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CULTURAL HERITAGE AND MULTIDIMENSIONAL REPRESENTATIONS OF BUILDINGS – A SEMIOTIC APPROACH TO GI-ONTOLOGIES

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ABSTRACT

Cultural heritage means something to most of us and historical buildings play a role in many peoples daily life. As part of historical or architectural research those buildings represent in themselves former ways of living that has to be documented, analysed and communicated. Furthermore those buildings can be represented in various ways due to a variety of purposes in society. Dealing with city management in general the complex of information concerning historical buildings is for instance present when handling building permissions or city renewal processes, facilitating tourism as well as branding the city or cultural environments in a broader sense. In the geo-information community as well as in the built environment metadata and meta-information as means of communicating content and usability of datasets and information setups has been a key matter for several years. The approach in this paper is the belief that a more abstract level for reflection and understanding of the various modelling processes is needed. Addressing this matter a semiotic modelling tool will be introduced as a formal ontological schema capable of framing the various representational levels concerning complex multidimensional geo-phenomena present in a city management GI-infrastructure. The semiotics of Peirce is of increasing interest as means of understanding the fabric and dynamics of representation as well as the processes of communication in general. So it is argued, that the semiotic principle of constantly considering the relations between the three basic elements – the representation, the object of the representation and the way the object is represented – establishes an abstract cognitive framework for handling the analysis of the various communicative aspects related to the complex questions of data quality and metadata, meta-information or even meta-understandings.

INTRODUCTION

In a Danish urban context planning and management procedures have moved towards more and more holistic procedures dealing with ecological, cultural as well as social matters and involving various professions, politicians and residents depending on various kinds of multidimensional and geospatial information. At the same time the ongoing implementation of digital management at al levels in the Danish society increasingly reveals the needs for new tools capable of handling the communicative aspects related to sharing data, information, and knowledge across professional domains and organizational borders. The approach to this paper is the belief that adressing those interdisciplinary demands concerning metadata issues or semantic interoperability in a broad sense a meta-conceptual level of reflection and

communication is needed. The considerations presented in this paper is based on a PhD-project dealing with such meta-communicative aspects of representation of data usability in the modern knowledge-based society. The major concern in the project has been the search for tools capable of framing and thereby communicating the pragmatic use-oriented and value-based understandings and methods characterizing the disciplines and organizational contexts involved. As means of dealing with such diffuse matters of representing concepts and procedures from all over the practical and scientific work fields the semiotics and pragmatism of Charles Sanders Peirce (1839-1914) will be introduced, and a conceptual modelling tool based on a formal ontological schema representing those basic principles will be presented. Finally some examples will be given to illustrate the potential of this modelling tool as means of framing various GI-ontological aspects regarding cultural heritage in an urban planning and city management context.

BACKGROUND

In the geo-information community as well as in the built environment metadata and meta-information as means of communicating content and usability of datasets and information setups has been a key matter for several years. Dealing with a PhD-project concerning such aspects regarding buildings in a Danish urban renewal context *(Schrøder, 2002)* created a need for a general modelling tool capable of handling various representative aspect and levels systematically. The project furthermore indicated how conflicting structures, procedures or methodological approaches to some extent have to be communicated rather than standardized. Finally it became more and more obvious that the interdisciplinary information modelling processes themselves had to be represented as such to be able to frame and thereby communicate the various conceptual elements and levels of the debate *(Schrøder, 2005)*.

Buildings, semiotics and GI-ontologies

Complex interdisciplinary matters as city planning or city management illustrate perfectly how the different professional domains involved characterized by specialised training, practises and tools have defined specific understandings as well as various ways of handling information related to buildings. Though efforts have been made to establish procedures supporting sharing and exchange of Danish building data, consensus concerning object definitions has still not been achieved as well as legal aspects remain unsolved. Though, from one point of view the emerging multidimensional GI- and VR-technologies within the Danish professional disciplines dealing with city planning processes or the design, construction and management of the built environment is leading to a demand for a core data set of four-dimensional building objects as part of the public geo-information infrastructure. The other way around it can be argued that the recognition of the building as a multifaceted geo-phenomenon will provide a valuable framework for understanding different data sets concerning buildings represented in multiple ways with the capacity of supporting a shared understanding across professions and universes of discourse *(Schrøder, 2005)*.

