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CULTURE BOUNDARIES IN SEMANTIC WEB

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Master Thesis:

CULTURE BOUNDARIES IN SEMANTIC WEB

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ABSTRACT

Culture, being created by any and every of us, is the expression form of the society. We easily manipulate this term in everyday life, but defining the culture brings a lot of discussions in between scientists. The most common approach of understanding culture is from anthropologists (Harris & Johnson, 2006; Tylor, 1871) who associate culture with the common developed complex pattern of the society life expressed through knowledge, believes, art, morality, laws, traditions and other features. Approaching extinct cultures all this can be found and interpreted just from archaeological artefacts. Despite many culture definitions, the spatio-temporal aspect of culture is brought mostly by archaeologists. All in all the culture and cultural area understandings remain very fuzzy, though culture area is always formalized as a crispy one. Due to such fuzziness, author would guess, there was no hurry for cultural area or boundary digitalization as it happened with other cultural data in Europe within last decades. The cultural boundary question stayed 'taboo' in semantic web also, that is recently developing for cultural data in order to help to represent the meaning in a restricted sense. It is therefore in this thesis the culture boundary representation in semantic web is analyzed.

1 INTRODUCTION

The question of boundaries of cultural areas have always been the study of social sciences having a great discussion on both subjects: the concept of *boundary* as well as the concept of *culture area*. Discussion on cultural area concept within social scientists got really popular last decade due to cultural area association with social and ethnical identity areas and related problems such as immigration, racism, group rights. For same problems the boundary question in between such different groups is always an interesting research. Remarkably, empirical social research focused on boundaries as itself can generate insights of general social processes and phenomena like boundary shifting, boundary crossing, territorialization, relocation and so on. (Lamont & Molnár, 2002).

Such phenomena is hard to study in geographical space and therefore boundary question is often dismissed by geographers, especially such question as the culture boundary visualization. In case it is touched, culture areas are represented individually by different scientists and it is often a case, a common agreement on one boundary of one culture is never achieved. The author suggests that it is due to unclear perception and definition of boundary itself. So within this thesis a cultural boundary cognition is analyzed from different sciences perspectives to understand the variability well. Such knowledge is needed to be able to define boundary clearly for better interoperability between different fields of sciences as well as different languages as culture is often researched nationally or even locally.

Together with technology development the demand of data on web had initiated the digitalization process that has bloomed within the cultural sector as well. In Europe it was strengthened with European Commission juridical documents ("EUR-Lex - SEC/2008/2372," 2008) and so many archive collections, usually related to the culture, were digitized. Though new juridical documents have recently appeared promoting the open data as a new engine for innovation ("EUR-Lex - 52011DC0882," 2011). It partially shows that the interoperability which was expected in earlier documents wasn't reached even in Europe, that is nothing to talk globally. No-one knows if new documents will really help to reach the goal of data being open. Though the solution already exists that was proposed back in 1997 by T. Berners-Lee searching for the web of trust or web of logic. The semantic web was presented and became like a movement for the interoperability of data. Semantic web dealing with meanings in restricted sense is very much important for culture as it faces much larger challenge "to re-present changes in ways of knowing; changing meanings in different places at a given time (synchronically) and over time (diachronically)" (Veltman, 2004).

After getting to know the variables of the topic and the diversity of it, one can easier raise and formulate new questions and search for solutions. Therefore, after over-viewed some cultural topics and noticed the lack of literature on culture boundaries from different perspectives, the main and quite abstract way of the thesis was formed.

The **aim** of the thesis**:** to contribute to the development of the Semantic Web for Culture with a culture area and boundary representation.

Following with three **goals:** 1) to overview the literature on cognition as well as representation of culture area and culture boundary; 2) to discuss a culture area representation in semantic web which already results in modeling a new vocabulary for cultural boundary; 3) to create an interactive visualization of culture areas in semantic web as a suggestion for possible representation.

According to exposed question the thesis structure was built. The 2'nd and the 3'rd sections are used to overview and to discuss the literature. 2'nd section is for the culture related literature and section 3'rd is for the culture domain in semantic web. The semantic web importance for culture domain is analyzed to come to the main question of culture area representation in semantic web nowadays and what are the problems. Existing ontologies and vocabularies are overviewed searching for solution of that specific question.

The discussion of the work and the methods used to reach the depicted results are described in the 4'th section of the thesis. Firstly the work-flow is depicted with difficulties confronted and the goals reached. Secondly a methodology is described, from information collection and analysis up to the software engineering.

Further follows the results of the work described in the 5'th section of the thesis. Vocabulary created for culture boundary representation in semantic web is presented and described. For testing the vocabulary the case study is done using the example of Lithuania which is chosen due to the previous research done on a topic by the author. Shortly the data of the case study is presented depicting the culture situation of the Lithuania of chosen time to give the idea what problems the author is seeking to solve. The data used in the work is collected by the author itself just for illustration. At the same time such situation as collecting raw data by the researcher itself well depicts the real situation that during the digitalization boom still there are lot's of data not digitized and so lots of data not freely available, what in turn does not fulfill goals the European Union, together and all countries members, raise. Lastly the visualization is done and so it is presented as the last step of the thesis. During the work new ideas have come and so the thesis is finished with some advises and notes for future work on culture area topic.

The author would like to notice that culture concept is fuzzy not just from the spatial

aspect, but also from the temporal, reminding that when talking about boundaries one can talk about the space as well as the time. Within this thesis the author would like to restrict the focus on cultural spatial boundaries. As first of all, the temporal boundaries have already been disused from the semantic perspective (Kauppinen et al., 2010). Second, there was no data available, as well as there are not much literature to have a great background talking about it bias. It should be stressed that in general cultures tend to have different fuzziness due to their own features, the environment, neighborhood, time they appear. For this reason the generalizations from one example can be not suitable for all cases and so the author representing the Lithuanian case, does not make the generalizations about culture boundaries. The example of a case is used to test the culture boundary vocabulary for culture area visual representation.

2 Culture area cognition and representation

2.1 Culture and culture area perception in social sciences

Culture understanding is widely varying across different social sciences, that have emerged just after the enlightenment age and so has a very short philosophical history. But the word and concept itself is much more older, which we can already see from the etymology of *culture,* coming from Latin *cultura* for cultivating as can be found in any etymological dictionary (Harper, 2011).

The enormous variety of culture definitions was already noticed a half of century ago by American anthropologists that wrote a critical review on this concept over-viewing the history of word 'culture' and presenting over 160 classified definitions (Kroeber & Kluckhohn, 1952). It is possible we have so many different views of culture as it is considered to be “the most central problem of all social science” (Malinowski & Leopold von Wiese, 1939). So each social science focusing on different aspect define their research problem – culture – slightly differently.

One of the most important definitions of culture was formed by E.B. Tylor in early 1870 as “Culture or Civilization, taken in its widest ethnographic sense, is that complex whole which includes knowledge, belief, art, law, morals, custom, and any other capabilities and habits acquired by man as a member of society.” (Tylor, 1871). By this definition the word culture with it's scientifically technical meaning and was established, notices American anthropologists (Kroeber & Kluckhohn, 1952). It became the most quoted one (Gísli Pálsson, 1993) and many other definitions have been modeled on it[1] (Gísli Pálsson, 1993; Kroeber & Kluckhohn, 1952).

Anthropological definition of culture talks us about the complexity, but we can see just the social aspect of culture - culture existing in a man. Some anthropologists emphasize social heritage considering culture as the sum of the “social heritages <...> and of the historical life of the group” (Park & Burgess, 1921) or “inherited artifacts, goods, technical processes” together with not material culture (Seligman, 1930) . Within anthropological definitions we usually do not find the spatial concept in the definition or explications while they are the 'biggest writers' on culture and cultural boundary questions.

The ethnologists perspective meanwhile is already spatial since culture they interpret as a feature of a particular *ethnical group* that differentiates from another ethnical group (Oed, 1989) and so ethnical group has a homeland that is “connected with a specific geographical area” (Abel, 2003). This gives a spatial view of ethnical group with a link to culture as a feature so it can

1 Kroeber and Kluckhoh differentiate a section “Broad Definitions with Emphasis on Enumerator of Concept: Usually Influenced by Tylor” in a group of descriptive definitions where they list 20 definitions.

be interpreted that culture as a feature should also have a spatial or territorial aspect. But with a concept of ethnical group, “a membership which identifies itself and is identified by others” (Vermeulen & Govers, 1994), comes the fuzziness. It is hard to define properties that are used to identify, they can have different qualitative and quantitative importance, differently perceived by ethnic group itself and the others that differs. Nevertheless ethnical groups are often the ones analyzed territorially, and so it is the most common principle visualizing the spatial distribution of culture.

With spatial understanding of the culture through ethnical studies in the 19'th century the culture-historical approach of the prehistory got popular and a new concept of *archeological culture* was introduced. Without a clear explanations many European scientists, as well Lithuanian ones (Tautavičius, 1987; Volkaitė-Kulikauskienė, 1987; Žulkus, 2004) began to draw “an explicit analogy between the numerous geographically restricted remains <...> and ethnographic cultures.” Labeling prehistoric material assemblages as cultures mostly happened where had been a longstanding interest in tracing ethnic identities (Trigger, 1989). V.G. Childe who worked in Europe with such an ethnic mix in such a small territory suggested to call such complex of certain types of remains as cultural group or just culture (Childe, 1929) and so archeological culture twisted with culture carrying more fuzziness on the concepts. Luckily nowadays it's already clear that archeological culture is not identical with a culture inherent for an ethnic group. “Burial pattern is not a direct behavioral reflection of social pattern” as artifacts are cultural, but not social by itself and do not reflect cultural-social complexity because archeology is not a social science. It is more historical discipline from the British pre-historians point of view (Hodder, 1982).

Through ethnical and archeological approach that both gives a spatial profile of culture, probably the most important work should have been done by geographers analyzing cultures within their territories. Geographers in culture got interested just in late XIX'th century focusing on the environment and culture artefact at one glance. At that time cultural geography was developing fast and thus a lot of different concepts have appeared. One of the first cultural geographer C.O. Sauer believed that culture can be identified through the landscape, it was even called “'the agent' creating landscapes” as a practice of human (Sauer & Leighly, 1963). The *cultural landscape* concept was presented for the description of natural landscape with material things laid by humans. Later the definition centered on the significance and value of human practices. Then the role of politics was stressed and it come to the idea of cultures as 'texts' meaning not just written texts, but in general the idea of interpretation and the idea of interpreting landscapes along with other processes and institutions constituting them (J. Anderson, 2009).

The culture in geography science despite its shifting concept was often analyzed as a

geographic phenomena with a spatial extension having the area or territory and so geographers were creating spatial culture distribution theories. The very first who had drawn links between culture and territory was the German political geographer and ethnologist F. Ratzel. He contributed to the diffusionistic theory creating a culture circle concept – *kulturkreis,* believing that culture traits are created in one area and then they spread encompassing other societies. Further this concept was developed into a theory by L. Frobenius who was exploring patterns of such diffusion. Later *kulturkreis* approach was found too limited as it was standing for one culture, the most capable, having a racist attitude (Erickson & Murphy, 2008). Afterward C. Wissler developed a *cultural area* concept from just geographical grouping towards specific social grouping for cross-cultural analysis. He described cultural area as internally dynamic with an innovative cultural center and externally prevented by physical barriers, cultural habits and psychological characteristics from close relations with the tribes of other cultural areas (S. A. Freed & Freed, 1992). The approach of the strongest properties being created in the center of the area of culture is often leaded.

