A way to improve management of underground utilities

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1. Introduction

Underground utilities are buried underground cables and pipes used for purpose of supplying ground structure with the: electricity, gas, water or sewage. Nowadays the sensitivity for better care over the underground structures is addressed. Large amount of spatial data about pipes and cables are collected and stored over different places like Cadastres or Utility companies, different databases etc… In practical daily work is recognised the need for use and structure of those data for the purpose of solving practical problems in construction phase.

Lifecycle of the utility looks roughly like this: surveying-planning-surveying-construction-register-use-maintenance. Usually at the end of the construction when all the tasks are finished and some things are not working properly the responsibility over the certain phase of construction are discussed. Decisions through the construction are taken on different professions, and each one is responsible for its work, but there is gap when for example a civil engineer has to decide over the surveyor's job, or the surveyor has to decide over the project drafter work. In many practical cases this situations are normal and the question is how one profession should judge the work of another profession, whose responsibility is at the end such decision.

Management task that are faced in practical work with construction of cables are firstly the problematic that each involved profession has responsibility over the certain phase. Project drafters are the one who are using 2D or 3D representation of specific field and drafting their project in CAD or some other tools. Surveyors are then transferring 2D models on real ground determining the position of exact shaft and pipes, and then the civil engineers are using both information's drafted in project and determined on the ground together with all specific construction details that they are implementing in it.

Mistakes that are done are the warning that decision as they were undertaken are not sufficient, the most important thing is to determine the processes of decision and responsibility over the certain task and relationship between different tasks.

- Surveyor's perception of the space is based on coordinates and determined by the registers as they exist today in 2D shape. So the most important data are the border of the parcel and position of the new cables.

- Project drafters are focused on the existing cables in underground and for them the data that are taken from surveyors are taken as such, but the spatial perception for them are mainly focused on construction and details connected with it. So the coordinates are taken, but to measure the amount of construction work is devoted only to the exact project, so for them the name of the project, geodetic basis and other infrastructure available at specific field are the most important data that are used as background for drafting the project.

- Civil engineers are mainly orientated on organisation of work on site and integration of all possible cooperating professionals, workers, surveyors, investor… Information's that are used are project draft together with positions of the cable on the ground which is determinate by the surveyor

To be able to organise such comprehensive work, one should understand all the professions integrated and all the rules that they have to follow, together with time management and human resources management. Giving a proper answer on the challenges that are happening on the field, engineers usually have to have years and years of practical experience and knowledge to know how to solve problems, otherwise, each profession is putting blame on another profession, and there is no real solution. Gap is between the drafted and executed project.

Our research aims to provide a model of the construction processes overcoming the difficulties on the field and allowing predictions of forthcoming obstacles for better decision making, which integrates the different professions involved and their responsibilities. Preliminary research direction is in modelling of the existing knowledge and data together with visualisation of such data in dynamic and real situation in virtual reality. Three dimensional models could be a tool for integration of large amount of knowledge needed for better decision management and understanding among same task over different professions. Part of the knowledge is indeed related to spatial configuration of objects during construction; there are spatio-temporal aspects (4D) which must be considered.

Therefore the need for finding Core data for all the actors in this field and simplicity of model with basic topological relations could be an answer on integration of huge amount of knowledge, better understanding and interoperability among actors.

Models are used for a purpose of better decision making and as collectors of knowledge that is not easily accessible among different professions and different perceptions over the same task. Although we wish to adopt an ontology-based modelling strategy, we will not discuss deeply this aspect here.

This article is structured as follow. After a brief state-of-the art, we present the main objective of our starting PhD research, i.e. the development of a knowledge based model as a support for underground utilities construction management. Then, we propose a way to structure core information about cables followed by a discussion about the relevance of considering qualitative 3D relationships instead of (or complementary to) quantitative information (namely, coordinates geometry). Finally, we present future research directions and we conclude.

2. Current developments in the field

Up to now networks of underground pipelines are only registered in cadastres, utility companies, and different datasets without unique specifications. System for registration demands high coordination effort to store those data. There is a need for better integration of data and gathering of them at one place, with the model which purpose is not to register the cables but rather to create interactive ground where for shore the use of those data will increase their accuracy and take control over the structures.