As means of ensuring semantic interoperability across information domains creating operational ontologies has been a key issue for several years. Inspiration from scientists dealing with multidimensional representation of geo-phenomena *(Raper, 2000)*, GI-ontology in general *(Bishr & Kuhn, 2000)*, and information systems for urban planning *(Laurini, 2001)* initiated the hypothesis that a shared multidimensional understanding of the building phenomenon would increase usability of various datasets by providing a richer semantic

framework. Investigating this idea resulted in considering the conceptualization of a meta-communicative framework of modelling and representation the key matter. In the interdisciplinary fields of artificial intelligence, knowledge management, communication or cognitive science the semiotics of Peirce is of increasing interest as means of understanding the fabric and dynamics of representation as well as handling concrete representations of data, information and knowledge *(Sowa, 2000)*. Regarding geographical information science Jonathan Raper *(Raper, 2000)* as well as Donna J. Peuquet *(Peuquet, 2002)* is referring to semiotics in general as carried out by researchers as Bertin and MacEachren. Describing the field of data mining Raper is referring to Gahegans use of the concept of abduction invented by Peirce. Gahegan has further developed this approach when describing the general processes of GIScience by means of semiotic concepts *(Gahegan, 2005)*.

To be able to frame the various representational levels concerning ontologies of information systems related to the built environment as well as being able to handle the complexity of the semiotic theory itself a schematic modelling tool based on the formal ontology of Pierce has been developed *(Schrøder, 2005)*. This sign-model furthermore expresses the idea of abstract meta-ontological concepts possessing the potential of mapping between various universes of discourse and thereby enabling communication across disciplines and organizational borders. Based on this cognitive approach it can furthermore be argued how the concept of multidimensional building information frames various representational views which can be related to a kind of four-dimensional reference-object though the idea of the spatiotemporal building phenomenon itself remains an abstract vehicle for collaborate thinking.

The cultural heritage approach

According to Thomas R. Gruber an ontology is a specification of a conceptualisation *(Gruber, 1996)*. The ontological aspects revealed by the sign model in the PhD-project still remains on a very abstract conceptual level. Therefore, as means of modelling operational ontologies due to the practical needs of the GI-society the semiotic approach needs further evaluation. A case-study specifying the ontology while considering the complexity of cultural heritage issues *(The Cultural Heritage Agency, 2003)* due to representational forms, professional views, and user needs related to the information flows and communicational processes regarding historical buildings in a city management perspective seems to fit this purpose.

Cultural heritage means something to most of us, and historical buildings play a role in many peoples daily life *(European Council, 2004)*. As part of historical or architectural research those buildings represent in themselves former ways of living that has to be documented, analysed and communicated *(The National Forest and Nature Agency, 2001)*. Furthermore those buildings can be represented in various ways due to a variety of purposes in society *(European Council, 2001)*. Dealing with city management in general the complex of information concerning historical buildings is for instance present when handling building permissions or city renewal processes, facilitating tourism as well as branding the city or cultural environments in a broader sense.

The cultural heritage aspects are in general present in the Danish physical planning procedures *(The National Forest and Nature Agency, 2001-1)*. Furthermore the concrete matters of documentation of historical building phenomena by means of various techniques and representational forms *(Lagerqvist, 1999)*, handling of the concrete datasets *(Gregory, 2003)*, as well as the communication issues concerning multiple use of the actual representations and databases *(Ogleby, 1999 and 2001)* are quite suitable for the purpose of

illustrating the general complexity of problems concerning usability of the variety of building data in such GI-based collaborate working environments *(Hansen, 1999)*. In the following some of the basic semiotic concepts will be introduced as well as the sign-model will be presented. On this background it will be exemplified how those concepts can be useful when dealing with representations of historical buildings and the creation of ontologies fit for mapping across domains by communicating the content and usability of those datasets.

