On Structuring and Sharing Learning Material: A taxonomy for Geoinformatics and Surveying Engineering

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Abstract: Geoinformatics is an interdisciplinary science that relies a lot on the use of technology in order to achieve both research and educational goals. On the other hand, the last few years a lot of attention has been devoted in supporting e-learning efforts in all educational institutions. Most of these efforts exploit web technologies and recently follow the initiative of the Semantic Web. In order to be able to use Semantic Web applications to support e-learning you need your resources described in a uniform way in one of the semantic web languages and following a uniform vocabulary of concepts. These concepts, apart from categorization, provide a semantic network that is connected with is-a, part-of and other relationships. In this work we provide such a taxonomy that gives the necessary concepts in order to be able to describe Geoinformatics related resources and provide also the is-a relationships among them. These concepts can be extended and readily used by the semantic web applications in order to share resources among different institutions.

Key words: knowledge management, taxonomy, Geoinformatics, Surveying, semantic

1 Introduction

Over the last few years, learning process within institutions of (especially the tertiary) education has been both formally described as a sequence of operations and supported by means of semantic descriptions that make the described material more easily to be exchanged and manipulated. These efforts were broadly described by the term *e-learning* (or distant learning) and share common characteristics such as the use of advanced web based technologies, the organization of the learning material under specific thesaurus, taxonomies or ontologies (including not only traditional learning material like lectures and exercises but also discussions, comments and the built of user communities around them) and the concise effort for interoperability among the different actors (institutions, individuals and software).

The cornerstone of e-learning systems is the notion of learning objects (LOs) that capture any chunk of learning material regardless of its form, granularity and functionality. By definition LOs encapsulate both learning content and appropriate descriptive information (i.e., metadata). LOs aim to provide self-describing learning material that once developed can subsequently be exchanged, retrieved and reused. The key factor for supporting large scale interoperability, portability and reusability of LOs is the quality of the semantic description of LOs, i.e., its metadata specification (McGreal and Roberts, 2001). Several e-learning specifications have been proposed in literature like ARIADNE[1], IMS (IMS, 2008) and LOM (IEEE, 2002) which are recently encoded using Semantic Web languages like RDF/S (Klyne et al., 2002 and W3C, 2004). But LOs and e-learning systems use and are described in generic learning terms using concepts like class, lecture, exercise, etc. These concepts are generic enough to be used in any discipline but do not capture the meaning of the categorized resources; they only refer to their educational (or learning) use. So the work presented in this paper is actually complementary to such works referenced above in the sense that it is discipline specific and allows users to categorize their learning resources according to their meaning and not their learning role. E-learning systems can readily exploit such categorization along with the LOs. This makes possible to assign each resource in two distinct categories (at least): one that explains its value for learning and one that explains its position in the discipline. Although one can find a lot of work in the first area (the references provided above is just a small fracture of the overall available taxonomies/ontologies for learning material), there is limited work available in the Geoinformatics discipline that accounts for such taxonomies/ontologies that would describe the discipline as a whole.

Some disciplines have already provided a more organized view on the available material by using specific taxonomies or ontologies (like the ACM Taxonomy for Computer Science[2]). In Geoinformatics such taxonomies are not available yet for many different reasons. One reason is that Geoinformatics is emerging as an interdisciplinary science only the last few years. Thus a broadly acceptable definition for it is still pending. Moreover since the field is still emerging it becomes more difficult for people to agree on the concepts that actually describe and limit it. In order to overcome this, always delicate, discussion in this work we were based on the curriculum of the Department of Geoinformatics and Surveying, since the need of the taxonomy initially emerged while trying to provide a meaningful classification of the available learning materials for the department's classes.

The introduction of the Semantic Web (Berners-Lee et al., 2001) has changed the way people think about publishing their data on the web. Not being fully exploited as of yet, but gaining broader adoption by the day the Semantic Web promises an era when the data will carry their semantic descriptions along and thus moving us to a more *intelligent web* where machines will be able to understand the meaning of the data without human interpretation and intervention. In order to be able to achieve this goal, the semantic descriptions of the data should follow more (ontologies) or less (taxonomies, thesaurus or vocabularies) strict mathematical formulations; thus allowing for a machine to interpret their meaning and associate them accordingly. In that sense they will allow users to make more intelligent searches and navigate easily through the appropriate learning material regardless of location and probably original scope.

