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Semantics Visualization – Definition, Approaches and Challenges

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Abstract

The visualization of the simulation results must be done in conformity with beneficiaries perception and professional domain understanding. It means that right data must be identified before. Semantic technologies provide new ways for accessing data and acquiring knowledge. The underlying structures allow finding information easier, gathering meanings and associations of the data entities and associating the data to users' knowledge. Even though the focus of the research in this area is more to provide "machine readable" data, human-centered systems benefit from the technologies too. Especially graphical representations of the semantically structured data play a key-role in today's research. The meaningful relations of data entities and the meaningful and labeled clustering of data in form of semantic concepts enable new ways to visualize data. With these new ways, various challenges are related with deploying semantics visualizations beyond analytical search and simulation. The goal is to give a common understanding of the term semantics as it is used in semantic web. This paper dealt with the general idea of semantics visualization. First a short introduction to semantic formalisms is given followed by a general definition. Subsequently approaches and techniques of existing semantics visualizations are presented, where-as a new classification is introduced to describe the techniques. The article concludes with future challenges in semantics visualization focusing on users, data and tasks.

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1. Introduction

Semantic technologies provide new ways for accessing data and acquiring knowledge. The underlying structures allow finding information easier, gathering meanings and associations of the data entities and associating the data to users' knowledge. Especially graphical representations of the semantically structured data play a key-role in today's research because data visualization in conformity with domain professionals understanding is critical for decision-making support tasks. Semantic data provide various benefits for information visualization. The semantic technologies are not in focus of this paper the review of the research is implemented on a higher level of abstraction. The goal is to give a common understanding of the terms semantics and semantics visualization.

2. Foundations of semantics

Semantics is used heterogeneously in various disciplines, e.g. linguistic, logic, and computer science including programming languages and semantic web[1]. The origin of the term "semantics" lies in semiotics, the science of studying signs. Semiotics is closely related to linguistic and investigates the abstraction, meaning, and rules of languages [1,2]. Beside the use of the sign studies of semiotics in linguistics, it is a common instrument in logics for describing rules and meanings [1,2,3]. An early and common definition of semantics in relation to semiotics was proposed by Carnap. The definition of Carnap gives not only a linguistic view on semiotics and semantics. It involves the aspect of logic too. He outlined that semantics is just the relation between expressions and designate [2]. With other words, semantics is defined by Carnap as the not user influenced meaning or meanings of expressions. In terms of linguistic these expressions (syntax) can occur as, e.g. words and consists of a logical structure.

Likewise to semiotics, where a sign invokes a concept (identifying an abstract or concrete thing in the world), semantics is used to interpret a data fragment's potential usage [4]. Representing this data semantics as explicit metadata is the core of research in context of semantic web [5]. The research focuses on supporting data re-usability, machine-readability, inference mechanisms and semantic interoperability[6]. Therewith the term semantic in semantic web represents a formalized meaning in form of metadata of data and data entities [1,3,5,6].

3. Introduction to semantic formalisms

Obrst introduced a continuous classification of semantics in context of ontologies with the poles of "weak semantics" to "strong semantics" [7]. He characterized the strength of semantics with its expressiveness of meaning [7]. This classification starts with relational models, which provide taxonomy as sub-classification-of relationships and continues with more meaning in form of thesauri in Entity-Relationship (ER) models to conceptual models. The higher level includes formalized knowledge in form of logical theory, which is characterized by transitivity of properties and disjoints "sub-class-of" relationships. Examples for this class may be the Unified Modeling Language (UML), the successor language DAML+OIL, OWL, and Description Logic (DL) [7]. More focused classification was proposed by Geroimenko in context of semantic web visualizations [8]. He classified XML-schema as primitive ontologies and the lowest level of formalization of information, whereas the components of semantic web, e.g. URI, XML, XML- namespaces are premised for the formalization. Another classification was proposed by Uschold and Gruninger they differentiate between "kinds" of ontologies in terms of their formalization degree and arrange them on a continuum [9]. With moving along their continuum the amount of specified meaning and the formalization degree increases by reducing the ambiguity [9].

Guarino et al. applied this model and revised it slightly in order to express the significance of logic in ontologies [4]. Their revised model uses for the most formalized category the abstracted term of Logical languages. Further they classify the strict subsets of first-order logic into the family of DL, e.g. OWL-DL and logic programming, e.g. F-Logic [4].