PRAGMATISM

Addressing the general need for a formalized interdisciplinary understanding of model-based communication the pragmatic semiotics of Charles Sanders Peirce developed a century ago seems to have a great potential providing a meta-theoretical framework for describing elements, relationships and dynamics of reasoning based on multidimensional representations of geo-phenomena. Though, those in his time revolutionary theories of signs and pragmatic concepts remain very complex and comprehensive. Furthermore, his way of thinking at first glance might seem very strange to the mind of a scientist grounded in the rationality of mathematical formalization. Anyway, Peirce himself, besides solid philosophical and mathematical studies, was educated as a chemist, and he had worked with surveying for a long period – so even if some of his concepts are changing due to continuous refinements and the evolutionary development of the various major semiotic concepts during his entire lifetime, there is a strict underlying logic defining the basic elements and dynamics of his fundamental sign theory.

Firstness, secondness and thirdness

Even if the semiotics of Peirce intends to incorporate all possible aspects of signs, his basic concept is quite simple. Due to Peirce all aspects in the world belong to one of three different universes characterized by *firstness* (1), *secondness* (2), or *thirdness* (3). In 1908 Peirce (1998) describes the objects of the first universe as ideas or *possibles*, the second is referring to an universe of actual *existents*, while thirdness express the idea of necessity functioning as a habit or law in an universe, whose objects he calls *necessitants*.

The idea of a sign is incarnating this triadic principle as the sign vehicle by its *qualities* (1) is *actualized* (2) by some relation to an object, and *mediated* (3) by an interpretation representing this relation and its elements. Based on those basic principles Peirce developed a semiotic ontology of several sign categories defining the possible types and triadic combinations. Regarding this Peircian concept of *semiosis*, knowledge (3) is created during the cognition processes by the analysis of signs (1) compared to what we already know (2) about the phenomenon. A typical example is archaeology based on finding and translating signs into models and theories describing our historical past *(Rosenstein, 2003)*. So it can be argued, that the basic semiotic principle of constantly considering the relations between the three basic elements – the *representation* (1), the *object* (2) of the representation, and *the interpretation* (3) representing how the representation should be understood by *someone* – establishes an abstract cognitive framework for handling the analysis of various communicative aspects.

Diagrammatic reasoning

This cognitive approach led to formulating the pragmatic scientific concept as described by Peirce (1994) in his lecture "Pragmatism and abduction" presented at Harvard in 1903. The first step is *abduction* (1) where the hypothesis or preliminary conclusion is formulated. Then follows *deduction* (2) where the necessary consequences are identified. The final step is *induction* (3) where the hypothesis is tested by generalizing the various results providing a general picture of the value of the hypothesis (Peirce 1994).

The process of deduction is closely related to Peirce's concept of diagrammatic reasoning, as the deductive argument is based on a diagram showing a necessary connection between the premises and the conclusion. This experimental procedure based on diagrammatic and in its core mathematical constructs is resumed by Liszka (1996) as follows:

1. The statement of the hypothesis in general terms.
2. The construction of a diagram which is an icon of that hypothesis.
3. Observation of the diagram.
4. The determination that the relation observed would be found in every iconic representation of the hypothesis.
5. Statement of the results in general terms.