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[1] http://www.ariadne-eu.org/

[2] http://www.computer.org/portal/site/ieeecs/menuitem.c5efb9b8ade9096b8a9ca0108bcd45f3/index.jsp?&pName=ieeecs_level1&path=ieeecs/publications/author&file=ACMtaxonomy.xml&xsl=generic.xsl&;jsessionid=L7lRgdGNJlL7wTGB4lyHWyScv8MN6JXDy3900ySMHxyf7LyQ3gPF!-2060471945

This paper describes an effort to develop, describe and to every possible extend justify such a taxonomy for the “Geoinformatics and Surveying” discipline. The proposed taxonomy attempts to structure the concepts used by scientists in this specific and emerging field. Our primary aim is to classify the educational material that is used as part of the educational process taking place at the Academic Department of Geoinformatics and Surveying of TEI of Serres in Greece. We extended our focus to include and support diverse material coming from sources like: scientific bodies and agencies, companies and the public sector. Our proposal will be put to everyday use through a dedicated (semantic) web portal built and supported by our department, accessible both by students and the general public.

2 Learning Systems in the Semantic Web era

Semantic Web (Berners-Lee et al., 2001) brings into learning two very interesting challenges. The first one is that it is not enough anymore to just accumulate a pile of resources and present them to users. The problem here is twofold: first of all the number of available resources is increasing constantly, by day and by large numbers, secondly users demand more intelligent searching and understanding of resources in order to be able to use them. The second challenge is to provide the necessary interoperability among resources without requiring the users of learning new applications and interfaces all the time. If we also include here the promise of the Semantic Web that all involved resources will be “understandable” by the machine, we can hope for a more promising future for learning applications in general and in Geoinformatics as well.

In achieving these promises the metadata architecture plays a critical role (Nilsson et al., 2002). On the other hand the way used by the semantic web to support common metadata architectures is largely based on ontologies, taxonomies and thesauruses. These mathematical tools allow the construction of a uniform, extensible and mathematically sound framework that serves all the goals discussed earlier (Aroyo and Dicheva, 2004). A lot of work and discussion has been carried along these lines and researchers tend to agree (Dufresne and Rouatbi, 2007) that the necessity lies on building concrete and widely acceptable ontologies, taxonomies or thesauruses. Unfortunately we can identify a vast lack of such knowledge representation tools in the area of Geoinformatics. Moreover recent work in the field suggests that the support for emergence and evolution of knowledge can now be provided by semantic web tools and applications developers (Tzitzikas et al., 2007); thus we can now rely on supporting the full learning lifecycle including changes in beliefs, changes in science and changes in academic curricula.

In our case the basic incentive came from the effort to build a comprehensive web based tool that will categorize intelligently Geoinformatics and Surveying related learning resources. The resources were firstly categorized and annotated by using traditional methods like storing them in a database. Although the resources are in principle usable, problems related to the capability of identifying the relationships among them were identified. Also is-a relationships were not captured in any meaningful way. These issues initially led us to turn to the solutions offered by the Semantic Web initiative in order to be able to capture meaning, semantics and relationships among the participating learning objects, their creators and their users.

3 Geoinformatics and Surveying Taxonomy

The basic problem we faced when started developing the proposed taxonomy, was that the Geoinformatics and Surveying discipline is a rather large and extended discipline, mostly due to its multidisciplinary nature. Thus we made considerable efforts to cover the contents of the discipline to the broadest possible extend but without being extremely analytic in all cases. So, we are fairly confident that we cover the breadth of the available information to begin with. On the other hand for reasons of clarity and compactness we do not present the taxonomy to its fullest depth, thus not extending all the concepts to their available specializations after a point, considering the fact that this would offer little to the current discussion and would leave less space for community discussion and formulation. Due to the mathematical definition of a taxonomy resources that belong to a subclass of a class (concept) do also belong to that concept (class); thus providing a uniform way to infer and extract knowledge from the classified learning resources.

