g. sketch tool, text wiki, Idea Generator, etc; DEL – removing the node from the system with all its documents (see user rights); System zoom – zoom in, zoom out, zoom to - for direct access to the system zoom level; Status – Information and query about any node: Anytime / Anywhere; Help – the help screen opens up. Through the user action "mouse-click" on the "?" button, information about the node opens up in an overlaid transparent panel, containing node name, owner, date created, keywords, MIME type, and description (abstract). By clicking on the "+" button the zoom-in modus is activated. If through clicking on the "+" sign of the non-current node in the node cloud system zoom is activated it displays only nodes that are related to the direction the clicked node is positioned within the current node cloud. If the current node "+" sign is clicked, the system zoom displays all nodes of the cloud. Keywords provide information on the content of a cluster.

Zoom-In modus makes it possible for the user to see the nodes big enough for review and to edit them. GUI elements are: Node name, Content info and Command icons. The image below shows the zoom-in level with nodes related to the specific directions or all nodes in the cloud. Their z-order position (front-back) presents the distance to the current node. Any node can be brought to the front for reviewing purposes and subsequently be returned to its previous position.

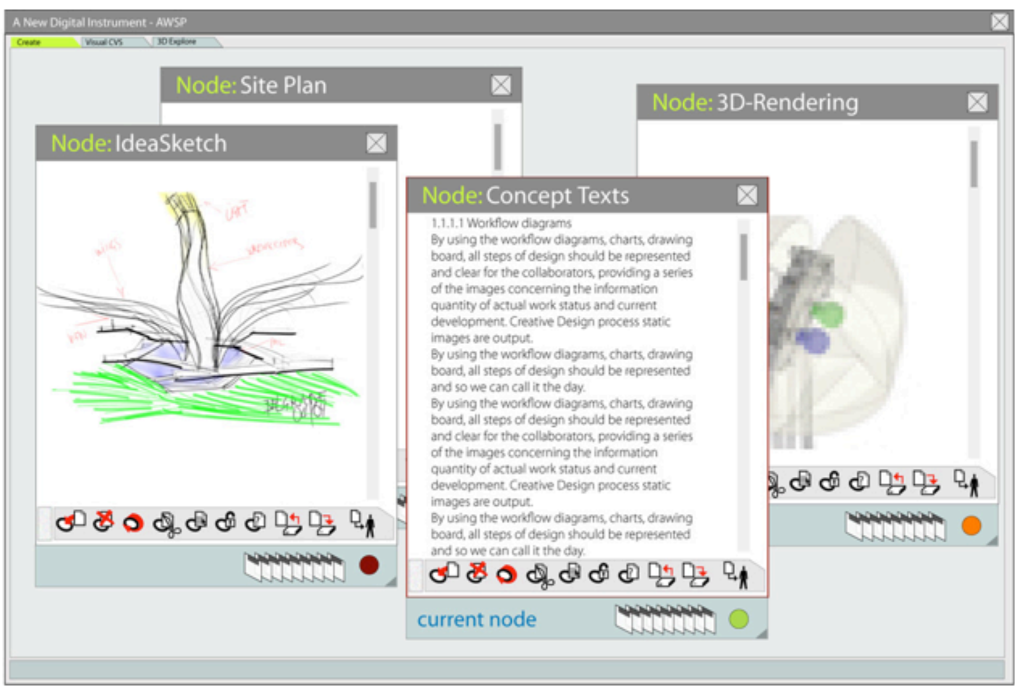

Fig. 18: Zoom-in mode with related nodes from previously defined information cloud in zoom-out mode.

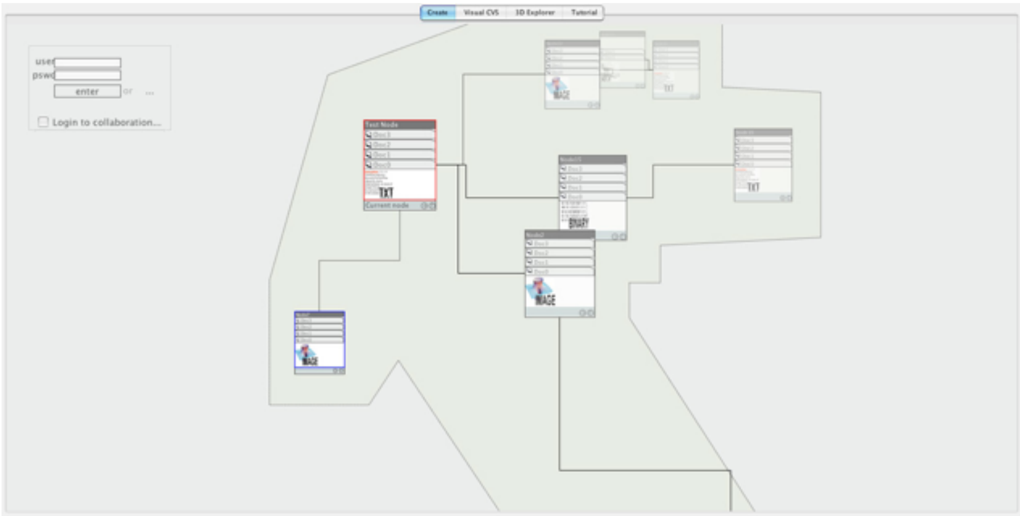

Fig. 19 shows the start screen of A.N.D.I. with test nodes and login form. It is useful to implement a demo mode and test nodes into applet for two reasons: firstly, even in situations when the connection between A.N.D.I.Server und A.N.D.I. Applet can not be established, the presentation of the system is possible and working; and secondly, with demo mode the whole functionality of the system with all aspects can be explained to the user. Additionally there is a psychological effect which gives the user the "feeling" that the action design can be started right away – no project set-up or preference adjustments, etc. are needed.

3.4.1. Final tools of A.N.D.I. prototype

Through the usage of the system and constant reworking of the interface usability based on users' reports, there have been made the major improvements of tools and working procedures. The steps from registration to the beginning of the actual work have been simplified. The explanation of the process and tools makes the system understandable for the reader. The user has to be registered to access the database. A new session can be created or an existing session selected or– the system will remember the last user's activity. The nodes are represented as rectangles. The node framed with a red line signalizes the *current node*. The small icon within it provides quick visual information about the node's MIME type. If the node contains documents it will be represented as a doc icon – up to four documents. The node shows its name as well, and by pressing the question mark additional information about name, owner, created data, keywords, MIME type, and description can be obtained. A new user will probably start with search. For a text search one can chose between node, document or event. As a result, the system delivers the list of nodes containing the search topic within, the node name, and the keywords or description. The small icon will provide additional information on the MIME type. The search is actually a tool container as well, like the other tools.

By dragging the rectangle with mouse press down on the screen a new node will be created. The first action by the user is to define which tool should be used based on the purpose (text, image, file upload, sketch, etc.), because an empty node can not exist in the system. Naming the node is very important since this is the only parameter, which can not be changed later on. By clicking anywhere on the screen a context menu will pop up. Depending on in which context the menu has been called the presented options may vary. However this menu includes all tools and options available within the system: selection between zoom-in and zoom-out mode, navigation (parameters sensitivity & deepness), change Point of View, project export, Linger plateau, sketch tool, text tool, idea generator, collaborative work report, and search tool.

Fig. 20 shows three states of zoom-out mode of the same Infospace based on changed parameter deepness and Point-of-View.

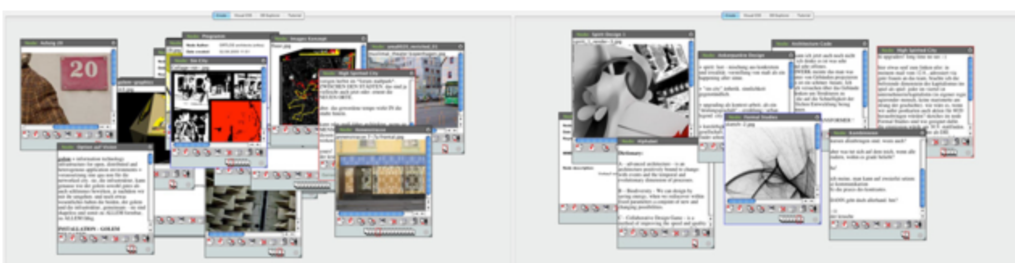

Fig. 21 shows the approximate state of the zoom-in mode based on the above zoom-out mode.

Text tool is a container holding one or more text documents. The icons on the bottom represent general commands within tool: add new document, refresh node, upload document, download document, edit document, delete document, node properties, change node security settings, and send document via e-mail. Clicking on the disc icon can open each document. Every user has his/her own color representation. The node can be closed, but on next Infospace state change, e.g. from zoom-in to zoom-out that node will appear again. To delete a node from the database all documents within the node have to be deleted (since an empty node can node can not exist within the system) – deleting a node that contains documents temporarily removes it from the representation within one state mode.

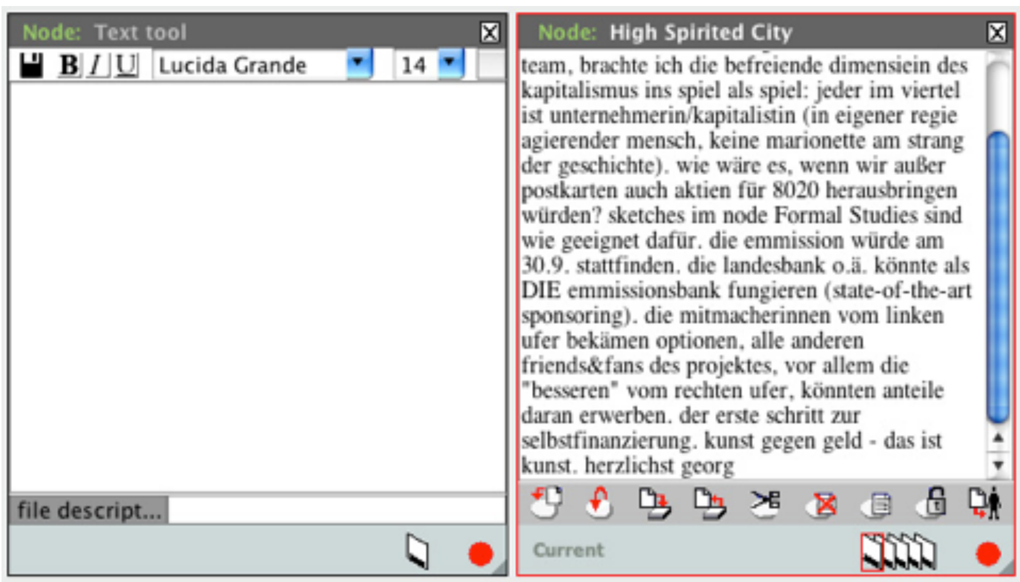

Fig. 22: Text tool

The sketch tool, which is similar to text tool, can contain more sketch documents, within the same node, but it also can contain more galleries within one document. In edit mode the commands are: save all sketches in node, select objects, draw rectangle, draw circle, pencil (free draw), pen for Bezier curves, text, zoom-in, and with the control button pressed zoom-out, eraser, paint bucket, color chooser, save sketch in library, bring object to front, bring object to back, start collaboration. When the user presses the “start collaboration” button, the sketch tool will pop-up for every user who is online in this particular session and enable real-time collaborative drawing. This so called in-sync collaboration means that two or more users are capable of using the same drawing canvas at the same time.

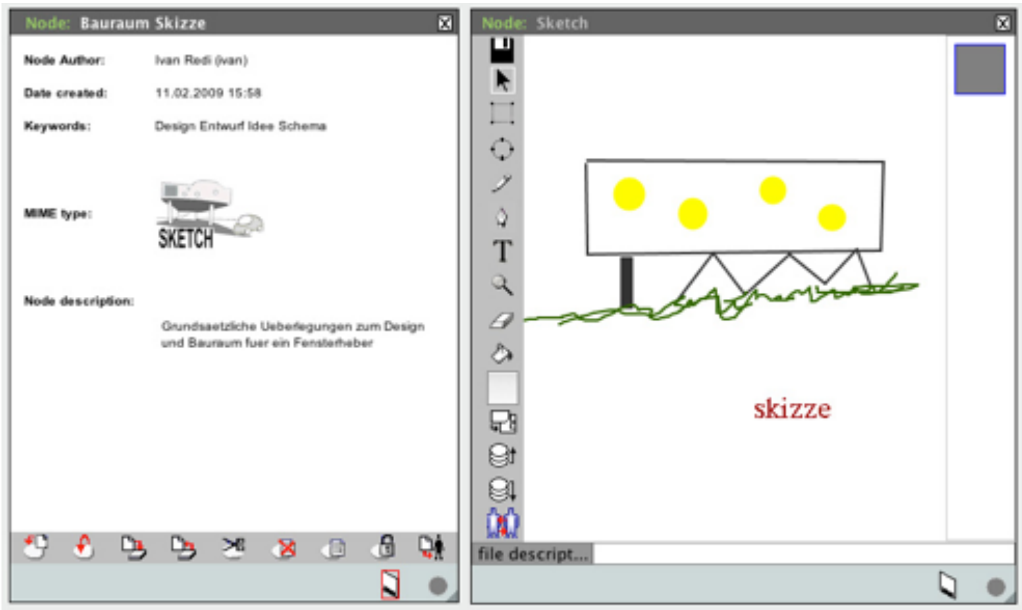

Fig. 23: Sketch tool

The idea generator is a brainstorming tool and is a unique tool because it does not limit the user to one file type. It is a tool for the mind mapping of ideas and it can run in three modes: quick rite, review mode, and event mode. In case the event mode is turned on the same tool will pop-up on the screen of every user being in the same collaborative session, for the sync collaboration in real time. In edit mode the commands are: select ideas, add idea, delete idea, connect two ideas, edit idea, properties ideas/connections, export to event, save idea node, upload document to idea, and edit note (a note is the description of an idea)..

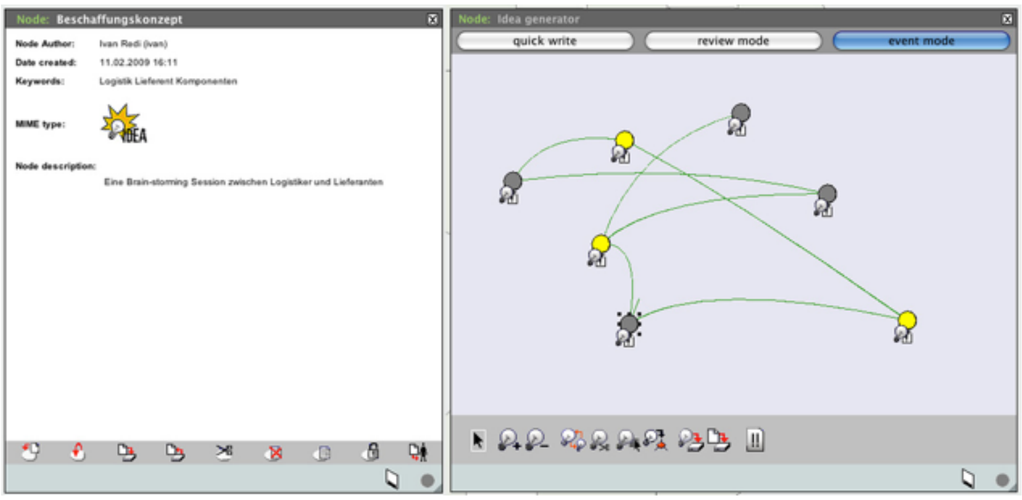

Fig. 24: Idea generator

3.4.2. Test phase of A.N.D.I. System

If a calendar is a tool for helping us to think about the flow of time, and a pie chart is a tool for thinking about statistical distribution, then Infospace provides a set of tools for supporting the transdisciplinary design collaboration. The tools and behaviors described here are on the structural level and do not control the system directly, except on a presentational level. This condition will make unexpected output possible in a self-organizing manner, especially when users develop their own plug-ins within the container system. Test projects investigate the current and future options of A.N.D.I., with respect to performance requirements, which are defined for the specific applications of the user. An important aspect in this phase is to test the user interface on usability. Two major purposes of comparative testing are to provide technical information for the modeling and design of the prototype and to provide input for the design and development of A.N.D.I. at the earliest possible stage.

It was planned that A.N.D.I. will comprise a first test phase containing an urban architectural project "City Upgrade". The test phase was performed to find first estimations on the potential performance of the system. This test phase started as soon as the prototype of the operation system was available. Based on the results of this phase the A.N.D.I. engine has been redesigned and redeveloped.

An interdisciplinary and international team has performed the design and development of the projects for the purpose of conception. Special emphasis has been put on different environmental investigations. The test consists of a validation part used to test the technical functioning of the prototype for further improvements, and a technical evaluation part to determine the overall performance of the new application.

The second test phase trials and optimizes the final operating system. The validation part will be based on the experiences gained during the test and will concentrate on critical situations found through this test. The evaluation part will be performed in close collaboration with potential users.

4. The Practical Application of A.N.D.I.: Case Study "City Upgrade"

"It is a phenomenon of transconsistency, a network. It represents a threshold of deterritorialization because whatever the material involved, it must be deterritorialized enough to enter the network." [96]

This chapter presents the results obtained by using A.N.D.I. in architectural practice and describes the findings, which came about by the collaborative process. It starts with a synopsis of the Case Study "City Upgrade". This is followed by A.N.D.I. implementation and process of using it as the collaborative environment. It is an observation how and in which manner project participants used the Infospace for creative process, and these actions have been then evaluated. And finally the discovery and analysis of the behavioral patterns within Infospace by stakeholders involved into the "City Upgrade" project during their collaboration. The evaluation of the Case Study also mentions the emergence of the spin-off project "City Lab" as an example of an innovative moment during a project.

4.1. Case Study Description

The project "City Upgrade: High-spirited Networked City" was initiated by ORTLOS Architects in 2004 and premiered at the steirischer.herbst Festival of New Art in the medien.KUNSTLABOR in Kunsthaus Graz from Sept. 30th – Oct. 10th, 2005. It has also been an attempt to automate the "increasingly complex task" of collaboratively developing and designing a project by switching from individual to multiple authors. By higher orders of information input, the findings of this synergy of research and design should help initiate and influence urban development concepts in a more sensitive and inflected manner

[96] Gilles Deleuze, Félix Guattari, "City/State," in Rethinking Architecture, ed. Neil Leach (London: Routledge, 1997) 313.

than it would be possible within the framework of conventional architectural practice.

The intention of this four-year-project, which started with a one-week workshop in Forum Stadtpark in Graz in November 2004, has been to test and develop, within a cross-disciplinary networked community, a series of intelligent concepts for a city upgrade on “the other bank of the River Mur” in Graz Annenstrasse (zip code 8020) by means of heightened dematerialization, i.e. intangible things such as IT infrastructure for open, distributed and heterogeneous application environments, being enabled by next-generation computing (grid, ubiquitous, autonomic) and a wide-spread enterprising spirit. This was a complex task due both to the topic and but also in a sense of managing the team of experts involved in the project, each coming from the different disciplines.

Content-wise our city upgrade approach for 8020 has been focusing on already available urban “hardware“ and has been trying to infuse it with new “software”, which enables the “old” to adapt to the “new” due to its continuous electronic engagement with interconnected open information systems working according to the principle of distributed intelligence: everywhere at the same time and nowhere in particular. The real and the virtual occur here consequently as two multi-layered, complementary elements, allowing a broad range of societal players to actively take part in developing and designing the future within so-called hyper-real plug-and-play worlds built according to a “game structure” to make it more convenient for people to interact with information, devices and other people[97]. These worlds, not unlike human prostheses, can easily be implemented within old buildings by mixing both the real and the virtual, for it is all about consistent interfaces. The result will be intelligent, programmable on-demand environments.

What has been in the foreground of our interest, hence, has been the implementation of information technology infrastructure for open,

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97 See Kas Oosterhuis, “Protospace 2.0 _ The ITC-driven Collaborative Design Working Space,” in Georg Flachbart, Peter Weibel (eds), Disappearing Architecture: From Real to Virtual to Quantum (Basel: Birkhäuser, 2005) 225 ff.

distributed and heterogeneous application environments, empowering the city to “know itself”, i.e. to react in a highly efficient, self-managing and self-diagnostic way to data input from multiple, distributed sources in addition to traditional centralized data administration by city authorities. The implications for city-users would immediately be evident: a network of self-organized, “smart” computing components distributed throughout the city (or a network of buildings) that would give them what they need (e.g. light, warmth), without a conscious mental or even physical effort; much in the same way our autonomic nervous system regulates and protects our bodies. Because of our continuous electronic engagement, the IT infrastructure learns how we live and, in doing so, discovers different patterns (algorithms) in our behavior. It optimizes these patterns and proposals for new kinds of applications, which, on the other hand, will continuously be updated by users’ feedback loops[98]. By shifting available resources to higher-order acting of as many individuals as possible, the impact of materiality could exponentially be reduced and investment of capital minimized, and our vision of *heterarchitecture*[99] as the enabling platform available for all.

To enable the creative process and support idea-finding phase of the project “City Upgrade” the system A.N.D.I. (A New Digital Instrument for networked creative collaboration) has been used. As previously described A.N.D.I. is an open-source platform for creative transdisciplinary collaboration, allowing the team members to work jointly on the project on an equal basis at every stage of the project following the principle of distributed intelligence: everywhere at the same time and nowhere in particular. This was the preposition and departure point for the implementation of A.N.D.I. as an instrument for the transdisciplinary collaboration within the project “City Upgrade.”

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98 William Mitchell, ME++ - The Cyborg Self and the Networked City (MIT Press: 2003), 32

99 “Heterarchitecture is conceived as a hybrid, mixed-reality environment, could help accelerate the process of our automating liquid logic in much the same way as IBM’s vision of autonomic computing could help manage the increasing system complexity of high performance information technology application environments, which will be largely self-managing, self-diagnostic and transparent to the user.“(Flachbart, 2005).

4.2. A.N.D.I. Implementation

This section explains the process of using A.N.D.I. system, described by usage of tools and users' actions, to evaluate the implementation of A.N.D.I. within the transdisciplinary collaborative environment and to gain insights on postulated assumptions. Furthermore, observing and monitoring the usage of different tools from the users' point of view and the reaction upon the System Interface reflect the users' habits and provide some insight into working methods before and after the usage of the system - as to compare the established and the newly introduced working methods.

