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Short Term Scientific Mission Report – Towards spatial ontologies

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### *The motivation of the S.T.S.M.*

The aim of the Short Term Scientific Mission (S.T.S.M.) was to open up the conversation and find the common denominators using spatially motivated entities. The rough work plan of an S.T.S.M. outlined following tasks for the grantee.

- Comparing modeling activities and urban sprawl
- Operational work to define a common spatial ground on sprawl and corresponding neologisms of dissolving polynucleated urban landscape via agent base modeling
- Defining and setting common grounds for data requirements and model calibration

Due to the nature of this S.T.S.M. as a first mission of the entire Action C21, it was realized in discussions between the grantee (Joutsiniemi) and members of the host institution DiAP Politecnico di Milano (Rabino & Caglioni), that the most beneficial for the entire action would be to report the practical and theoretical preliminaries of spatially motivated concepts of urban form. The forthcoming S.T.S.M. by Caglioni would in turn focus more clearly on ontology creation.

This S.T.S.M. report thus summarizes several discussions that took place in Milan during the mission between 9.1.-22.1.2006. The report focuses on two major topics that can be seen as spin-offs from *urban morphology* related topics outlined in previous COST C21 meeting at Lyon 13.8.2005. (Presentations of Rabino on Sprawl and Joutsiniemi on Spatial ontologies). First discussion concerns the nature of possible extent of *spatial ontologies*. Second discussion in following report concerns hypothetical extensions caused by remarks on first discussion (to be taken as suggestions only) to Towntology software approach.

### *Bridging between ontologies*

I'll offer in later text the definition of *ontology* in its most general form. Ontologies are seen as an *explicit specification of conceptualization* (Roussey 2005). Further definitions provided by Roussey include properties of machine readable *formalism* and *consensus* achieved within a group, which also seem practical guidelines for the preliminary objective of action C21. In the following text I shall omit more detailed classifications based on purpose, expressiveness and specificity, since at this point of C21 action it seems not to be possible to restrict oneself in any of these predefined categories.

Since by the above definition of ontologies the knowledge is created with concepts, one should also keep in mind some basic restrictions of the approach chosen. By doing this it should be possible to outline the true scope of ontologies and explicitly see the benefits and drawbacks of strategy and not to raise expectations that eventually are not even theoretically reachable. Obvious primary limitations concern the semantic nature of ontologies. The branch of analytical philosophers have concluded in the work of the Vienna school and the great Ludwig Wittgenstein that major limitations are created by the language itself. Although this is sometimes understood as an inevitable break between the physical reality and its conceptualizations a more rewarding discussion

may be found from the contexts of these language games. The specificity of the various contexts naturally opens up a new discussion how separate these different conceptualizations can be from each other. And if one agrees with the separation this simply leads implicitly into a causation concerning a possible conceptual *underdetermination*.

A more classical form of this problem of underdetermination may be found from the so called Quine-Duhem thesis<sup>1</sup>. The original discussion of Quine's was concerning words, their referent and a problem of translation (among other things). At the bottom line the remarks of the writer claimed that *ontological relativity* is inevitable. By this he recalls that our ordinary talk doesn't properly refer to objects, but is instead largely determined by the surrounding semantic relations. This approach causing significant restrictions to ontologies once again is to be understood, not as a destructive, but as a constructive attempt to limit the scope of ontology building to a pragmatic level. In that sense the pre-consensus approach taken by Towntology software seems fruitful, because it (at least in theory) enables one to reach beyond fixed structures and exploration of evolving concepts.

The more severe draw back of underdetermination can be found in relation to the formalism requirement of ontology definition. Obviously semantic structures are only one type of formalisms and thus this approach of ontology definition opens up an alternative discussion. To ensure the representativeness of any formal model should naturally catch the essential characteristics of its referent without significant underdetermination. In other words using Albert Einstein's quote the minimum requirement is to "make everything as simple as possible, but not simpler." Thus despite the apparent benefits of Towntology software an attempt to build a tool more robust to handle spatial implications is still worth further discussions. The major implication for C21 action to decide is the still unanswered question how to handle (and combine) the ontological knowledge created with other means beyond semantics.

It is important to realize that in ontology building, we are not in fact talking about ontologies of space, but instead of *ontologies of spatial descriptions*. And naturally there is some variation between these descriptions: some conceptualizations simply are more powerful than the other ones. For example we can clarify this idea with a *concept of accessibility*. One can understand it as "easiness of movement" or sometimes more accurately as "sum of affordances" and so on. Spatially speaking a great advance is achieved, when understood in more general as a "potential of location defined by its surroundings". Suddenly this spatially motivated concept shoots out of semantic realm and creates a possibility to search new combinatory spatial properties. Obviously these emergent spatial properties are also only operable with formalism that provides the information of these surroundings. Not surprisingly it is other than words.