The upper level of the taxonomy covers the basic concepts that define the field of “Geoinformatics and Surveying”. The concepts cover a wide range of topics including *Geographic Information Systems, Planning, Transportation, Remote Sensing, Topography, Photogrammetry, Geodesy* and *Cartography* (Figure 1). A note should be here regarding the fact that while concepts from other disciplines are already from this level included (e.g. Transportation) this does not contradict or somehow devalues the taxonomy; on the contrary it makes clear that we need to move towards a semantic network of concepts in all disciplines so that we can explore readily available information from other fields, annotated by semantic schemata created by experts.

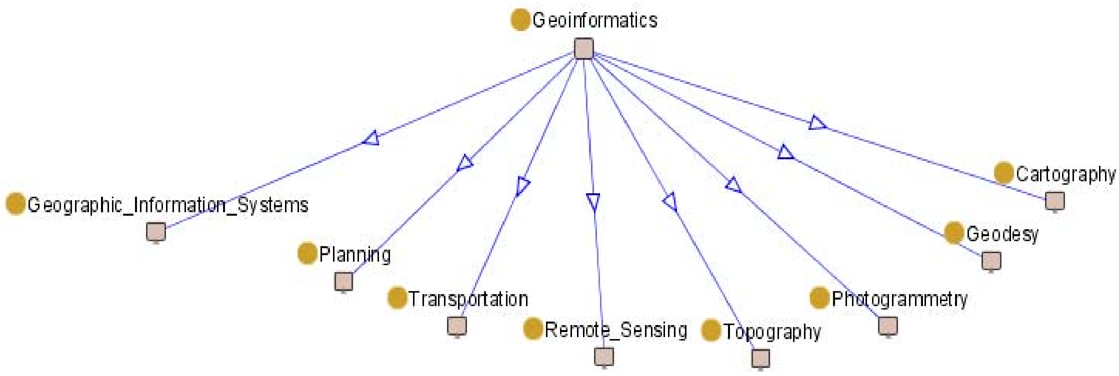

Figure 1: The first level of the Geoinformatics Taxonomy.

Then each one of the different concepts is further analyzed in order to provide more fine grained concepts. The concept of Cartography can be further specialized to *Automated* and *Thematic Cartography* (Figure 2). On the other hand *Geodesy* has a richer specialization. This is due to greater availability of resources and availability of more experts in the team that creates the taxonomy. This makes obvious the necessity to support such efforts by adopting them by the greater Geoinformatics community. Geodesy is specialized to: *Ellipsoid, Reference Systems, Quality Control, Reference Surface, Projection Systems, Geodetic Networks* (basically the basic geodetic equations along with the geodetic networks they are applied within), *Positioning* and (as its subclass) *GPS*.

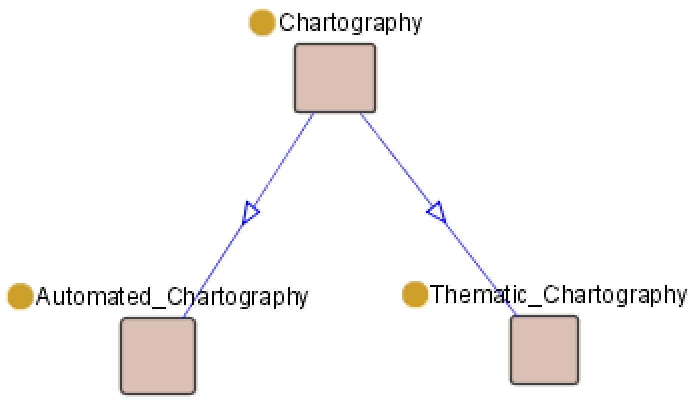

Figure 2: The analysis of the "Cartography" concept.