4.2.1. Key concepts for implementation of A.N.D.I.

During the implementation of A.N.D.I. within this Case Study the following concepts have emerged during working process and have been implemented in a final evaluation.

Management of the relationships

Detailed guidelines for the management of the relationships between the single resources and the people involved are important in this context. Trusting each other, showing understanding for the dependencies within the team, as well as the manner in which people collaborate are tremendously important for the development of projects. The documentation of the activities and steps during the whole development process is an important experience for being able to realize problems at an early stage within further projects or sub-projects, and to be able to avoid previously made mistakes and misunderstandings. Additionally, are cognitions about the used tools and additional software for the analysis of how to optimize the "work-flow" of are importance.

Avoiding loss of information

When the dislocated team members and project partners use different programs it is not only significant to find out whether data exchange is successful, but also if additional communication tools are necessary to avoid conversion problems, and thus to minimize the loss of information. Through the tracking of actions in the sense of project development “proposals” can be made with a system that shows artificial intelligence to project partners through the analysis of especially successful projects and team constellations. This method is effective concerning cost reduction and it is easy to evaluate because it is scalable and applicable independent of the team constellation (within one enterprise or between different ones). Knowledge exchange is based on the relationships that are established during process-like work, which does not demand investments in additional IT infrastructure.

Work reports

“Work Report” (“Knowledge enabled engineering and context management“) is an AI- Interpreted-Model (AIIM). Artificial intelligence uses ontologies and semantics oriented reference models that describe the dependencies and relationships between the relevant Nodes (as sum of certain facts which depict the effect on a solution through defined demands, know-how, decisions, and data). A new flexible data base search is needed for semantic constraints, which should be acknowledged by all team members equally.

Dynamic configuration of demands

The working process supports the dynamic configuration of demands and just-in-time decision making, as well as the linked integration of the whole *Infospace* during the work independently of which working domain one is currently located at or on which detail level one operates. The context oriented knowledge search, the visualization of previously made experiences, and the tracking back of transdisciplinary integrative processes and information flows are important here as well.

Freedom of decision making

Decision-making in a creative and collaborative environment is also strongly dependent on the “freedom” to make decisions without letting the whole system crash in the course of it or to negatively influence process flow of production, and last but not least on learning from “mistakes”. No information or action within the whole Infospace of Infospace is considered “incorrect”. A concept or idea that could not prevail will just be meaningless for further processes. Therefore, an “undo” key has not been intended; or a hierarchical structure of steps of procedure has been abstained from (history free feature). The advantage of this approach are freely operating agents who work in a content oriented way and do not need to busy themselves with finding out where in the PDM structure their contribution can be ranked, or which connections can be disrupted if a “Feature” is removed from the system.

Collaboration request

“Request for Work” motivates and asks team members to concentrate on the actual work and their creative input (action design), rather than having to occupying them with the constant reorganization of their contributions. This condition certainly increases creative, non-linear production. Other benefits are the unexpected new configurations that cannot be predicted at the beginning of a creative working process. This leads to a better understanding of complex processes and it becomes possible that for example designers and constructers can look at these from their own point of view and therefore profit from each other and do not consider each other as competition. The actual competition consists in each team member giving her/his best and not in “beating” others. Everyone stays an expert in the individual domain, aiming at a common goal.

There are various ways in which a collaborative design environment can be conceived when used as a testbed for confirming the presumptions stated at the beginning of the research. One possible method in that regard would be by observing the users’ actions during the working process and analyzing their behavior within the system. Based on this information the system could be adapted and further developed. A.N.D.I. implementation within Case Study “City Upgrade” is part of evaluation methodology. Therefor, in this section, some functions and tools, that a collaborative design environment should provide to support the required aspects described before, will be examined and discussed based on their utilization. Step by step explanation of process of using A.N.D.I. will help validating the implementation of practices based theories previously defined.

4.2.2. Process of implementation of A.N.D.I.

Beforehand project started the basic introduction of A.N.D.I. system has been provided to all project members during the first set-up workshop. Prior to this meeting the user's manual has been submitted to each of participants (see Appendix 8.3.), accompanied with some additional coaching on an individual basis. Additionally intense organizational work was necessary to explain and convince the users that the content has to be created within the system, and not simply uploaded, imported or copied into the system. Some complaints by project participants, e.g. not being able to "copy & paste" previously written texts into text nodes, or questions about uploading the files (mostly images), showed that users were using A.N.D.I. parallel to their commonly and previously used tools. However, after about two weeks of usage, the users became comfortable with the working process, and the *Infospace* has started to grow.

The initial action in working with *Infospace* of this Case Study was to create a main node named "High Spirited City". Figure 25 shows the situation where this node is set as current node as well. The current node means a node from which are all other nodes are connected through different "Point of Views". Users have generated various "Points of View" mainly based on their own profession: e.g. philosophy, urban design, architecture, media art, photography, literature, etc. However some users still worked in cross-disciplinary manner, by adding new nodes, documents within nodes or editing the existing ones, to Point-of-Views which are not their main area of expertise. The top node in particular, was altered several times, and as the project progressed, the new documents were added in this text node, which is illustrated in the Work Report tool in Figure 26. This has somehow determined the further development of the project, since all participants intuitively considered this node as departure point. It was also useful for the new users to step in to the project very quickly and to gain an overview of the progress. Disadvantage of this condition is that some users understood the graphical representation of Infospace as a tree-like structure, which automatically leads to top down thinking in the design process.

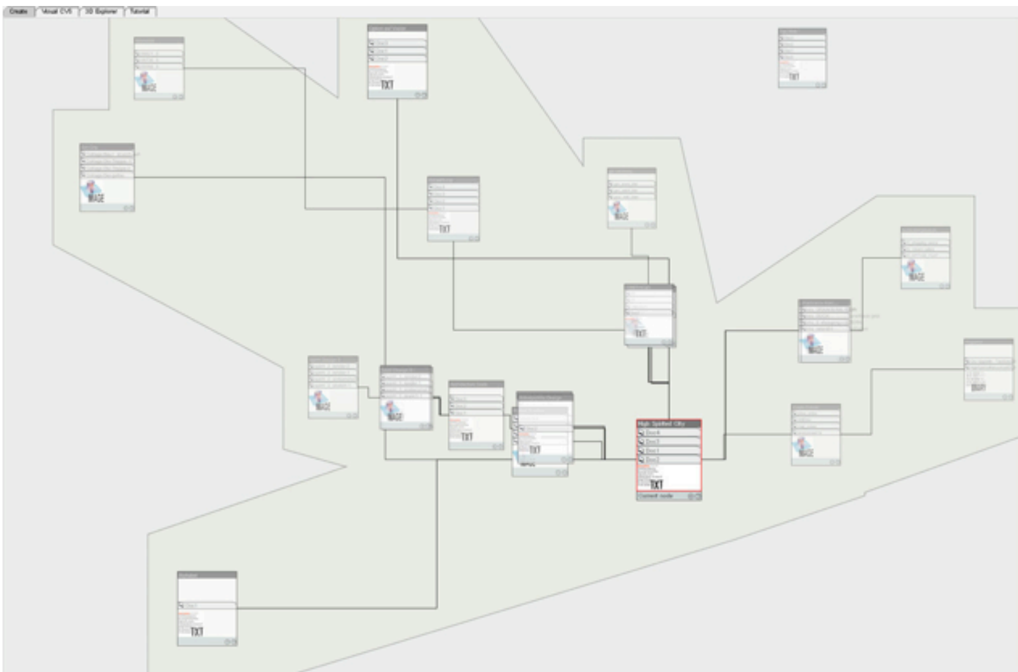

Fig. 25: Infospace (Active Work Server Pages) has two zoom-modes: navigation (zoom-out) and manipulation/working (zoom-in) modus. In the navigation view it is possible to organize a huge amount of data (and various MIME types) without getting lost, with options such as: change point of view, sensibility or deepness, etc. The nodes are arranged around the 'current node' with the representation of a node cloud.

Some users expressed concerns about other users changing "their" nodes by adding documents to it, or even changing the actual content e.g. within the text document. This became an issue especially during the collaboration between architects, leaving some project partners with a feeling that others override "their" content. This problem always occurs when some people do not truly understand the meaning of sync collaboration, but nevertheless use A.N.D.I. as a representational platform for their own project achievements. Many other similar issues have arisen based on traditional collaborative experience and methods, where users felt the urge to protect their own intellectual property, etc.

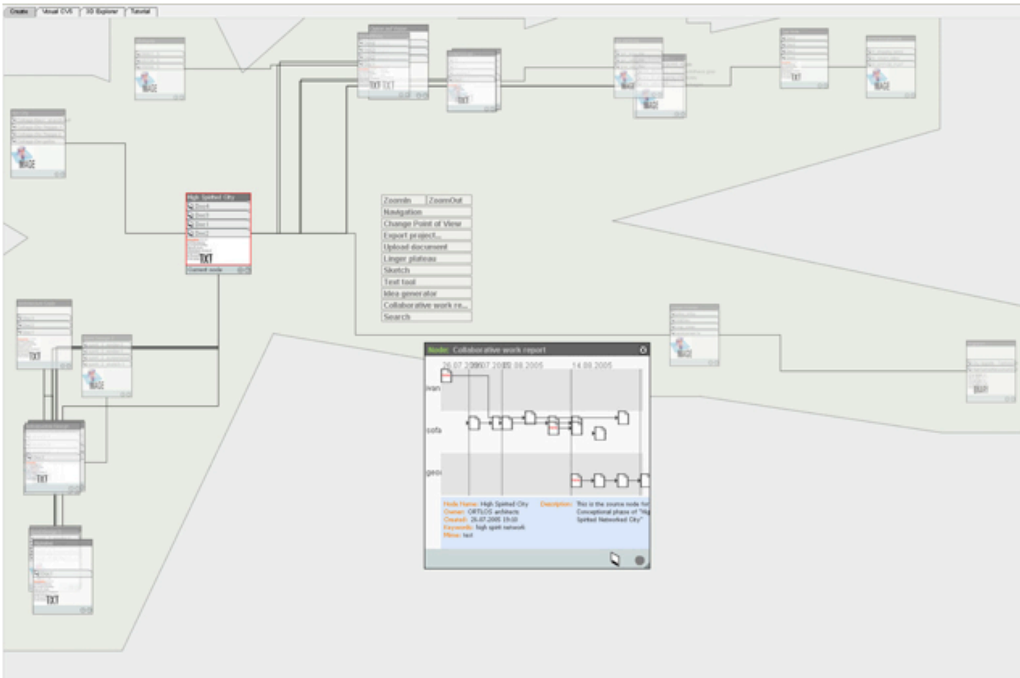

Fig. 26: A.N.D.I. screenshot. Right click on any node opens the context menu, and within any tool – e.g. 'Collaborative work report' is a possibility to track inputs from various users throughout the project based on timeline graphical representation.

Additional issues turned out to be problematic because of the fact that some did not agree on the content of other users. On the other hand, the moment they set their node to the current one, the Infospace reconfigured itself and all other nodes disappeared because there was not enough *deepness information*, which made users think that they were not connected to the system anymore. Therefore, most of the users set the "High Spirited City" back again as a current node. Since some users provided more content than the others, the ones with "less" nodes sensed their contributions might be "disappearing", compared to the information overflow from the others who were being more productive within the system. That experience provoked some competition between the partners.

When the user logs-in into the session of "City Upgrade" the system shows the exact last setting from which the user was left his work. The previous current node shows up in the upper right corner as a single node, since there is no undo command. It has been observed that many users intuitively did not understand that the command “delete” from the context menu did not meant to actually delete that node, but to remove it from the screen. On the other hand the most of the users felt comfortable with the use of Point-of-View, sensitivity, and deepness as navigation options in the zoom-out mode. After the login, most of the users switched very quickly to the zoom-in mode and started working on the nodes’ content.

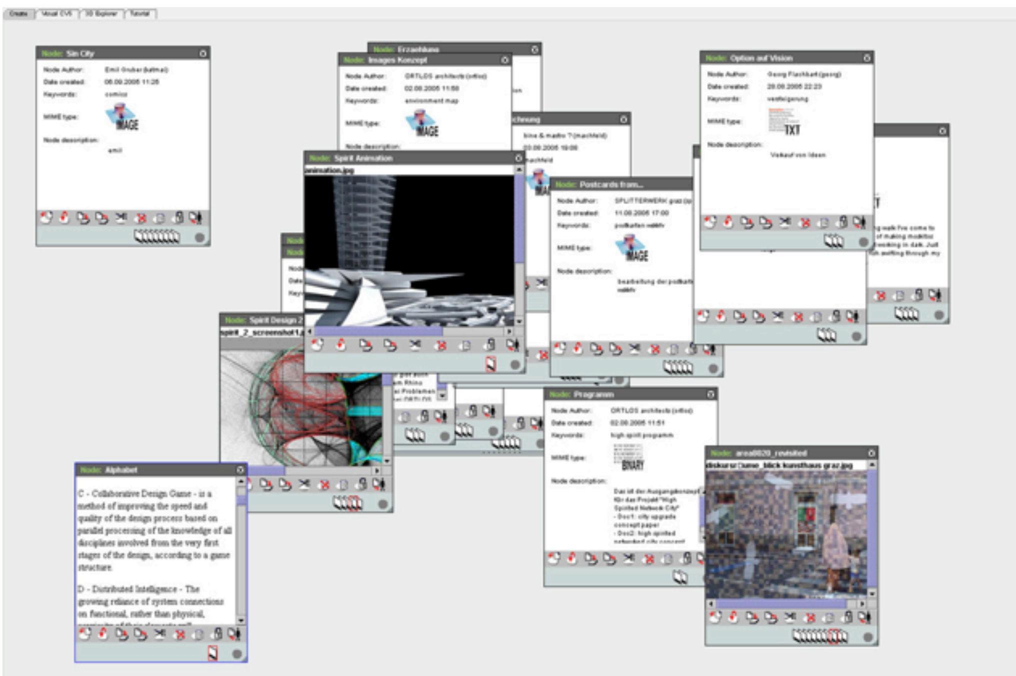

Fig. 27: In zoom-in view it is possible to work within each node and its specific documents. One node can consist of only one MIME type (e.g. text, image, video, etc.), but more documents from different users can be created. Other tools, such as sketch tool and idea generator, can be used for synchronic collaborative work as well.

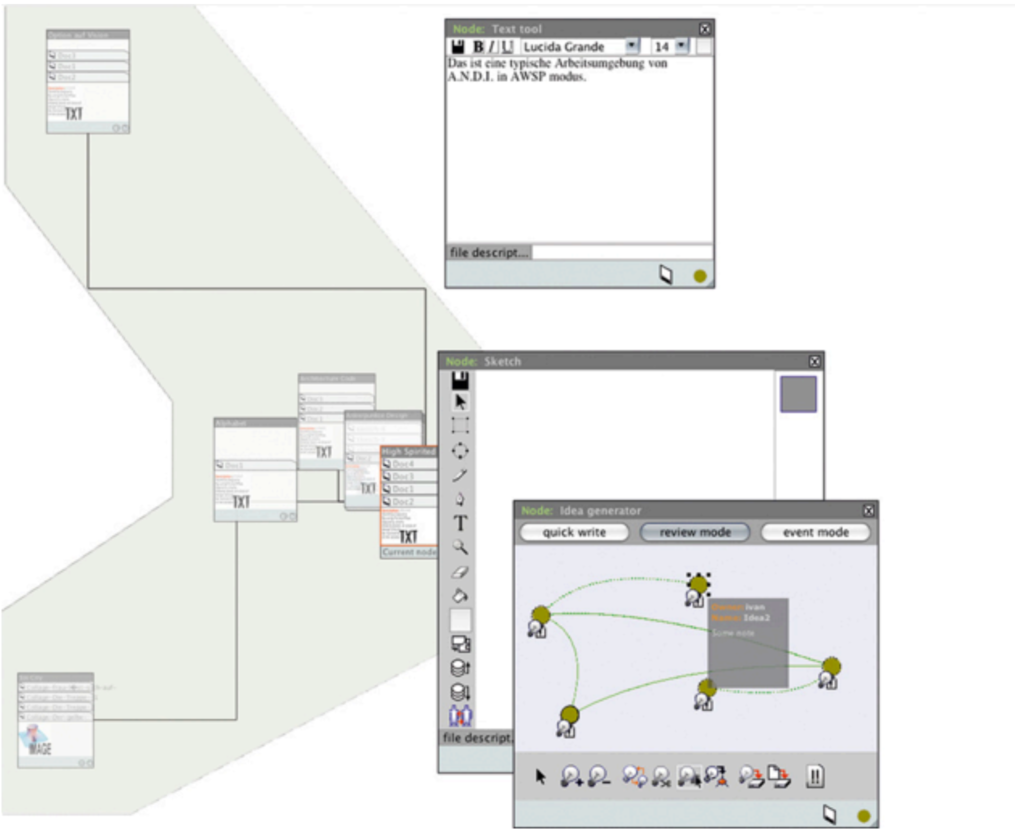

Fig. 28: Idea generator tool in zoom-out mode

In terms of collaboration "in-sync", the user can find out who is on-line by starting the tool *Linger Plateau* (Figure 29). That brought up some technical issues, since it is a 3D chat module it needs JOGL (Java Open GL) classes to be run. This was a technical barrier for some since JOGL was not implemented in Java2 at that time and it needed to be installed separately. Another problem was that users could still be aware of other users being on-line and working, but vice versa not. Thus, it became clear that an additional messaging system (even off-line) was needed for all users to make clear that the collaborative session had been started. This was partially solved through a "start collaboration" button in almost every tool. When the user presses this button on his system the same tool, e.g. the sketch tool, pops-up on the screen of every user being in the same collaborative session automatically.

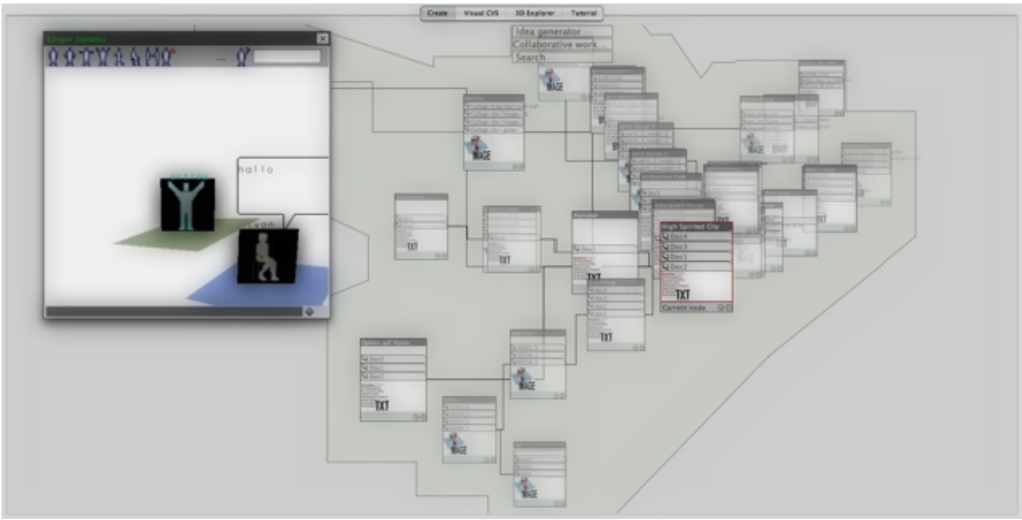

Fig. 29 shows "Linger Plateau" tool. It reveals which user is on-line at any given time within the collaborative session and in its basic version can be used as chat tool.

It has been observed, based on node types, that the most commonly used tools have been: text tool, image tool, sketch tool, upload document (binary files), search and collaborative work report (tracking who did what and when); and rarely Idea generator. It can be assumed that a lack of willingness to collaborate and an inability to synchronize the working hours caused this. The detailed usage of tools will be explained in next section, based on analysis of working procedures and processes.

The feature such e.g. "Point-of-View" shows among other information which can be evaluated, how open each expert was to set-up his/hers activities within categories other then own discipline. However, the most of architects went for category "Architecture" finding logical to make a contribution within the domain of own expertise. Furthermore, the tools they have used have been the closest to the tools they use in a daily practice. In this section the reader will be walked-through this behavioral patterns.

At the beginning with the node "High Spirited City" chosen as *current* node, *sensitivity* and *deepness* set to maximum in the navigation menu, the whole Infospace of the collaborative session "City Upgrade" is shown (as in Figure 30). The zoom-out mode is used for the navigation of the system or for the creation of new nodes. Node icons show also which MIME type a particular node has. The node with a red frame is the current one. The node with a blue frame is the selected node. By clicking anywhere on the screen, the context menu will be opened.

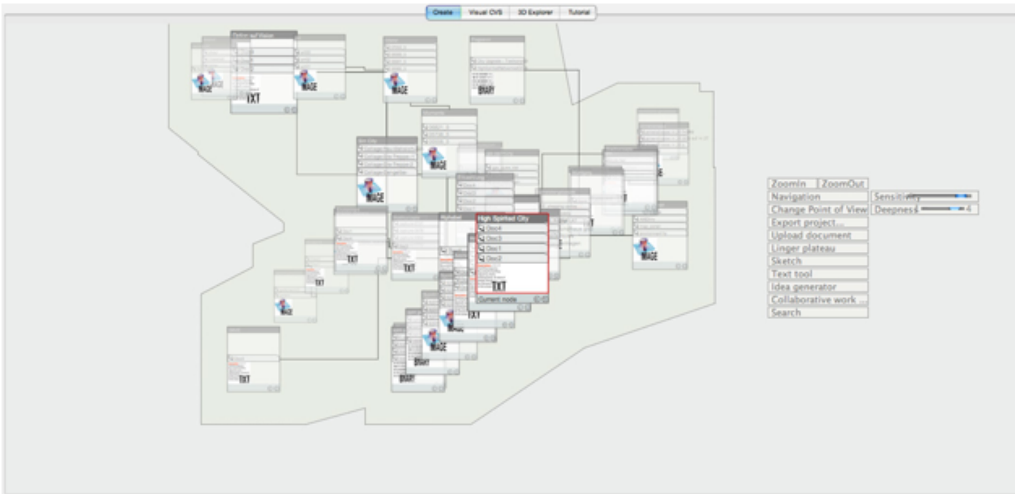

Fig. 30: With sensitivity and deepness set to maximum all nodes within the collaborative session "City Upgrade" are shown in zoom-out view.