### *A plea for spatial ontologies*

The most simple example to demonstrate the ontological rupture between verbal and spatial realms is given by A.A. Leontjev. (Leontjev 1965/1979) One can, following Leontjev's example, think about the world of a bookworm. In a bookworm's world the books exist only to be eaten through. The ontological contradiction arises when trying to think how much damage is done to books when the worm travels through the encyclopedia from the front cover of volume 1 to the back cover of the volume 2. At first glance one probably thinks having two ruined books, but of course this is not the case. "Properly" ordered encyclopedia actually have nearly no damage at all, since the front cover

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<sup>1</sup> QDT is often stated in context of scientific theory and it is the claim that a theory cannot be tested in isolation; a test of one theory always depends on other theories and hypotheses. (see: Quine 1960)

of volume 1 is actually leaning to the back cover of volume 2. More over this example actually doesn't really have anything to do with the bookworm either, but with the profound mismatch between verbal (*front & back; vols.1&2*) and spatial organizations (*encyclopedia as is*). The logic of a book naming convention is incapable of covering the logic of this tiny "book system". Thus it can be recognized that the concepts used are clearly *spatially underdetermined*. Not surprisingly this is very true with several other concepts in today's turbulent state of urbanism.<sup>2</sup>

Also the previous work of the grantee and the host institution suggested that there are great regularities in this newly forming urban landscape. Typically the newly formed urban landscapes are classified as an uncontrolled crescendo of present day urbanism – the sprawl. During the S.T.S.M. several field excursions were made to get hold on the expanding Milan region. Despite the obvious similarities that include remarkable decrease of density in built-up areas as well as seemingly unregulated building typologies also some aspect seem to indicate national characteristics of this recent low density urban field. At this point of the action it seemed too early to focus on these characteristics in more detail, and instead it was chosen to give attention to more clearly how the spatial characteristics of this morphological change could be captured to ontologies in the most convenient way.

The common denominators of this reformation of urban outskirts can be rather easily simulated with urban growth models and new information extracted from calibration parameters of these models. Preliminary cross comparisons were made by Joutsiniemi and Caglioni with the SLEUTH model which indicates that there truly exists some locally determined growth patterns. More detailed information will be released during the action as soon as the essential adjustments for datasets are being prepared and necessary information derived from analyses.

Even the quickest examination to the literature will make one certain that a major source of power of this urban change is private vehicle movement. It is also nearly as apparent that this private transportation is causing increasing problems in local scale as well as in global scale in terms of pollution etc. It would be all too naive to claim that this privatized mode of transport would somehow disappear from peoples everyday life, especially because it has already caused major changes in urban structures and lifestyles, that simply can not survive without it. It would be tempting to claim that instead of entire abandonment still more adjustments are expectable until acceptable level of sustainability in all scales is reached. Surprisingly these inevitable futures are not only technocratic daydreams, but in fact already effectively under implementation (Schmidt-Bleek 1994/2000) Truly: "The objects in the mirror are closer than they appear."

It is most interesting to realize that this large scale balancing of ecology and economy is facing us in near future. This forthcoming economy that has stripped of major externalities obviously has its physical appearance that is nearly impossible to capture with semantic ontologies which do not have the system related features built-in quite yet. But like from the previous examples one can see different branches of UCE effectively working with these issues with alternate formalisms. Again these formalisms are different modeling approaches that can effectively operate with relations based on physical reality more accurately than semantics. As one can sense from above examples one major benefit of using alternative descriptions of to avoid caveats caused by unnecessary normative loads easily drifted with semantic ontologies. Again it is important to stress that these formalisms are not entirely separate from each other, but largely interlinked.

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<sup>2</sup> See for example Sieverts 1997/2003, Oswald & Baccini 2003, Graham & Marvin 2001 for more detail. Also entire C10 action was focused on these unbundling concepts of urban form.

Previous examples are only chosen to demonstrate the specific requirements for formalizations that characterise the field of urban civil engineering (UCE). Since mere verbal definitions are clearly insufficient to cover all necessary physical systems in general, some common ground ought to be found from different UCE descriptions. To cover the need of spatially driven conceptualizations it seems to be necessary to extend formalizations into common mereo-topological foundations.<sup>3</sup> Literally mereology means “theory of parts” and describes the whole-part relations in general. But there is also a theory, called topology, which operates with the *is-connected-to* relation in general (Borst 1997). Borst continues by claiming that simultaneous benefits from connectivity and whole-part approaches can be achieved in two ways. One is to add mereology with topological is-connected-to component. Another is to absorb Clarke’s more precisely defined mereo-topology (ibid, p.35). No matter which one approach is adopted, it is easy to see that this is the common foundation between spatial and semantic ontologies that is necessary to reach if one is willing to cover the scope of UCE. This seems to be the common ground at which such diverse communicative needs as defined in MoU of C21 are possible to unite.