Parallel to cultural area a cultural region concept was created, with differentiation into formal, functional and vernacular. Looking at the formal region definition "an area inhabited by people who have one or more traits in common, such as language, religion, or a system of livelihood" (Domosh, Neumann, Jordan-Bychkov, & Price, 2009) it looks alike to ethnical group area. Though in the cultural region the properties to define a region are more generic as the purpose is to define a region. Anyways which properties are the important ones to define a region depends just on the geographer and on the specific purpose of the research. But just the ones that talk about regions starts talking about locating borders and border zones.

Looking at the culture definitions, none of them are directly talking about area or boundaries, neither looking at it as a phenomena having spatio-temporal features. Instead it is often treated as a property of society or social group or even landscape and so the property distribution is analyzed spatially searching for some patters. And despite how we are going to call the distribution of some culture - region, territory, area or even district – from ontological perspective it stands for the same idea (Couclelis & Gottsegen, 1997).

Thus following to be clear the definition of culture used in this thesis is given, as a social phenomena expressed by society through some complex pattern that occurred in some time in some space. Which means that it can be understood as a spatio-temporal phenomena with its area and boundaries.

2.2 Culture boundary concept definition and fuzziness

In general the idea of boundary have preoccupied social sciences since last three decades and mostly political sciences which clearly present three related concepts: 'frontier', 'boundary' and 'border'. Frontier is defined as the precise line at which jurisdictions meet, usually demarcated. The term border can be applied to a zone, usually a narrow one, or it can be a line demarcation. And boundary is used to refer to the "line of delimitation of demarcation" and this the narrowest of the three terms (M. Anderson, 1982). Since then the definitions have varied as concepts are fundamental to disciplines. In social sciences the most common is a boundary concept, which is often understood and analyzed just socially and sometimes can have territorial counterparts (Barth, 1969).

Boundary concept is the most suitable for cultural area definitions and it is the least defined one, bringing again fuzziness to the topic. The concept, according to A. Stroll is „pretechnical or at least non technical" and „in a prejorative sense of the term, we can say that it is a concept that belongs to folk physics or folk semantics" (Boniolo, Faraldo, & Saggion, 2008)**.** So from social side it was always used nontechnical and logical approach with formalization was done by mathematicians and computer scientists, which means the dialog in between was hard to find. Therefore following for boundary formalization the cognitive and computational approach is presented.

Defining boundary of the culture as phenomena means having some kind of geometry of culture distribution. The property of geometry is inherent just for the objects, as one kind of geographical model, but it is hard indisputably to claim culture being an object. The common understanding of objects is they are human artefacts with clearly defined boundaries and on the other hand we have fields representing nature of things, physical discontinuities notices H. Couclelis (Couclelis, 1992). Having those two mental models objects or entities vs. fields, that represents any geographical variation (M. Goodchild, 1994), it is hard to credit culture to one of them. After all culture as a social phenomena is kind of continuous all over where humanity exists, but depending on the definition it can defined as occurred just at some space some time. But not trying to solve the question where culture should belong to as a phenomena, in this thesis the author generalize the culture into an object.

It is observed that the object models (or entity) have more in common with everyday human spatial cognition than the field models (M. Goodchild, 1994). Besides, every natural object turns into an object just after it is drawn, meaning digitized and so gets its' clear geometry with boundaries which is useful for a topological modeling and so for human cognition, providing a

certain pattern. But it is important to stress that cultural area is not an object by nature neither it is a natural phenomenon that area and boundaries could be pictured remotely or recorded anyhow differently using nowadays technique. Culture boundary by itself exists just when it is drawn. The scientist just makes a decision to lie it depending on his own observations and studies on cultural agents he supposes to be the most significant for such and such culture area. That is the main point how it differs from other fuzzy boundaries, that are observed differentially and differentially defined and for such scale and the concept definition are the main factors of boundary fuzziness. While the fuzziness of culture boundary comes from sightly different resources.

Despite the scale for *culture boundary fuzziness* is important as for any phenomenon occurring on the earth, it is not the main reason. Exceptionally for culture phenomenon main causes of fuzziness are the agents used for the culture area identification and scientists drawing boundaries. The agents cause the fuzziness due to their uneven distribution. As well as it is often the agents are not fully investigated and so they are with different importance, having different weight in forming the boundary. Or different investigation methods are used and so different information could be deducted, or investigation methods are with different precisions. As well as different investigation methods could be used just because different agents are being investigated like material and non-material. All over having so much different agents carrying inconsistent information it is hard to make any kind of statistical analysis and so make clear and unarguable conclusions. When talking about the composition of agents that forms the culture pattern, the fuzziness comes from scientists as they personally make such choice. Despite groundings and reasons, due to different choice of agents used for investigating the culture pattern area different boundaries of 'the same' or - the same name having - culture can appear. Even in the case when scientist is using the 'full' composition of agents, that is always just the ones possible now as the completeness of agents describing the culture pattern is impossible. And quite often the choice of agents is done due to different focus on particular social science or particular attitude and so different boundaries are produced. Nevertheless scientists still try to visualize cultural areas analyzing the pattern of the properties like cultural artefacts and so determine the boundaries.

And so naturally we understand cultural boundary being unclear, undefined and definitely not crisp as it never bounds all the elements of agents that belongs to the set, having elements inside the set that does not belong to that particular culture as well as having the elements far outside of the area. As well as culture itself is a vague concept as explained a bit earlier. But the theoretical and practical side of vague cultural concept was never analyzed by social scientists. Mathematicians already half a century ago introduced a fuzzy set (Zadeh, 1965) where by definition each set member has the grade or degree of membership in interval [0; 1]. Topological set provided a natural

framework for generalizing many concept of topology, like union, intersection, containment, neighborhood and similar, that can be named fuzzy topological spaces (Chang, 1968). Decade later a fuzzy boundary was defined as the union of all boundary points that are fuzzy points of a fuzzy set (Pu & Liu, 1980). Further studies on fuzzy boundary and it's properties have been raised very recently (Athar & Ahmad, 2008), as well as on fuzzy regions and topological relations (Du, Qin, Wang, & Li, 2005; Tang, Kainz, & Wang, 2010), but with not so much focus on culture.

Th. G. Whitley was the first to present crisp and fuzzy boundary concepts (as two different types of boundaries) from cultural side, though mostly from archaeological. The author underlines that archaeologists interpret boundaries as simply as possible. It might be for this reason they were the first to talk about spatial boundaries from theoretical logic side and apply for a particular case using GIS solving the fuzziness by thresholds and producing crisp boundaries (Whitley, 2004). But no other papers were written explaining how to define the culture boundary, neither how they themselves are doing that or how it should or could be done technically.

In generally it observed that humans tend to transforming everything into a crisp classes (Kainz, 2010), so that's where from the tendency of defining any boundaries as crisp is coming. Moreover such are easier to manipulate in the geographical systems which are exactly created for applications and so it is much more often we try to categorize everything to objects (Couclelis, 1992). In this case it is easier if one could define the concept clearly and determine the culture area as a polygon with a crisp set with all the elements that belong to that set. Following, the boundary of crisp set is also crisp (Kainz, 2010).

Despite the discussion how to define the boundary further question is how to represent and to visualize it as the best understanding of spatial distribution is the visualization. And so following the question of how to visualize is raised regarding the nowadays interactive visualization possibilities, not just paper ones anymore.

2.3 Culture area and culture boundary visualization

Humans are geographical beings always orientating themselves and so visualization in general is a powerful strategy for leveraging the visual orientation (Miller & Han, 2001). And so focusing on the culture, we can find various different visualizations from simple 2D paper maps to the augmented 3D reality, all for the same purpose of presenting and explaining. Both are using graphics for the reason of visual thinking and visual communication with a user as it is created fro him. Nevertheless their roles and features of explaining obviously differs: while paper map is great in depicting the abstract view with some emphasis on required features, interactive 3D visualization is often up for separate features and their details in a great scale.

Recently together with a digitalization process of cultural objects a lot of projects appeared presenting 3D techniques for cultural heritage representation (Gruen, Remondino, & Zhang, 2006; Manferdini & Remondino, 2010; Remondino, 2005). Besides there were studies on 3D landscape visualization as well as on cultural landscape visualization (Griffon, Nespoulous, Cheylan, Marty, & Auclair, 2010). And it seems like cultural area with its vague concepts have been forgotten recently. Sadly it's true as for cultural area the geographical data of polygons are needed which haven't got any attention during the urge of cultural heritage object data digitalization in Europe due to EU projects. Though it is very much related, the cultural objects that are digitized have mostly lost their place of identity or place of manufacture, but they have their value due to being in the museums which makes it much easier to register. At the same time, nobody can register the boundaries and apparently they cannot be exposed in museums and thus for now forgotten.

The peak of some cultural boundary visualization on paper maps were together with the research on ethnical groups and archaeological cultures as well as regional approach in geography. In generally cultural boundary visualization should be the research question of cultural geography, but often the focus was on the cultural objects, not on the synthesis. Different maps were created representing different cultural areas, regions, boundaries using different thematic cartographic techniques.

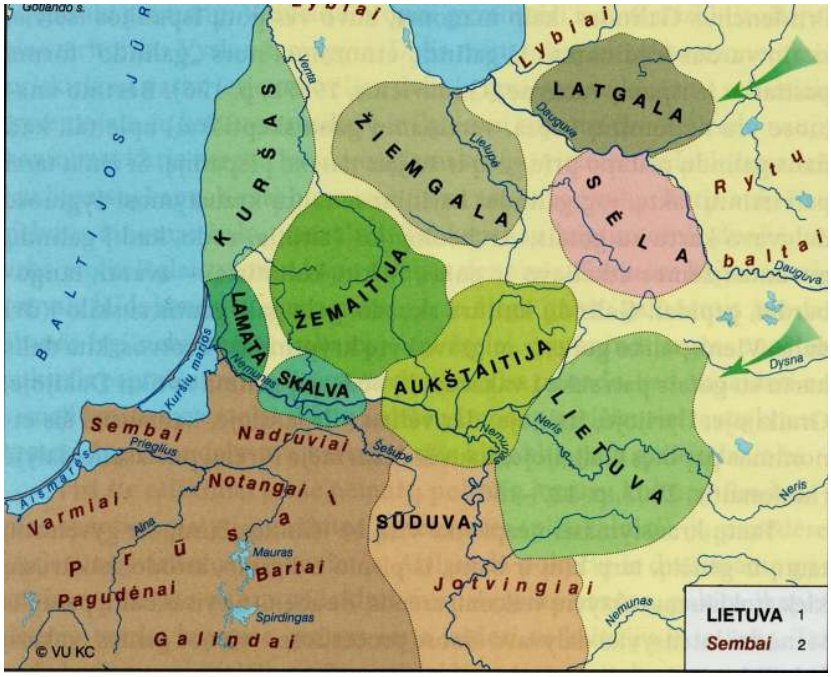


Illustration 1: Baltic tribes V-VIII c. (Istorija II, 2007)

Sometimes areas are not really marked, just naming an approximate location where that culture can be found or was found as it is visualized in the picture below (Ill. 1). Or the most common one, as have been noticed, is a simply marking the area with an approximate poly-line, that can devolve into dashed line or sometimes disappear at all, like when bumps into the national border. Though it also common to make the chloropleth maps that cartographically are the most common visualization of areal phenomenons, differentiating the areas with a color or patterns (Ill.1). Below there is an illustration of Lithuanian tribe cultural areas defined by archeologists.