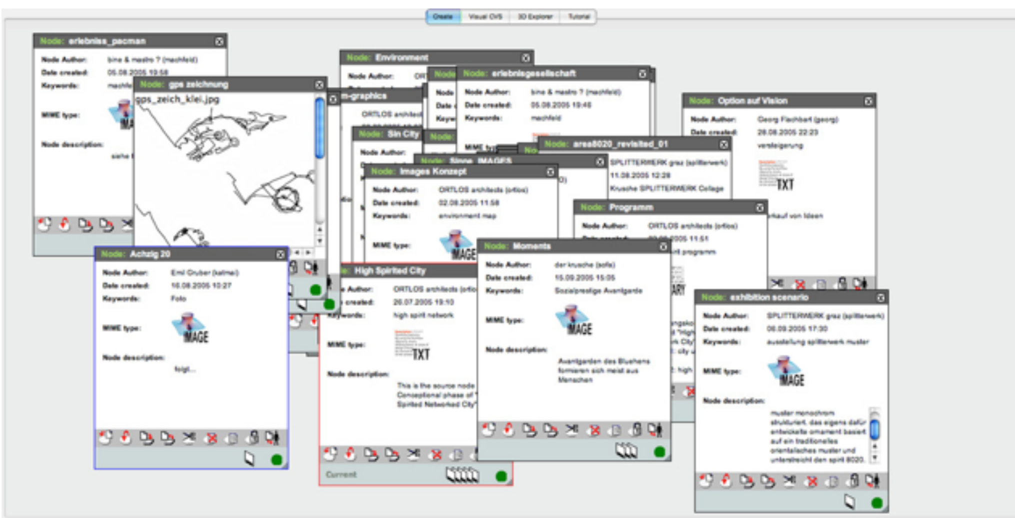

Fig. 31: The same Infospace as in Fig. 51, but showing the zoom-in mode.

The node "High Spirited City" has been established as a top node with the purpose to make it easier for new users to join the collaboration. However, this had also a disadvantage, namely that many users understood the whole model rather hierarchical or top-down. Eleven Point-of-Views have been created, with a total of 60 nodes and significantly more documents within those.

The most dominant "Point-of-Views" settings were: Architecture, Urban planning and Media containing 65% of all nodes, which was a logical output based on the fact that the "City Upgrade" project has been an urban project. Therefore, architects have dominated the team during the first two years. Thereafter, the first public presentation was a mix-media installation at "Medien.Kunst.Labor" in Graz. It seemed that for the actors it had been clear what their domain of contribution or expertise was - for example, an architect primarily looked for Point-of-View architecture.

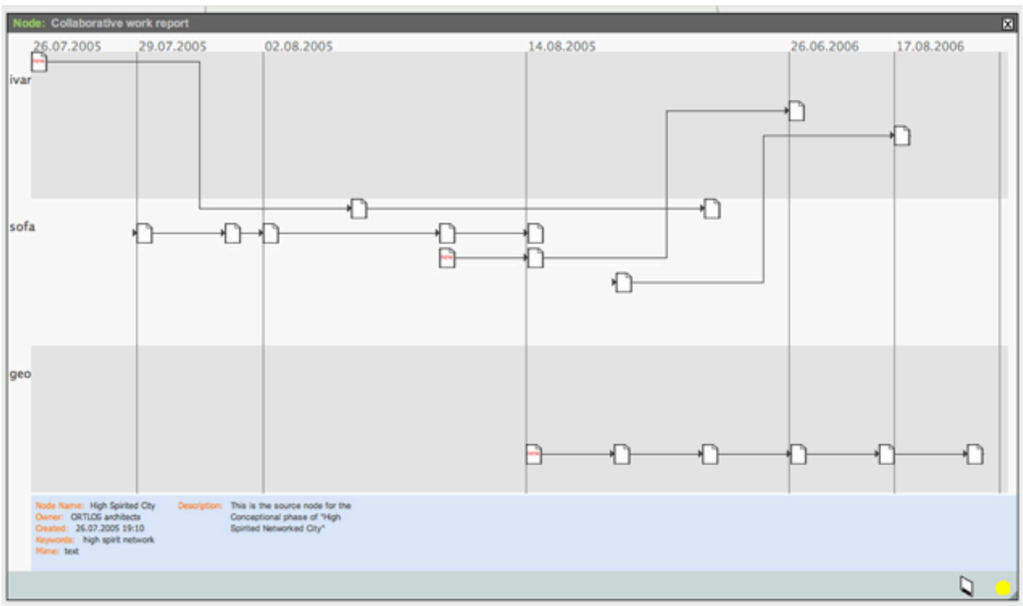

Fig. 32: Collaborative work report on the node "High Spirited City" with MIME type text. In the period of one year three users have worked on it, by changing documents of other and adding new ones. ORTLOS as the project leader was the creator of the node, and contributions came from philosophers and writers which have been the main actors for shaping the general course of the project. All others had accepted the general idea of the project and did not actively participate on the overall strategy. The tool "Collaborative work report" does not show how often and when this node has been accessed – it only tracks the changes to it.

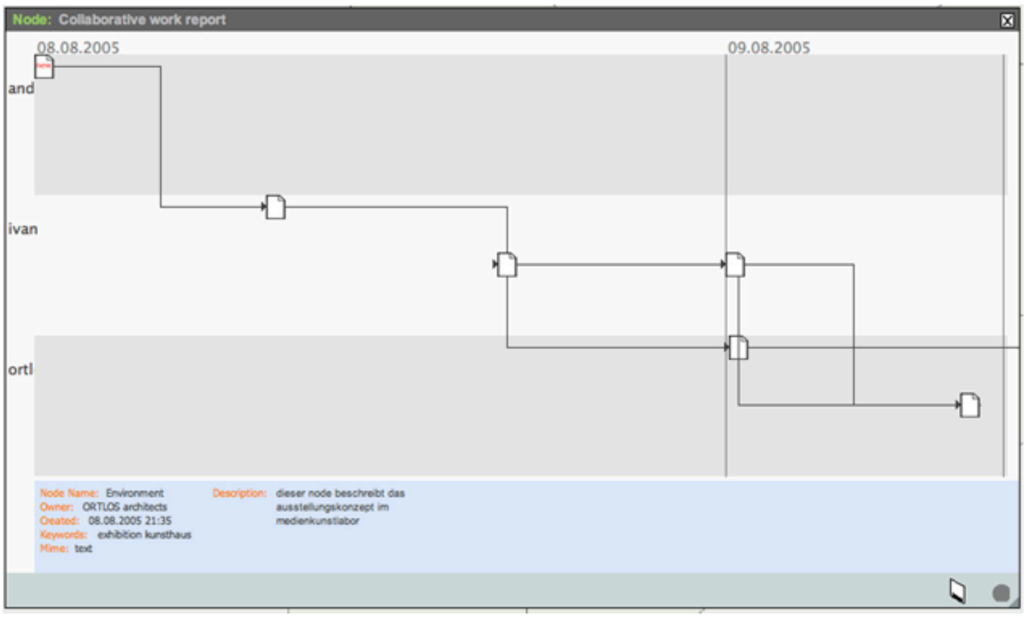

Fig. 33: The collaborative node for the conception of the first joint exhibition. In similar cases the users did not feel in charge of certain proceedings, or did not find the right way of how to contribute their input. In this particular Collaborative work report the inputs of three ORTLOS member are shown, but containing no feedback from others, except of passive acknowledgment.

The Image tool was the most used tool - more then 50% of all tools. Team members intensively used the Text tool as well. However, the users considered adding more text documents to one and the same node, which of course reduced the total number of nodes. The binary tool was used as a repository, mostly to exchange CAD data, or in some cases to upload pre-formatted Word files e.g. for press releases or exhibition programs, etc. The tools “Sketch” and “Idea Generator” were used during the creative collaboration, but no significant content were saved. The users preferred workshops and other team gatherings for brainstorming or sketching ideas. This was another indication of a lack of synchronic collaboration or in same sense the building of “islands” within the project team – small groups that used other collaborative channels beyond A.N.D.I.

Point of Views	Nodes	Text	Image	Binary
Architecture	14	3	8	3
Display	1	1	0	0
Environment	7	4	3	0
Photography	2	0	2	0
Graphics	3	0	1	2
Literature	5	1	4	0
Media	10	4	6	0
Philosophy	1	1	0	0
Urban planning	15	4	11	0
Start	2	0	1	1
Total Nodes	60	18	36	6

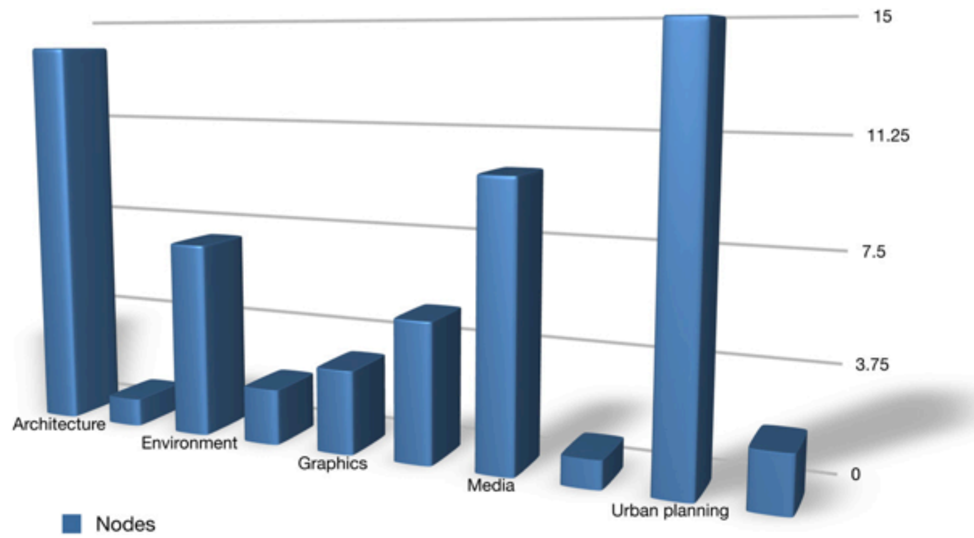

Fig. 34 shows total nodes based on Point-of-View and MIME type of each node. This diagram documents the importance of each "Point-of-View" category based on the number of the nodes created, and therefore system's usage, as well as the type of nodes points toward most popular tool within the system.

Following the users' actions within the system and tracking down their activities can be useful method to evaluate not only the system and its tools, but to obtain insights in users' working habits, working methods, and even thinking within design process. Clearly since "City Upgrade" is an urban design project the most nodes, as shown in Fig. 34, are generated within the Point-of-View "Urban Planning" and "Architecture". More than half of the nodes are Images, since the language for these disciplines is mostly visual. It seems like automatism that if the project is about urban design, that the most common way to look at it would be through urban planning or architectural point of view. However, the half of nodes are created in other Point of Views, with emphasis on media, environment and literature (also connected to participants' profession), which is an interesting moment for transdisciplinary collaboration. To better understand how this transdisciplinary collaboration emerged through the usage of A.N.D.I. system and how this worked or not, we need to examine the behavioral patterns within the Infospace and to discover the relationship model underneath the interaction between the users.

4.3. Discovering patterns within Infospace

Discovering patterns within A.N.D.I.'s Infospace is used as a method to understand how different stakeholders, involved into project "City Upgrade", worked and how they collaborated among each other. The discussion described in previous section about the tools and features provided by A.N.D.I. system facilitates the insights not only about technology but also about collaborative mechanisms within the transdisciplinary environment. However, in this section the A.N.D.I. system will be evaluated by Case Study "City Upgrade" through detailed analysis of collaboration patterns among stakeholders involved in design process. The participant and their roles based on their profession have been introduced in the section 2.3. Here, it will be explained in more detail who did what considering the contribution of each team member or group to specific node. The particular method considers the analysis of the database entries, which have been collected during the collaborative work. The method describes the collaborative relationship between the users and the nodes they have created or modified during the collaboration. The actual content of the node is not considered, but only the data about its creation and adding / editing of content performed by users.

To visualize users' different Point-of-Views existing in Infospace the Hidden Markov model (HMM, see Figure 35) has been used. This model shows, based on database analysis, the interaction of users among each other and the interaction of users with nodes during the creative collaborative process. This observation could be understood as a pattern recognition method, which is used for evaluation of the Infospace and further insights. The evaluation has been modeled with unobserved (hidden) states of the content itself.

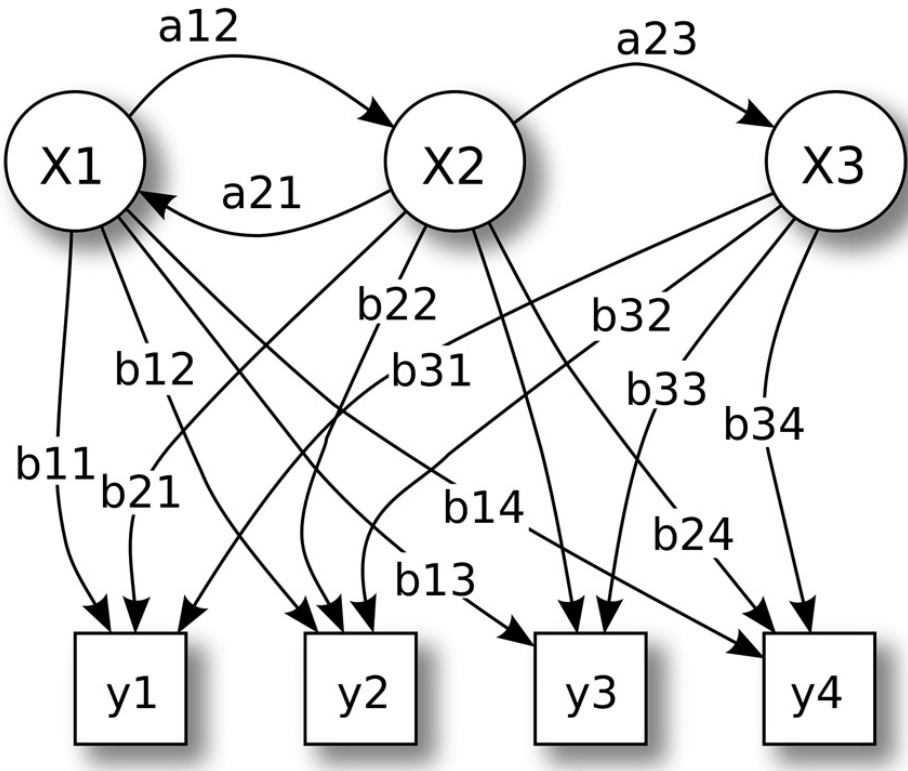

Figure 35: The diagrams used in this section (as e.g. in Figure 56) are based on a “hidden Markov model” (HMM)[100]. The reason for using HMM is that these diagrams should provide more statistical data about relationships and less about the content itself. Parameters of a “hidden Markov model” in above example are following: x — states; y — possible observations; a — state transition probabilities; b — output probabilities.

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[100] “HMM is a statistical model in which the system being modeled is assumed to be a Markov process with unobserved state. An HMM can be considered as the simplest dynamic Bayesian network.
In a regular Markov model, the state is directly visible to the observer, and therefore the state transition probabilities are the only parameters. In a hidden Markov model, the state is not directly visible, but output dependent on the state is visible. Each state has a probability distribution over the possible output tokens. Therefore the sequence of tokens generated by an HMM gives some information about the sequence of states. Note that the adjective 'hidden' refers to the state sequence through which the model passes, not to the parameters of the model; Even if the model parameters are known exactly, the model is still 'hidden'.
There are three canonical problems associated with HMM: 1) Given the parameters of the model, compute the probability of a particular output sequence, 2) Given the parameters of the model and a particular output sequence, find the state sequence that is most likely to have generated that output sequence, 3) Given an output sequence or a set of such sequences, find the most likely set of state transition and output probabilities.
Hidden Markov models are especially known for their application in temporal pattern recognition such as speech, handwriting, gesture recognition, part-of-speech tagging, musical score following, partial discharges and bioinformatics” (Wikipedia, April 2009).

During the working on “City Upgrade” project there were three levels of parallel collaboration: 1) the creation of nodes within the A.N.D.I. system, 2) in-person collaboration during workshops, meetings and other gatherings, 3) the collaboration established through the use of other communication channels. To understand how the project has developed and how the spin-off projects and numerous following collaborations have emerged it is important to look at the participants and their professions. The crucial change in the mixture of experts during the first 3 years of the project has also delivered some unexpected outcomes and provided important experiences, some of which have made transdisciplinary settings more productive. In addition, it has been interesting to observe how the project members related to inputs from other actors changed their own input. The following analyses of cross-disciplinary input within one Point-of-View allows us to better understand collaborative interaction among the participants.

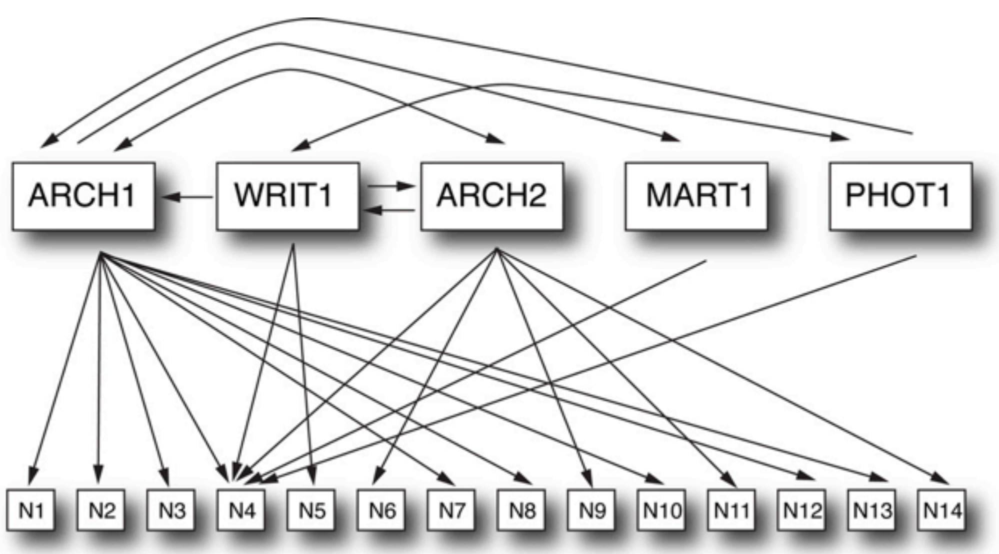

Fig. 36 shows collaboration within “Point-of-View” ***Architecture*** *(Nodes: N1…N14, Roles: ARCH1 = Architect group 1, WRIT1 = Writer, ARCH2 = Architect group 2, MART1 = Media Artist, PHOT1 = Photographer)*

Within the particular “Point-of-View” *Architecture* (as shown in Fig. 36) two Architectural Teams (ARCH1 und ARCH2) have created the most nodes[101] – 9 nodes and 4 nodes; the Writer (WRITZ1) has created one, during the Media Artist (MART1) and the Photographer (PHOT1) have created none. It seems that this Point-of-View is used by architects to "present" their design intentions or to exchange data. Still there is one node about "architectural code" (number 4), which is based on the collaborative work report and which provoked most discussion. All participants reacted on this text node by either adding new documents or by changing the existing input. Unfortunately, because a deeper feedback system was lacking, architects did not pick up these issues to re-think their positions. These issues couldn't be resolved within the system. However, this topic was taken on and discussed in-person during the workshops that followed. Additional information about collaboration on particular node can be obtained through the built-in tool "Work Report" (as shown in Fig. 37). In graphically presented timeline the information who worked when on selected node can be obtained. Each overlap means that the collaboration was successful in sense that one user reacted upon the input of the other one.

[101] Numbering nodes N1 ... N14 in this context have the only meaning to extract the information about node creator and node editing, which is preferred to misleadingly introduce some hierarchical classification into a weighed graph and relational model of A.N.D.I.. The representation of dependencies in this particular case is more oriented toward a Hidden Markov Model to introduce the statistical evaluation of collaboration.

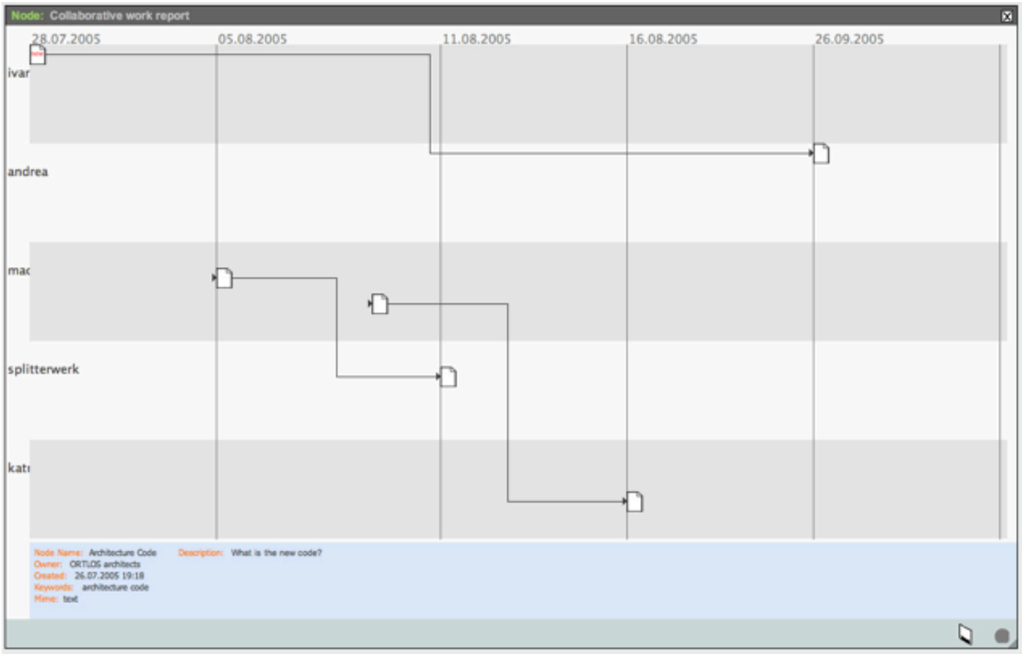

Fig. 37 shows the collaborative Work Report on Node 4 "Architecture Code" from Fig. 56. So-called "Work Reports" diagrams conduct the evaluation. The know-how which is gained through the "life-cycle product development" is made available as detailed methodology. Different scenarios can generate new functional demands later on.