As described by Liszka (1996) deductions can be *necessary* or *probable*. *Necessary reasoning* as performed when the diagram is observed (step 3.) has two species: *Corollarial* and *theorematic*. In a *corollarial* deduction the conclusion is immediately present in the diagram, while the process of *theorematic* reasoning demands experimentation with the diagram. *Deductions of probability* are deductions whose interpretants represent them to be concerned with ratios of frequency, and they can be either *statistical deductions* or *probable deductions proper*. A *statistical deduction* is a deduction whose interpretants represents it to reason concerning ratios of frequency with absolute certainty, and a formal form of induction and abduction can be derived from statistical deduction. A *probable deduction proper* is a deduction whose interpretant does not represent that its conclusion is certain but that precisely analogous reasonings in the long run of experience would produce true conclusions from true premises in the majority of cases. Those distinctions concerning kinds of deduction illustrate the potential of the diagrammatic concept as a meta-theoretical making it possible to bridge the various processes of modelling and levels of representation present in complex information systems.

Alikeness as foundation for modelling and mediation

In Peirce's terminology *(Peirce, 1994)* the iconic aspect of representation is very important as it expresses the qualitative likeness between the sign and the phenomenon represented. Signs as means of communicating ideas have to possess the potential of being recognized, which makes iconicity the core of modelling and model-based communication. The iconic signs, in the terminology of Peirce called hypo-icons, have three forms: *Image* (1), *diagram* (2) and *metaphor* (3). In general there will be a progression from *images* representing qualities to *diagrams* representing actual relations and further on to *metaphors* representing something by representing a parallel in something else. The qualities of the ideal virtual world of the hypothesis or vision of a possible solution must be recognized as an *image* before the structures of that world can be conceptualized in the virtual world defined by a *diagram*. Likewise, *metaphors* (3) to some extent can be understood as generalizations making *diagrammatic* structures understandable by visualizing the communicative context by means of familiar parallels.

As an example of the classical use of diagrams Peirce *(1994)* mentions the architect creating precise drawings of a house making it possible to decide whether the suggested construction will fulfil the aesthetical as well as functional demands. In general this process is recognized in various modelling processes characterized by trial and error experiments based on visual diagrams or mathematical simulations making it possible to predict the possible empirical consequences due to different kinds of structural alikeness between the model and the phenomenon pictured.

SIGNS OF METACOMMUNICATION

Trying to provide the contours of a concept framing the systemic aspects of reasoning and knowledge generation the semiotics of Peirce possesses a challenging potential. The concept of abduction explains the basic foundations for creating new knowledge, and the dynamics of the process as a whole is expressed in the pragmatic iterative concept of reasoning based on diagrams.

Modelling the sign-model

Even if the semiotic framework of Peirce is based on an idea of "knowledge systems", and the concept of semiosis is incarnating processes of communication, the dynamics and relations among the various levels of elements are not that easy to communicate. Inspired by Luhmann's concept of social systems interacting by means of communication *(Luhmann, 2001)* a conceptual framework based on the fundamental distinction between a system and its context is established. Within this meta-contextual setting the basic elements of signs and semiosis are then introduced as illustrated in the diagram below (fig. 1).

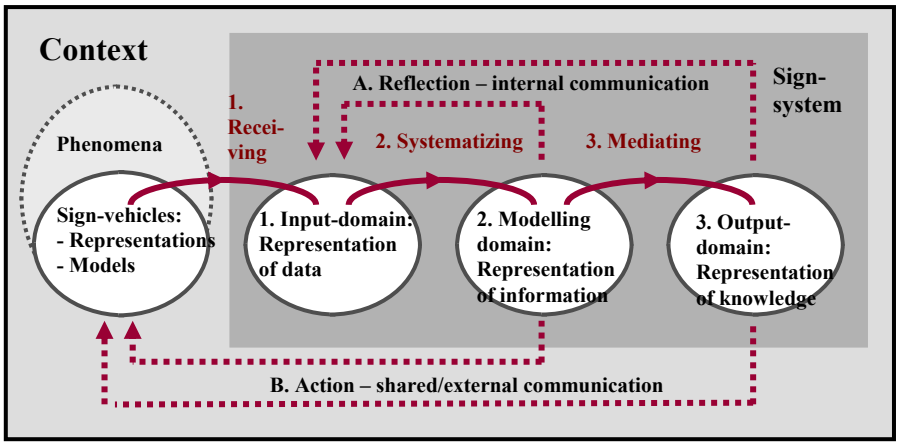

Figure 1: The basic semiotic concept of a communicational sign-system.