To visualize culture area showing it's fuzziness the non-technical visualizations are made applying the fading color from center towards the outside. It is not technically appropriate as first of all the fading is done for the impression, without any mathematical grounding. The degree of fuzziness can not be understood or read from the map. Secondly it is also impossible technically to visualize fuzziness with fading as geographic technologies can deal just with crisp classes. So, sometimes areas are tried to bound with crisp boundaries and just at the very unclear and fuzzy areas boundaries are visualized as a transition zone, marking in stripes (Ill. 2).

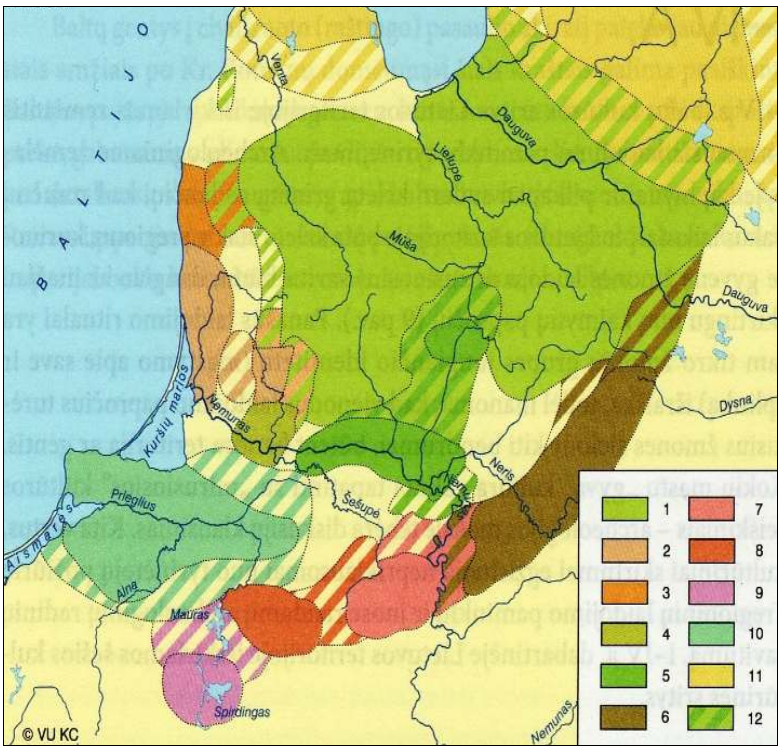


Illustration 2: Baltic cultures I-IV c. (Istorija II, 2007).

Technically or indeed mathematically fuzzy region is considered as a fuzzy set of locations, where each location as a point has its' membership grade (Verstraete, 2010; Zadeh, 1965) and it happens that all locations belong to the regions but some more then others. As interpretation of definition a figure (Ill.3.) is provided where we actually can see the curve of membership grade for the profile of the region. To remind the membership can be evaluated within the interval [0; 1], where both sides are included. And so below the visualization of fuzzy region, that has exactly the representation of area with a fading tone, we see how much at each place the point belongs to the fuzzy region. And so we are able to see the width of fuzzy edges. "As the region itself is fuzzy, it's logical that its boundary will be a fuzzy entity" which leaded into the presentation of the boundary itself (ΔA), the interior (A^o) and the exterior (A^-) boundary (Verstraete, 2010)

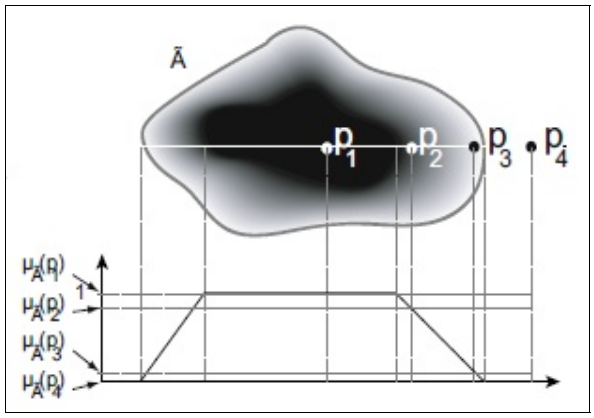


Illustration 3: Fuzzy region representation (Verstraete,, 2010)

In the picture above the boundary itself would be the gray part. The key point is the membership grade of 0.5 that completely belongs the most to the boundary and all the points that

are closer to 0 or to 1 belong less to the boundary. Then the interior boundary in the image is black and very dark gray tones. It is the one where all the points with a membership grade 1 belongs to to the boundary and all the points that are getting closer to 0.5 membership grade belong less. And the exterior boundary in the picture (Ill. 3) is white and very light gray tones. The points that strongly belong to exterior boundary are 0 and the ones that membership grade is getting close to 0.5 belong less.

Suggested approach (Verstraete, 2010) is very theoretical and it's usually hard to have such data in cultural areas domain to apply. Though already in 1982 three archeologists did the research on the identification of the location of regional cultural boundaries and presented boundaries as territorial areas that are like fall offs graphically (Ill. 4). Statistically curve fitting methods were applied for a sample of data that gave interesting results about detecting a constant average boundary (15-16 km) of researched cultural areas (Kimes, Haselgrove, & Hodder, 1982). But here it is important to stress that data it was applied to was a pre-roman coinage distributions in Britain. As it was already explained in 2.1. section while talking about archeological area definition, it is slightly incorrect identifying the coinage area with a cultural area, as it is analysis on one object, not on the assemblage of objects and second the object itself is not the main of identifying a particular culture. Coins, used for trading, exactly are not the feature of one culture that could be distinguished from other, but contrary can better show the interaction of cultures.

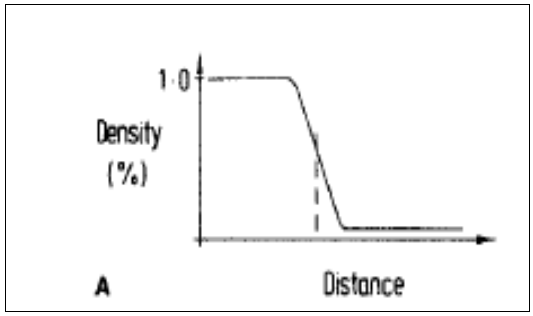


Illustration 4: Fall-off in artifact find-location density expected across a single boundary (Kimes, 1982)

Conceptually different fuzzy region solution was recently presented creating **plateau regions** as an implementation where not crispy regions are transformed into plateau region consisting of a finite number of crisp regions. The inside boundary of a crisp region consisting of points as a line is shared by *n* crisp regions with a bigger membership value then crisp region defines. The topological relations as intersection, union and difference were analyzed and presented with examples. The authors claims being it the first implementation concept on fuzzy regions. (Kanjilal, Liu, & Schneider, 2010). But no practical case solution is given. And one can admit that nowadays GIS and spatial data systems deals just with crisp, precisely defined regions, but many objects, including cultural areas do not follow such pattern. Defining such areas as fuzzy regions makes it difficult to handle with GIS as in all over it is a huge set of points with associated different values of membership. In contrast, plateau regions suggest to model fuzzy areas into many "plateau" that are formed of points having equal values of membership. Figure below (Ill. 5)

demonstrates the concept of generalization into 9 plateau regions (r9) with particular membership values: from 0,1 to 1. For the boundaries shared by several crisp regions ($n \geq 2$), they to belong to that fuzzy region with the highest membership value among the membership values of the n regions. Such solution also enables to have logic operators as union, intersection and difference that are well analyzed in the paper mentioned. Despite that, apart of the example for modeling air pollution, no real cartographic application was done.

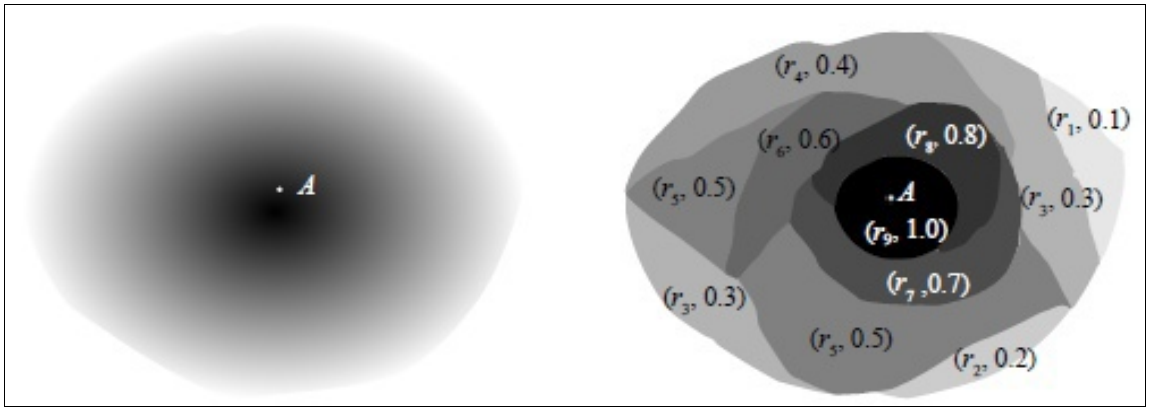


Illustration 5: Example of fuzzy region (on the left) and its representation as a plateau region (on the right) (Kanjilal et al., 2010).

Cartography in general is such a vast and interdisciplinary field that it is hard to be a great cartographer embracing all the fields and cartographers tend to specialize (Thrower, 1996). Obviously there is no such specialization as cultural cartography and many of cultural mappings are done by other specialists with some geographical education meaning that they posses some cartographic knowledge though not always enough. And so neither cartographers nor geographers have applied the technical possible visualizations as have been presented above for cultural areas that here are defined through the complex pattern of society.

As well, it's important to notice, that the cultural area visualization haven't changed recently, as well as haven't been the popular research question, despite the digitalization boom. Indeed digital information enables „creation and exploration of large collections of data“ as well „interactive exploration“ and „collaboration <...> fundamental to the Web” (Stone, 2008) . The map as a mean of communication has also changed, mostly due to the improvement of visual qualities that has developed (Thrower, 1996). But on the other had, it also makes easier to miss-communicate and give a wrong information just because the readability for an end user can be simply incomprehensible due to overload of information and graphics.

3 Culture field representation in semantic web

3.1 Semantic web importance for culture domain

The idea of semantic web has been born due to the 'wild' growth of data on web, data of something somewhere by someone and people using the web felt the lack of trust, sometimes the lack of logic. Therefore, semantic web was developed like an extension of existing web (Berners-Lee, Hendler, & Lassila, 2001) making data machine-readable (Fensel, Domingue, & Hendler, 2011) and so bringing the concept of meaning to the web-pages (Smith & Alesso, 2006). There is much more visions and explanations about semantic web, that are well exposed by T.B. Passin, already in the introduction of his book laughing that semantic web has almost became a celebrity nowadays, even Scientific American published an article, although almost most people don't know what it is and indeed there isn't a semantic web yet (Passin, 2004). What is known, it is an initiative of W3C that seeks to maintain interoperability of web, especially in the activities of the W3C Linking Open Data (LOD) project. And here it just can be stated that interoperability between science, scientists and scientific domains is just the best thing to help for the development. The development of any kind of domain, and what is more important to link the domains. Indeed that's how semantic web idea has appeared back in 1990, in one of the biggest research centers, in CERN seeking for an ability to share the data (Fensel et al., 2011).