There exist a variety of further classifications of semantic formalisms and ontologies respectively [10,11]. Further classifications investigate in particular the ”heavyweight” ontologies [6,11]. Heavyweight ontologies or semantic formalisms provide more restrictions on domain semantics by adding formal axioms, functions, rules, and procedures in contrast to lightweight formal semantics.

The introduced classifications outline that the spectrum of semantics may start with less meaning of terms [4,9] to the formalization of knowledge by using higher-order logics. There is a continuous spectrum of formalization, whereas the formalization is the conceptualization of knowledge as proposed by Gruber [12]. In this context various languages for describing ontologies arose that specify a conceptualization in a more or less formal way and provide a meaning to data or information entities.

4. Definition of semantics visualization

Semantics provide formalized knowledge of a certain domain. For visualizing semantics, the aspect of human interaction with semantics plays an important role. Information seeking or search may have various steps or involve different activities as exploratory search models shows [13,14]. The construction of knowledge can be actively supported by exploration and discovery of the information space [13,14,15,16]. Information visualization is predestinated and suitable for exploration, e.g. simulation tasks, whereas the aspect of information seeking is not supported actively [14]. Even in context of semantics, visualization techniques commonly aim at visualizing the formalized structure of the conceptualized knowledge domain and refer more to ontologies. In this context commonly the term ontology visualization is used [17]. Ontology visualizations aim at visualizing the semantic relationships between concepts or instances within formal domains of knowledge. Some of these technologies provided further functionalities for editing or annotation. User-centered approaches for solving information seeking tasks by exploring the information space, retrieving overview and detailed views, and enabling the ”investigation” of the domain knowledge as proposed by Bloom [15] or Marchionini [13] were commonly not the focus of research and development.

Semantics in a lower formalization represents meaning of terms, resources, or entities. Thus information visualization is defined by Card et al. [18] as ”The use of computer-supported, interactive, visual representations of abstract data to amplify cognition” [18]. The relations of semantics are commonly designed as triples, e.g. as a subject, predicate, and object in RDF. But if we take a look at the reference model of information visualization [18], the first transformation step is the data transformation to data tables with a set of relations. And if it is assumed that a table can be defined as triple of row, value, and column, then human can retrieve meaning from this structured table. Thus in information visualization human and his informational perception plays an important role [19,20].

With this definition of semantics, ontology visualizations are a subset of semantics visualization, which includes the visualization of any meaningful data relation. The main goal is to provide user-centered interactive graphical representations for solving visual tasks with semantics. Therewith semantics visualization bridges the three dimensional gap between users, tasks and data. Based on the criteria introduced above semantics visualizations can be defined as:

- Semantics visualizations are computer-aided interactive presentations for effective exploratory search, knowledge domain understanding, and decision making based on semantics, whereas:
  a) Semantics is defined as data with meaningful relations of at least two information or data entities, to provide in best case a disambiguated meaning,
  b) Exploratory search is defined by Bloom [15] and Marchionini [13,14] and includes the activities of Lookup, Learn, and Investigate with the various sub- activities, e.g. analyze, synthesize, and compare.

The semantics visualizations support both a top-down approach, as proposed by Shneiderman visual information seeking mantra [21] and a bottom-up approach: from detailed-view to the abstract semantic relations of a knowledge domain.

5. Approaches for visualizing semantics

Current approaches of visualizing semantic information aim at presenting different aspects of semantic structure and attributes. As described in the previous section, the semantics formalism may contain various levels of information. The formal structure of semantics allows a distinguished visualization of concept-relationship, entity-relationships or the visualization of semantic properties.

Existing approaches utilize various graphical representation techniques from visual computing, visual analytics and information visualization. According to the visualized aspect of the semantic data the existing approaches for visualizing semantic data are categorized into:

- Hierarchical semantics visualization
- Relational semantics visualizations
- Entity-based semantics visualization

Hierarchical semantics visualizations are focused on visualizing hierarchical aspects of semantic information, e.g. the concept taxonomies or inheritance structures. Relational semantics visualizations use the meaningful relations of semantics to represent correlations between semantic entities. The property-based semantics visualizations make use of several features of semantic attributes, e.g. time-stamps, geo-tags or implicit information about the semantic. These categories are not mutually exclusive. Further some existing approaches for visualizing semantic information will be presented.

5.1. Hierarchical semantics visualization

Hierarchical semantics tree-based visualization is used for Skopje bicycles inter-modality simulation results presentation (see Fig. 1).