### *First principles of spatial ontology*

From previous discussion one can see that the problem of parts and wholes gets different when brought into the level of spatial units. The recent difficulty in urban planning is that exactly same units as before are forming completely different wholes, which also makes the semantic conceptualization somewhat vague. The interaction between these units is clearly determined outside the immediate neighborhood. Thus the conceptualization in spatial ontologies must not only focus on mereology, but also largely on topological is-connected-to relations that are normally handled with models of different type.

Unfortunately it is not possible to cover more than one or two brief example cases. The main impetus of the chosen cases is to give a reader a brief idea of how these are possibly convoluted in level ontology. The major unexplored field seems to be neighbor relations of spatial units. Although one clearly needs some mathematical descriptions of the most primitive forms and shapes to start with. (see Lord & Wilson 1984/1986) Yet this most simple task seems already a little frustrating, since the categories of primitives, as far as I have found, are already carrying important relational information along them. In fact several objects themselves are not primitives in the traditional sense, but actually contain implicit neighborhood definitions (B-splines of different order, NURBS etc.) and thus fall into a category of modeling, which in terms of ontology are largely unexplored.

Another example of complex relation between formal descriptions of spatial units can be found from cadastre. Although it is easy to define a formal spatial relation between cadastral units, properties within also fall in a strictly defined proper-part-of relation (i.e. <<) with them. This relationship that is one of the key relationships in morphological processes on the other hand is far more difficult to formalize in more detailed level. And somehow it would seem rather odd not to compare the typomorphological knowledge collected from several cultural surroundings (Caniggia, Conzen, Vernez Moudon, Panerai & Castex to mention a few) with more mathematically based formalisms.

These examples were chosen to shed a little light on spatial interaction, which in its simplest relations between primitive units which extends into a configurational properties and ever larger collective interplay across different scales. At the bottom line all these issues seem to tangle with the processes of *agglomeration* and *deagglomeration*, and various enumerable *aggregate* and

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<sup>3</sup> A brief summary to mereo-topological foundations of ontologies I have followed in this report can be found at Borst (1997, pp. 25-54).

*disaggregate* units. Thus different GIS and CAD data models seem essential starting points for spatially motivated ontological categorization. Also modeling plays a significant role in this game as an activity oriented towards more advanced spatial relations. At this point it is most important to realize that the process of entitation (albeit often dependent on ad hoc classification of a specific modeling task) doesn't significantly differ from other conceptual mapping of semantic ontology. Recent techniques such as agent base modeling as well as previously mentioned cellular automata (SLEUTH example) have clearly made the similarity of these activities explicit. (Rabino 2005)

### *Towntology software as a topological construction*

Domain specificity of concepts that was chosen as one starting point for the actual ontology building provides a fine starting point for the C21 action. Although it should be noticed that this approach also carries along limitations that are founded deeply on QDT (see discussion above). This is normally handled with generic category of common concepts. In some sense a more open ended solution would be to take these necessary selective domain specific ontologies and attempt to expose the necessary connectivities to neighboring domains. The crucial step towards this is to make the selective nature of ontologies explicit and thus actively strengthen the disillusion of completeness in any realized ontological structure.

Due to the general mereo-topological foundation of any ontology also the Towntology software could easily support this ontological relativity approach and provide the user with explicit knowledge of this. The chosen concept (node, vertex) and relation (link, edge) based primary structure actually already joins two isomorphic structures to each other. Graph theory (including hypergraphs) actually is just an alternate form of gathering the extracted ontological knowledge. This offers a great possibility to allow the user to choose within the user interface (UI) the most important relations in bases of domain and relation type on the run and thus explore between different personal preferences. Presumably this would make it easier, as ontology user, to position oneself in relation to the entire ontological structure and also more easily orient on specific domains other than one's own field of specialization. Also additional graph based information such as measures of centrality and connectivity (e.g. depth, betweenness, ringness etc.) could be nearly effortlessly provided with color coding to the user and this way ease navigation in large ontologies.

The major modifications caused by implementation of a more detailed mereo-topological approach on the other hand are the properties associated with relations per se. Currently the relations in Towntology software may be parameterized according to symmetric, transitive, optional features of chosen relation. Of these asymmetry and transitivity being pure mereological properties (Borst 1997, p. 29) but more detailed classifications on relations are not currently possible. The following brief examples already outlined in presentation by Joutsiniemi (Relations in ontologies) in Florence meeting 8.11.2005 hopefully clarifies why the semantic ontologies slightly neglects the deeper classification of them. In addition it is important to stress that in spatial formalizations usually the situation is somewhat similar even though the complexity on relational aspect is during past decade getting more and more scientific interest.