Following the semantic web main key point will be introduced from a technical side for better structural understanding and interlinking with the focus of this thesis. So, the best way to keep the web interoperable is through Resource Description Framework (RDF) as a standardized format for publishing data on the web. RDF integrates applications using XML for syntax and URI's for naming and it's structured in the data model of triples: *subject*, *predicated (describes the like in between)* and *object.* Such data publishing paradigm already leads to “more effective discovery, automation, integration and reuse across different applications” (Smith & Alesso, 2006).

But semantic web isn't built just on RDF data description, though it is one of the cornerstones of it, that is visible in the well known graph explaining the layered

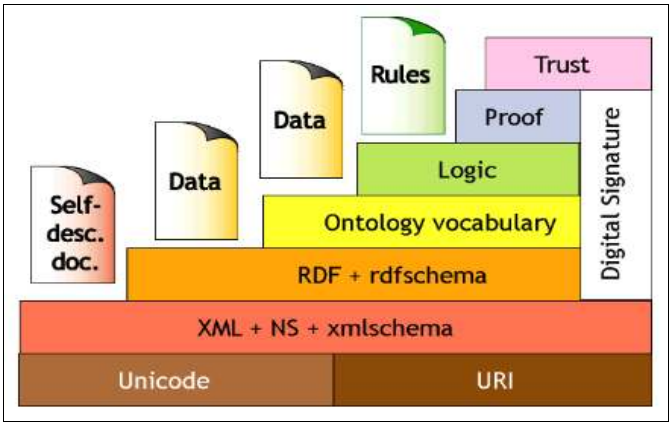


Illustration 6: Semantic web architecture. Source: http://www.w3.org/2000/Talks/1206-xml2k-tbl/slide10-0.html

structure of the semantic web (Ill. 6). And on the RDF with RDF Schema (RDFs) as a vocabulary description language of RDF strands the notion of ontology with vocabularies, which basically just helps to share the meaning across the wide web. Ontology in the information science recently developed the meaning from T.R. Gruber's definition as “an explicit and formal specification of a conceptualization”(T. Gruber, 1993; T. R. Gruber, 1993). It helps to describe formally any domain, defining the concepts, which are classes of objects, and relationships between these terms, and such information provides a shared understanding of any described domain web (Antoniou & Van Harmelen, 2004).

Talking about semantic web importance for a cultural domain as it was already noticed, we cannot restrict the research just within cultural domain, as that doesn't help for the development. Especially in such a wide domain, that many sciences cross and talk using the same concepts but just from their perspectives. That's how so many meanings of cultures appears and none of them is more right or better, it's just this concept is such an old developed through ages each time with other and another definitions. (The definition used in this work is provided in the end of the section 2.1 discussing the culture perception). And so bringing meaning to the web, the Semantic web is developed and that helps to for both: humans and machines to define better the concepts, further to share and so to use. The Semantic web should really help to integrate those different definitions of one concept in the web providing some data with a conceptual definition inside a web, not in a separate paper that has no relations with data or even worse not inside the head of some scientist.

Cultures are spatio-temporal phenomenons and they are and were spread over the world and through the nowadays political borders that usually has very less in common with cultural boundaries. But the research is often done nationally as scientists are funded by the national funds, although there are international research groups as well. The national cultural research within smaller countries it is sometimes impossible , especially the research for cultural boundaries, as they can be visible just partially. For such reason cultural boundaries should be studied globally and so “the RDF data model is inherently designed for being used at global scale” (Heath & Bizer, 2011).

For global studies the agreements of concepts should be made as well as the data sharing and interoperability should be available and so with semantic web it is the easiest way, making your data available and describing it in triples - an easy understandable schemata not just by humans but also by machines. Ontologies and vocabularies play an important rule to provide a different conceptual definitions and to draw the relations between them. So, cultural domain can be better integrated to the semantic web having a domain ontology. Nowadays looking at the existing web data topology a broad 8 domains appears as a topology, that's cross-domain, geographic, media, government, libraries and education, life sciences, commerce and user generated content data. There

is no such a cultural domain, but existing culture related ontologies and vocabularies, that will be presented in the following sector, are mostly used to define the cross-domain. That's just reassert the importance of semantic web to the cultural data and all the development of cultural domain.

Usually the importance of semantic web for one or another domain is not a discussion point, but the author finds that there is no an integrative vision of culture as a phenomena concept within the existing ontologies of semantic web and so the doubt can come – maybe it's not important. Just one recent research on cultural domain has been done and recently published in the book "Handbook of Research on Culturally Aware Information Technology: Perspectives and Models" (Blanchard, Campbell, Schwier, Kanuka, & Neumann, 2010), where the cultural domain structuring under already existing great ontologies has been done. The individual Upper Ontology of Culture (UOC) is proposed that is orientated towards a new technologies and new folks people are using to discuss cultures as well as integrative attitude from different social sciences about culture. Nevertheless it is focused mostly on the outcome of culture not the culture as a phenomena and so not about culture areas. As the authors say themselves it is still a long journey developing UOC (Blanchard & Lajoie, 2011).

After the first idea of UOC it stayed in the theoretical approach. One can argue there is a CIDOC defined as a "formal ontology that would enable the exchange of information and ensure the information integration on cultural domain" ("CIDOC(CRM) v5.0.4," 2011), but when looking closely at it the main focus is not on the culture as a phenomena, but on the artefacts that culture produces. And so it's the focus of many other papers. There are discussions on the semantic web importance for cultural heritage (Benjamins et al., 2004) as well as the modeling peculiarities (Pattuelli, 2011) or data applications (Byrne, 2008). Usually talking about cultural heritage it is just about the one stored in the museums. The author would think that such trend has formed just due to the data availability. The museum data was the most easy to reach, as the registries should have been done in paper and later relational databases, as well as with the data that should have been registered by governments like historical cultural heritage. With a case of Lithuania, the cultural heritage database (http://195.182.68.156/registrai/) is still within the level of relation database, though the recent cultural heritage objects stored in the museums, due to European initiatives as Europeana (www.europeana.eu), have started being described in RDF model to be integrated to the semantic web.

3.2 Culture area and boundary problematics in semantic web

Culture field in semantic web is not a newborn issue, thus ontologies and vocabularies are already existing as it was noticed in the previous section. There was also a stress made that most of

them are focused on cultural heritage instead of culture in general. Besides, there are many other vocabularies, that are not culture focused, but it is still possible to used some parts to describe cultural objects or spatially distributed objects. Thus following the author overviews the existing ontologies and vocabularies that are related to the culture area.

Probably the most related and the best known cultural domain describing ontology is CIDOC (CRM). It got name from the International Committee for the Documentation of Culture (CIDOC) that started working in 1996 on the Conceptual Reference Model (CRM), a formal ontology that would enable the exchange of information and ensure the information integration on cultural domain. CRM defines the semantics of database schemata and document structures used in cultural heritage and museum documentation. Since 2000 CRM Special Interest Group collaborates with the ISO working group ISO/TC46/SC4/WG9 to make CRM an International Standard with it's form and and status ("CIDOC-CRM Overview," 2011).

It is underlined that CRM is extensible and users are encouraged to create extensions for their needs of more specialized communities ("CIDOC-CRM Overview," 2011), but already from the objectives of CRM we see it is orientated towards the heritage, which are objects. This thesis focus is the culture areas that are formed by cultural phenomenons which are quite often defined by cultural artefacts, which are recognized as heritage. And so CRM ontology is focusing on heritage object which is described as a Persistent item (E77) class on the same hierarchical level has such classes as Temporal Entity (E2) and Place (E53). Those three classes being on the same level shows the spatio-temporal understanding of analyzed object. But Place (E53) in CRM ontology is defined as the homogeneous object being "determined by reference to the position of 'immobile' objects such as buildings, cities, mountains, rivers.." with properties as consists of (P88), falls within (P89), overlaps (P121) or borders with (P122) other Places. Such spatial approach for cultural area is often not the case and neither culture could be described as Persistent Item which can be subdivided into Actor (E39) or Thing (E70). As a phenomenon, it might go under the Temporal Entity, which is the case in other ontology – DOLCE ("DOLCE," n.d.). But here the temporal entity has one section as event. And so, just using the resources meaning classes and properties provided it would be impossible to describe culture as a phenomenon with it's fuzzy region and boundaries.

Another well known domain ontology-vocabulary is **Open Cyc** ("OpenCyc," 2011) existing already since 1986. It is an upper ontology with lot's of vocabularies integrated like spatial relations or geography as the most relevant to the topic. One can find such entity as *SpatialThing*, but it can be anythings that has location. As it is joined with WGS84 geographical vocabulary, it is interpreted to have just a pair of latitude and longitude ("WGS84 - Geo Positioning," 2009). There

is term *area* that it is used in this thesis for culture area, but in Open Cyc it is defined as some amount of 2D space and is a specialization of Scalar Interval. There is also *regionArea,* meaning that the physical size of region. Region is defined as *geographical region* that is "a tangible spatial region that includes some piece of the surface of a planet". While culture is not really tangible, though it is visualized geographically. And there is nothing about region or area boundaries in Open Cyc vocabularies. There is just entity as *border* in the separate political vocabulary that doesn't fit for culture regions as term border is political as a demarcation mark, dividing something, just like as we are usually used to see.

Another upper level fundamental ontology is DOLCE (Descriptive Ontology for Linguistic and Cognitive Engineering). It is based on a fundamental distinction between *enduring* and *perduring* entities ("DOLCE," n.d.). Looking deeper at the perdurants we find events, that can be found on CIDOC as well. But in DOLCE events are divided into achieved and not achieved, that has a subclass called *phenomenon*. That is described as a process without active participation, „it can be seen as an accomplishment when some intentionality puts boundaries on it." But the ontology does not talk further about boundaries, though provides a property like *boundary* or *boundary-of ,* that is more applicable to endurants as definition says.

Though upper or domain ontologies as it was described partially could describe the culture and area it occupies, there is still a need of more specific vocabulary. And there are lot's of smaller ones but not any orientated towards the phenomenon of culture and it's boundaries.

The ontology for geographical phenomenons **Geo-Ontology** was proposed and it's design presented suggesting spatial thing to divide into three classes as Physical Geo-entity, Human Geo-entity and Geometric Thing, further subdividing physical entity into the NatureEntity and GeoPhenomenon, and human entity subdividing into GeographicalRegion and Ecological Region (Y. Wang, Dai, Sheng, Zhou, & Gong, 2007). It is quite unclear why GeoPhenomenon can not appear nearby the human entity, which would be exactly an example of culture phenomenon that for sure is not a physical entity. Though the idea of Geo-Ontology as such is really good and there is definitely a need for such, but the concepts should be over-thought better.

After examining many different ontologies and vocabularies, it have been noticed several trends. First of all, every cultural domain ontology is mostly focused just on describing cultural heritage, artificial objects found and often already well described and preserved in the museums. While having such data already prepared or stored in digital formats. And ontology just helped to describe data in standardized way, to order data logically and make it semantically available. Cultural heritage lets us to understand culture better, but one cultural artifact does not stand for the

culture itself, as a complex social structure. Analyzing culture spatially or as many would name it geographically, one should analyze it as the phenomena. And so for such purpose there is still no ontology or vocabulary developed. Such observation leaded into raising the goal of a new small possible vocabulary development, that is described in further sectors.