Considering the meta-level of this sign-model there are some *phenomena* represented by various kinds of *sign-vehicles*, which by means of the sign-system might be translated into what could be termed *data* (1), *information* (2), and *knowledge* (3) about the phenomena. According to Peirce (1998) the *object outside* the sign-system (dynamical object) has to be distinguished from the *object inside* the sign (immediate object). In the model this distinction is represented by the *phenomena* outside the system and the *modelling-aspect* within the

system organizing the received data concerning the phenomena according to what is already known about it.

On this background the sign-system contains the basic triadic elements: An *input-domain* (1), a *model-content-domain* (2) and an *output-domain* (3). The main flow expresses the irreversible transformations performed through the system: *Receiving* (1) due to the selection of input, *systematizing* (2) understood as the transformation relating input to existing knowledge, and finally *mediation* (3) expressing the process making the transformed input communicable. Furthermore this triadic process of transforming signs from input to output is reflecting the idea of the interpretant as a general triadic concept, which is analyzed and revised in the writings of Peirce at various levels *(Liszka, 1996)*. The *internal feedback mechanism* (A) expresses the act of reflection or revision inside the system while the *external feedback mechanism* (B) expresses the various forms of communication outside the system. The processes of the systems are irreversible, as something that has been done cannot be made undone. The feedback mechanisms also represent the ways of interacting with the system, as they are closely related to the idea of acting *in* the system or acting *on* the system.

Dealing with methods and representational forms within the widespread area of communication, multi-media and design practice the pragmatic semiotics of Peirce is of growing interest as his concept of abduction points out the necessary creative aspect of reasoning and scientific research. This pragmatic scientific process combining the three types of argumentation *abduction* (1), *deduction* (2), and *induction* is quite easily framed by the general principles of the sign-model (fig. 2).

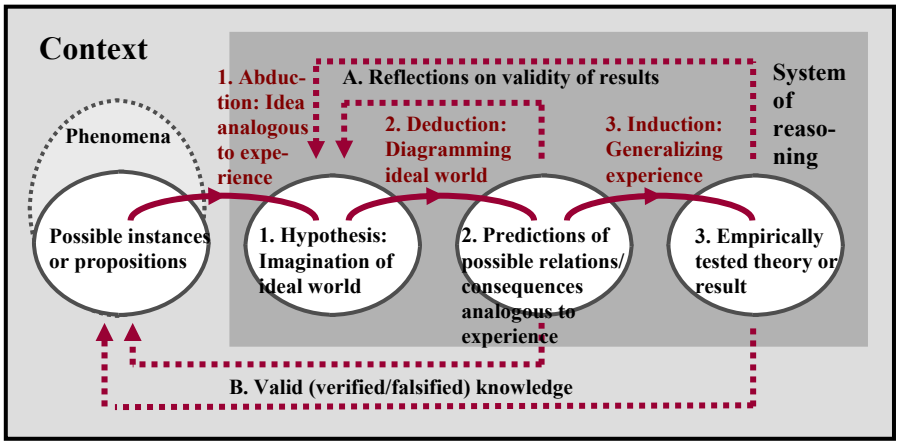

Figure 2: A model representing the identification, analysis and validation of arguments in research, professional practice as well as daily life.

The pragmatic process of Peirce is very general and its principles as described by the sign-model are directly observable in Karl Popper's hypothetic-deductive approach *(Øhrstrøm, 1998)* which implies: *Empirical observation*, *hypothesis generation* (1), *design of experiments* (2), and finally *empirically testing* (3). The idea of the professionals involved in city planning or city management as practitioners reflecting in virtual worlds – a view inspired from Donald Schön (2004) – as means of constantly modelling views of reality due to all kinds of purposes seems to have a lot in common with the formal concepts of visual conceptualization and visualized investigation theorized and practiced by Peirce.