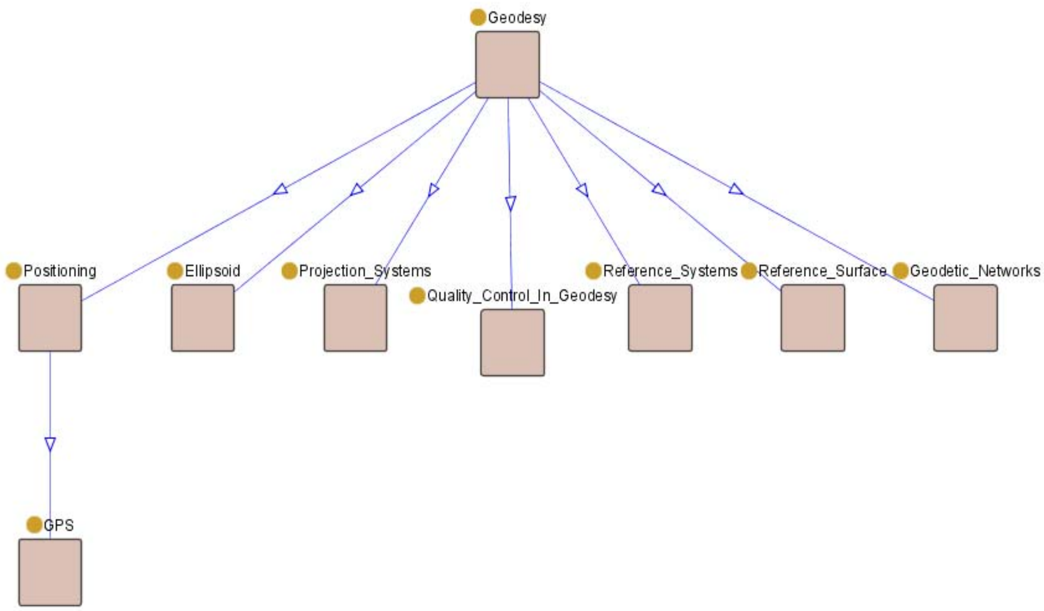

Figure 2: The analysis of the "Geodesy" concept.

The *Geographic Information Systems* concept is the richest one (Figure 3). It goes 3 levels deep and yet not all the available specializations are included. As mentioned earlier this richness can be attributed to more detailed knowledge of this specific area by the taxonomy creators and to a larger set of available resources. Here one can find concepts "borrowed" from Computer Science (like *Software* and *Hardware* for GIS and various *Data Models*). This means that we can extend the available subclasses since Computer Science is an area where taxonomic systems have been primarily developed. The same is true for the *Remote Sensing* concept since one can also identify common concepts like *Satellite and Digital Imaging* (Figure 4).