3.3 Visualizing cultural data from semantic web

First of all when talking about visualizing the semantic web, technicians first of all start talking about the graph visualization. As the data is stored in triple format in semantic web and those triples are related to each other, one can visualize them showing the relations between data or between vocabulary classes. But it is not this side of the visualization that the author is interested to present here. The idea would be to show what kind of geographical visualizations are possible to do without programming, which is always possible, but is not the interest of this thesis. As well to look at the projects done that provides cultural data and it's geographic visualization in semantic way.

Since there is no proper vocabulary for describing culture spatially, there is no data available and there were no great projects done to visualize culture areas. Although one can say that extinct cultures are not so important to understand and therefore there is no development in this domain, likely it is different as there is a great society interest in cultural domain, just from the cultural heritage side. And there is a lot of data in museums, that is already digitized, and nowadays described in semantic way. As a great example there is a CultureSampo – Finnish Culture on Semantic web project (http://www.kulttuurisampo.fi/?lang=en). It is also focused on cultural heritage, getting data from the museums and showing their relations with place. The local finish ontology was created for this project. Nevertheless the culture is not analyzed as a phenomena showing it spatially. It is just analyzed the national heritage within Finland borders. The geographical visualization is used, simply Google maps API for visualizing the cultural objects.. The very similar project still in beta version is pat.mapa – linking Catalan cultural heritage implementing linked data principles with a complex data visualization (http://patmapa.gencat.cat). The technical process is challenging due to mapping data between different databases and managing metadata. The pat.mapa project is implementing CIDOC (CRM) ontology, as the project is focused just on the cultural heritage. And the visualization part is similar to Finnish project using GoogleMaps API for cultural heritage as points visualization.

Indeed semantic web is orientating to the intelligent user that is able to take, modify and use the data himself. There are technical guides and tutorials written how to program semantic web (Segaran, Evans, & Taylor, 2009). One part of the book is analyzing examples of practical solutions.

And one chapter is dedicated to already existing project for data visualization and sharing the *Exhibit tool of SIMILE* (Semantic Interoperability of Metadata and Information in unLike Environments) that is conducted by the MIT Computer Science. The open source software is really easy to use and seems their goal as "to simplify the reuse and sharing of data, and to build tools that make it easy to work with data" was reached. There were lot's of small visualizations created (http://www.simile-widgets.org/exhibit/), the same tool was as well used for some parts in finish project CultureSampo. The same tools is also used in this thesis for a case study testing the vocabulary and making the visualization of the culture areas withing the further 5.3 section.

Creating effective tools for visualization requires technical skills, visualization skills, and a deep understanding of the problems and tasks critical for a particular domain. One common criticism of visualization research is that it presents techniques that are technically interesting but that do not provide solutions to real problems. This is a classic problem in research tool and system design, where technologists have a vision, based on what is computationally possible, but lack an understanding of what is really needed to solve the problems of their potential users. (http://www.clir.org/activities/digitalscholar2/stone11_11.pdf).

4 Methodology of work

4.1 Workflow

Culture domain being so wide and ambiguous it always takes a while to get into the topic as well as to find a problem that could be raised for a work as master thesis. As well as the semantic web domain, being still new and fast expanding, should be enough known for the author to analyze, overview and evaluate the culture domain within it. Primary focus of the thesis on the culture heritage has been changed several times after more and more reading have been done and some tendencies have been noticed. That resulted in forming the topic around aeal and phenomenal side of culture and its boundaries – a slippery and such a vague concept in terms of formalization and representation, and the tendency was, not so many researchers have touched this question before. It is difficult to understanding the variety and the differences of culture concepts that differs so much between sciences and does not help determining culture area and boundary. And despite all, the culture boundary is always represented as a boundary that would stand for anything else, being crisp, clear and challenging as everybody knows that culture doesn't have such. Although it took time to formulate the problem, it is very important and the first step in research process (Kothari, 2004; Kumar, 2005).

The research about culture areas was started widelly as to understand the topic objectivelly one had to get to know the archeological, historical, anthropological and geographical literature. The step of literature review is not less important especially in more analytical type of research (Kothari, 2004). For that reason the big part of the work was the information collection and analysis, that is given in the 2 and 3 sections. Researching the literature it helped better to reformulate the research problem.

Following in the research process the next step is a research design, for which an exploratory manner was chosen. A problem was formulated for more precise investigation considering different dimensions of the problem (Kothari, 2004). There was no clear hypothesis erected to be tested, just the question raised of how could culture areas be represented with semantic web and visualized interactively. And to research such question the kind of experimental visualization was done with a sample of data, which leaded to a case of Lithuania design with a type of non-probability sample that can be called purposive sampling (Kothari, 2004). Though it is very important the avoidance of bias, with a purposive sampling the items are selected deliberative and there is also a danger of selecting the sample that yield results in favor of researcher. But such

sample was chosen due to the lack of data available, as well as due to time saving. The sample chosen is the Baltic cultures within Lithuanian territory VI to XII century, the epoch of tribes existence. About those centuries all the data is coming just from the archeological resources and so archeologists work on artefacts, analyze and produce the possible culture areas of cultures as a paper map. So for the research it was used a secondary data, the one collected from maps by the form of digitalization, plus bibliographic entries.

Having data collected it needed to be processed, as it needed to be expressed in triples in rdf data model for semantic web. The knowledge of semantic web was collected parallel to literature analysis. The data procession consisted of several steps and different research types. The conceptual research - new vocabulary modeling or engineering - was hold after analyzing the existing vocabularies used for triple description. There are so many ontologies created that is hard to overlook all and find whether the raised idea could be described with existing vocabularies. But the decision was made to model vocabulary, though it went out to be a very tiny one and specific for the culture as a phenomenon with areas and boundaries that are fuzzy though realized as a crisp. The new concepts were introduced in order later to apply for the data sample resulting in a processed data file. Following to solve the research problem a visualization was done, using the created scripts to visualize semantically described data. There was no software development, but using already created SMILE scripts a web page was on the University server was created and the data sample was implemented making an interactive visualization for further observations. During this stage it was found that SMILE required the triples to be in RDF/XML format that would be published on the web. Since WWU provides a small space for students it wasn't a problem. The problem come visualizing polygons with SIMILE scripts that did not work properly and a separate script was needed.

After the visualization, the data was shortly described and analyzed, but further and deeper analyzing and interpreting the results, reasoning and searching for insights. After all, everything is expressed the master thesis as a report of the research conducted.

The most time was spend on analyzing the cultural concepts an learning semantic web like triple expression in different ways. Although there was no software engineering, it took a while to learn and understand the scripts. Publishing and build an HTML based page was much easier and interesting, though it was hard to try to apply the cartographic rules to already built-in tools. It also took time writing the report, structuring it and interpreting data.

4.2 Used research methods

There are several methods used to solve the raised goals and to come to the results as desired. Mostly empirical analytical methods are used as literature, qualitative and cartographic analysis. For the vocabulary modeling and the web page creation an ontology engineering and software engineering methods were applied.

Literature analysis method is one of the most common and the most basic method to understand the research. Various attitudes of social and theoretical scientists have been over-viewed and analyzed from journals, articles, books.

Another method used was a qualitative analysis as the most popular when presenting a case study. It is useful to get deeper into a study and well understand the data as well as the entire environment for a critical point of view playing with data and interpreting it.

Cartographic method nowadays is more and more used for analysis as it helps to understand the research object spatially and visually. The interactive web visualization was used applying some scripts on a GoogleMaps that lets an easy layer overlay which can be controlled by user. Overlaying the culture areas (visualized with transparency) of different scientists resulted in giving new areas. The fully colored areas, where the color intensity is highest due to all points of view crossing over, and areas where color intensity is very low. This method leaded into creating a hypothesis that plateau region theory (section 2.3) could be applied for a new areas that visualization provided. The different membership grade can be assigned to a different intensity colored areas, meaning that the areas could show how strong they belong to that particular culture area giving the idea of the culture boundary fuzziness and moreover the area of fuzziness.

Ontology engineering method was used for creating a cultural boundary vocabulary. Although partly it can go under the software engineering (Fernandez, Gomez-Perez, & Juristo, 1997) the author overviews is separately as for creating vocabulary no software was used and this vocabulary is not used as a part of any software. Ontology engineering being quite a new method does not have many documentation, but the process indeed is well clarified. Creating a vocabulary mostly were used advises of Methontology (Fernandez et al., 1997) and the ontology of M. Uschold (Uschold & King, 1995). Firstly the purpose of possible vocabulary was identified, then key concepts collected and important terms identified and formalized. Secondly it is very important to integrate into already existing ontologies creating an interoperability. So needed concepts that were already described in other ontologies have been changed in order to reuse existing terms. Moreover new concepts were joined under the upper ontology expressing some classes as subclasses of such.

Going within the circle of ontology development an evaluation is important, which can be done just by implementation. And so here for implementing an ontology a web page was designed for creating an interactive visualization of culture boundaries and so the software engineering method was applied. The web page was created and results were described, but no further evaluation has been done due to time restrictions. For that reason the vocabulary wasn't published and documented in standard way. The documentation of entities and properties are provided within this thesis.

The software engineering method was applied creating a web page with interactive visualization. Although there are many different methodologies on software development the most common model to follow is waterfall model (Jalote, 1997). Since the goal of this web page was interactive visualization for semantic data a tool was first of all chosen that was SIMILE open source tools. Firstly, there are no other open source tools for web visualizations fully developed already. And so the design was mostly planned by tool designers. Just implementation was done and design within a web page meaning the available tool composition. Implementation leaded testing and that was a cyclic task, setting up differently the provided or data descriptions and implementing again. This web page creation is just the test of possible culture boundary vocabulary visualization that leaded to further investigations.

5 Culture boundary spatio-temporal modeling and visualization for a case study in Lithuania

5.1 Vocabulary modeling for culture area representation

There is no certain standardized way of ontology engineering and especially of vocabulary design or modeling. But many agree on a truth, that they are created for being reused and so the best practice creating a new ontology or vocabulary is to reuse existing terms as that is an important part of creating inter-linkages (Heath & Bizer, 2011). Though if one could not find the terms to use, the practice is simple – create it. And whatever new creating the rule is to know the purpose of that. As it was previously discussed (section 3.2) there is no ontology created to describe the culture spatially and so the goal was raised to create a possible vocabulary for that.

Ontology engineering is relatively new and immature discipline by itself, but there are already several methodologies written to discuss about the ontology development (Fernandez et al., 1997; Uschold & King, 1995). As well as there is already an overview of those several methodologies done for evaluation and comparison (Lopez, 1999). As a method used in the thesis it is shortly presented in the methodology part (section 4.2). Though the goal is just to create a vocabulary, that is much much smaller compared to the ontology, some suggested methods and advices can be used.

Starting with the problem identification as culture boundary description, following concepts have been named to describe culture as a spatio-temporal phenomena: *culture*, *culture area*, *time* and person which in this case is a *scientist*. Plus *publication* concept for where the cultural area map was published. The main idea is having a culture as a phenomena or an entity as an object that is described not just spatially at some time, but also personally. The attitude feature in cultural domain is very important since the culture and especially culture area is a very bias thing. It comes, the geo-atom proposed by M. Goodchild (Goodchild, Yuan, & Cova, 2007) and later implemented by E. Pultar, T. Cova, M. Goodchild, M. Yuan (Pultar, Cova, Yuan, & Goodchild, 2010), for this domain could be extended from tuple of location (x) and property (Z) following by value of a property in particular space-time <x, Z, z(x)>, towards the triple by adding the attitude (A) of a person on that particular property in this case culture area expressed at specific time (x^a). It might be expressed as following <x, Z, A, $z(x^a)$>.