Use of Knowledge-based systems as a way to improve construction management has been identified (Lee00). The author argues that a solution for a common understanding of practical situations on site lies in generalisation which is interpretation of the term on a level to cover all the possible uses of that term (Lee00).

We must refer to existing standards for data model developed to facilitate interoperability in the building industry are:

The Industry Foundation Classes (IFC) developed by the IAI (International Alliance for Interoperability) data model is open specification and an object oriented file format with a data model. The main purpose is exchanging date between CAD tools.

Building Information Modelling (BIM) is the process of generating and managing building data during its life cycle (Lee01). Main purpose is rich representation on building components, where IFC is a common language for transferring information between different BIM applications.

Coming from the geo-information world, we have to mention CityGML which can be seen as complementary to above mentioned models. CityGML is realized as an open data model and XML-based format for the storage and exchange of virtual 3D city models. CityGML has standardised these levels of details. It is a common information model for representing 3D urban projects enabling the storage and exchange of virtual 3D city models. Some papers are discussing the visualisation of underground infrastructures with the purpose to locate the damage and purpose to monitor the already constructed pipes. Using GML, CityGML, X-VRML.

All those models and tools are obviously important and useful; however they are not sufficient from our point of view.

We believe that what is needed is a model which is mainly practical, able to store all possible knowledge and processes in construction and to visualise them to be able to create all possible situation and get a good answer in difficult situation where the model will show the possible obstacles of certain decision. Its use is not for registers; its use is for store of all new created knowledge to be used in other constructions. That kind of knowledge we call experience and today is only available if you know the person that has been facing the same situation.

CityGML as a common information model for the representation of 3D urban objects can be a good candidate for visualization of our model, although IFC and BMI standards are recommended as such to be used for modeling of any construction.

At this stage of our research, we consider Croatian law propositions that are mainly ISO standards. Limitations and risks that should be included before the modelling start are the low precision of data that are at 20cm per meter, as proposed by Law. Many software applications that are keen to determine the outlook of the model are based on the role of certain discipline in the lifecycle. Traditionally responsibilities and work of each discipline is completely isolated. Where the 3D models are not realistic for example the accuracy of Google earth is not questioned but it is really powerful tool for visualisation of semantic data (seriousness with low precision). There is also limitation to integrate all the named fields that are implemented in this model, and to use visualisation to represent all the data.

In summary our what is needed is a model that not serving only register purpose but serving true information for better decision purpose through knowledge based system and visualisation together.

3. Our modelling strategy – main research objective

From section 1 and 2, we believe that there is a need for development of ontology based model for better decision management during the construction of underground cables and management of spatial information as well as entitling of practical problems described through modelling strategy and choice of core importations that are going to be modelled.

Objectives are to:

- Integrate the lonely islands of information and to create a river of information or reality that could connect all data of everyone involved with utilities…
- Avoidance of duplication of data and widening of the spatial perception
- Improvement of the performance of the utilities during their full life cycle
- Planning and better decision making during construction phase and afterwards for emergency planning, urban planning and response

Following issues must be covered; (1) communications between users during all utilities life-cycle, (2) spatial accuracy, (3) semantic accuracy, (4) legal responsibility (data providers). We believe that a solution is to develop a model which could be used at different levels of complexity. We wish to propose an object model where information would be accessed through different views depending on applications. By doing so, simple queries could be performed even with incomplete information. Furthermore, allowing just simple queries on a limited number of attributes could be a way for data providers to share their data with less legal constraints.

By a successful decision in construction processes of pipes through model the whole knowledge could be stored and better organised. Difference in perception of space and unique language of understanding among the different professions could be solved over the 3D model which should contain available knowledge, and should be able to create action-reaction cases.

So the most important issues are:

- Understanding that there is a need to make a model for this process
- No need to have a lot of experience and knowledge to give a comprehensive decision
- Easier to predict and to learn the results of your actions
- Pipeline monitoring is coming on stage after the construction; it is a huge organisation task and money consuming as well.