Another interesting Point-of-View with similar preferences to *Architecture* was *Urban Planning*. As shown in the Figure 38, teams of architects dominated this direction. The Writer (WRIT1) and the Photographer (PHOT1) did not produce any node, but they were involved in the discussions during the workshops and on-site work. It can be assumed that the experts other then architects haven felt enough competence to be active in terms of content creation. Architectural team ARCH2 gained a creative momentum by creating nodes that are related to other team members' inputs, and intensified this during the workshops and internal meetings. Unfortunately, they have used only their already prepared content to produce the interaction (their interpretation of the inputs of others) and did not relay on the possibility to work within Infospace, and therefore neglecting its relation model. It could be said, as illustrated in Figure 39, that this was interaction beyond the system and not interaction among participants supported by the system. Therefore, other participants, although their content had been referred to, stayed disconnected. To avoid this it would be necessary for all participants to interact with the content produced within the system and not with content produced in off modus beyond the system and then uploaded back into the system. That was a moment when two major hubs emerged within the team, since the two design strategies between ARCH1 and ARCH2 became clearly incompatible. ARCH1 as the project leader had the feeling that the project would take an unwished course, and were unable to reconnect to the inputs of ARCH2. The main reason for this occurrence was again that ARCH2 did not use A.N.D.I. system as a platform for creation, neither as a working model for creative collaboration, but rather as a repository for content exchange.

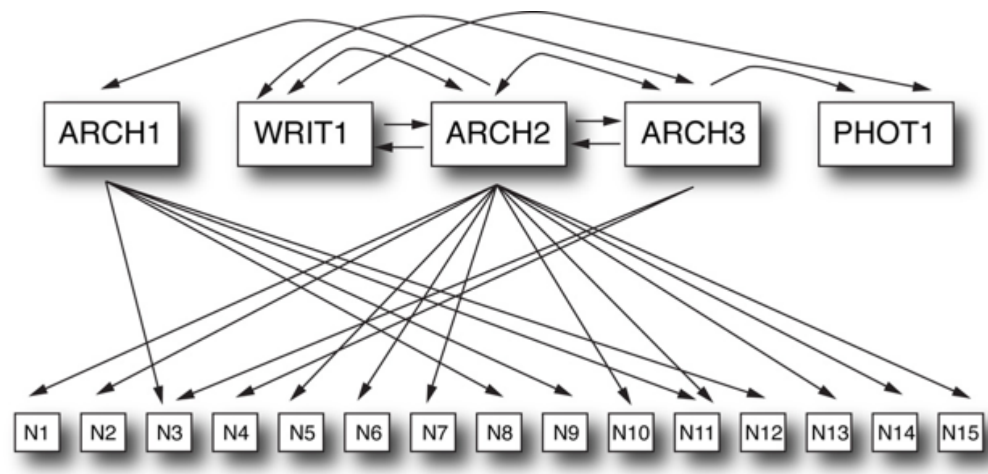

*Fig. 38 shows the collaboration within Point of View **Urban Planning**. The group "Arch2" was focused more on the issue of urban design and therefore claimed authority in this field.*

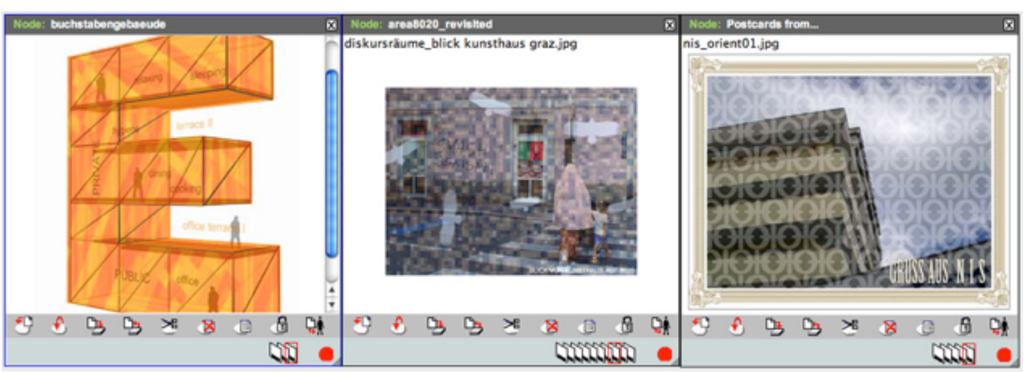

Fig. 39: Screenshots show ARCH2 team reflections on other participants' inputs.

Beside the Architecture and Urban Planning directions, there was another important Point-of-View: *Media*. Although the live gatherings within workshops and during the work on-site produced some distractive alliances, for many reasons e.g. loosing the scope of the work, breaking the project apart into small sub-projects, and was contributed only by a few project members, etc. they were important to discuss and introduce individual idea to the other project partners.

As visualized in Fig. 40 the Media artist group MART1 did not pay enough attentions to these accompanying measures and were left more or less in isolation for two reasons (only one project partner somehow collaborated). Firstly, they felt “in-charge” of the direction media, not understanding that was only a point of view, not a category, by which users normally choose to classify their contribution. Therefore, they did not relate to other nodes and missed some of the crucial workshops. The physical meetings have been important exactly for the reason to clarify the misunderstandings in the communication. Secondly, sophisticated feedback or rating of the system within A.N.D.I. was lacking and made other users not aware of the MART1’s input (the work report have been the only evaluation / feedback tool, see Fig. 41), and if not so they did not pay much attention, since MART1 did not relate to other inputs either (the only input of writer within “their” direction seemed more like a lost piece, since it was left without any comments or intensions to reflect on it).[102] This condition created a situation of “project within a project”.

[102] Mark Granovetter explains this phenomena as following: “It is like coming to a party where everybody knows everybody except of one person. To start a conversation that person would just make a random statement, but the others because of not knowing much about that one person or because the statement does not fit into their discussions rather tend to ignore the ‘stranger’. A true collaborator and communicator would pick up that statement, since this is one of the important parameters of the collaborational model based on the so-called ‘the strength of weak ties’ theory” - Mark Granovetter, *The Strength of Weak Ties* (Amer. J. of Sociology: 1973), Vol. 78, Issue 6 – From the people we know very well, we collaborate on a regular basis with, or from those who are from the same professional domain, we can only learn the same things. By the use of weak ties or as claimed here through transdisciplinary work we are able to expand our knowledge horizon.

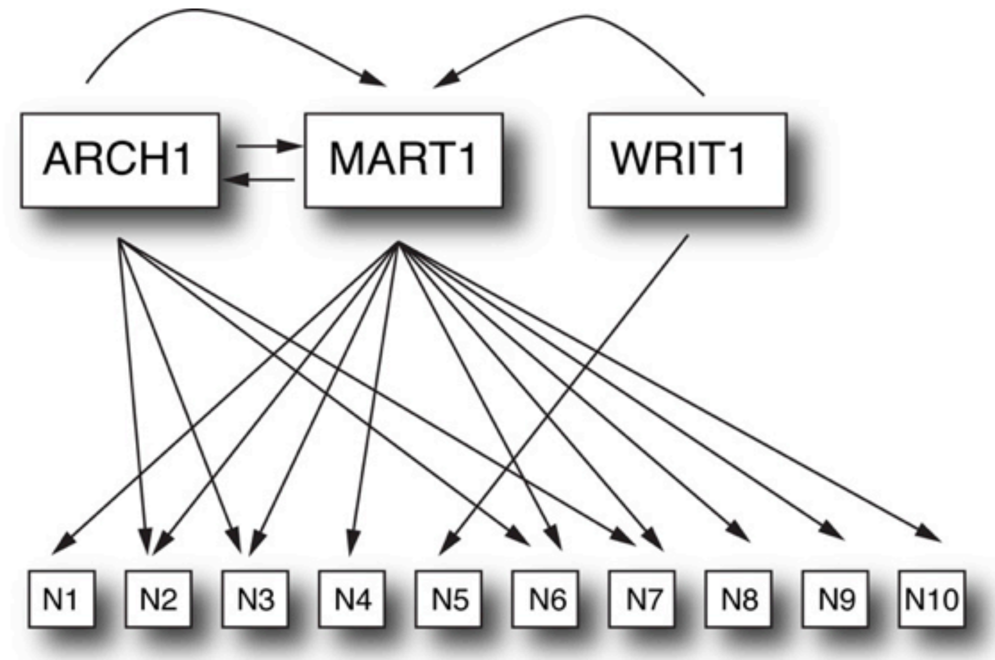

*Fig. 40: Nodes and interaction within Point of View **Media**.*

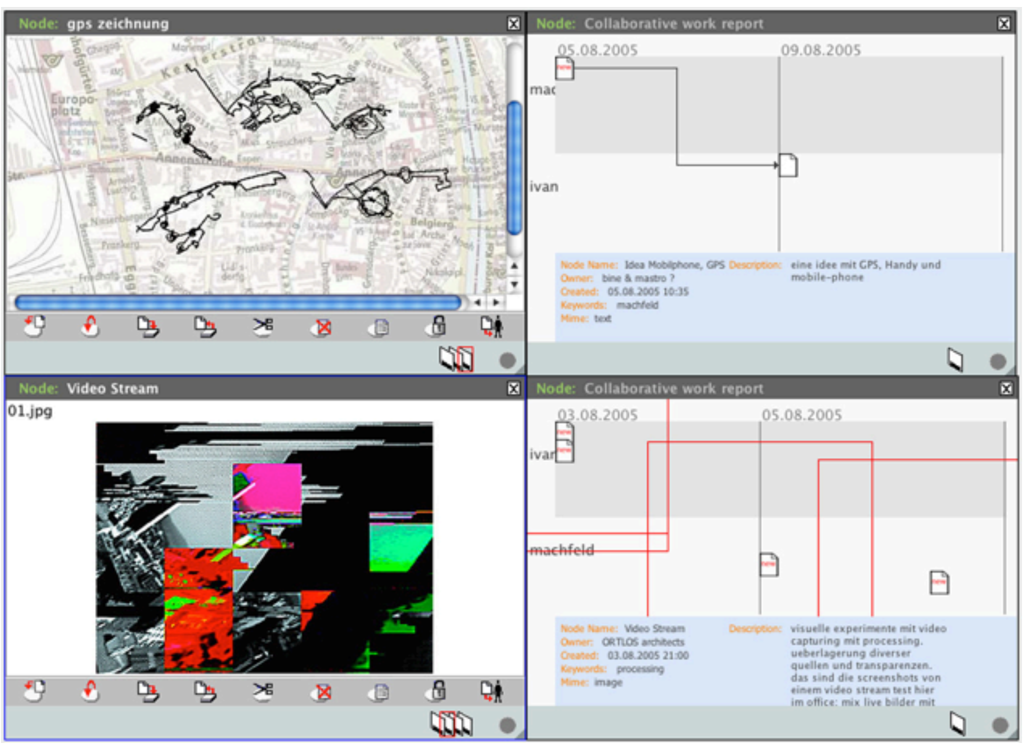

Fig. 41: Examples and reports on collaboration between only two team members within Point of View media.

The strong focus of media artist MART1 on the direction (Point-of-View) Media and the non-connectiveness to the inputs gained from other project participants, the so-called “decoy effect”[103] has been created, speeded-up the building of two strong hubs. These hubs include the team’s network, as well as the lone media artist, and these hubs then unite. This pattern was also obvious during the collective exhibition in “medien.kunst.Labor” later on after the Case Study “City Upgrade” has been finished. As explained in previous example basically three strong groups have been built around two architects teams and media artist.

4.4. Case Study Evaluation

Based on analysis of collaboration patterns within Case Study “City Upgrade” and further exploration of the collaboration interaction, the network graph Fig. 42 has been created, which is showing parameters of collaborative network. This diagram is based on parameters how the actor nodes are connected, the emergence of hubs, and the occurrence of functional relationship between quantities of different intensities. Surprisingly enough the two main hubs were the architectural team ARCH1 (project leader) and the writer WRIT1 because the two architectural teams had been following different design strategies, not ARCH1 and ARCH2, which would have been the more obvious outcome. The actor Writer was very active in networking not only within A.N.D.I. but also in using all other available channels of communication – especially e-mail, to prolong his ideas. That fact invoked also a conflict with the Philosopher, as the other person whose expertise was a conceptual part as well. The two design teams were instrumentalized based on a conceptual disagreement on a general project strategy. After the first collective exhibition of the project the core team split exactly into two teams based on the above diagram: ARCH2, ARCH3 and WRIT1 continued the collaboration within some other projects, and other, new partners have

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[103] “In marketing, the decoy effect is the phenomenon whereby consumers will tend to have a specific change in preference between two options when also presented with a third option that is asymmetrically dominated. An option is asymmetrically dominated when it is inferior in all respects to one option; but, in comparison to the other option, it is inferior in some respects and superior in others” - Shankar Vedantam, *The Decoy Effect, or How to Win an Election* (The Washington Post: 2.4.2007)

joined the City Upgrade project team with a more balanced expertise and agreement on common strategies and goals. However, after the research phase, this first creative collaboration of stakeholders has significantly marked the future development of the "City Upgrade". Summing up it appears that the more balanced teams, with only one stakeholder representing one discipline, are more efficient in regard of transdisciplinary collaboration, then teams where the experts from the same or similar discipline are in competition.

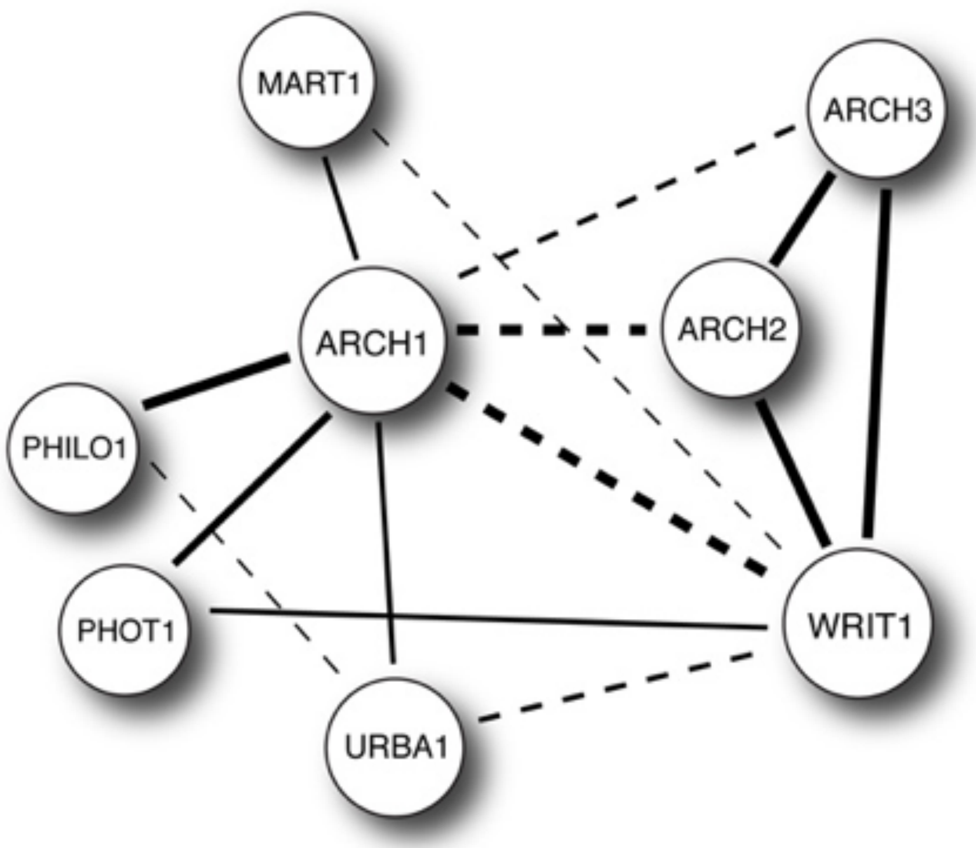

Fig. 42 is showing the connectivity of the significant (and the most active) actors considering the collaboration within the A.N.D.I. system in 2005. The thicker lines show higher intensity of collaboration.

Within the Case Study "City Upgrade" the postulated hypotheses have been used as departure point for evaluation of A.N.D.I. system and as evidence suggest following:

- even in a strong collaborative environment, design remains a subjective point of view of each participant,
- multiple authorship can succeed only when recognition of one's own input is clear and traceable,
- no information gets lost and redundancies are reduced,
- new inputs can be generated without losing the scope and coherence of the work,
- density of "re-used"/"re-worked" information assesses the relevant input for the project
- sub-projects (spin-offs) are possible, without reducing the quality of the main output.

4.5. Questionary

In the aftermath of the Case Study "City Upgrade," the questionnaire about the project and the usage of A.N.D.I. system has been submitted to all participants of the project. This questionnaire has been developed to reflect and to learn from the outcomes achieved through usage of A.N.D.I. system. Considering the fact that ten out of eleven involved project partners have answered the questionnaire the results can be considered as relevant and therefore they can be used for the evaluation of the final results. The online platform "Umfrage Online" has been used for the questionnaire.[104] The participants are either single personalities from creative industries or representatives of various institutions (architectural office, academia, companies, association).

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104 https://www.umfrageonline.com/results/851faa8-899f005 (last visited September 2014)

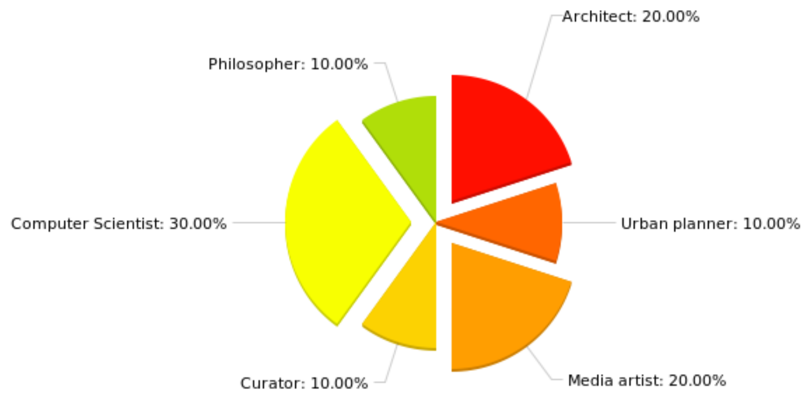

Fig. 43 The Area of expertise as defined by participants of the questionnaire. The positive effect is the balanced amount of disciplines, which could help to get better insights in the transdisciplinary aspects of the collaboration.

First, the participants were asked to describe their practice. 90% of respondents explained that their practice was multi-disciplinary, including a wide range of fields. However, asked about regular experience with trans-disciplinary projects such as "City Upgrade" only 40% answered positive. The participants for the project were chosen based on their qualification, but also on the previous collaboration experience with ORTLOS. This means that the team didn't consist of randomly chosen project partners – the team has been constituted on purpose to establish a well balanced group of experts, which will already bring some knowledge about advanced collaboration methods. These pre-requirements led to the quicker establishing of the common ground among the participants coming from different disciplines. When people with different educational background and expertise cooperate they have specific knowledge, terminology they use, already established methods and workflows of collaboration. Concerning the "City Upgrade" project the following aspects: the terminology used, the methods other team members used and the requirements on cooperation of team members for the most of the participants have been clear or clear towards the end of the project. That led to the positive approach toward trans-disciplinary project with unforeseen outcome, with an expectation for higher results in terms of innovation (on scale of 1 to 10, the arithmetic middle have been measured as 9).

In the chapter 1.3, the formation of the transdisciplinary collaborative team has been discussed and as well the importance of well balanced expertise within the team. For the 80% of participants the heterogeneity and the diversity of team experts involved in the project "City Upgrade" meant “new insights in other disciplines”, followed by “new solutions” and “creativity”. Only 30% recognized the diversity in team as possibility for “conflicts among team members”. However, asked about personal experience with “City Upgrade” project, some answers describe as negative aspect too much emphasizing of the social component during the physical team meetings and workshops (to quote one of participants: “the social aspect of meetings was more important than any fast and effective solution finding”). This critique opens the discussion how to find the right balance between hard skills and soft skills, the right balance between efficiency in a workflow and the social competence during the situation when participants expand their business relationship and introduce more private personal communication. On the other hand most of the participants have been satisfied with process itself and especially results, describing this as: “vivid, creative, high-spirited”, “very good atmosphere”, and finally “the group was extremely productive, and produced tangible outputs at a fast pace - at the cost, of course, that it was not completely clear what it actually was that we had produced.” By answering the question about “the most positive and the most negative aspects” the participants have risen many important issues. For example: usage of “different terminology for similar things” connected to “different logic that disciplines use” and “main problems were to find the same language”, or ‘strong’ opinions by engineers during the creative phase (probably as difference to more ‘soft’ opinion of art-based participants), but also a proof that “complete openness - even to the point of project goals being seemingly undefined - can still lead to very concrete results in a very short time frame”, “a brave expedition into the unknown”, good atmosphere and discussions during the project described as “nice and also hard discussions focusing on the goal of the project". And last but not least the usage of A.N.D.I. system described by one of participants as following: "... positive was the use of the platform A.N.D.I. in terms of enhancing our creative process. The system was a way to work just in time though we were at different places - so you did not lose time to wait until your next direct meeting. The next positive aspect is the tracking of the multiple authorship - who did which input at which time - everything was written on the system, so no one had to be scared, that someone steal his ideas. To find answers for complex questions without losing the complexity during the working process."

	didn't work (1)		worked (2)		worked ok (3)		worked fine (4)		don't know (0)		
	Σ	%	Σ	%	Σ	%	Σ	%	Σ	Ø	±
Technical aspects and ...	-	-	5x	50,00	3x	30,00	2x	20,00	-	2,70	0,82
Common language an...	-	-	3x	30,00	5x	50,00	2x	20,00	-	2,90	0,74
Encouraging team coll...	-	-	2x	20,00	3x	30,00	5x	50,00	-	3,30	0,82
Reflecting on inputs of...	-	-	3x	30,00	3x	30,00	4x	40,00	-	3,10	0,88
Ways to document inp...	-	-	1x	10,00	2x	20,00	6x	60,00	1x	3,56	0,73
Reducing the redunda...	2x	20,00	1x	10,00	2x	20,00	4x	40,00	1x	2,89	1,27
Combining interdiscipli...	-	-	1x	10,00	-	-	9x	90,00	-	3,80	0,63
Formation of random ...	-	-	1x	10,00	3x	30,00	4x	40,00	2x	3,38	0,74
Possibility for synchron...	1x	10,00	3x	30,00	2x	20,00	2x	20,00	2x	2,63	1,06

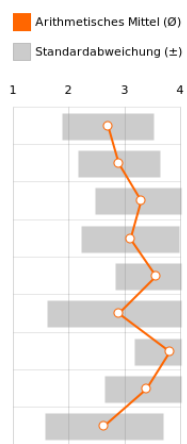

Fig. 44 Shows the factors that are the most important factors for success of a virtual working environment? When thinking especially of the virtual collaboration through A.N.D.I., the participants have been asked what worked out fine and what didn't work out.