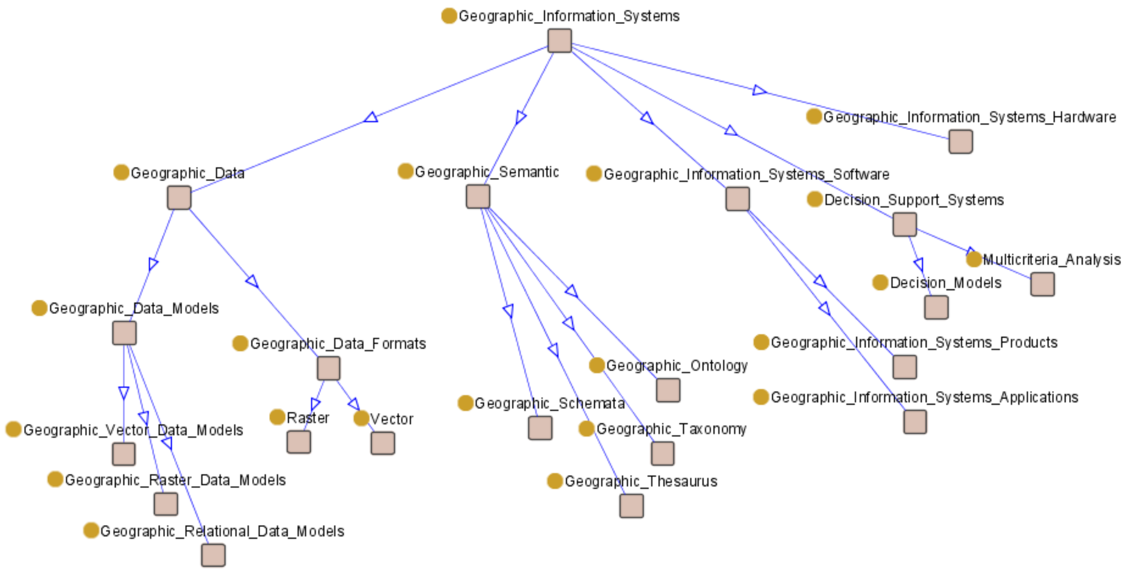

Figure 3: The analysis of the "Geographic Information Systems" concept.

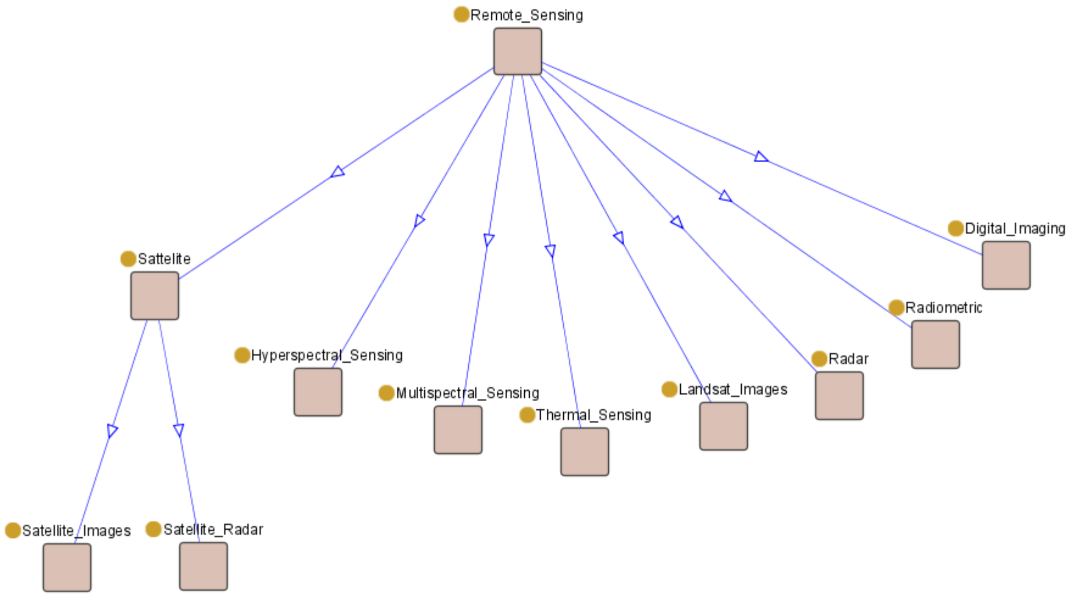

Figure 4: The analysis of the "Remote Sensing" concept.

Photogrammetry is another core concept of Geoinformatics and Surveying. It covers the imprinting of large areas using various photographic methods and the subsequent digital processing of the outcomes (Figure 5). On the contrary *Planning* (Figure 6) deals mostly with methods, algorithms and models that account for decisions in the *Urban* or *Regional* environment. Since *Planning* can also be considered as an independent discipline we will not delve too much into details. The same is true for the *Transportation* concept (Figure 7) since it is a recognized different discipline. We feel that since Geoinformatics is at least adjacent to that, it should be included in the available concepts. Nevertheless other field experts are required to extend and validate the current work. More specific concepts in this area include but are not limited to: *Highway* and *Traffic Engineering* and *Transportation Planning*. These concepts are specialized even more.