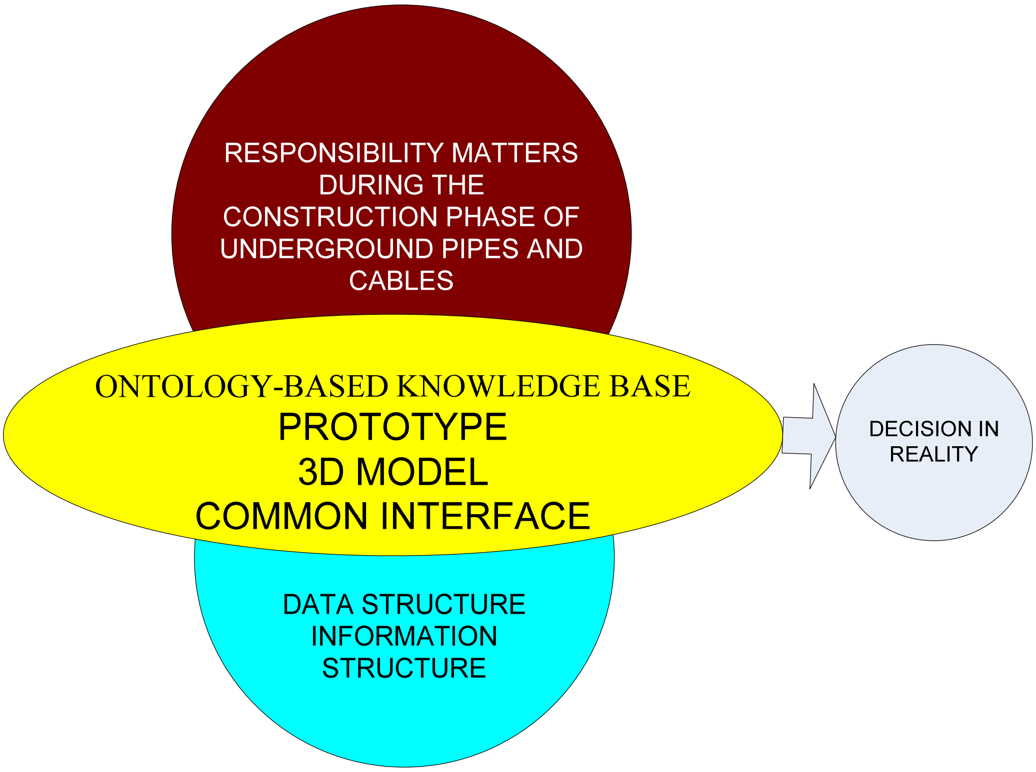

Figure .1 Structure of work, integration of law and data structure through 3d model and common interface

Figure 1 is showing the main idea of this work, on idea level, where the integration of responsibility matters (as proposed by law) and information structure over the creation of database are integrated through ontology based data structure and modelled in 3D model and finally visualised through the common interface as a tool for interaction.

Model that contains all the data during the construction period will provide a powerfull management tool since it will be able to store all the data implemented in construction. Where the simplified visualisation itself will create users who will be able to interact the proccess.

Due the reason of reluctancy of providing the data from some of the owners, the Law is the one that should be imposed over the publicity of the data. Another way is to imply certain level of generalization of collected data to create an freedom for exchange of the data. Generalisation and free providance of data are the issues that should be further discussed.

Consideration of advances that should be given through this model is huge. Model as should be powerful managerial tool to overcome the difficulties of collected information and to be able to respond to the task with the quality decisions based on information's that is available now but should be integrated in some decisions. As well as exchange of data through common language, it will definitely create easier understanding, prevent misinterpretation and help to prove the truth of certain solution

4. Core information to be modelled

The justification of core data of piplines could be found in the propositions of 3D cadastre «A registration for cables and pipelines will in the first place serve the need to indicate the person who is resposible in case of damage instead of the need to avoid disaster, as mostly is pretended» (Stoter04).

Semantics ar formally basis for various geo-operations on internet and are the need for this model, in this case it means location, the name of the area and the formal administration borders. Relationship between different pipes should be modeled on a simpliest level as well.