Coming back to the main concepts, and the advices of methodologies, the good manier is

to check the other vocabuliers to avoid the term repetition. The term '*scientist'* is already explained in the linked science (LSC) vocabulary (http://linkedscience.org/lsc/ns/) as a 'researcher' (http://linkedscience.org/lsc/ns/#Researcher), that is already named as a subclass of a 'person' in a FOAF (friend of a friend) (http://xmlns.com/foaf/spec/) vocabulary, like that creating interlinkages. From the same LSC vocabulary term '*publication*' (http://linkedscience.org/lsc/ns/#Publication) is used, which is already defined as a subclass of 'document' in the bibliographic ontology (http://purl.org/ontology/bibo/). To define time there is a separate ontology Time-OWL (http://www.w3.org/TR/owl-time/), from where the concept will be taken to reuse.

Two left concepts as culture and culture area goes together not defined anywhere. One option that author choose for this thesis would be just simple define culture as a type of 'phenomenon' class that is under the accomplishment class, under the event and then the perdurant (http://www.w3.org/2001/sw/BestPractices/WNET/DLP3941_daml.html#phenomenon%20#4) in DOLCE ontology. By putting boundaries one make the process achieved and so described as a phenomenon as written in DOLCE. But it is a very wide ontology and author would think that the better option would be having a geo orientated ontology that would have more precise terms for property description as areal phenomenons often share common features like having a fuzzy spatio-temporal distribution, and they are objects of geographical field research. There is already one geo-ontology proposed that has a feature of phenomenon though was never put into practice and still in the process of development. If such ontology would be well developed it would be enough to use it to describe culture as an areal phenomenon, tough not yet.

For the vocabulary it is not enough just good definitions and relation to other vocabularies. A documentation is needed (Fernandez et al., 1997; Uschold & King, 1995) as for any software engineering. The best practice would be to do it with human-friendly labels and comments – `rdfs:label` and `rdfs:comment` that are designed for this purpose. Though since this vocabulary is just experimental and very small, it is not going to be published and so the documentation is just given here, in the thesis.

class: *Culture.*
namespace: cb/culture#
documentation: a social phenomena expressed by society through some complex pattern that occurred in some time in some space.
subclass of: dolce:phenomenon

class: *CultureArea*
namespace: cb/cultureArea#

documentation: a space where in this case culture takes place.
(~same as: dolce:quality-space)
class: *Boundary*
namespace: cb/boundary#
documentation: boundary understood as the clear expression of culture area.

The expressed concepts where just the classes, that are objects in semantic web terms. To make relations between objects and better describe the properties are used, that technically in semantic web goes as predicates. Further there are predicates defined by the author suggested for the culture boundary vocabulary.

property: *cultureName* – defines the official culture name. Can be further broken down in different languages.

property: *hasArea* – culture as a phenomena spread in some area.

property: *hasTitle* – a particular title for area identification

property: *composedOf* – area can be composed of other areas

property: *cultureType* – depending on the methods used to identify culture the culture spread area can be different. The best way to describe type is to name the method used or the science domain of the research like archeological, anthropological, historical, etc.

property: *memerbershipGrade* – the term is coming from fuzzy theory to identify how strong the element belongs to the set in range [0; 1]. The theory of plateau region is applied here, where one fuzzy region can be split in a crisp areas that define a certain 'plateu' of the same membership grade.

property: *hasBoundary* – when area is defined it is bounded. Here it is assumed boundary is a crisp line.

property: *boundaryType* – default boundary type is external if it is just one boundary. If boundary is expressed as area, then boundary should be defined as area having boundary type of internal and external. As well as since area can be split into areas with different membership grades, different boundaries can appear, the external boundary and the segmental boundary.

property: *pointOfView* – culture boundaries are not natural ones and cannot be fixed by distant methods, they are a boundaries from a researcher perspective. This property joins a researcher class.

property: *fromTime* – culture has it's life cycle and so it boundaries can change over the time. When visualizing cultural area it's usually fixed at which time. When it is just approximate one time spot is defined it is described as from time. When a period is given, the other property is used to add the end time.

property: *tillTime* – when visualizing cultural area it's usually fixed at which time. When a period is given, the end time is expressed as till time.

property: *hasGeometry* – the closed set of coordinates, polygon as geometric type for a crisp boundary visualization.

property: *published* – time the research was published. Since it was not defined in linked science vocabulary for the lsc: research, it's done here.

When the relations are made a graph can be created to show all the entire vocabulary (Ill. 7). As well as the vocabulary version is further provided in rdf data modelling format.

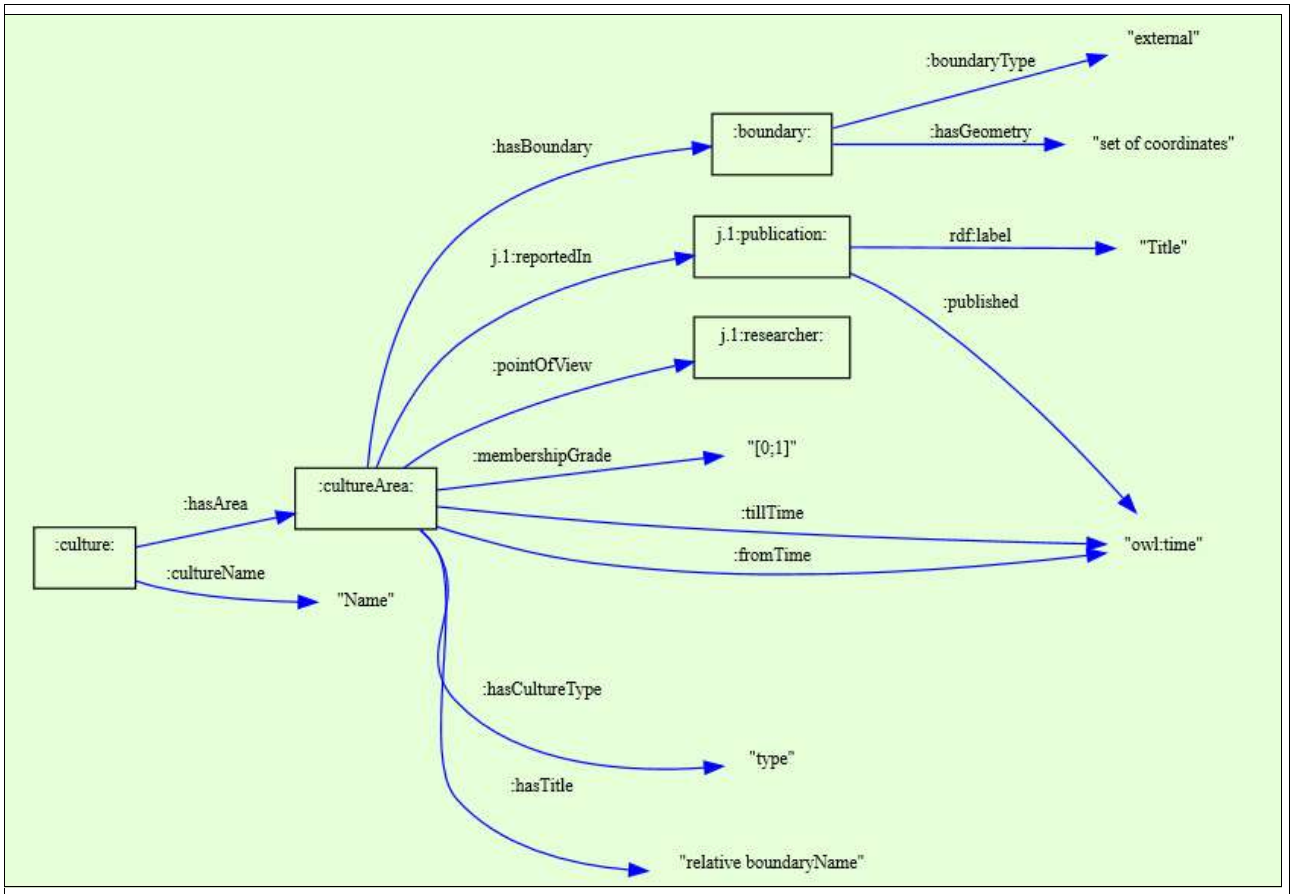


Illustration 7: Cultural Boundary (cb) vocabulary

```
<cb:culture>
<cb:cultureName>Name</cb:cultureName>
      <cb:hasArea>
            <cb:cultureArea>
                  <cb:hasTitle>relative boundaryName</cb:hasTitle>
                  <cb:hasCultureType> type </cb:hasCultureType>
                  <cb:fromTime>time</cb:fromTime>
                  <cb:tillTime>time</cb:tillTime>
                  <cb:membershipGrade>[0;1]</cb:membershipGrade>
                  <cb:hasBoundary>
                        <cb:boundary>
                              <cb:hasGeometry>set of coordinates</cb:hasGeometry>
                              <cb:boundaryType>external</cb:boundaryType>
                        </cb:boundary>
                  </cb:hasBoundary>
                  <cb:pointOfView>
                        <lsc:researcher></lsc:researcher>
                  </cb:pointOfView>
                  <lsc:reportedIn>
```

```
                        <lsc:publication rdf:label="Title">
                              <cb:published>time</cb:published>
                        </lsc:publication>
                  </lsc:reportedIn>
            </cb:cultureArea>
      </cb:hasArea>
</cb:culture>
```

After the research done about existing vocabularies, a new vocabulary was proposed, which is very small. As have been noted down it is not published as author finds that it could be better to integrate phenomena description in such a domain ontology like Geo-Ontology. Such would be more meaningful then publishing a small for a very certain case applied vocabulary. But the presented vocabulary can be used as a material for describing and classifying phenomenons in an upper level ontology. The author with this vocabulary wanted to show that there is a lack of ontology that could cover the fuzzy areal phenomenons and that there is a need of such ontology or vocabulary for a culture researches. Ontologies are one of the great way to enhance the interoperability between science domains, researchers and between different nations as culture phenomena doesn't stop within national borders.

After the vocabulary is well modeled it should be published, so that can be reused and so integrated into semantic web. The best way of publishing vocabularies are as static RDF/XML files (Heath & Bizer, 2011). Such publishing approach is the best when having a relatively small RDF files that are maintained by a single person. The developed vocabulary is very small and clearly should be integrated under some ontology or bigger vocabulary analyzing all geographical phenomenons substantially, which is just a research trend nowadays (Fu, Jones, & Abdelmoty, 2005; Huang & Deng, 2009; Hong Wang, Li, & Song, 2005; Y. Wang et al., 2007).

5.2 Vocabulary implementation and testing for a case study

5.2.1 A case study: culture areas in Lithuania

'Lithuania's current political borders have contained a variety of cultures throughout different historical time periods. Just before the first Lithuanian land was formed politically and Lithuania stood up as a country in XIII c. there was a tribe period VI-XII c. when different tribes with different cultures were growing into the fight to build their own country (Volkaitė-Kulikauskienė, 1987). Apparently just some of them formed country, as other cultures completely disappeared, some were assimilated and turned into other cultures. So the newly formed country couldn't encompass all old cultures' territories, about which archeology talks to us from the

archeological artefacts. There were other countries forming around on the base of some of those cultures. Already then happened that cultures within Lithuania land expanded further out from Lithuania borders. After long years, nowadays Lithuania political borders are even smaller and does territorially overtake many different cultures, but often just small parts of it. It doesn't help for the research, as some neighborhood countries have different attitude to cultures' research, different political regime that also doesn't allow whenever to make a field research or even an archive research. Information gathered about extinct cultures is in different languages, described using different measurements and so on. And it is not just about Lithuania case, there is probably no single country that would overtake all of some old culture territory, as that's the natural life cycle of culture, it is never stable.