DIAGRAMS AND CULTURAL HERITAGE IN URBAN PLANNING

In a broader sense abduction understood as the hypothetical element of any communication generally speaking makes the Peirce's pragmatic process of abduction, deduction and induction a very useful formal framework. Especially the intuitive sketching processes of design or planning practice fits very well into this pragmatic concept based on diagrammatic transformations, which also in its core can be understood as present in the traditional processes of systems analysis or GI-modelling dealing with formalized model-based reasoning – in its prototypical form the geometric projection of real world entities onto a sheet of paper.

The pragmatic principles are grounded in the classical syllogisms of Aristotle characterizing arguments by the combination of premises and conclusions (Peirce 1994):
Deduction: Rule + case → result
Induction: Case + result → rule
Hypothesis: Rule + result → case
Expressing those arguments by the mechanism of the sign-model leads to considering the *premises* (1) as the input-element, the *conclusion* as the output-element (3), while the *model-aspects* illustrates the kind of performance (2) characterizing the actual information system. The *internal feedback mechanism* is characterizing the reflection or revision inside the system (A) while the *external feedback mechanism* is expressing the kind of action (B) produced by the knowledge system. Furthermore, it will be possible to distinguish three levels of systematizing referring to three ways of assuring arguments due to *instinct* (1), *experience* (2), and *habit* (3).

Abductive reasoning

The process of abduction is present in reasoning processes of all kinds. Dealing with cultural heritage it could be the process of creating a hypothesis concerning the history of a building to be able to reconstruct the presumed appearance according to a specific period (fig. 3).

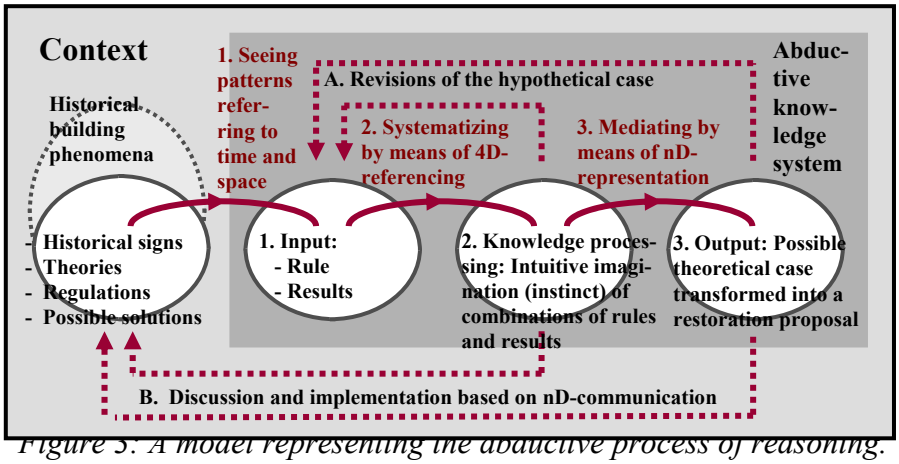

Figure 3: A model representing the abductive process of reasoning.

Specifying the elements of the sign-model shows:

Step 1: Selecting input, which could be various kinds of spatiotemporal patterns concerning historical building phenomena, which could be knowledge concerning methods used in specific historical periods (rules) and some actual historical remains in the building (results).
Step 2: Systematizing this input by means of 4D-referencing and processing knowledge by intuitive imagination (instinct) of combinations (creating cases) of rules and possible results.
Step 3: Mediating the hypothetical reconstruction of the historical building by means of multidimensional representation referring to a 4D-conceptualization of the building phenomenon.
Feedback A: The internal revision of the hypothetical case within the planning system.
Feedback B: The collective process of discussing and implementing planning proposals based on 4D-vizualitations.
The "sign-vehicles" understood as cognitive artifacts representing various aspects concerning the historical building phenomena outside the system can then be conceptualized as for instance "historical signs", "theories", "regulations" as well as "possible solutions".