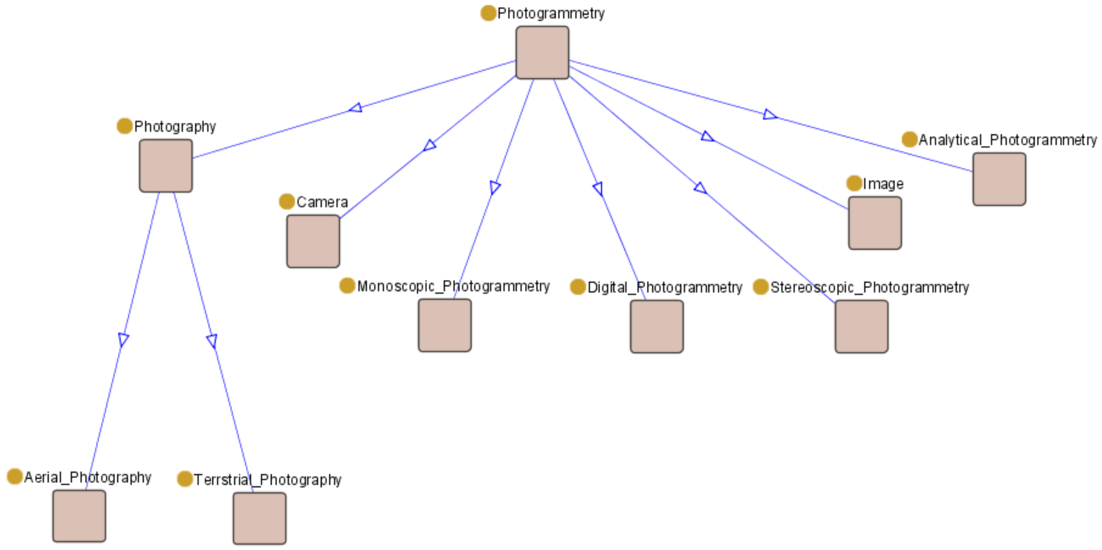

Figure 5: The analysis of the “Photogrammetry” concept.

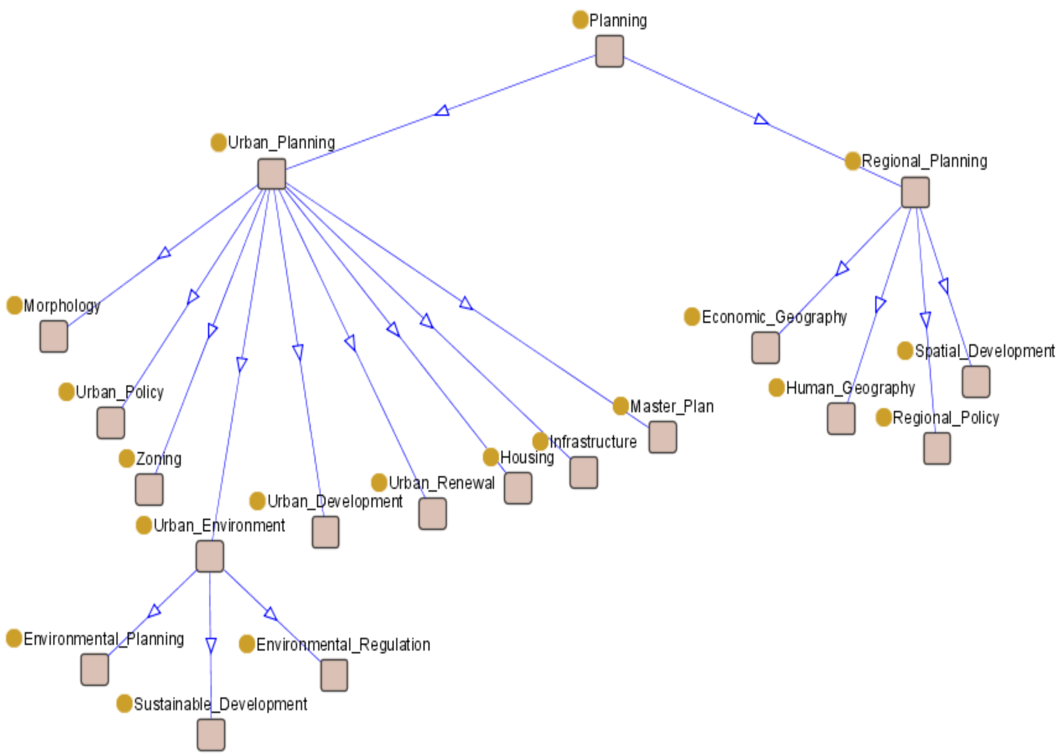

Figure 6: The analysis of the “Planning” concept.