It is recognized by the participants that the communication issues, social competence, openness for new approaches in working methods, organization and management structure of the project, have been important for the overall impact and success of the project. When asked which are the most important success factors of a virtual working environment that worked out or not, when thinking especially of the virtual collaboration through A.N.D.I. (as shown in fig. 44), 90% of the participants pointed out "reducing the redundancies in the work process" as major criteria. Not a single criteria passed the threshold of "worked ok" and "worked", but as slightly disappoint can be considered "ways to document inputs by each team member" and "technical aspects and tools". On the other hand "reflecting on inputs of other team members" received very high marks, which lead us to the conclusion that the collaboration and providing a feedback on input of others worked well.

When talking about tools implemented into A.N.D.I. system, interestingly enough, descriptions such as "intuitive design", "lightness of interface", "simplicity", etc. have been noted. However, one respondent reported that A.N.D.I. was "way too complicated," containing "too much elements at once." A closer look shows that the users with less technical background had some problems adapting to entirely new interface, which neglects the common Windows-like user interface. Some others recognized A.N.D.I. still being a conceptual tool, developed at the time when Facebook and co. haven't be born, and not an out-of-the-box production quality software, suggesting some improvements as for example "the integration of knowledge management methods such as ontologies and thesauri, combined with machine learning techniques for the information harvesting."

As shown in Fig. 45, the highest acceptance and rating got the "Idea Generator" – a brainstorming tool – described its necessity by one of the participants as "high importance from the point of view of an architect". Further importance for transdisciplinary collaboration and impact the tools made judged as highly positive had "Design Visualization Tool" (overall view of the nodes, which user can browse in two modes: navigational and operational) and "Visualization of the Collaborative Work" (tool to track users' inputs and documents' changes), as well the "Text Tool" (a container holding one or more text documents). As less important have been seen the tools "File Node" (tool for upload of any kind of binary data) and "Sketch Tool" (contains more sketch documents, within the same node, but it also can contain more galleries within one document). First because there are better file repositories existing and second because there are more advanced tools for collaborative sketching then A.N.D.I. system. Further, these tools are not applicable for collaborative work in a way how A.N.D.I. has been conceived, namely not as an archive system or file container system (file could and similar). In their day-to-day professional practice the most participants stated that they are using: e-mails, file repositories and Skype. From the answers could be concluded that there is still not an appropriate system, which combines different tools and instruments to support the transdisciplinary collaboration in the first creative phase of the project.

	highly negative (1)		2 (2)		3 (3)		4 (4)		highly positive (5)				
	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%	Ø	±	I
Design Visualization To...	-	-	-	-	2x	20,00	5x	50,00	3x	30,00	4,10	0,74	70%
Text Tool (a container ...	-	-	-	-	2x	22,22	5x	55,56	2x	22,22	4,00	0,71	67%
Sketch Tool (contains ...	-	-	3x	30,00	4x	40,00	-	-	3x	30,00	3,30	1,25	60%
Idea Generator (a brai...	-	-	2x	20,00	2x	20,00	5x	50,00	1x	10,00	3,50	0,97	57%
File Node (tool for uplo...	-	-	-	-	3x	33,33	3x	33,33	3x	33,33	4,00	0,87	79%
Linger Plateaus (tool f...	-	-	2x	20,00	3x	30,00	4x	40,00	1x	10,00	3,40	0,97	53%
Visualization of the Col...	-	-	1x	10,00	2x	20,00	5x	50,00	2x	20,00	3,80	0,92	80%

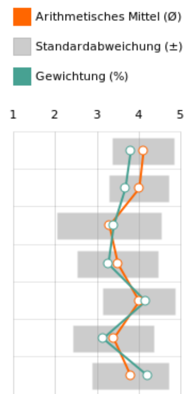

Fig. 45 A.N.D.I. offered a variety of tools to support the virtual collaboration. This diagram illustrates in which way did these tools influenced the work process within project "City Upgrade" and made the impact. Additionally the importance of each tool for the transdisciplinary work process has been judged.

Considering the Case Study “City Upgrade” besides the usage of A.N.D.I. as a toolset, the question was what impact A.N.D.I. had on tteam cooperation, e.g. in decision finding, communication process, resources needed; etc. It has been acknowledged as possible way “of taking part in an innovation process, a good way of getting early insights and early ideas from a much larger team.” Generally it has been seen that the method of “sharing and mixing information, that produces new information, leads to new ideas and creativity at the end.” One important aspect was the enhancing of communication, which goes beyond the traditional collaboration tools. Different ways of using the system, the experimentation with the process itself, browsing through other people’s creative contribution and discovery of unexpected inputs, have been regarded as positive impact too. Furthermore, the participants experienced the reduction of resources in terms of time and space, customization of the system based on personal preferences, decision finding based on relevance of inputs and finally intriguing ongoing interdisciplinary debate on different subjects within the heterogeneous team.

Asked about any memorable event or milestone which could be claimed as crucial for the innovation in the transdisciplinary collaboration, by comparing “City Upgrade” with other project experiences, the majority of participants pointed out the social component of collaboration. A series of good ideas, which emerged during the creative process and later on became side projects have been pointed out. Important moment for almost all participants has been during the discussions to expand the boundaries of own discipline. However, only few participants talked about actual project “City Upgrade” itself. In that sense one participant noted: “I became acquainted with the problems of city development and the devastating effects of modern urbanism with respect to city centers - and the interesting possibilities through new media.” Conclusion would be that the innovation mostly happened on the way, quasi en passant, not as single event or milestone, but as constant byproduct of creative dynamic group interaction.

Through the evaluation of the questionnaire especially in which way did usage of A.N.D.I. system influence the creation of knowledge and new insights, within the project City Upgrade, the most participants saw the emergence of new knowledge by professionally different people as the most innovative moment. 80% of participants have been able to cope with an unanticipated outcomes of the project “City Upgrade”, which have not been foreseen and not defined as a goal at the beginning of the project. The usage of A.N.D.I. indeed “enabled ‘the clash of cultures’, i.e., radically different viewpoints from every participating discipline.” However, the participants distinguish between the innovative output and innovative process, stating that “it was more the information flow and less the design process” and “A.N.D.I. influences the team-spirit in a positive way.”

When discussing how knowledge production and communication were used, the A.N.D.I. system helped to embrace the innovation and new ideas during the creative design phase of the project City Upgrade. Results showed two answer categories: first the “accelerated exchange of ideas and solution proposals to get results, often even unexpected”, and second instrumental for organization of creative process with “permanent accessibility of information and inputs” and utilization of different perspective by different experts on same topic. It could be said that impact of using A.N.D.I. for the “idea-finding phase” of the project is much higher then the actual “design phase.”

Almost all participants, as shown in Fig. 46, think that the transdisciplinary collaboration and the corresponding tools should play important role to contribute finding new solutions in architectural practice. However, the question is how could architecture more specifically profit from collaborating with other disciplines beyond the building industry, when searching for new solutions? The answer to this question could be a argument for this thesis stating that the change and the real innovation in architecture could be establish through the change of architectural practice by opening itself toward transdisciplinary collaboration. Interaction between disciplines enriches each discipline. In opinion of participants “it certainly could enrich its conceptual stage when finding the right approach to the very challenge, a building e.g. or landscape. It's a way to avoid profession myopia or even blindness.” Further architecture can be a carrier or enabling platform for advances in technology, which automatically means embedding other disciplines into architecture. The contemporary architecture needs to solve complex problems. Working with other disciplines can expand established practice and will bring new results in solution finding, with other words “different disciplines provide a different view. They open the architectural field, show new ways.” Without input from other disciplines architecture would be reduced simply put to technical design of buildings only. Concluding with words of one participant: “the impact from the humanistic disciplines could be more effective in the establishing of the information and knowledge base (the starting phase), when clearing up programmatical and conceptual starting point of a project. In the case of urban design it is important in the initial and the presentation phase, when integrating the public in the political decision making."

links	1. Spalte (1)		2. Spalte (2)		3. Spalte (3)		4. Spalte (4)		5. Spalte (5)		6. Spalte (6)		7. Spalte (7)		8. Spalte (8)		9. Spalte (9)		10. Spalte (10)		rechts		
	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%		Ø	±
less important role	-	-	-	-	-	-	-	-	-	-	1x	12,50	-	-	1x	12,50	-	-	6x	75,00	very important role	9,25	1,49

Fig. 46 shows the answers to question which role should transdisciplinary collaboration and the corresponding tools play to contribute finding new solutions in architectural practice.

5. Results and Discussion

Data obtained, as shown in literature, when applying transdisciplinary knowledge production in architecture and urbanism indicated that results of the research can hardly be put in numbers for evaluation purposes. The most of these studies are personal reports based on experience of authors and observations gained through case studies. However, the method applied in this thesis about interpretation of findings is based on four sources: 1) the questionnaire with all major participants of the Case Study "City Upgrade" 2) analysis of formation of the transdisciplinary team in course of Case Study 3) observation of the implantation process of A.N.D.I. system within the Case Study and 4) discovering of collaborative patterns between the participants during the work on Case Study. This methodology is expanded by author's analysis in which regard the theoretical assumptions made on the beginning of the research has been successfully implemented in the practice later on.

5.1. Results

The discussion of the results in this section is based on several topics that provide guidance for the future transdisciplinary projects in architectural practice, but as well be an useful for the further research on this issue. However, the problem with these results is that it cannot be clearly stated that by simply implementing the transdisciplinary approach in architectural practice automatically and obviously implicates the innovation. Eventually only the combination of different aspects and parameters will lead to new and innovative results. For example it has been shown how finding the right balance of disciplines involved into creative process create positive effects when applying transdisciplinary approach. Already the description of A.N.D.I. implementation and Case Study "City Lab" discussed the research process both in terms of its successes and failures, however some concepts need to be highlighted, with aim to contribute to the knowledge not only about the research objective, but also about the nature of design processes (work practice in architecture) in general.

5.1.1. Formation of random views in information network

Formation of random views in one information network is essential for hierarchy-free bottom-up systems. Naturally, each team member will focus more on his/her own view, but agreement and commitment to the common goal also means that these Point-of-Views can interact or be shared by several actors. The "Point of View" methodology within the A.N.D.I. system is also a chance to be inspired by perspectives of other experts even if their perspectives have only marginally and indirectly to do with one's own field of activity. Diversity within one Infospace also produces also outcomes that cannot be predicted at the beginning of the creative process. Since apparently many problems today need more then one kind of knowledge to solve them, the different perspectives on the same problem need to be enabled through methodology for transdisciplinary collaboration and according collaborative instruments.

5.1.2. Semantic structuring and clustering

Semantic structuring and clustering within the A.N.D.I. system is described as navigation by constant manipulation of parameters: *sensitivity* and *deepness*, as well as the user interaction within different *Point-of-Views*. Each actor can individually decide which information is important and which one is less important by changing the start value of the sensitivity parameter during creation on the micro level. On the macro level this parameter may gain new value based on the other's inputs. It is likely that by working in complex information structures many important things are overlooked or not even considered because of a lack of knowledge. The system-sided value of variable deepness is taking care that the unconsidered information emerges visually for the user to decide whether this input is worth of consideration at any given time. In case of user interaction the new values will be established for these parameters.

5.1.3. Manipulation of information structures

Through action design the creation and manipulation of nodes, and connecting them within different directions, the information structure is manipulated. The developed mechanism of the synthesizer will couple the relevant nodes together by filtering them based on project constraints. Evoking an event brings a series of synthesizers automatically as a package into final result for execution in following design steps. This information can be brought back into Infospace as established knowledge, after being truly tested and optimized. These events are information structures, which are overseen and approved by the project leader, e.g. project manager, whose responsibility is that the right information has been taken over.

5.1.4. Analysis of transdisciplinary data structures

To make analyses of transdisciplinary data structures it is important to understand topological preferences of the collaborative network. Besides its presentational purposes the developed "Collaborative Work Report" tool helped to understand how the interactive work flow influences product creation and development. From the side of the user, knowledge can be gained where and when the problems and issues have arisen based on the particular output – simply put: what, when, and why something went wrong or right. From the server-sided approach this knowledge becomes more important for the recommendation engine to qualify the information through mathematical models of evaluation. Every invention relies strongly on previously made experiences. However, the actors have to have useful access to that information. It is therefore a working tool, not only a presentational tool, since it can identify and co-opt redundant resources. This result is a way to document intellectual property and to report on who did what, when people with different training have difficulty communicating and they are trying to achieve different things.

5.1.5. Enabling of the emergence of intellectual ecologies to create innovation

As mentioned earlier the observations on implementation of knowledge from different disciplines in creative process confirm previous studies of interdisciplinarity, which emphasize the value of teams, of collaboration between different disciplines, and the ability to cross boundaries between different kinds of knowledge. However, it could be also identified the essential role of the leaders of these collaborations - someone who is able to draw together a disparate team around a common goal, but in the expectation that the most valuable outcome will be something other than the original goal. The leader must be able to recognize opportunities for other outcomes, and be skilled at harnessing excitement among members of a team as they arise. Transdisciplinarity becomes central to the process of innovation, as well as a contributor to the quality and content of innovation. The necessarily unanticipated outcomes can offer benefits in these situations. This approach also draws attention to the importance of developing an environment or knowledge ecology that supports a range of disciplinary knowledge, making them available to produce and develop the consequences of investment in these kinds of enterprise.

5.1.6. Provide an environment encouraging team collaboration and reflections on inputs by the others

A.N.D.I. as a system is a coherent Information System (Infospace), which is not able to import any information from outside the system or to represent such. It also has no feature for semantic or any other mapping of information coming from some other source rather then internally created content. A.N.D.I. is a system that emerges from active and creative actions of its users. During the interactive and synchronal collaboration of actors the system builds the dynamic Infospace and learns from manually established relationships during the work process. Some time is needed therefore, until the system reaches a critical mass of information to produce meaningful outputs through events, which can be then used in a production workflow. Bearing this in mind, it becomes clear that it does not only follow the logic of networks, but fully supports the principles of emergence. It is critical not to view the A.N.D.I. System as an addition to common PDM, CVS, or file repositories, but as an instrument for the development of strategies for a creative networked (distributed) transdisciplinary design collaboration. This has created new body of knowledge or insight, organized around the shared values and knowledge that the team has developed.

5.1.7. Introducing forms of knowledge production that embrace imagination and uncertainty

If A.N.D.I. as a system is thought of as a purely representational entity, it would allow a repository system or other data management system. It is partly representational in terms of user interface: images or binary files can be uploaded, project texts can be written, etc. and the inputs of the others seen/modified. In the A.N.D.I. system there is a medium, a message, and an audience, no different to other collaborative tools. The difference is that those elements and other tools exist alongside a set of rules that govern the flow of collaboration within the system. The “interactivity” as a collection of interlinked pages one follows in his/her own way by using any web-based platform, is the different category from the self-organizing relational model of A.N.D.I. by ignoring the rules, the performance of the platform is reduced to a level on which the better CMS systems, such as Drupal or the Wiki technology, would do better. A.N.D.I. has clearly, by combining disciplinary knowledge in teams, considered the unanticipated outcomes. However, two extremely important features have been neglected so far and not implemented, namely: an off-line messaging system[105] (informing the users when they are not logged-in about content that is new or maybe of interest) and a mix of positive and negative feedback on somebody's input pushing the system toward a particular state based on the activities of the participants. This aspect should be covered by parameter sensitivity, where users "rate" other then their own inputs based on how they build the relationships to them. The artificial intelligence of the system would then "reward" the most related inputs to all team members as a suggestion.

5.2. Discussion - interpretation of findings

The interaction between team members has shown some patterns of self-organization, evident at the beginning of the project, but they were not adaptive in any way, rather predictable – some project participants started building sub-alliances to gain more importance in the process of making decisions. There is great power and creative energy in self-organization as described before, but it needs to be channeled towards specific forms to develop itself into something intelligence-like. The almost lack of system deepness, based on created content, points out the problem considering the "collective intelligence". In short, the project is not a sum of individual intelligence each trying to take over and prove itself as the best one, but a network of connections between team members trying to rise the common achievements to the next level.

The intensity of team cooperation would be even greater if the users did not rely on classical asynchronous tools such as e-mail, ftp-file repositories, chat or mailing lists. However, when it comes to projects with a clear vision but unknown output/result, based on a "new subjectivity of

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[105] Workflow of internal messaging system would look like this: user opens the tool *"Linger Plateau"* to see who is currently online. In case other team members are logged-in and are within the same collaborative session, the user would start collaboration mode from a tool supporting this feature, e.g. sketch tool or idea generator. That would be the invitation for the collaboration. Some tools have not this feature because of technological limitations: for example in the text tool it can happen that one user overrides the text input from the other one if they would both edit the same text document at the same time.

a distributed author" in addition, one has to disband the familiar working principles and accept the fact that a new deal is needed not only in terms of how we see, understand and create space in general, but also how we deal with other dislocated team's members in a transdisciplinary collaboration. In short, an ANDI-based collaboration worked well when the tracking of individual achievements/inputs was possible. When this aspect was omitted, some "ego-centric noise" appeared immediately that might, in the long run, would have made a constructive collaboration impossible.

The intelligence of the platform/software does not provide a perfect solution through some kind of voting at the end of the day, but the necessity to crawl through numerous connections and relationships in the database and to search for patterns of likes and dislikes, which then reports the findings back to the user. It is worth mentioning at this point that A.N.D.I. should not be understand as a "recommendation agent"; it is not suggesting you that you will like the five nodes that it recommends. It merely says that there is a relationship between the node you are currently working on and the other nodes created by someone else through previous collaborations. The decision about whether this information is useful or not is one that each team member will make for him/herself. Pattern recognition and decision making will always stay at certain degree a task for humans in creative process, and can not be utterly outsourced or even substituted by an software application (we also accept a "human error" as a fact), but intelligent computer systems can very well assist creators for future designs in dealing with complex systems and huge amount of information. Hopefully this work has brought some insights in this direction.

> "Humans are far more skilled at recognizing the patterns than in thinking through logical combinations, so we rely on this aptitude for almost all of mental processes. We do not have time to think too many new thoughts when we are pressed to make a decision. The human brain relies on precomputing its analyses and storing them for future reference. We then use our pattern-recognition capability to recognize a situation as compatible to one we have thought about and then draw upon our previously considered conclusions."(Kurzweil, 1990)[106]

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[106] Ray Kurzweil. *The Age of Spiritual Machines: When Computer Exceed Human Intelligence* (New York: Penguin Books, 1990).

6. Conclusion

"Ivan, Andrea, how can one approach a world characterized by ambiguity, contradiction, infinite complexity/unknowability which is simultaneously smaller, faster, flatter. Quintessential question." Thom Mayne in Introduction to "Architecture of the NetWorks"[107]

As a trained architect the author has always tried to understand the world he is living in - the world of information overflow and the world of infinite possibilities; a world which as a linked universe does not rely on random networks, but on huge amounts of interlinked data which is sometimes just too complex for us to cope with it or to process. Therefore, it is important, more then ever, not only to understand network workings and to describe network topologies, but also to develop novel tools and instruments to proactively deal with these networks. In other words, it is crucial to develop useful applications that will help us make progress in the future within creative, connected, collaborative, and transdisciplinary environments. Transdisciplinary collaboration is important because of the huge amount of information we are confronted with which by exceeding our biological capacities as a single unit make any known scientific method that has been used until now obsolete.

Throughout history, architecture, more than any other discipline, has been defined by many dependencies on the cultural and technological progress of our civilization. If we do not understand architecture simply as building technology, architecture interferes with all aspects of human existence be it of political, social, cultural, philosophical, or technological, etc., nature. There is no other discipline that provokes discussion on the overall view of human living, in which anything is connected to everything. However, it has been always of author's interest to ask what is beyond that.

[107] Ivan Redi, Andrea Redi and David Carson, *Architecture of the Networks* (Ostfildern: Hatje Cantz Verlag, 2005)

This "other" is not the same "das Andere" as defined by Freud, something we do not recognize but it is conceived by our sub-consciousness. It goes beyond our cognitive knowledge and it is something we cannot possibly know. It is a momentum when *constructivism* shifts to *connectivism*. To answer the questions: How do we gain knowledge from this endless sea of information? And when does pattern recognition really make sense? The author has tried to define a new kind of thinking how creative architectural design practice can be organized. Those ideas do not only consider the design of computer networks, but outline the structure of collaborative, creative processes within computer networks and deliver strategies which are useful to deal with these.

No matter whether we are dealing with product development (the product may be a car or it may be a space), human cell structure, the World Wide Web, or economic development, if we use a relational model and logic of networks that has been described in this thesis, we will be able to understand any complex system and deal with it, without breaking it apart and losing complexity and crucial information.

Ovid talks[108] about the house of the goddess Fama as a kind of *ortlos* space. It is a space without place, or more likely an *Infospace*, as being a place where all the information of the universe can be perceived as "undulating" sound by having an access to information about everything that exists.

> "Full in the midst of this created space,
> Between heaven, earth, and skies, there stands a place,
> Confining on all three, with triple bound,
> Whence all things, through remote, are view'd around,
> And thither bring their undulating sound."

The *Infospace* is a central element of A.N.D.I. operating system. It is a space that goes beyond the definition of objects through their formal or functional descriptions. It is a space that accounts not for what things mean or what they look like, but how they perform in terms of their relationships. Of course, for a foreigner or outsider who enters the "House

[108] Ovid, *Metamorphoses – Book XII*

of Fama", to conceive overall information as a sound means to only hear a non-understandable noise. It is only noise, because one has no possibilities or tools to decode and decipher the information.