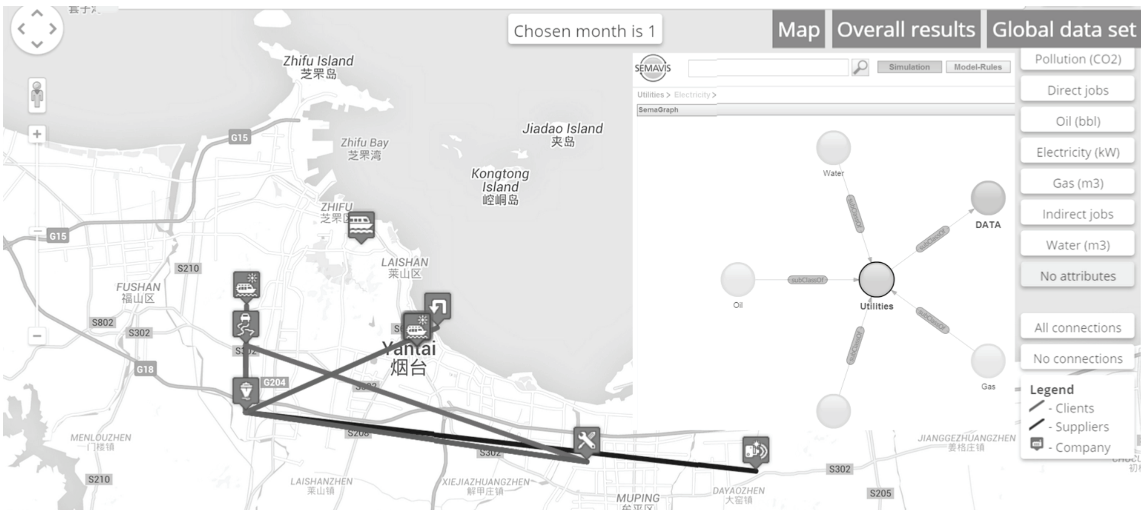

Fig. 1. Skopje bicycles inter-modality simulation results visualization.

Hierarchies provide the opportunity to categorize domain-specific resources in inherited concepts and allow a topic-related access to the modeled domain knowledge.

Already light-weight semantics may contain hierarchical structures and provide a comprehensible view on the knowledge. Users are able to locate a search topic in the hierarchical structure and get thereby a starting point to abstract his query by querying the parent node or precise his search by choosing a sub-node.

Vice versa the overview on hierarchical structures provides the ability to find the starting point and locate or verbalize the knowledge-resource of interest. Hierarchies can be visualized in various ways: nested [22], treemap [23,24], indented [25], or top-down and left-right structures intuitively as hierarchies.

The hierarchical view on data with different perspectives enables to gain an insight on an entire knowledge domain or a relevant sub-part. Although, many systems and approaches [26,27,28,29] provide sufficient visualization techniques for hierarchical structures, the main task of semantics, namely providing an efficient human information acquisition by exploratory search and learning is not actively supported by the introduced systems. A bottom-approach is missing in the hierarchical visualization of semantics at all.

Skopje bicycle inter-modality simulator [42] is based on agent-based modeling in Symphony Repast environment and is created to find useable solution for bicycle station and track building location in the city of Skopje. To encourage the intermodal transport, the citizens are also involved in the collection of ideas on how bicycle inter-modality can be fostered. The citizen participation is supported including the use of a simulation tool and ticketing. Visualization is based on SemaVis [43] tool application.

5.2. Relational semantics visualization

Relational visualizations aim to visualize the semantic context of information and provide navigation and browsing abilities within an information space. Common approaches for visualizing semantic relationships are usually based on graph- based visualization techniques and provide navigation through the nodes and semantic neighborhoods.

Relational visualizations play an essential role in visualizing semantics. The natural structure of semantics is predestinated for visualizing semantic relationships and thereby a structural view on the domain of given knowledge [30,31,32,33,34]. A relational view on semantics is important, due to the ability to get an overview of the entire knowledge space or see the relations of resources to interact and browse for a knowledge path. However, the requirements of exploratory search cannot be fulfilled with relational visualizations only. It is far more necessary to provide multiple visualization views on the same or on different information spaces.

Relations based semantic visualization is shown in Yantai economic development simulation results presentation use case [44] (see Fig. 2).

Yantai is located in the middle of Shandong province and includes five districts, one county and one state-level economic and technological development zone. The total population is 6.47 million, but the total area is 13.7 thousand square meters. Around 1.8 million of inhabitants live in the city.