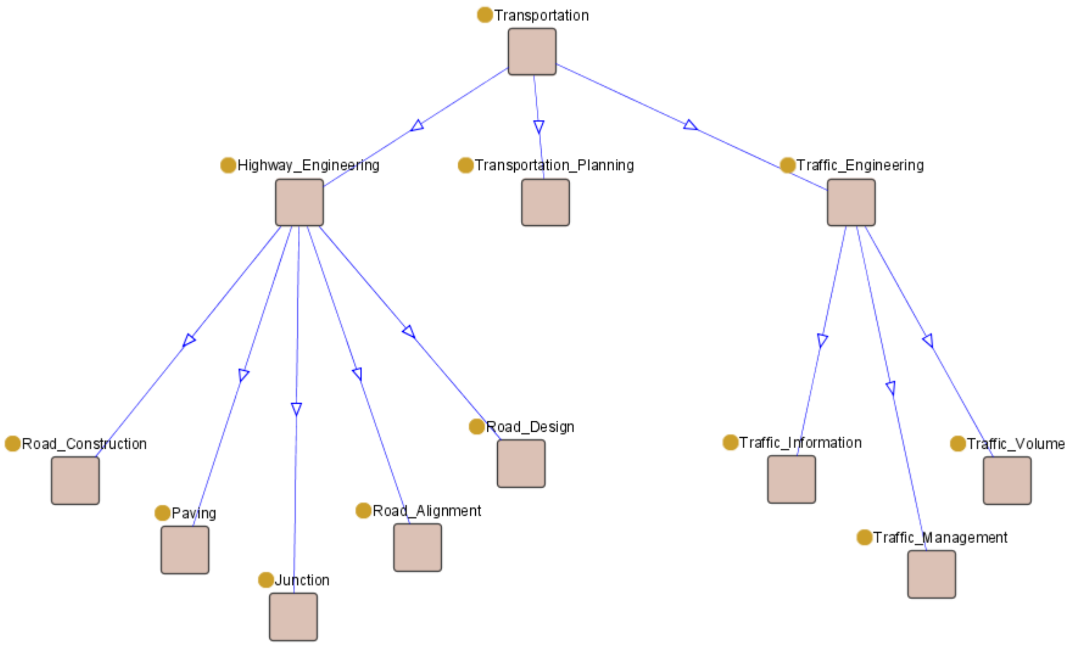

Figure 7: The analysis of the "Transportation" concept.