Deductive reasoning

The process of deduction is the fundamental aspect of diagrammatic reasoning processes characterized by handling various cases by means of known rules. In an urban renewal process the deductive modelling process can be recognized, when for instance potential renewal sites is located by means of the 4D-city management model (fig. 4).

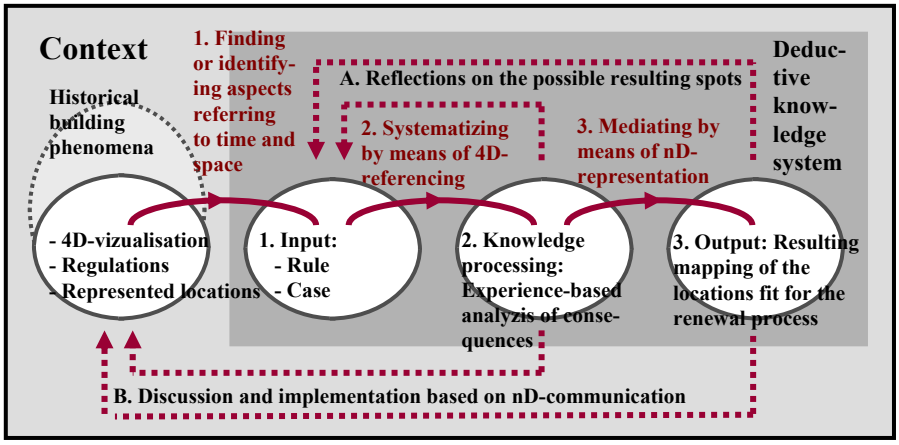

Figure 4: A model representing the deductive process of reasoning.

Specifying the elements of the model illustrates:
Step 1: Selecting input which could be referring to identifying the spatiotemporal setting of the historical urban space represented by the 4D-citymodel including various legal regulations (rules) for the situation of the renewal process (case).
Step 2: Systematizing input due to earlier *experience* and processing knowledge by analyzing and diagramming (mapping) the consequences (creating results).
Step 3: Mediating the locations fit for renewal (results) by various means of multidimensional representation (nD-representation).
Feedback A: The internal revision of the resulting locations within the planning system.
Feedback B: The collective process of discussing and implementing the renewal process based on multi-dimensional communication (nD-communication).

The "sign-vehicles" understood as the accumulated prouction of cognitive artefacts referring to the field of problems or tasks concerning historical building phenomena outside the system can then be conceptualized as for instance "4D-citymodel", "regulations" and "locations".

Inductive reasoning

The process of induction can be understood as the third process of argumentation in the pragmatic concept of reasoning, where knowledge is generalized due to a specific purpose. In the planning context dealing with historical buildings it could be referring to the proces of generating knowledge by means of a mediated methodology (fig. 5).

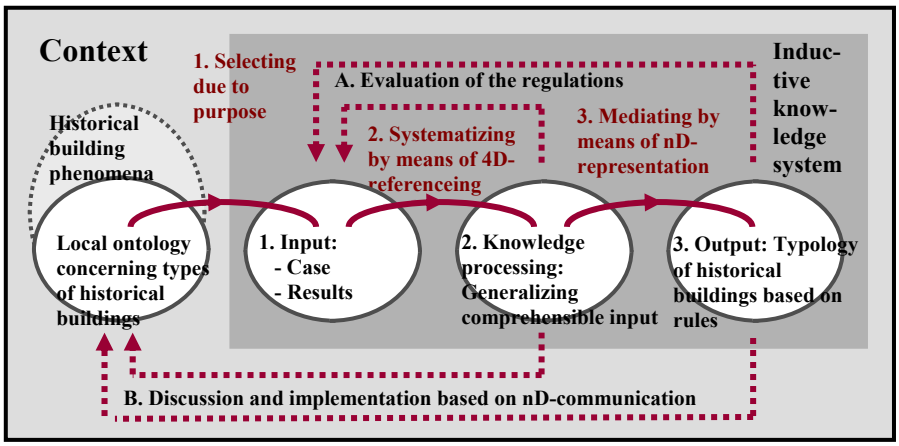

Figure 5: A model representing the inductive process of reasoning.