The most natural extension of relational properties is naturally the domain specificity that is already taken in account in concept definitions. Naturally the domain specificity concerns the relations as well as concepts. Also some more advanced relational structures may be defined. Leech (1974/1981, p.109) have collected some taxonomies of the semantic relations, which seem to clarify little bit the Towntology approach as well. The great benefits of having user defined relations with maximum degrees of freedom also have some obvious draw backs: Generally there seems no possibility to evaluate how well the creators of the ontology have succeeded in selecting them or whether there

are some important relationships left unexplored. Using categories of Leech we can on the other hand find some significant regularities in them.

- binary taxonomy (+LIVE, -LIVE)
- multiple taxonomy (‡METAL, ◊METAL, ∞METAL, □METAL ...)
- polarity (↑SIZE, ↓SIZE)
- relation (→ANCESTOR, ←ANCESTOR)
- hierarchy (1 LENGTH, 2 LENGTH, 3 LENGTH ...)
- inverse opposition (▲CERTAINTY, ▼CERTAINTY)

If we compare these classes of Leech shown above with well known classes of data quantification below, some structural merging is obvious.

- nominal (=, ≠)
- ordinal (<, >)
- interval (+, -)
- relational (\*, /, ^ ...)

It is interesting to realize that all previous semantic taxonomies fall into two upper categories and thus forms two subclasses on bases of the *degree of quantification* as follows.

- difference (NOMINAL; binary & multiple taxonomies)
- hierarchy; scale (ORDINAL; polarity, relation, hierarchy)

Generally the more advanced quantifications of concepts are not easily achievable, but instead several other formalizations of space can naturally benefit of them. The rough systematization on the other hand gives some guidelines for creator of ontology some kind of checklist to evaluate the completeness of his/her work. Also the rough framework gives the possibility for the user of the ontology to check whether the accuracy of ontological description reached the precise level of practice or whether there is a need for ontology of other detail level. (For example are is-located-in, or is-located-on relations precise enough for the usage or is there a need for an alternate ontology of physical systems.)

All the propositions in this report are naturally for the action C21 itself to discuss and decide the necessary accomplishments for future work. At this point the remarks documented in this report are only a first attempt to cope with multiplicity of ontological discussion within action workgroups and most likely further redefinitions are necessary. The author hopes the group finds the issues documented in this report inspiring and encouraging for future work. If the reclassification of relations is to be considered for implementation supposing at least the following preliminary attempt for merged classifications of relations should be taken under discussion.

- degree of quantity
- domain (e.g. LEGAL, ADMINISTRATION, SPATIAL)
- agency; tool
- causality; correlation
- certainty

## Bibliography:

- Borst, W.N. (1997). *Construction of Engineering Ontologies for Knowledge Sharing and Reuse*. CTIT Ph. D-thesis series No. 97-14. [<http://doc.utwente.nl/fid/1392>]
- Graham, S.; Marvin, S. (2001). *Splintering Urbanism – Networked Infrastructures, Technological Mobilities and the Urban Condition*. Routledge. London & New York.
- Leech, G. (1974/1981). *Semantics – The Study of Meaning*. Second Edition. Penguin books.
- Leontjev, A.A. (1965/1979). *Kieli ja ajattelu*. Kansankulttuuri. (Finnish translation of: *Jazyk I rozum tšeloveka*. Moskva. 1965).
- Lord, E. A.; Wilson, C. B. (1984/1986). *The Mathematical Description of Shape and Form*. Ellis Horwood Ltd. Chichester, West Sussex, England.
- Oswald, F.; Baccini, P. in association with Michaeli, M. (2003). *Netzstadt – Designing the Urban*, Birkhäuser, Basel, Boston, Berlin.
- Quine, W.V.O. (1960). *Word and Object*. MIT Press, Cambridge, Mass.
- Quine, W.V.O. (1969). “Ontological Relativity”. In: *Ontological Relativity and Other Essays*, Columbia University Press, pp. 26-68, New York.
- Rabino, G.A.; Girotti, A. (2005): *Ontology of Multi-Agents Processes of Spatial Decision*. Paper Presented at 14<sup>th</sup> European Colloquium on Theoretical and Quantitative Geography. September 9-13 2005. Tomar, Portugal.
- Roussey, C. (2005). *Guidelines to build ontology: A bibliographic study*. Unpublished COST C21 memorandum.
- Schmidt-Bleek, F. (1994/2000). *Luonnon uusi laskuoppi*. (Finnish translation of: *Wieviel Umwelt braucht der Mensch? MIPS – das mass für ökologisches Wirtschaften*. Birkhäuser Publishers, Basel 1994)
- Sieverts, T. (1997/2003). *Cities Without Cities*. Spon Press. London & New York. (English translation of: *Zwischenstadt*. Birkhäuser. 1997)