Yantai has a complete infrastructure. There are 9 ports. The Yantai Airport is the national top grade opening airport. Railway, expressway and telecommunications are convenient. The reserves of minerals like gold, magnesium, molybdenum and talcum rank among top five in the country. The region has the biggest gold reserves and production in China. The coastal continental shelf is rich in petroleum and natural gas. Yantai has seven backbone industries: mechanic manufacturing, textile, food, gold processing, e-information, bio-pharmacy and new materials. There are 420 manufacturers of autos and auto parts, 19 shipbuilding and related businesses, 337 modern chemical businesses, 554 food industry related businesses. Yantai has forged a trade partnership with more than 200 countries and regions around the world. In 2011, the total imports and exports of the city reached 45.3 billion US dollars.

However the resources for developing the industry and possibilities of environmental regeneration are limited. Therefore resources must be spent reasonably. The municipality is interested in the promotion of industries and enterprises bringing highest incomes to the city budget and giving jobs to the local inhabitants, at the same time ensuring an acceptable impact on the environment.

The main objective was the development of simulation tools that offer the administration of Yantai the possibility to study the current situation of these industries in order to make decisions about a company's upgrade or closure in order to decrease resource consumption and impact on the environment. The Yantai urban economic development assessment simulator is agent-based and specifies industry evolution regarding energies consumption, pollution and other indicators, in order to decide which companies should be closed to reduce resource consumption.

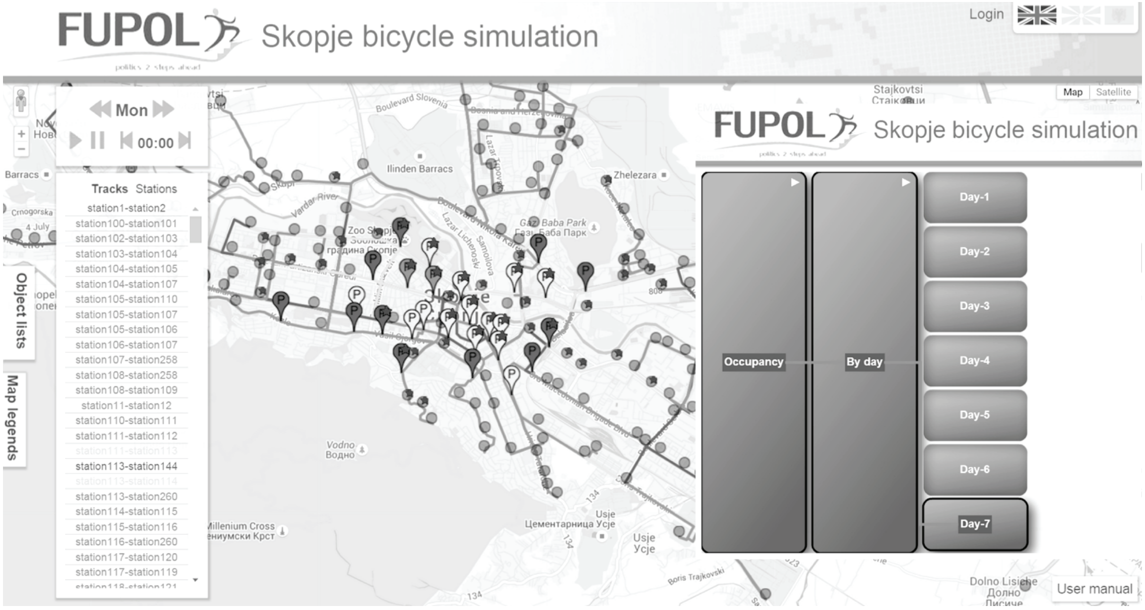

Fig. 2. Yantai region economic development assessment simulation results visualization.

Simulation results visualization allows recognize relationships among data. Visualization is SemaVis based.

5.3. Entity-based semantics visualization

Entity-based semantics visualizations focus on the queried set of entities and provide either an exploratory approach by navigating through a visual structure or retrieving information by a specifically defined query. This class of semantics visualization is designed for search tasks. The result visualization as a set of entities is the main focus. Further approaches for graphically representing the relationships or hierarchies are secondary and are commonly used to support the search process.

Entity-based visualizations aim at giving a kind of interactive ”picture” on resources, documents, text [35] or other kinds of entities that builds the content of the underlying visualized data. The entity-based visualizations are aimed at providing a kind of investigation of the resources themselves [36,37]. They mapped the entity to certain contextual information, e.g. time, location, or semantic similarity. The idea of providing contextual information for certain semantic entities and support the entire search process is promising, but not yet solved.