Specifying the elements of the sign-model shows:
Step 1: Selecting input due to a specific purpose, which could be the process of creating an ontology (case) typologizing the historical buildings due to various characteristics (results).
Step 2: Systematizing input (referring to space and time) due to *habit* and processing knowledge by generalizing (creating rules).
Step 3: Mediating generalizations by means of various kinds of representation (nD-representations) resulting in operational knowledge (rules) concerning how to document, understand and communicate aspects of the historical city.
Feedback A: The internal reflection and revision of the suggested typology.
Feedback B: The collective process of discussing and adapting the typology concerning the historical buildings based on various kinds of descriptions, pictures or models (nD-communication).
The accumulated production of "sign-vehicles" representing the field of typologizing historical building phenomena outside the system can then be conceptualized as a "local ontology concerning types of historical buildings" referring to a global ontology of the city management system.

Communicating pragmatic modelling processes

Dealing with different universes of discourse and multiple ways of representing knowledge Peirce's classifications due to his triadic concept *(Peirce, 1992)* has a large potential as means of distinguishing various kinds of value-based setups. For instance Peirce is characterizing the *normative sciences* as dealing with *esthetics*, *ethics* or *logics* related to kinds of goodness:

1. *Esthetical goodness* dealing with *beauty* – referring to *feeling*
2. *Ethical goodness* dealing with *rights* – referring to *action*
3. *Logical goodness* dealing with *truth* – referring to *representation*

On this background it is possible to compare various kinds of diagrammatic representations and characterize the modelling processes of different knowledge domains due to their distinctive values and spaces for understanding. The roles and tasks of the architect, the surveyor, and the engineer in Denmark are good examples. The architect is communicating by means of beauty referring to the aesthetical values of arts and communication. The surveyor is mapping and managing rights and limitations for acting in society referring to ethical values and common laws. The engineer is following the logical laws of modelling searching for the true representation of the situation.

CONCLUSIONS

In the geodata community as well as in the built environment metadata and meta-information as means of communicating content and usability of datasets and information setups has been a key matter for several years. The approach to this article was the belief that a more abstract level for reflection and understanding of the various modeling processes is needed. Due to this demand a modeling tool based on the semiotics of Pierce has been introduced as a formal ontological framework capable of systematizing and communicating the various cognitive aspects and representational levels. Within this framework a model is conceptualized as a diagrammatic representation of an argument that only can be understood if related to the actual system of communication referring to a specific organizational setting or historical context. Finally, as exemplified within the cultural heritage context it has been illustrated how the fabric and dynamic of models referring to the three kinds of arguments, abduction, deduction, and induction, can be distinguished by the model.

FURTHER RESEARCH

Considering the goal of creating an ontological framework capable of documenting and communicating usability of multi-dimensional representations of building phenomena in an urban cultural heritage context the sign-model as illustrated by the presented examples still appears on a very abstract conceptual level. Therefore, further specification and investigation concerning the various matters of creating, using and maintaining documentation and meta-documentation concerning cultural heritage in an urban data management setting will be conducted. On the theoretical level the semiotic concepts introduced have to be concretized and related to other methodological concepts in the emerging scientific and practical fields dealing with ontologies for multipurpose information system. On the practical level a case study taking place in 2006 will address different representational and communicational issues regarding documentation of postwar industrial heritage environments in the municipality of Aalborg. As the case study will be carried out at Aalborg Historical Museum as part of a national cultural heritage strategy and in collaboration with the municipality of Aalborg it will furthermore represent some of the general aspects of interdisciplinary conceptualization characterizing the ongoing processes heading towards digital management at all levels of society.

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