Data that are used of registries of cables are:

- Name of the pipe (water, sewage, electricity, telephone, gas, cable TV)
- Name of the owner of the pipeline (Utility Company, County or Region)
- Location name (determined by the nearest city or town, borders of the municipality and specific natural appearance-Semantic), usually are the part of the name of the project
- Relative spatial positioning (horizontal and vertical positions)
- Geometry of each pipe

  3D coordinates, X and Y as proposed by the coordinate system and Z relative depending on the surface (example -1.2meter…etc)

Hierarchical structure of data is represented on Figure 2.

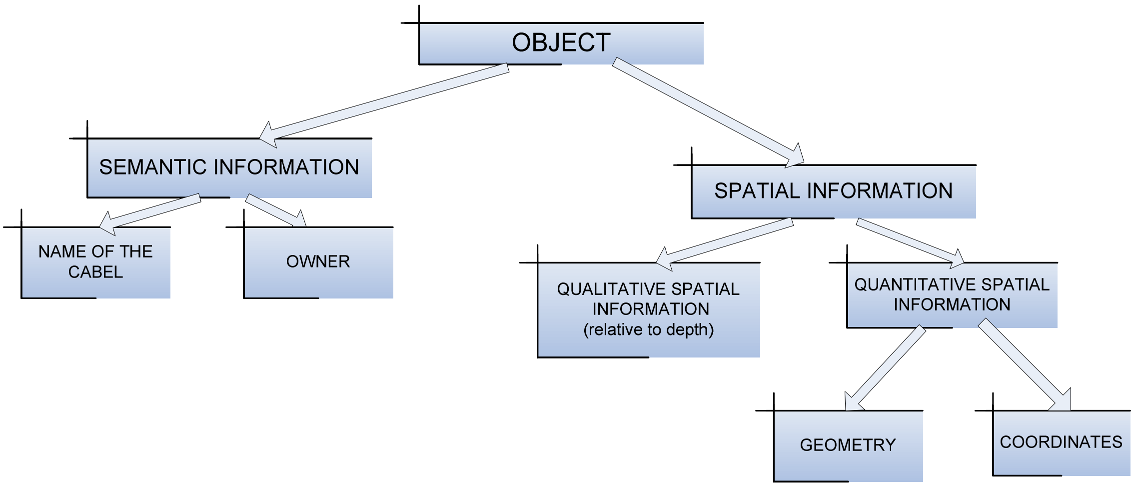

Figure.2: Hierarchical structure of data

Geometrical accuracy issues

As known up to now the accuracy regarding measurement of underground pipes was ±20cm, which is quite low accuracy if we think on today measurement instruments and methods. The reason for that is the register which is 2D and real need of coordinate is to determine the position in case of some risk and damage.

Discussion about geometry accuracy is connected with the type of register that pipes are stored for, and of course the purpose of the data.

Compatibility of data

In Croatia existence of new Cadastre of utilities is just in phase of establishment and the software itself is proposing the specific format that data will be stored. Following the ISO specification, up to now AutoCAD 2004 was the format of data, and layers and thickness of the line of certain cable and all other possible drawing details, like colour, font size and scale… is precisely written. We consider it as a specification.

Responsibility over the data

Legislative issues over the data could be explained through the structure of certain Spatial Law in different countries. For example Sweden has a specific Land Code that is holding all the data regarding Land under the one Code. Croatia in contrary due the reason of different definition of ownership and registers doesn't have Land code and the Laws about responsibility over such data are found in many different Articles of the different Laws. Like the new The Law on State Survey and Real Property Cadastre, The Building act, The Consolidation act… etc.

Responsibility in case of cables is divided through the construction phases which are the construction, material and maintenance responsibility. As it is considered in Croatia after the registration of the pipe, which is done before the pipe is officially open for use, the whole responsibility goes to the owner of the pipe. Owner has to take care over the maintenance and monitoring of the pipe or cable. Responsibility could be understood as the rules of the game and relationship between data.

Relative spatial positioning presented in vertical and horizontal way is shown on figures 3 and 4.