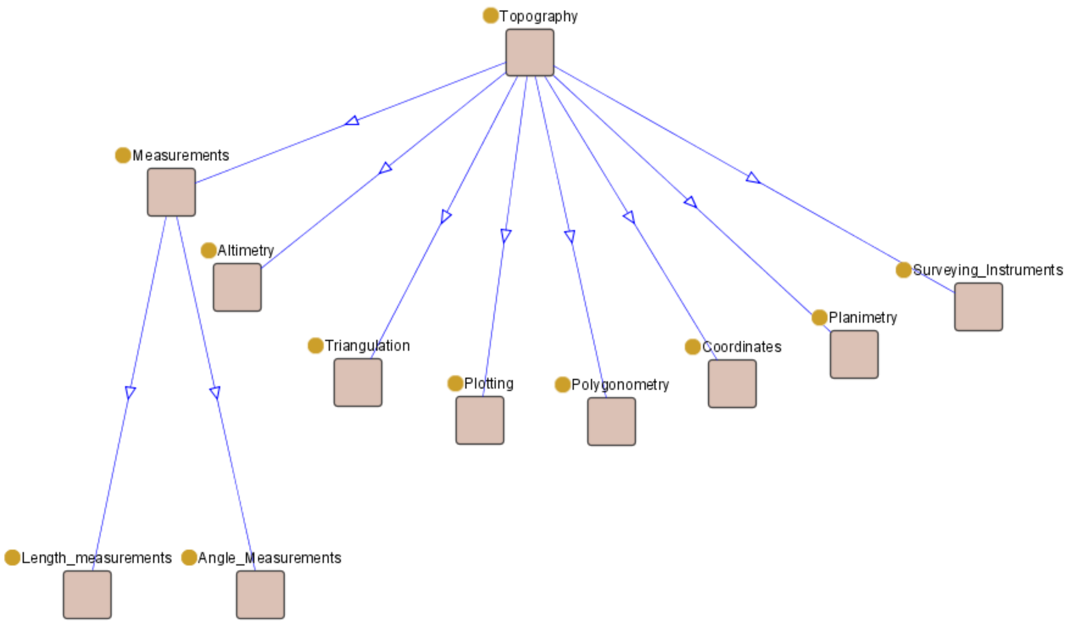

Figure 8: The analysis of the "Topography" concept.

Finally *Topography* (or Surveying) plays an important role in the discipline. It covers all the different needed measurements and the instruments (both physical and mathematical) to support them. These are detailed and depicted in Figure 8.

Finally, we should note that a concept can potentially be multiply classified. This means that it can "belong" to two or more higher level concepts and that the resources classified under it will be automatically classified under both these concepts. In the current work we avoided following that path for reasons of clarity, since it would make the whole picture more complicated than it already is and would add little information. Nevertheless it is a valid tactic and we plan to explore it in the future.

4 Related Work

Since the whole field emerged basically based on the Geographic Information Systems (GIS) there are preliminary efforts in the area covering mostly GIS, like (Mark et al., 1999) and (Grimshaw, 1996). The early approaches contribute to this discussion by the limited scope of GIS where the primary focus is to use the concepts to actually differentiate geographic data and not so much learning material. Moreover not the full extend of the discipline is covered. The same argumentation but starting from a different perspective can be given for the paper by (Johnson et al., 2005). In the same sense (Fonseca and Egenhofer, 1999) discuss the use of ontologies to actually drive the GIS itself as an information system but they are still not interested in using the ontologies to annotate anything different than geographic data.

There is one interesting work that actually suggests a thesaurus and domain ontology for Geoinformatics by (Deliiska, 2007). In this work a taxonomy for Geoinformatics is actually suggested and presented. We find this work extremely useful but also too generic in terms of using those concepts to annotate learning material. Nevertheless we plan to integrate it to the best extend possible into our suggested taxonomy, which we will also like to further extend.

5 Conclusions and Future Work

This paper presents a taxonomy for the Geoinformatics and Surveying Engineering discipline. We do not claim that this taxonomy is either complete or validated at the fullest extend in real life scenarios. This taxonomy has been built in order to cover the need to explicitly classify educational material, as part of the educational process in the tertiary education and its support by modern e-learning systems. Nevertheless we feel that this is a first effort in the field to cover to the broadest possible extend the concepts involved in the discipline and move later on towards a full and broadly acceptable domain ontology.

Thus we plan to expand this taxonomy on the one hand in order to cover concepts in greater detail. This means that more concepts will be introduced and some might need to be changed. Except from refining the concepts we would like to see additional information becoming available, such as information about other *non is-a* relationships among the concepts and turning in that way the taxonomy into a domain ontology. Experience from other disciplines show that the path towards that is usually a long and rocky one, so time and patience along with the broadest possible community support will be necessary.

Moreover we would like to evaluate the use of the proposed taxonomy in more real life environments. We are currently using this taxonomy to structure, describe and publish related learning resources on the web. This web portal will contain educational material like courses, lectures and assignments as well as supporting material as bibliography, theses, electronic publications, and links to related government and non-governmental agencies and will be available to whoever willing to access and use it. Additionally the resources annotated and classified under the proposed taxonomy will easily shared by all e-learning systems that understand semantically described data.

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