6. Challenges in semantics visualization

6.1. User-centered approach establishing

Information visualization techniques provide approaches to bridge the gap between data and users for solving heterogeneous tasks. The heterogeneity of users’ pre-knowledge, expertise, skills and preferences is rarely investigated in previous research.

Semantic data structures provide a suitable foundation to model users' based on their interaction with data and their behavior with visualizations. With the given structure the triangle of data, user and task can be modeled adequately. This leads to adaptation the visualizations to the given task, user and the underlying data. A main future challenge is incorporation of machine-learning algorithms to use the semantic data structure.

6.2. Semantics enrichment for visualization

Usually, domain definitions and the semantic schemas respectively are manually built by domain experts. The resulting semantic structures including sophisticated taxonomies, conceptualizations, classifications and relational schemas are not designed to enable a human centered access. They are more focused on the provision of a framework for enriching resources with machine-readable meaning and aim at the establishment of interoperability between heterogeneous systems. Here methods from visual analytics can be applied to visualize more than entity relationships and semantic conceptualizations. Semantic analytical visualizations would provide furthermore a comprehensible visualization on quantitative attributes of the semantic data. Another possibility to extend the semantic space of semantics visualizations may be the exploitation of usage behavior that directly reflects the information need for a specific search intention [38,39]. Regarding the semantics enrichment the automatic inference activities also can be applied. The automatic reasoning and inference techniques often need a human validation, if facts are missing in the modeled structure. Here semantics visualization may bring essential advantages to bridge the gap between human and a strict formalism. With the upcoming ideas of semantic web and distributed and shared semantic data, the process evolved to reuse existing formal semantics in further domains. In particular a number of definitions for ontology state the notion "shared conceptualization" [10,40]. This reflects that ontology captures consensual knowledge developed and accepted by a group [40]. A future challenge may be to use semantics visualization for understanding the implications, benefits and drawbacks of a given shared conceptualization.

6.3. Process-driven semantics visualization

Semantics visualizations enable working with massive data to assure the overview on the complex structure. An overview visualization of huge amount of linked data may lead to get lost in data space. The high structuring and interlinking of data may drive the users' attention to non-important data aspects. Here formal definitions of visual information tasks would help to ensure a guided interaction through the complex structure of data. Process-oriented visualizations, which use various influence factors for guiding the user through the visualization steps, may help to reduce the complexity of the given representation. In combination of automatic role, activity and task recognition, the functionalities and the complexity of the visualization could be adapted. Approaches like Guidance and Wizards are appropriate to be used in complex analysis and decision making tasks [41].

7. Conclusion

This article introduces on the general idea of semantics visualization with a definition of the fundamentals. The definitions can be enhanced with the rising technologies and formalisms in the area of semantic technologies and represents an instantaneous definitions based on existing technologies. The further challenges consider the three main points of visualizations: user, data and task. Semantic data provide a good foundation to develop adaptive semantics visualizations. Semantics enrichment allows identifying, extracting, and presenting the relevant data semantics. Further the tasks can be subdivided to processes and sub-processes, where process-oriented visualization may help to solve complex tasks. Further orientation must be aimed to use of open source solutions to ensure wider audience and especially oriented for deploying on the Future Internet. It means that visualization software must be more or less SoA and web-services based. Such an open architecture makes more easy integration of visualization environments in different tasks.

One of application areas of semantic visualization is presentation of simulation results, which must fit to domain professionals understanding and perception. Challenging is semantics use in virtual and augmented reality applications which are used to achieve appropriate level of immersivity of visualization to be closer to perception of decision makers.

The next item in future research is enforced use of semantic search because validation of gathered raw data must be automated which is not possible by using classic interviewing. In addition interviewing asks for longer time, it is expensive and has low credibility.