Nowadays within Lithuanian borders approximately 8 culture areas of tribes (VI-XII c.) falls in. That is *aukstaiciai* which would be the highlanders, *zemaiciai* as lowlanders, in latin known as *Samogitians* in Latin. Both and the only fully falls within country borders being situated in the center of Lithuania: *aukstaiciai* being in the easter side that has higher latitudes, and *zemaiciai* being in the west side that has lower latitudes. On the seaside stretching up to the north reaching even Estonia were *kursiai,* known as C*uronians*, have just a very small part of their land in Lithuania. Their neighbours – *ziemgaliai* known as *Semigallians* in Latin, are on the northern part, having huge lands in Latvia, and just a little falling with nowadays Lithuania. Further the similar situation with *seliai* in Latin named *Selonians*. In the eastern side of nowadays were *lietuviai* – Lithuanians, that win the fight for the political administration in that XIII c. Their culture also extends much further to the east side. At the south there were *jotvingiai* culture, that are one of the smaller culture of the great Prussian culture, known in latin as *Yotvingians*. On the southwest side at the delta of Nemunas – the biggest river within those lands, the *lamatieciai-skalviai* were situated. There is no clear distinction in between those cultures as some authors name it using both names, some just one. Within this implementation it was used just a one name not to mix, as it is not the focus of this thesis to discuss which name should be more appropriate.

Lithuania as a case study was chosen just because the author is already familiar with its culture history and already have done the research on baltic tribes areal distribution. There was a master thesis written on the baltic tribes boundaries based on hydronyms (Nainyte, 2010). So, Lithuania as a case study was chosen again as it well illustrates problematics of researching extinct culture areas and boundaries when having different opinions thus drawing different cultural boundaries. It could illustrate the problematics about the research interoperability in between different countries as well, but there was no data available to help to illustrate that.

5.2.2 Data collection for vocabulary implementation

The data used for a cultural boundary vocabulary implementation was collected from already existing publications, where scientists have published maps of possible culture areas. So, the data still needed to be collected or extracted digitally, though it was already expressed on paper. Having documents scanned, the maps were digitized to get the set of coordinates that were the most important features that are going to be visualized. Of course related information as what is visualized and at what time as well as who did visualization and when is not less important. There were just several maps for the approximately the same age found from different scientists. All in all it resulted in having 26 polygons digitized. Most of the cultures: aukstaiciai, jotvingiai, kursiai, lamatieciai, lietuviai and zemaiciai have a 3 examples of areas from different point of views. For cultures: seliai and ziemgaliai 4 examples of areas in different points of view have been found.

Extracted data was modeled in triples: objects-predicate-subject and expressed in RDF/XML format. Every culture, every area was described using the vocabulary that is presented in the previous section. That resulted into having more than 250 triples, which is not a great sum and easily made without an automatic process, but it is enough for desired visualization. En example of triplified data is given bellow together with illustration how would look the graphical triple visualization that is done using an inspector tool. Although graphical triple visualization is just of a couple of examples, it very clearly shows the relations and connections of classes. It would be great to show joining other data-set for interoperability testing, but there is no data available.

```
<cb:culture rdf:about="http://www.example.com/cb/zemaiciai">
        <cb:cultureName>Zemaiciai</cb:cultureName>
        <cb:hasArea>
                <cb:cultureArea rdf:label="zemaiciai pagal Tautaviciu">
                        <cb:hasCultureType> archeological </cb:hasCultureType>
                        <cb:fromTime>0500</cb:fromTime>
                        <cb:tillTime>0900</cb:tillTime>
                        <cb:hasBoundary>
                                <cb:boundary rdf:about="http://...zemaiciai_tautavicius">
                                        <cb:hasGeometry>
                                        22.949585,56.062551| ... | 22.886611,56.096680| 22.949585,56.062551
                                        </cb:hasGeometry>
                                        <cb:boundaryType>external</cb:boundaryType>
                                </cb:boundary>
                        </cb:hasBoundary>
                        <cb:pointOfView>
                                <lsc:researcher rdf:label="Tautavicius, A.">
                                </lsc:researcher>
                        </cb:pointOfView>
                        <lsc:reportedIn>
                                <lsc:publication rdf:label="Lietuviu etnogeneze">
                                        <cb:published>1987</cb:published>
                                </lsc:publication>
                        </lsc:reportedIn>
                </cb:cultureArea>
          </cb:hasArea>
</cb:culture>
```

.

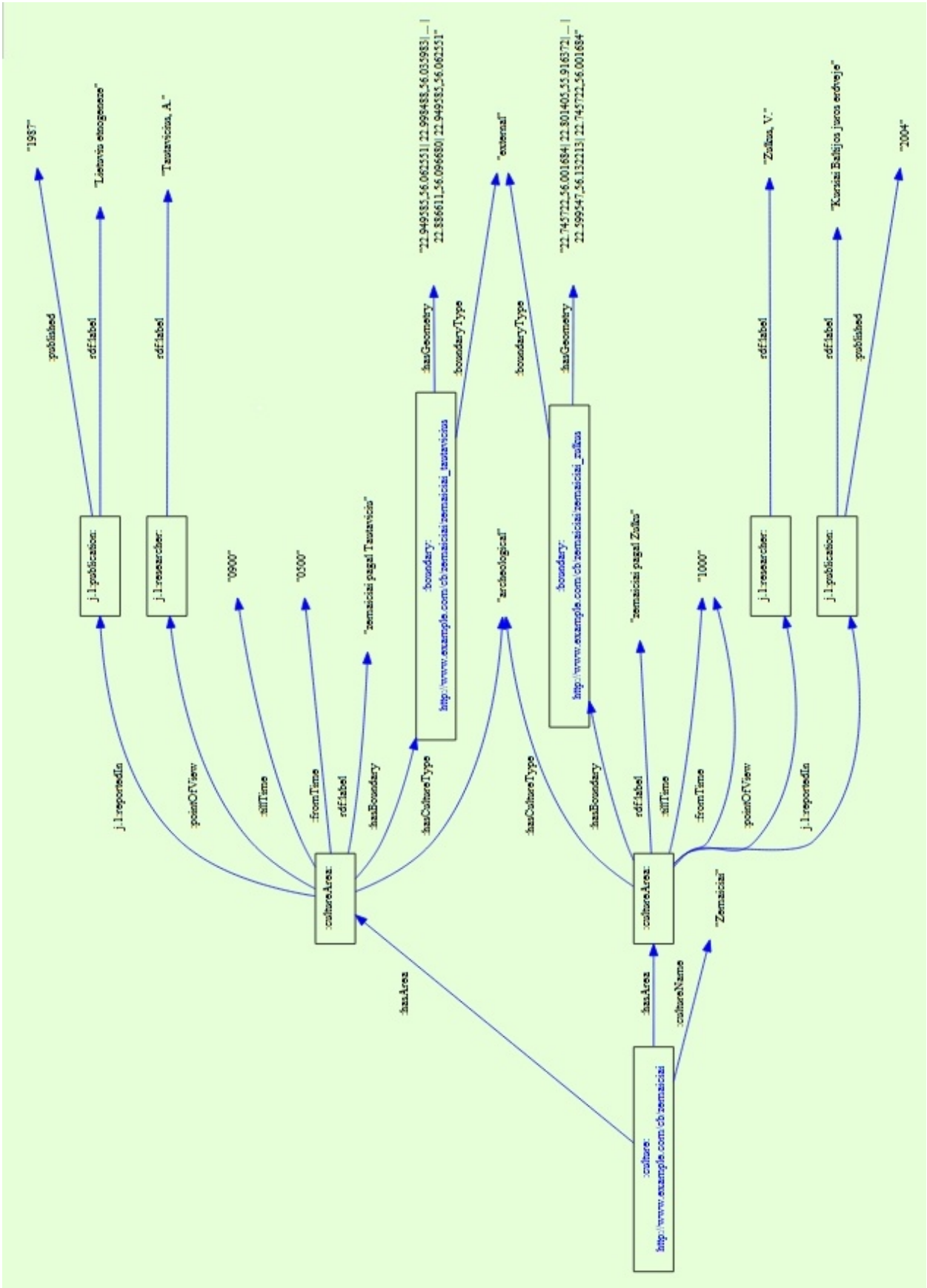


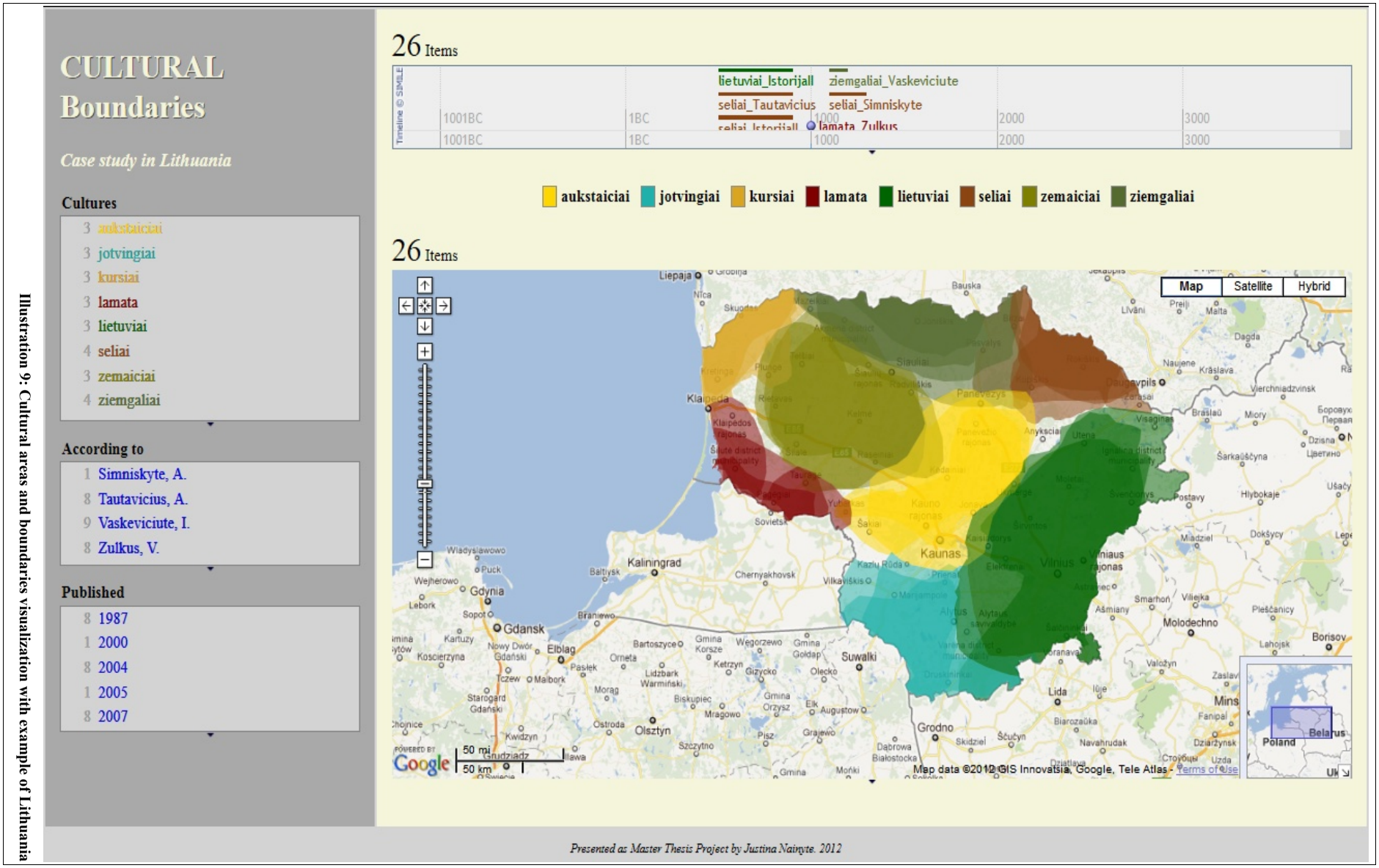
Illustration 8: Data sample described using cultural boundary vocabulary

5.2.3 Interactive web visualization of data

After making the research about the semantic web it was noticed that semantic web developers do not talk much about visualization in general, especially about the spatial data visualization. Semantic web is more about data storing and sharing and it happens it is more orientated towards the data consumers with technical skills that would know how to take data and create there own visualization. For such reason there is not much visualization abilities created.