The collaborative design process is sometimes very noisy, especially when it includes experts from different disciplines with communication difficulties. However, the novel architectural creative praxis (also the artistic one) is less and less expression of a single person or of an artistic collective. It is more an outcome of "connected intelligence". Second, unreadability or information noise (according to Ovid) and endless possibilities of interpretations are only interesting on the representational level, but not on an interactive, engaging and participating level. In author's opinion the "openness" of creative work is only interesting if somebody is able to do something with it and to relate to it; in other words if it is possible to evaluate what the doing does. The geniality of "Finnegans Wake" (as discussed in section 1.2.) is not debatable, but it is still captured within its own framework of specific language (in this particular case English). With the emergence of Web 2.0 technologies and the development that will come after it, it has become clear that not a technological revolution is the driving engine behind it, but rather the social, world-wide connectivity of creative people. This, of course, produces even more "noise". Therefore, it is enormously important to develop strategies and tools to deal with these quantities to even better grasp new relational networks.

The author has tried to show the application of "collective intelligence" in architectural practice to enable innovation within transdisciplinary design collaboration through theoretical discourse and by the Case Studies. In addition to point out that all this effort requires from the users as well a new "mind-set", since its ambition goes beyond common collaboration models. A.N.D.I. is a useful tool for a collaborative practice when the results and design outcomes are not predictable, which confirms the aspect of brainstorming in the first creative phase of design process. The intelligence of the system will not provide us with new solutions, but help us in the pattern recognition of possibilities that are based on previously gained knowledge. However, there are still more research and improvements needed. In the case of A.N.D.I. following tasks are targeted at as future milestones:

- further development of advanced methods of handling multi-disciplinary data
- adding new tools and plug-ins, as well the implementation of other familiar platforms
- improving the system intelligence based on "deepness" parameters
- increasing mobility usage through the application for mobile devices
- further and continues development of collaboration concepts
- creating of an intelligent recommendation model in sense of A.N.D.I. system

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9. Appendix

9.1. A.N.D.I. Internal Design - High level overview

To achieve basic purpose of this system, which is collaborative work over an active space with multi-related data, it was necessary to try to design modular software on several levels. Server component and GUI component follow the same logic, making the virtual space of nodes containing user expressions and ideas possible for managing using variety of tools plugged into GUI part.

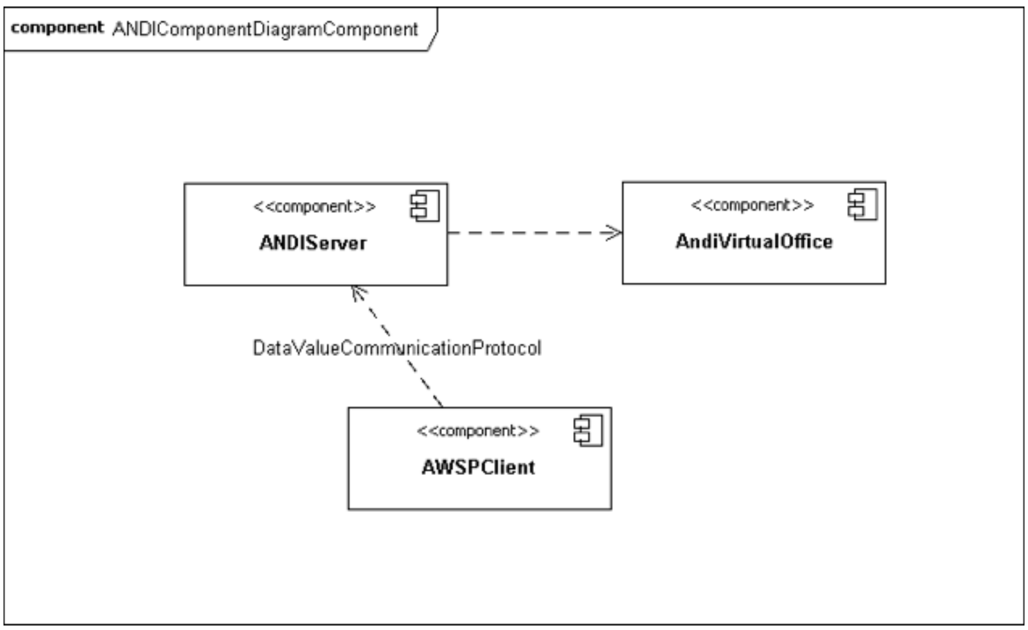


Fig. 46: A.N.D.I. Internal Design – Component diagram

As center of the collaborative engine, A.N.D.I.Server is designed to be able to communicate not just with Infospace Client component, but also with third party systems with the same or similar functionalities. With this in mind, there is a communication protocol defined for client – server data and command exchange. Server broadcasts messages to all connected clients and keeps all session data, for both named collaborative sessions and for all other, anonymous sessions as well. This is main functionality for the Communication component of the server. The center of the server is the Collaborative Work Engine. Main purpose of it is to parse messages received from the clients and invoke the server side command: broadcast message, persist node data, persist node.

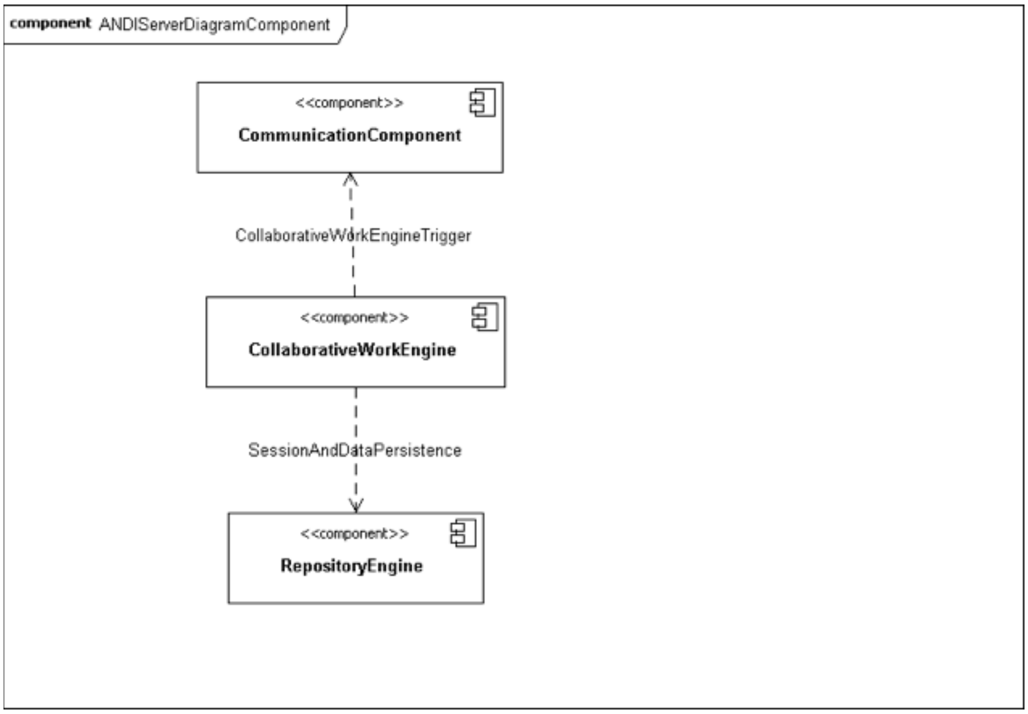


Fig. 47: A.N.D.I.Server component diagram

Objects involved in creative process supported by this system are permanently saved in the repository which is organized as composition of database and indexed file system. There is no logical or physical limitation on MIME type generated by the tools to be stored in the repository. Database holds multiple relations between nodes, enabling custom view over a cloud of nodes.

Beside ability to communicate with the server component of the system, client piece of the software (Infospace Client) is designed as platform supporting visual representation of the node space and tools for creative work. All tools implement the same interface, share the same communication channel. Such technology makes system extensible with more tools. Cloud can be seen in different zoom level. This feature is implemented in the system and provides possibility for the user to work on one node or on a cloud level.

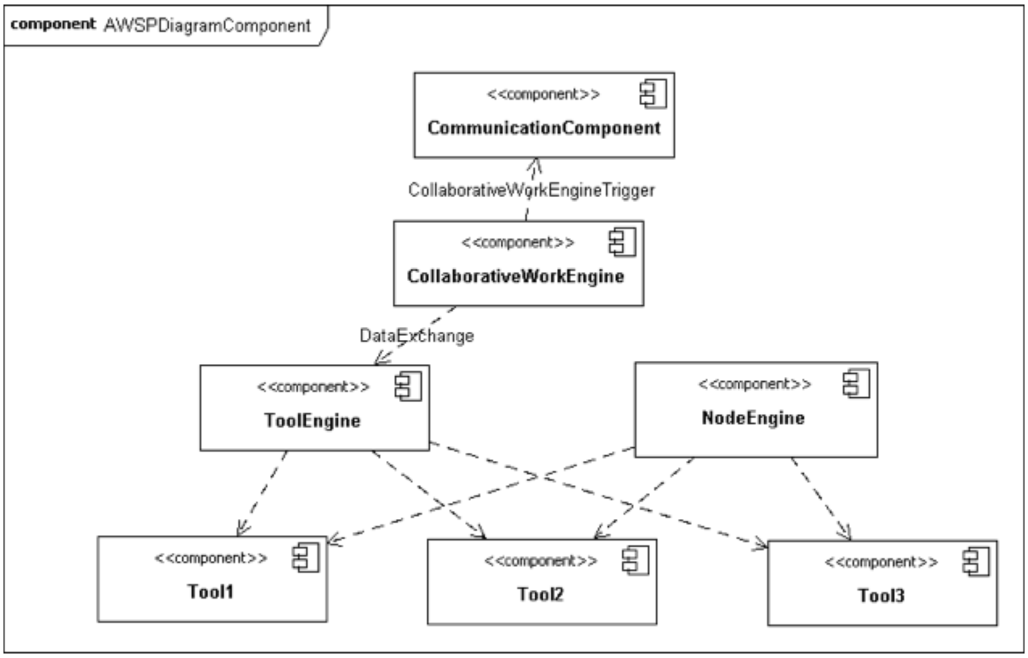


Fig. 48: Infospace component

A.N.D.I. system at whole recognizes several objects that are the core of the theory:

- Tool – general GUI holder for any purpose
- Node – an object generated by the tools, consists several document
- Document – simplest and basic product of work
- Message – data carrier for communication and upload/download nodes
- Collaborative Session – an object that can be serialized, also
- Relation – object for node connection definition by: direction and weight

In the repository, one node is indexed and registered in the database and its content (documents) is serialized and stored on the file system. Same object is represented differently in the Infospace Client, according to mime type of the documents in it. Tools for editing the documents are also different and the message engine enables broadcast of the changes over the collaborative network through server, so every individual involved in the creative process gets information of all other participants immediately.

To enable different points of view and data clouding according to user needs, relations are created between the nodes, with special attributes: weight and direction. Two nodes can have as many relations as covered topics within them require. This concept enables node reuse in independent creative processes. Each new process is privileged to have starting point way ahead previous processes because of growing knowledge and information base generated in the node space over the time.

Message object can wrap information that is needed to be sent to and from the server. It is designed to carry any type of the data, weather it is text or binary. System and tool commands are transferred with this object, also. Special object that connect subset of the whole node space relevant to one research is Collaborative Session.

9.1.1. Software Architectural Goals and Concepts

The presented system is to be implemented and delivered as an open-source environment for Internet collaboration. It should be open to all users in order to use, improve, and modify it by presenting custom solutions and integrating it in the user community. Database was chosen to be MySQL with InnoDB engine for all components. Infospace Client is developed as Java Applet, Virtual Office is Java Servlet/JSP combination and A.N.D.I. Server is pure Java multithreaded server module.

The way to enable applet access to a local file system of the client is to have signed applet. In case of Internet Café and similar environments, this kind of user will have some of the functionality disabled, namely not being able to download/upload files. Some of the packages will have to be installed while working (helper background applications or native code etc) and this will not be possible in general. Users' login extends security and access check. Session data stores relevant data in real time and it is active during work in all modules. This session requires for the user to create an Infospace session.

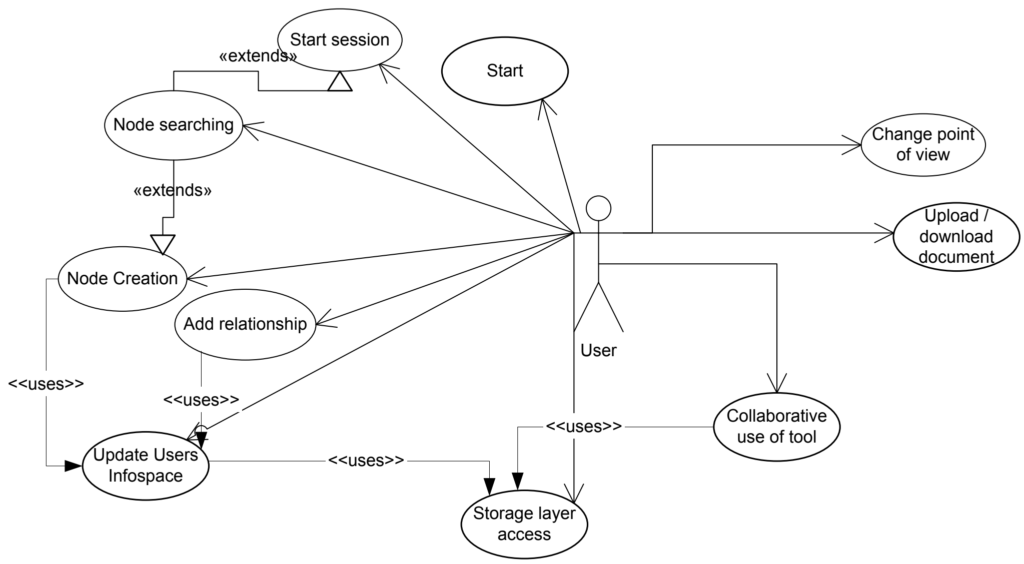


Fig. 49: Architecturally significant Case Study for general registered user

Case Study sequence in Fig. 40 explains the general process of collaboration between the client (Applet) and the server. When a user logs in, the session is created (UserProxy and Session) on the server's side. The UserProxy object has responsibility to accept all client requests and to send notifications to the client. The StorageLayer keeps the information about the client sessions. When a user wants intensive collaboration with other users he/she creates a denominated session. Other users can join the session through its name. They do not need to have the same current node while working in the same session. A session's data has to be packed into DataValue objects to be transferred through the network. The server is responsible for creating a Session object and attach UserProxy to the session. The StorageLayer saves all data about the session.

The process of node creation is divided into two sequences. The first shows the steps for updating the server's Infospace. The second shows the process of notification other users are affected by through the new node. All data is transferred by class DataValue.

Update user's Infospace sequence is included in the Node creation Case Study. Only users with certain *node cloud* settings will be notified. This means that if a node cloud embraces the new node the user will be notified. Only the difference in Infospace is transferred to the server.

A Node can be searched through various parameters. Applet creates the DataValue object with parameters for searching. The StorageLayer is responsible to create a database query based on searchData. The searching results will be packed in DataValue and sent to client.

Tool and behavior are the base for Linger Plateau, Sketch, Idea Generator, etc. (Core classes). Collaborative use of a tool shows the collaboration between two users by using the same tool. The Tool object keeps lists of all users (UserProxy) included in the collaboration. The Server object is also notified when changes occur. This notification is performed by using a listener mechanism.

The created document are nodes, and search information is also packed in DataValue. The StorageLayer unpacks the DataValue, creates the document through the file system by using FileManager, and enters the document properties in the database (relative path, document name, etc.). If a document is created by using the collaboration tool all relevant users will be notified.

Downloading document scenario describes the downloading of files from the server to the client the applet is executing on. The system chooses whether to edit the file (if applet enables such an action for the defined MIME type) or to download it to the local file system. The user is also enabled to explicitly launch the download. The file is then to be uploaded in a similar way, involving the same actors. Download resume is supported. IDownload interface gives direct access to a file which can be used by servlets. This sequence describes downloading by using Infospace applet. The applet can receive the whole file in the first message (download started) from server, if the Downloader which is executing in the applet space does not request chunks from the server until the download is completed. The difference between this scenario and the download of a file is in fact that the file is not saved to a local file system where the applet is executing but edited online and stored only on the server.

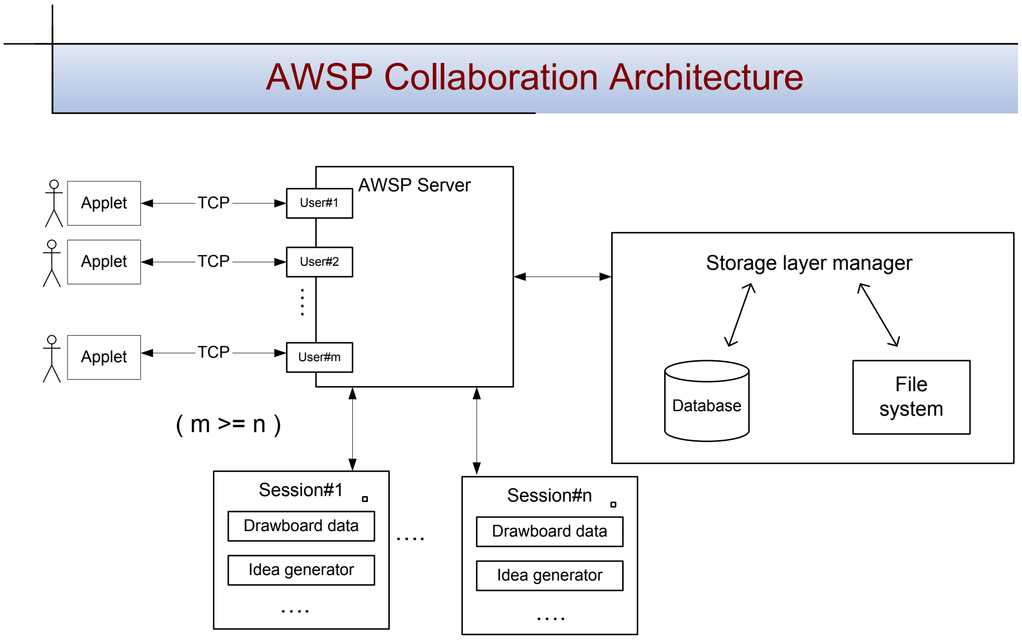


Fig. 50 represents collaborative work using Infospace tools. It addresses sessions and private user configuration of tools and a working data set.

Storage layer manager hides access to the database and file server from the rest of the system. This offers flexibility in defining the rest of the system, despite of the database and the underlying file system of the server. It is up to this level to define where the partial data will be stored, and how to organize it. It brings various set of data store interfaces into the rest of the system (factory pattern). In addition, it uniforms the data transfer to Infospace with a generic data structure that will be streamed through TCP. The knowledge of the data structure that was transferred is contained only at the end points that are computing it. The maximal number of concurrent TCP connections is limited. Through this kind of approach meta-info is moved to a higher level. The Storage Layer Manager can be described with the Data Access Object pattern (see J2EE design patterns) with a slight modification, namely that data objects will be generic hash tables or lists of objects. This of class type will enable faster development, and lose the coupling of data structure. Eventually, it will enable the transparent changing of the middleware part of the system and the adding of new clients with no need to recompile when adjusting data structure at one place.[110]

InfospaceManager hides complex structures from the rest of the system. It is designed by Facade pattern. This class contains (containment relationship) all directions, i.e. all nodes available within the system. It also contains NodeCloud and Event classes.

The **NodeCloud** contains only references to nodes which are interesting for the user (subset of nodes contained in InfospaceManager). The user sets node cloud parameters via the Infospace interface. NodeCloud has only reference to the current node. The current node and all other nodes have child nodes defined by the Relationship class. The Relationship class belongs to a direction from the direction set specified in the NodeCloud.

[110] This helper class is to be used everywhere in the system instead of various data holder/carrier classes, wherever it is too early for data structure to be finally defined. After prototype, all of the data can be optimized and turned to "static" code defined classes which will improve and gain in performances. This kind of approach gives the opportunity to compress some of the standard data types transparently.

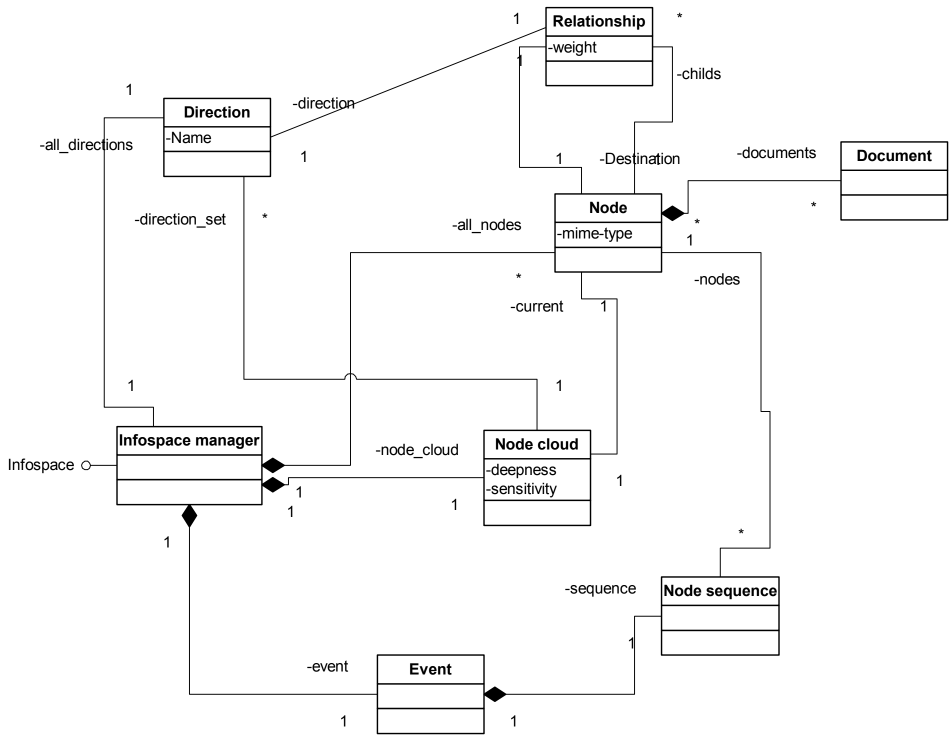


Fig. 51: There is only one Event class in the system and it is related to the NodeSequence class.