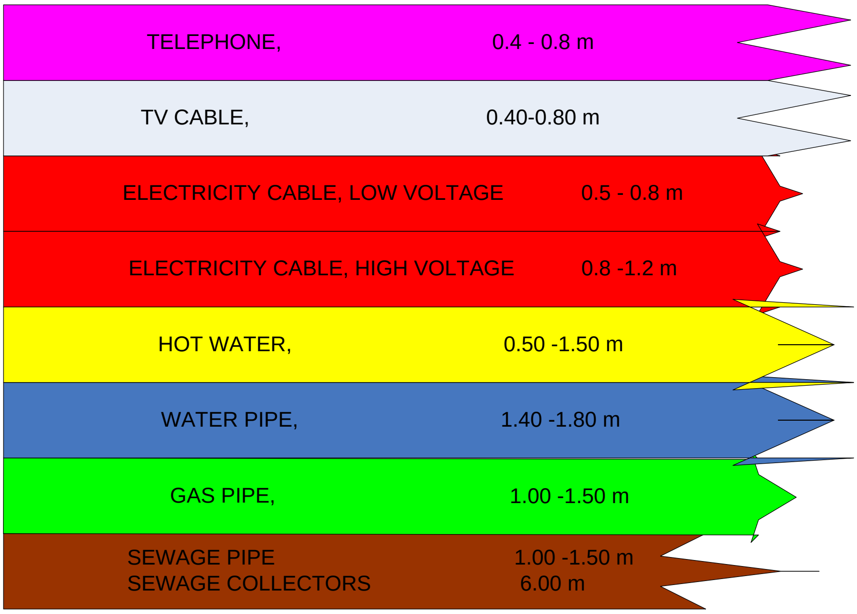

Figure.3: Vertical representation of underground cables (true colours as proposed by specifications of "**The Cadastre of cables and pipes" in Croatia** are used)

Relative spatial positioning

We can ask ourselves what could be the use of relative positioning information. We believe that a huge part of shared spatial information between users is indeed "qualitative information". Indeed, it is sometimes sufficient to know is a pipe is "above" another one. Therefore, we could classify needs of vertical information as follow:

- Pipe above or below (qualitative information)
- Intervals can be found by referring to law (see figure 2)
- Precise depth of the pipe can be found if needed by looking to its coordinates (quantitative information)

This is why we propose to store qualitative spatial information before quantitative ones

Considering qualitative information can be also a way to facilitate data sharing. Indeed, utilities companies could provide more easily such kind of information instead of precise geometric information which is more risky in terms of legal responsibility.

There are some specific construction rules that should be followed, pipes are not allowed to be put next to each other, and minimum distance is known.

Also the isolation details and geological details and many other data that are influencing construction itself are to be considered during the construction. In the model the rules will be implemented without use of geological data and buildings.

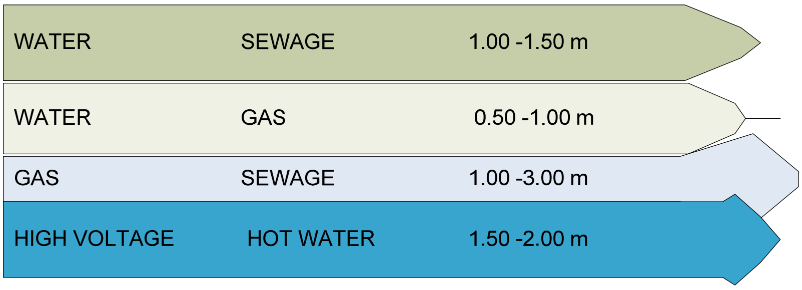

Figure 4: Horizontal representation of underground cables

The project itself is depending on the ground structures and underground natural obstacles, where the all together projects at the end looks like picture nb.3