For cultural boundary vocabulary testing an interactive culture visualization was done using the best known open source tool is SIMILE. It requires just a little bit knowledge of JavaScript language to use it, and so it was not hard to learn in short time to apply it. It was also found, that running SIMILE scripts from the computer, does not work for the semantically described data, it required data to be stored. Thus the data was put on the WWU ifgi server as a static rdf file. It was also noticed that the data to be readable needed to be in RDF/XML format. It was noticed in the very beginning, with the first examples trying to implement, thus all the data following was described in RDF/XML format that is the most common one. There were more notices about data description regarding the visualization. It was found that it is better to avoid the collections, like multiple triples with the same predicate as well as blank nodes as that can lead to modeling incomplete information. And so vocabulary was changed regarding such requirements.

For the web page one the most successful tools – Exhibit and as well TimeLine were used creating an interactive visualization. Exhibit lets to make the data sorting very easy with facets, for which one has to chose the property, the rest – selecting all the possibilities and listing it being already counted, does the Exhibit. An end user can chose within that property the grouped items to be visualized. It was used to created facets for the types of cultures as *aukstaiciai, zemaiciai, kursiai, ziemgaliai* and so on., the points of view, meaning different scientist names that can be chosen from, as well as the boundary publishing time as some of them are much newer then others. The TimeLine was added as well that shows the time period of each boundary. To visualize boundaries spatially on the map was a bit more difficult. Exhibit is well tested for visualizing the points as geometry type, and there are many visualizations created. When started playing with polyline or polygon visualization with Exhibit it was found that polygons were not working, it was just polylines and with limited set of coordinates up to 20 or 25. Therefore an alternative was found, adding just a little bit of javascript to visualize polygons with GoogleMaps API.



Presented as Master Thesis Project by Justina Nainyte. 2012

Illustration 9: Cultural areas and boundaries visualization with example of Lithuania

5.3 Visualization interpretations and insights for future work

"First and foremost an act of cognition, the ability on the development of thought expression, which can help distinguish mode, create and develop new order" (MacEachren, 1994) And so having spatial visualization, one can simply make a visuospatial reasoning for further discoveries going beyond the information given (Bruner, 1973). It is nicely explained by B. Tversky that going beyond information can be done in two ways: either "transforming the information", either "making inferences or judgments from it" (Tversky, 2005). With just an act of cognition there are judgments that have been noticed.

The chosen cultural boundary visualization, overlaying all culture areas together with some opacity, resulted in creating new regions one can recognize just looking at the visualization. The overlay of several points of view of the same region resulted in qualitative dimension of the visualization having some areas with very intense color and areas around with different color intensity due to different amount of layers falling on each other. The created visualization corresponds some kind of plateau regions (Kanjilal et al., 2010) that are presented in the 2.2 section.

Such reasoning can lead to deduction that the most intensive region got is the territory where every scientist (or point of view) agrees that this territory definitely belongs to that culture, kind of assigning the membership value equal to 1 that comes from a fuzzy spaces theory (Chang, 1968). The areas with lower intensity gets lower membership value that we calculate from the number of layers of that culture overlapping divided by the number of all layers of that culture like in the example (Ill. 10). There are culture *zemaiciai (Samogitians)* visualized with 3 different layers

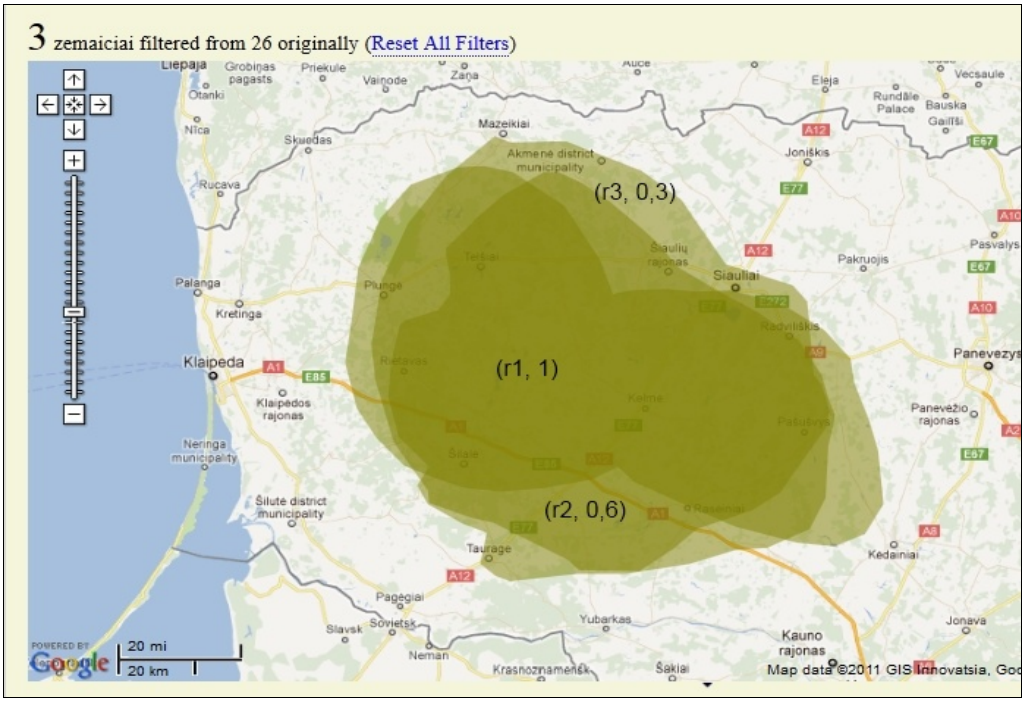


Illustration 10: Map detail : Zemaiciai culture plateu regions with membership grades

that represent culture in V-X c. The most intensive region (r1) gets the membership value 1, there where two layers intersect the membership value is assigned as 0,6 and where just one layer falls the 0,3 value is assigned. The values are calculated applying following formula $\mu(r) = n(r^{o})/\Sigma\, n(r)$, where the number of layers at specific point is divided by the sum of number of layers. Meaning that each layer is evaluated equally.

Such can be used for further actions as with plateau regions all topographical actions as union, intersection and difference can be calculated. As well such visualization can be interpreted as the region with the biggest intensity (membership value equal to 1) is the culture region and all other regions with different intensities when membership value (0; 1) as a broad boundary falling around. Within this case we see that boundary area differs from a couple to kilometers (on the west south side) up to around 30 kilometers (on the south and on the north). The thinnest boundary on the west south lies within the river that is still now surrounded by forests. And the thickest boundary territories does not have significant natural obstacles that could have formed a natural boundary. But it is hard to summarize that having just several examples.

Every scientist usually present their created culture areas and boundaries like the 'right' ones, as there is no-one to judge – as some cultures did not have a clear boundaries in between, making intensive trades. With the visualization proposed the map viewer could have a possibility to choose and to reason himself. Though the judgment is left for the end-user, he is able to learn about the fuzziness of boundaries.

From the technical cartographic perspective the web visualization methods can have not just advantages. Interactive visualizations often strongly affects the readability, as it gets harder to read the map as it is. Though having interactive map the user can limit the quantity of visualized objects to ease the readability and enhance the details, to browse the map in different levels. But user should have some abilities and knowledge making intelligent selections. As interactive map is created for user to interact, not just observe.

The usage of interactive maps are growing, as now to make a map user does not need so much cartographic skills, what's needed is more the technical education. But often the problem comes that tools provided to create maps are designed by programmers and so it can result in the lack of functionality the cartographer would expect. Like with the feature of opacity, which does not come to the legend. And when overlaying layers new colors are produced that does not appear in the legend. The same case is within this example as well, which leaded to further discoveries, but it is clear the further cartographic decisions should be done applying such properties and probably within the legend a new keys should appear.

6 DEDUCTIONS

Scientists working with a complex culture concept tends to define it differently. Such can lead to misunderstandings when analyzing just the data related or about the cultures that is often given separately from the definition because people tend to think that everybody understands culture as it is such an old concept. Such problem can be solved when together with data anybody could know the concept description applying semantic web rules and describing everything with ontologies. Although despite there are many ontologies for culture heritage description there are not for the culture as phenomenon. First of all such situation happened due to data available that was collected for long time by governmental organizations and thus well classified and described. That allowed easier to put structured data under the ontology and make it available and discoverable. Secondly cultural heritage itself are objects that can be easily localized. Not least important the concept of cultural heritage is well defined and not as fuzzy as culture itself or culture areas.

Ontology for culture as a phenomena that would describe culture areas and boundaries could help scientists to work together better while exchanging information about culture localization. Extinct culture boundaries often exceed off the nowadays national borders that sometimes stop the researchers due to data and literature in foreign language available, but the cultures does not stop within the national borders. Semantic web helps to share the data as data can be described in different languages, as well as it makes data available, discoverable and so does not close the research.

As scientists tend to define culture concept differentially, they also define the culture area differentially making a paradox of one culture at some time having many boundaries. Describing one culture are it is useful to introduce the point of view, expanding the GIS data atom from tuple of location (x) and property (Z) to the triple by adding the attitude (A) of a person on that particular property meaning that properties value is expressed subjectively by that person. In this case the property of culture area can be expressed at some place of some attitude as following <x, Z, A, $z(x^a)$>. Such information can further be applied in searching for fuzzy culture boundaries. When visualizing several attitudes of the same culture area with opacity a new areas are created with different color intensities, which unluckily technically does not appear in the legend using the existing web visualization scripts. The color intensity comes from the number of points of view agreeing on culture area being in that place. Here plateau regions theory can be applied where the color intensity stands for the membership grade, meaning how strong the pointed place belongs to the culture area. And so the most intensive color defines the area that all the scientists agree should

belong to some culture, having a membership grade 1. Smaller intensity colors either can be recalculated to get the membership grade to know how strong one or another place belongs to culture area, or in general can be understood at the fuzzy cultural boundary. Such visualization can be helpful in further researches, especially about culture boundaries, trade places, as it shows there are boundaries of areas scientists clearly agree as well as there are ones that extends in great distances.

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