The top level class is InfospaceMain. The main class by functionality is GUI. GUI accesses GuiLevelFactory to instantiate 3 levels of system zoom views: FirstZoomView, which is displayed in the Demo tab of the InfospaceMain; NodeCloudView and LargeNodeView are displayed in the first tab and switched between via Zoom in/Zoom out.

PopupMenuPanel is the realization of the context (selection) sensitive menu in Infospace. The menu is displayed in GuiPart descendants in the first tab. The menu is extensible and adding new tools to it does not require recompiling the code, just defining it in XML file.

The New tool to be added to Infospace is a JPanel or JApplet descendant. After class files are added to the system, PopupMenuPanel defines the context for the activation of the tool. The tool is opened in ToolContainerPanel or InfospaceFrame depending on its configuration, or in NodePanel if the node document is edited in NodePanel.

The functionality of adjusting “Node Cloud” parameters and working with directions includes changing sensitivity, deepness and point of view. The first two are included in the context menu, and the point of view list is launched from the menu. The direction list is displayed when dropping the node over the cloud.

The root class of the communication sub system of the Infospace client is the Communicator. This class is responsible for analyzing the received data and for dispatching it to relevant clients. Clients implement DataValuePear interface and register with the Communicator to receive input from the underlying TCP traffic with the server. All of the tools and classes interested in receiving the data from the server implement DataValuePear.

The tool class represents tool data on the server (see Server Core classes). It is used to root multi-user tool messages and data between users and to store data and settings on the server. The corresponding client side tool representation implements the DataValuePear interface, and declares itself as a tool in DataValuePear.isTool(). It can be a JPanel or JApplet derived class that is extended with underlying communication and data exchange protocol to be used for runtime collaboration, with access to node/document structure of the system etc. At the same time, the user can integrate any other 3rd party tool (as the Some3rdClass is) which is not enabled to work with A.N.D.I. data space (ToolApplet extensions are equipped for such purpose) in A.N.D.I. In addition, one can choose whether to display one's tool inside ToolContainerPanel - in the same window as GUI or to display it in a different frame, which is used for heavyweight components (JApplets derived).

Large node view is the most zoomed-in condition. NodePanel is the container that holds IDocViewer implementations, tools or NodeDesc panel class for display and editing of node properties. Content is only one of them at a time based on the command picked from the footer. Based on the command from the footer, the node panel displays previews of the documents if there is a viewer that corresponds to the selected MIME type. Preview classes implement the IDocViewer interface. When the Edit document command is pressed from the footer, the corresponding tool is displayed on the Node panel with the selected document being open for editing. If the tool is not available for the selected document's MIME type the download for the document is launched to store the document in the local file system for editing outside of the Infospace.

Two ways of transferring data from the Infospace to the Project Development system are considered. The first way is related to the creation of the new project. The Power User sets basic project properties and chooses a template from the template list. In the created directory structure system the Power User sets a top folder for Infospace files with a substructure of the chosen events. The second way comes into play when a project already exists and the project leader or manager wants to transfer some additional data from the Infospace which guides him to the selection of the folder to which files need to be transferred then. These files can be part of the node in the Infospace and are to be copied into the project.

A.N.D.I. Server implements a multithreaded server. The Core classes of the server consists of:

- **UserProxy –** The encapsulate user communication represents the user on the server. The class is responsible for routing messages from/to the user client applet and for holding users' preferences and data set. UserProxy is responsible for tracking user connectivity, not by monitoring the TCP connection, but via keep-alive messages and timeout. This is used for determining the alive status of the user in the current session.
- **Tool** – is the base class for a variety of tool representing classes, for tools that are to be used by single users and collaborative tools. Collaborative tools classes hold data that is shared by multiple users.
- **Session** – organizes the logic of multiple users sharing the same data and tools in collaborative work; and for single working use alone as well.
- **Server** – is the centre of the Core classes, holds and instantiates all of them, and monitors the behavior of the system. It enables

multiple algorithms (plugged in) for analyzing the behavior and making changes within the system. This behavior encapsulates e.g. making conclusions of an event and notifying interested listeners, changing relations between nodes (learning the system), etc.

User proxies are in a 1-1 relation to the client applets and take care of the users' preferences in one session. Each time the user leaves the session, proxies are serializing to the session. Session containers are also related to the user's session data, but correspond to data that can be simultaneously accessed by multiple users, collaboration tools like *draw board* or *idea generator*, and to data in general which is related to such computation. Proxies and containers need to be stored prior to leaving the session. The Fig. 43 displays some of the database design topics, but it is presented here as server-storage interaction.

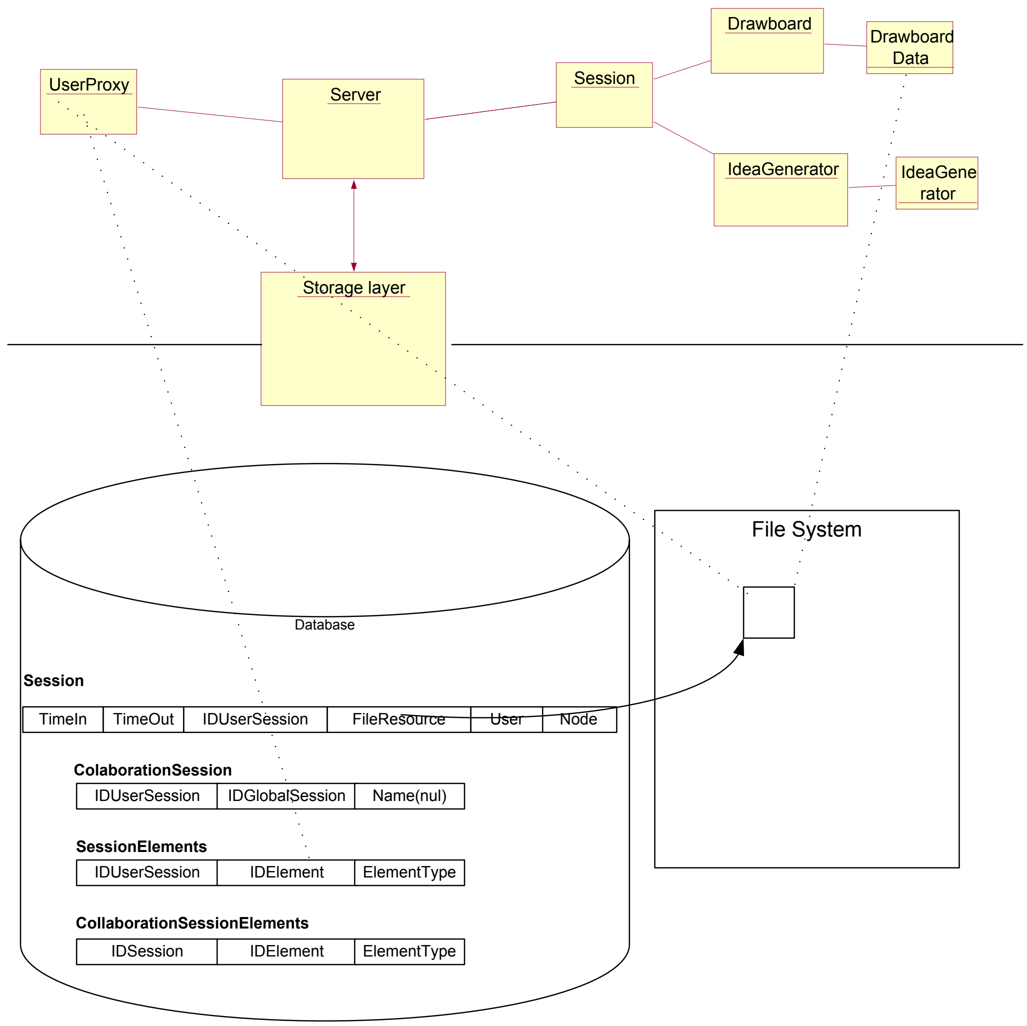


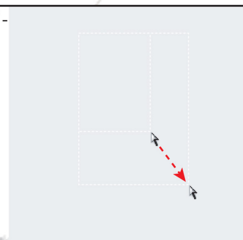
Fig. 52: Database design concept as server-storage interaction

9.2. A.N.D.I. Glossary

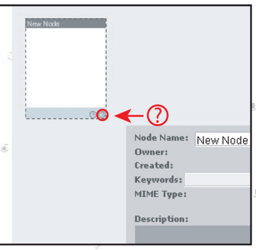
INFOSPACE	Entire data within the system consisting of nodes, node content and relations. System based on Infospace modules and components.
Linger Plateaus	Visual representation of users in a collaborative session (e.g. user avatars)
System Zoom	Levels of visual representation in the Infospace of the current creative process; displayed items are nodes, relations and manipulation tools
Direction	Node relation property that defines the direction of view which is user defined, this means that nodes can be related to each other but in different directions (meanings)
Deepness	Infospace view parameter; defines level of cascade related nodes which are represented on the work panel
Relation weight – Sensitivity	Number between 0 and 1; direct meaning: how strong the relation is between two nodes
Node cloud	Current presentation of the nodes on the work panel defined by parameters (Current Node, Deepness, Sensitivity)
Sequence	User defined nodes as part of one creative process result
Event	Modification of the sequence made through synthesizer. An event is the result of a creative process through one collaborative session.
Synthesizer	General term for a tool used for the computation of INFOSPACE data. We use these kind of tools for driving a creational process, to alter existing ones, and create new states and contents in the INFOSPACE in order to get an event.
Active screen	Interactive and sensitive representation of system intelligence providing the user with a graphical instrument for active design.
Active design	Active design process where the users concentrate on the collaborative creation of ideas and their relationships, not on the usage of the software.

9.3. A.N.D.I. Workflow tutorial

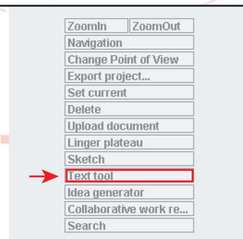
1. Make a new node ("draw" - click and drag - a rectangle with the left mouse).



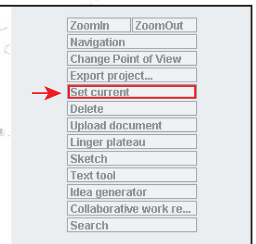
2. Click on "?" to add node properties : name, keywords and description.



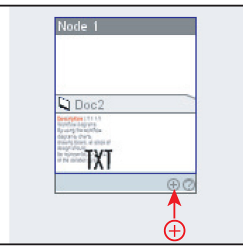
3. Use "Text tool" (from the main menu) to make an input to the new node and save it.



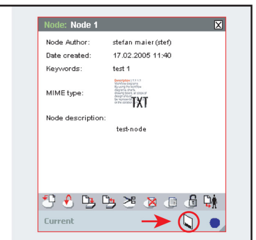
4. Set this new node as current (option from the menu "Set current").



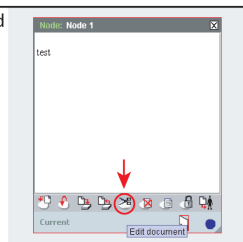
5. Press "+" for zoom-in (this switches into zoom-in display mode).



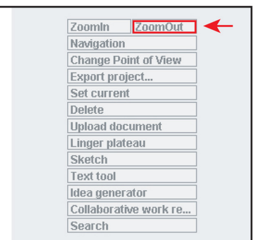
6. Select the first right document in the bottom bar (this is to view document).



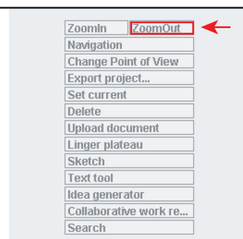
7. Press "Edit document" and with text tool change document as you like and save it.



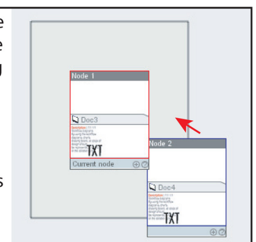
8. Do the same procedure for an other new node with text input (repeat step 1-7) but you have to use "zomm-out" option first, since you can not create nodes in the zoom-in mode.



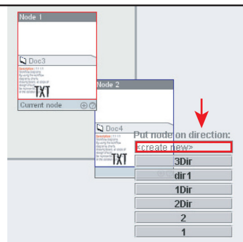
9. Choose "ZoomOut" to switch to initial view of the "create tab".



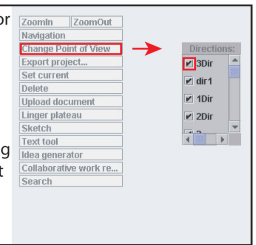
10. Add the last created node to the "node cloud" of the current node by selecting the new node and dragging it into "node cloud". The bolder line of the cloud border shows if this operation is possible.



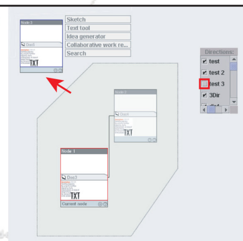
11. Type in the name of the new direction - press enter.



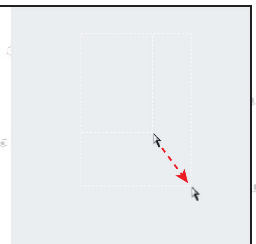
12. Repeat the steps 10 & 11 for an other new node. You can remove the last created node from the Point-of-View by selecting this node and removing it from the screen or selecting in the menu "Change Point of View" and deselecting the last direction you created from the list.



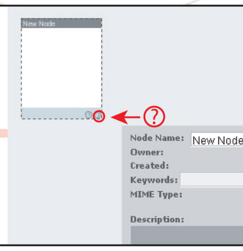
13. Remove the last node you created from the current node cloud.



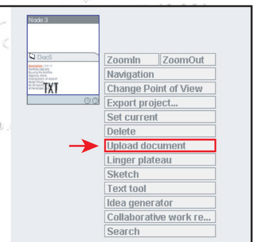
14. Create a new node as in step 1.



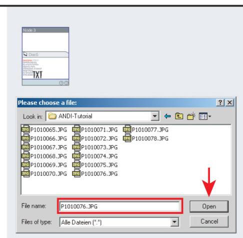
15. Click on "?" and define new node's name, keyword and description.



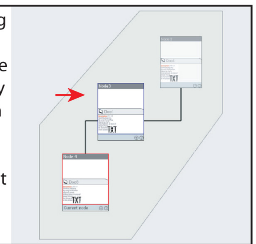
16. Select new node, if not, and select "Upload document" option.



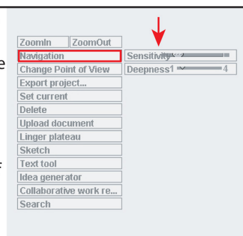
17. Choose with file browser one image file in jpg format and upload it.



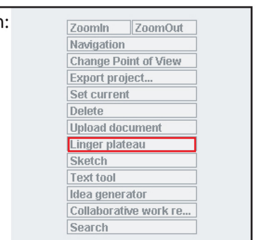
18. Select new node and drag it over the direction line between the current node and connected previously defined node we made in step 8. The direction line should be bold at that moment. It will define that this node is on existing direction.



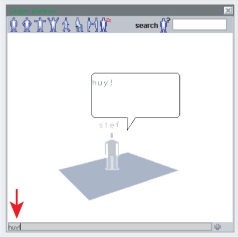
19. If you want to influence the weight of one node on existing direction please use menu options "Sensitivity" and "Deepness" from the menu "Navigation". On the other hand the system intelligence will take care of the node's importance in one point of view, based on usage of that node.



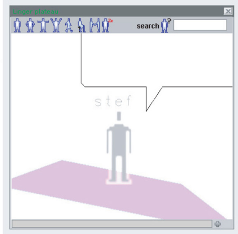
20. Let start communication: open "Linger Plateau".



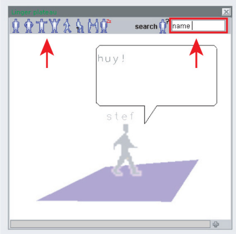
21. Enter your message at the bottom, which will appear in the speech bubble.



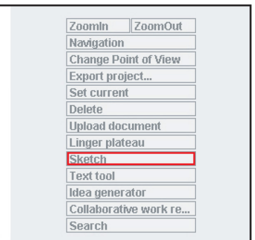
22. Use for navigation in the window: <Alt> + left mouse click to rotate view, <Ctrl> + left mouse click to zoom in, <Shift> + left mouse click to zoom out and <Space> + left mouse click to pan view.



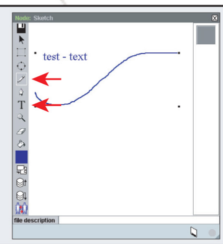
23. You can change your status by selecting one of the icons on the top and search for other user.



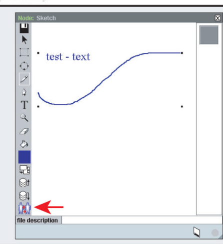
24. Open "Sketch" tool.



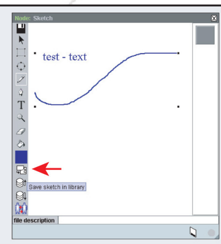
25. Draw something with free hand tool or text tool.



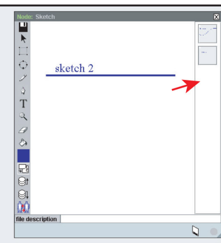
26. Press button for the collaboration (the last button on the panel left). If there is somebody in your creative session, the simultaneous drawing collaboration can start.



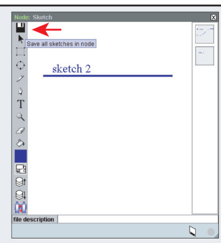
27. You can save this sketch in library



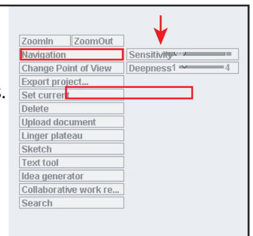
28. Make an other sketch (click for new one on the right panel) and save it.



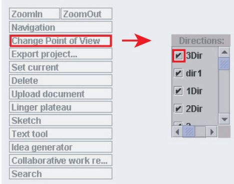
29. Save all sketches in one node by click on the small diskette.
New node should be created.
You can add this node to the existing cloud.



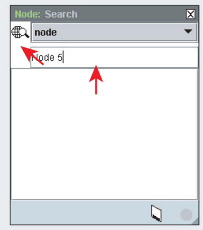
30. With the menu option "Navigation" you can change System sensitivity and deepness. You can try those options, but they will be more important as the system grows and become more complex.



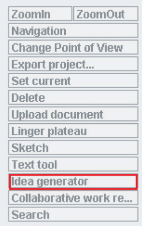
31. Choose "Change Point of View" and uncheck the previews direction.
With this option you can set and control your own Point of View.



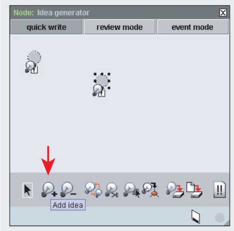
32. Choose "Search" tool.
Type in the name of the node in the text field, which was on previously deselected direction.
Press "search" button on the top left. Find the node in the list and select it. As you see the node was not deleted , but just hidden.



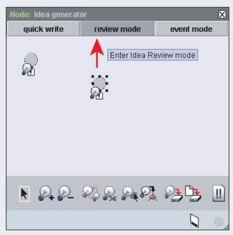
33. Open "Idea generator".
It is the first system's synthesizer.



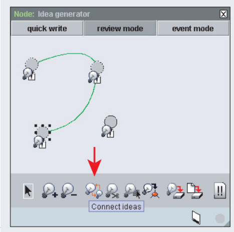
34. In "quick write" add a couple of ideas, and you can connect them if you want.



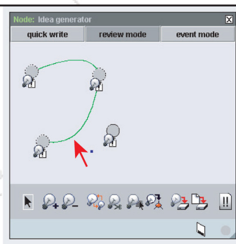
35. Switch to "review mode" (this is for reviewing of ideas).



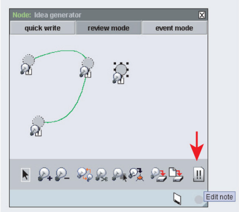
36. Create connections between wished ideas. You can connect even more ideas together.



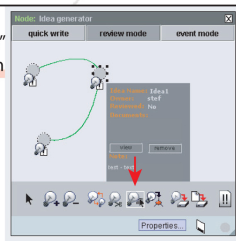
37. Select one connection and delete it.



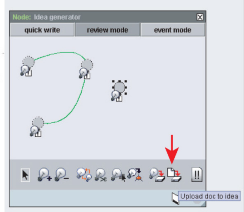
38. Select one idea and move it.
Press "Edit note" and add the note to the idea.



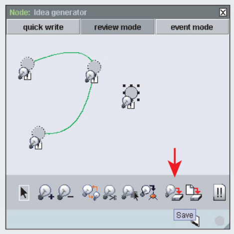
39. Click on the last edited idea and press "Properties". You can change them with "Edit idea" icon.



40. Create new idea and select "Upload doc to idea".
Beside the notes you can upload files into ideas as well, e.g. image files in jpg format.

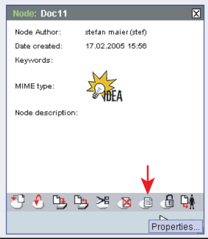


41. Press "Save" to save the ideas in one node.
New node should appear.

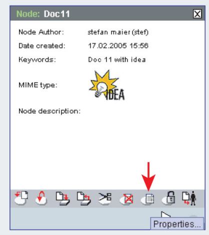


42. Click on "+" to zoom-in mode

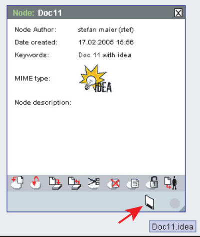
43. Click on "Properties" icon.
Change or add Keywords and Node description.
Author and date of creation can not be changed.



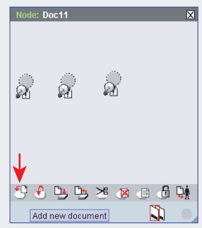
44. Click on "Properties" icon again to save them.
Those are immediately visible to all other users.



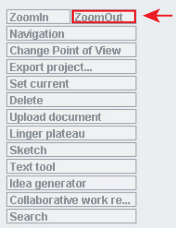
45. Click on document icon to view the ideas.