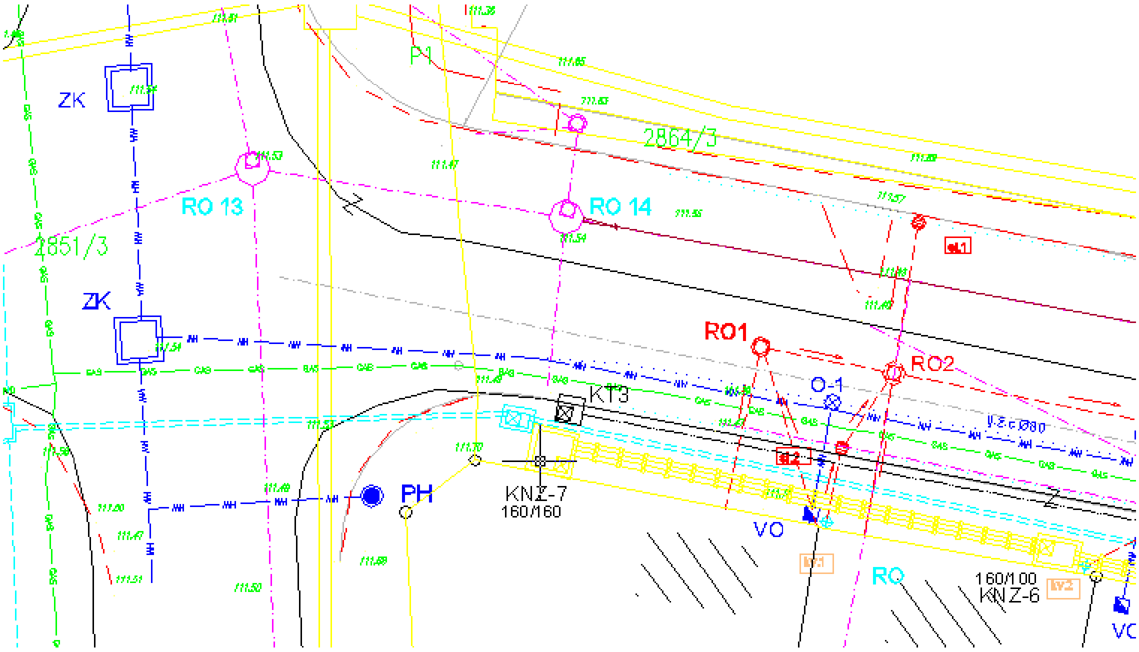

Figure .4 Horizontal and Vertical representation of underground cables in AutoCAD

Finally, we may ask ourselves how to get the data.

Pipes could be measured after they are constructed and not visible any more and that is possible only with few instruments. The principle is to integrate the iron wire on the top of the plastic pipe and then to let the electricity flow through such wire and to identify if on the ground with the instrument. But for this methods the pipe should be empty, and constructed of such material. In most of the cases nowdays the situation is that pipes are plastic and it means that there is no chance to discover it. In such case the ground has to be digged to be able to find the pipe, thats why is mandatory to performe measurement during the construction of the pipe, which is the case in Croatia and is proposed by the Law.

4. Conclusion

In this paper, we have presented some of our preliminary research objectives which are defining more precisely needs of the different professions involved in underground structures construction and identifying consequently relevant information to be modelled.

It seems clear that improving communication between professionals (engineers, land surveyors, designers, etc.) is a key issue. Therefore, we have explained that a solution could be to develop an ontology-based model allowing sharing of information between "users". Such model would not be only based on underground structures precise geometry, but would include other types of information, e.g. semantics or relative spatial positioning.

This paper is first step toward our long term objective which is to propose a model of the construction processes overcoming the difficulties on the field and allowing predictions of forthcoming obstacles for better decision making, which integrates the different professions involved and their responsibilities

REFERENCES

(Stoter04) J. E. Stoter (2004). 3D Cadastre, Publication on Geodesy 57, September 2004 Delft, the Netherlands, propositions accompanying the thesis point 4.

(Lee00) John Lee, D. McMeel, "”Pre-ontology" Consideration for communication in Construction", Ontologies for Urban Development, 2007, Studies in Computational Intelligence, volume 61, pp 170-179

(Lee01) Lee G., Sacks R., Eastman C. M. (2006) "Specifying parametric building object behavior (BOB) for a building information modeling system". Automation in Construction Volume 15, Issue6, Knowledge Enabled Information System Applications in Construction, November 2006, Pages 758-776

(Schall00) G.Schall, E. Mendez, E. Kruijff, E. Veas, S. Junghanns, B. Reitinger D Schmalstie, Graz University of Technology (2008), Handheld Augmented Reality for underground infrastructure visualization,

(Mendez08) E. Mendez, G. Schall, S. Havemann, S. Junghanns, D. Fellner, D. Schmalstieg: Generating Semantic 3D Models of underground Infrastructure, Computer Graphics and Applications, IEEE, May-June 2008, Volume: 28, Issue: 3, pp.48-57