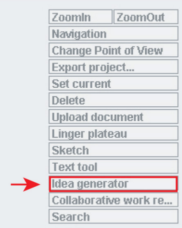
46. Choose "Add new document" icon.
Add some new ideas and "save".
New document icon appear in the bottom most bar.



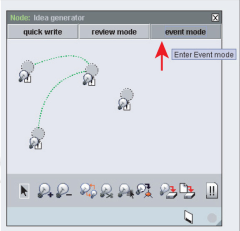
47. Select "Zoom-out" from menu.



48. Click over one of the documents in the previously created idea generator node and select "Idea generator".
This tool will upload last saved status and you can continue to work.



49. Switch to "event mode".
If another user is in the collaborative session his actions will be visible, too.



50. That is it.
For additional information, please sonsult manual.

10.Survey

New Insights in Transdisciplinary Collaboration based on ANDI System

Page 1

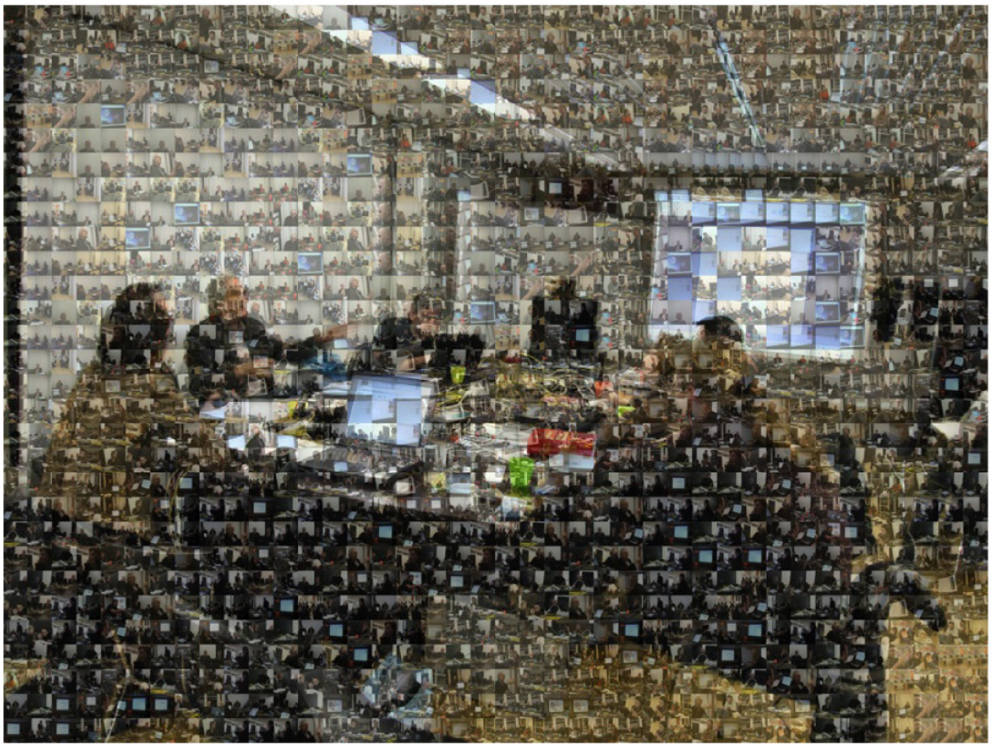
Dear participant,

This questionnaire has been developed in order to reflect and to learn from the outcomes achieved through usage of ANDI system. Please take few minutes of precious time and remind yourself of events and your own perception of the collaborative process during the “City Upgrade” project.

ANDI project had been in development since 2001. The project “City Upgrade” - High Spirited Networked City - in 2005 was the first case study for testing and debugging of ANDI. The findings of this synergy of research and design should help initiate and influence urban development concepts in a more sensitive and inflected manner.

For my thesis I would like to ask you a few questions considering your professional expertise and your experience during the project in order to evaluate ANDI and elaborate the proof of concept. Please take 15-20 min time to answer the following questionnaire. Thank you in advance.

Initial "City Upgrade" Workshop in Forum Stadtpark Graz



Ich brauche Ihre Unterstützung und bitte um die Beantwortung des nachstehenden Fragebogens.

Die Beantwortung des Fragebogens dauert etwa 20 Minuten. Ich bitte Sie, den Fragebogen bis spätestens 20. Juni 2014 auszufüllen.

Datenschutz: Individualdaten werden im Sinne des Datenschutzes verantwortungsbewusst und sensibel behandelt. Analyseergebnisse werden dritten Personen nur in aggregierter Form zugänglich gemacht, so dass diese weder unmittelbar noch unter Zuhilfenahme weiterer öffentlich zugänglicher Informationen auf Ihre Antworten schließen können.

Für etwaige Rückfragen stehe ich Ihnen gerne zur Verfügung.

Page 2

Please enter your name:

Name of your Studio, Company, Institution, Department, or similar:

Please choose your main area of expertise:

Please choose...

Would you describe your practice/studio as multi-disciplinary?

- yes
- no

If you consider your practice/studio multi-disciplinary, please enter the main disciplines it covers:

Page 3

For the transdisciplinary projects people with different educational background and fields of expertise cooperate. "City Upgrade" in 2005 was transdisciplinary project, did you have any comparable experiences of transdisciplinary cooperation before?

Before 2005 I had cooperated in transdisciplinary projects:

- Never
- Few Times
- Regularly

City Upgrade Conference at the TU Graz

Page 4

I/We had collaborated with ORTLOS or the team members / cooperation partners of City Upgrade project before the project City Upgrade started.

○ yes

○ no

Public presentation of City Upgrade

Page 5

“City Upgrade” was a project with partners from five to seven different domains working together from six to twelve months. Before “City Upgrade”, have you had comparable project experiences in terms of team composition and project duration.

I/We have had: [ ] (enter number of projects)

Team Meetings

Page 6

When people with different educational background and expertise cooperate they have specific knowledge, terminology they use, already established methods and workflows of collaboration. Concerning the "City Upgrade" project how did you experience the following aspects:

	completely unclear	clear	clear towards the end of the project
The terminology used by the City Upgrade team members was	○	○	○
The methods other team members used were	○	○	○
The requirments on cooperation of team members were	○	○	○

Workshops in Graz and Vienna

Page 7

A Transdisciplinary project approach is by its nature more intensive then the classical working method. To your personal experience a transdisciplinary project, when compared to “a classical approach” usually achieves lower – higher results in terms of innovation.

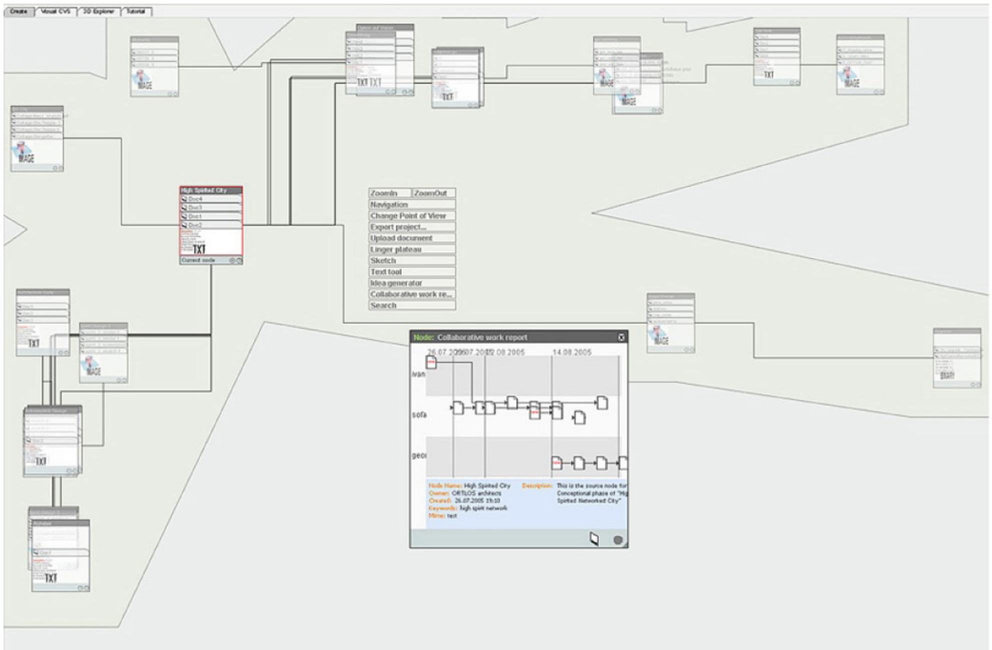
lower results	○	○	○	○	○	○	○	○	○	○	higher results

Page 8

In which way did this heterogeneity and diversity of team experts involved in the project "City Upgrade" influence the project results? The heterogeneity was a source of:

- ☐ Conflicts among team members
- ☐ Creativity
- ☐ New solutions
- ☐ New partnerships
- ☐ New insights in other disciplines
- ☐ Other

ANDI Interface



Page 9

In your own words considering the experiences with City Upgrade – please describe briefly what do you remember most (the most positive and the most negative aspects)?

City Upgrade Exhibition at Kunsthaus Graz

Page 10

Which are the most important success factors of a virtual working environment? When thinking especially of the virtual collaboration through ANDI – what worked out fine? What didn't work out?

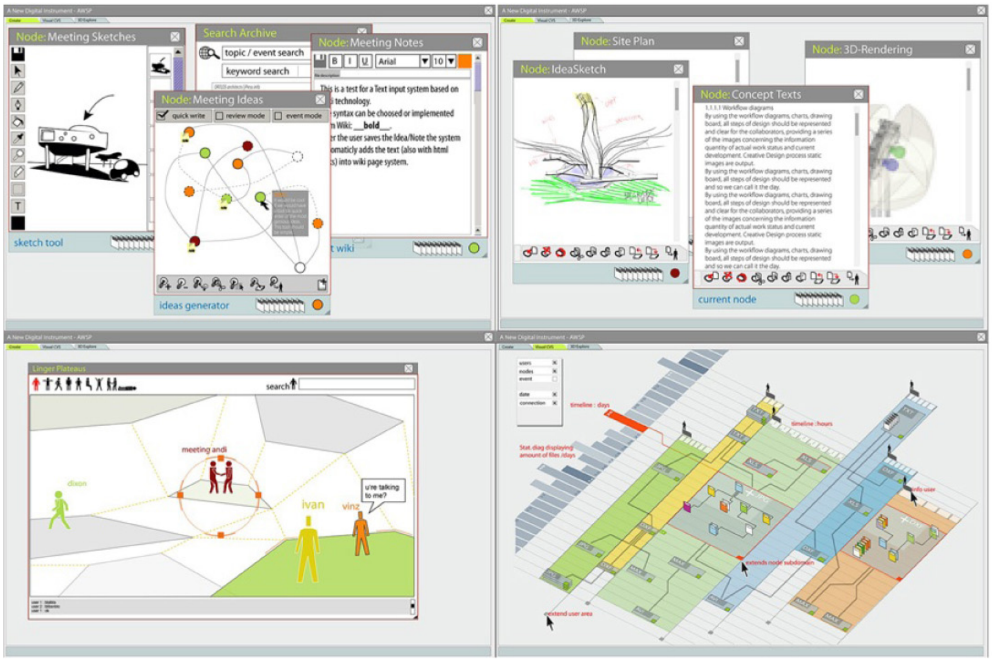
	didn't work	worked	worked ok	worked fine	don't know
Technical aspects and tools	○	○	○	○	○
Common language and methodology	○	○	○	○	○
Encouraging team collaboration	○	○	○	○	○
Reflecting on inputs of other team members	○	○	○	○	○
Ways to document inputs by each team member	○	○	○	○	○
Reducing the redundancies in the work process	○	○	○	○	○
Combining interdisciplinary knowledge	○	○	○	○	○
Formation of random views of team members	○	○	○	○	○
Possibility for synchronized just-in-time collaboration	○	○	○	○	○

Page 11

ANDI offered a variety of tools to support the virtual collaboration. In which way did these tools influence the work process within project "City Upgrade" and made the impact? Please rate from highly negative – highly positive impact, in a scale 1 to 5. Additionally please judge the importance of each tool for the transdisciplinary work process as well.

	highly negative	2	3	4	highly positive	Importance --	-	+	++
Design Visualization Tool (overall view of the nodes, which user can browse in two modes: navigational and operational)	○	○	○	○	○	○	○	○	○
Text Tool (a container holding one or more text documents)	○	○	○	○	○	○	○	○	○
Sketch Tool (contains more sketch documents, within the same node, but it also can contain more galleries within one document.	○	○	○	○	○	○	○	○	○
Idea Generator (a brainstorming tool for the mind mapping of ideas in team)	○	○	○	○	○	○	○	○	○
File Node (tool for upload of any kind of binary data)	○	○	○	○	○	○	○	○	○
Linger Plateaus (tool for instant messaging and visual chat among the users)	○	○	○	○	○	○	○	○	○
Visualization of the Collaborative Work (tool to track users' inputs and documents' changes).	○	○	○	○	○	○	○	○	○

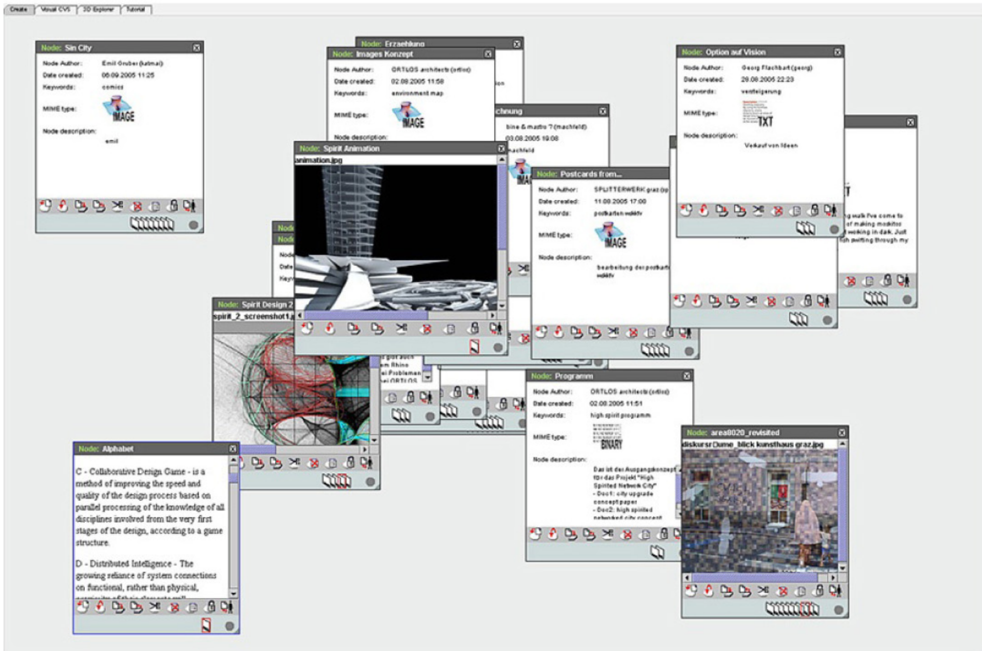
ANDI Tools / Nodes / Linger Plateau / Work report



Page 12

Can you describe the effects when applying the tools from your own personal experience? How do you remember these tools? What would have been needed in order to improve the positive impact?

ANDI Interface Zoom-in Modus with various inputs



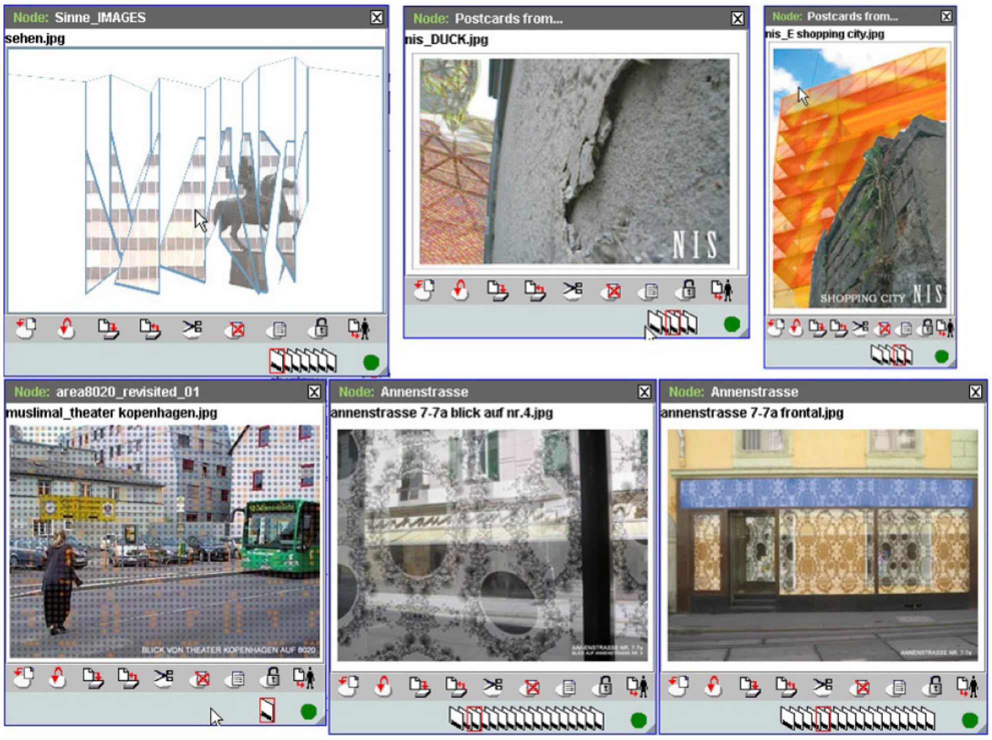
Page 13

What tools are you currently using for your projects comparable to City Upgrade in terms of transdisciplinary collaboration especially for first creative design phase. Thinking about City Upgrade: what would have been an alternative technical tools and platforms to ANDI you are using (e.g. file repository, CVS, wiki, etc…)

Page 14

Thinking especially about City Upgrade, which impact did ANDI have on the team cooperation? Please describe your experience in a few sentences. For example considering: decision finding, communication process, resources needed; etc.

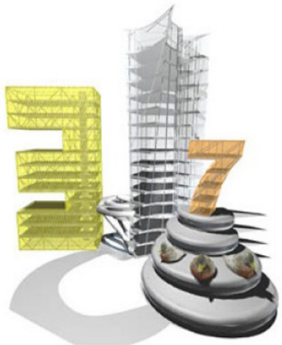
Collaboration SPLITTERWERK - Krusche - WSKKFV

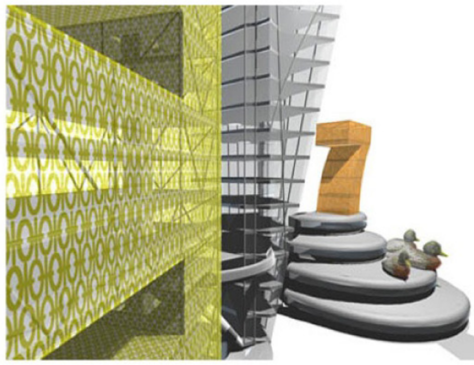


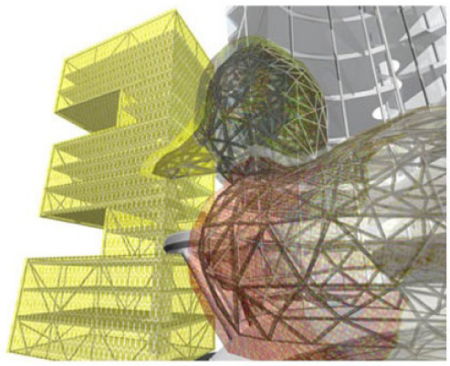
Page 15

If you compare City Upgrade with other project experience in which way did it differ most concerning the innovation? Has been any memorable event or milestone which could be claimed as crucial for the innovation in the transdisciplinary collaboration?

ORTLOS - SPLITTERWERK collaboration



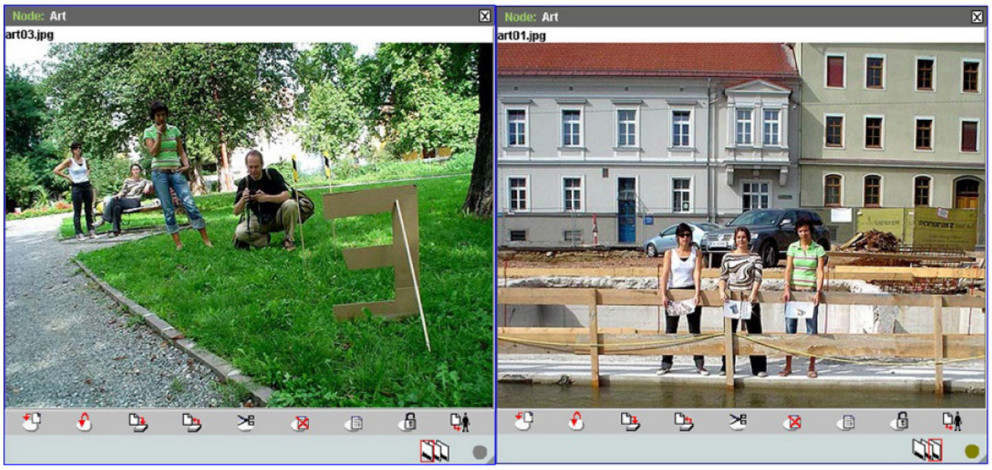




Page 16

In your opinion in which way did usage of ANDI system influence the creation of knowledge and new insights, within the project City Upgrade?

Collaboration Krusche - Gruber - WSKKFV



Page 17

Have you been able to cope with an unanticipated outcomes of the project City Upgrade, which have not been foreseen and not defined as a goal at the beginning of the project?

- ○ yes
- ○ no

Page 18

In your opinion compared to the other projects you have been involved, in which regard the knowledge production and communication by using ANDI system helped to embrace the innovation and new ideas during the creative design phase of the project City Upgrade.

Page 19

How could architecture profit from collaborating with other disciplines (not from the domain of the building industry), when searching for new solutions?

Page 20

Which role should transdisciplinary collaboration and the corresponding tools play in order to contribute finding new solutions in architectural practice?

less important role ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ very important role

Page 21

You have completed the survey. Thank you very much for your participation!

If you would have additional suggestions or remarks please do not hesitate to contact the author

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