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References

1. Hitzler P, Krotzsch M, Rudolph S, Sure Y. *Semantic Web*. Grundlagen: Semantic Web Foundations, Springer; 2008.
2. Carnap R. Empiricism, Semantics and Ontology. *Revue Internationale de Philosophie*1950; **4:**20-40.
3. Carnap R. *Introduction to Semantics*. Volume I. Cambridge, Massachusetts: Harvard University Press; 1948.
4. Staab S, Studer R. *Handbook of Ontologies*. Springer; 2009.
5. Guarino N, Oberle D, Staab S. *What is an Ontology?*. In *Handbook on ontologies*. Springer Berlin Heidelberg; 2009. p. 1–17.
6. Antoniou G, Groth P, Van Harmelen F, Hoekstra R. *A Semantic Web Primer*. 3rd ed. Cambridge, Massachusetts: Cooperative Information Systems. The MIT Press; 2012.
7. Beek W, Schlobach S, Van Harmelen F. Rough Set Semantics for Identity on the Web. In: Hendler J, Hitzler P, Janowicz K, eds. *AAAI Fall Symposium Semantics for Big Data*. Association for the Advancement of Artificial Intelligence; 2103. p. 10-13.
8. Gomez-Perez A, Fernandez-Lopez M, Corcho O. *Ontological Engineering: with examples from the areas of Knowledge Management, e-Commerce and the Semantic Web*. Springer Science & Business Media; 2006.
9. Obrst L. Ontologies for semantically interoperable systems. In: *Proceedings of the twelfth international conference on Information and knowledge management*. CIKM ’03, New York, NY, USA, ACM; 2003. pp. 366–369.
10. Geroimenko V. The concept and architecture of the semantic web. In: Geroimenko V, Chen C, editors. *Visualizing the Semantic Web – XML-based Internet and Information Visualization*. Springer; 2006.
11. Uschold M, Gruninger M. Ontologies and semantics for seamless connectivity. *ACM SIGMod Record* 2004; **33**(4): 58–64.
12. Guarino N. Understanding, building and using ontologies. *Int. J. Hum.-Comput. Stud*. 1997; **46**: 293–310.
13. Gomez-Perez A, Fernandez-Lopez M, Corcho O. *Ontological Engineering: with examples from the areas of Knowledge Management, e-Commerce and the Semantic Web*. 3rd ed. Springer; 2010.
14. Gruber TR. A translation approach to portable ontology specifications. *Knowledge Acquisition* 1993; **5**:199 – 220.
15. Marchionini G. Exploratory search: from finding to understanding. *Communications ACM* 2006; **49**: 41–46.
16. White RW, Roth RA. Exploratory Search: Beyond the Query-Response Paradigm. In: Marchionini G., ed. *Volume 1 of Synthesis Lectures on Information Concepts, Retrieval, and Services*. Morgan & Claypool Publishers; 2009.
17. Bloom BS. *Taxonomy of Educational Objectives*. New York: David McKay Co. Inc.; 1956.
18. Bruner JS. The act of discovery. *Harvard Educational Review* 1961; **31**: 21–32.
19. Katifori A, Halatsis C, Lepouras G, Vassilakis C, Giannopoulou E. Ontology visualization methods - a survey. *ACM Comput. Surv*. 2007; **39(4)**: 10.
20. Card SK, Mackinlay JD, Shneiderman B. *Readings in Information Visualization: Using Vision to Think*. 1st. ed. Morgan Kaufmann; 1999.
21. Treisman AM, Gelade G. A feature-integration theory of attention. *Cognitive Psychology* 1980; **12** (1): 97–136.
22. Wolfe JM. Guided search 4.0: Current progress with a model of visual search. In Gray W., ed., *Integrated Models of Cognitive Systems*, 2007; pp. 99-119. New York: Oxford. Available on: http://search.bwh.harvard.edu/new/pubs/GS4chapInGray07.pdf
23. Gray W. *Integrated Models of Cognitive Systems*. Oxford University Press; 2007.
24. Shneiderman B. The eyes have it: A task by data type taxonomy for information visualizations. In *Proceedings IEEE Symposium on Visual Languages*; 1996; pp. 336–343.
25. Storey M, Musen M, Silva J, Best C, Ernst N, Fergerson R, Noy N. Interactive visualization to enhance ontology authoring and knowledge acquisition in protege. In: *Workshop on Interactive Tools for Knowledge Capture*; 2001; p.93.
26. Baehrecke E, Dang N, Babaria K, Shneiderman B. Visualization and analysis of microarray and gene ontology data with treemaps. *BMC Bioinformatics*; **5**; 2004. p. 1–12.
27. Hauer T, Rogulin D, Zillner S, Branson A, Shamdasani J, Tsymbal A, Huber M, Solomonides T, McClatchey R. An Architecture for

Semantic Navigation and Reasoning with Patient Data - Experiences of the Health-e-Child Project. In: *The Semantic Web,* Lecture Notes in Computer Science 2008; **5318**; p. 737-750.

28. Zillner S, Hauer T, Rogulin D, Tsymbal A, Huber M, Solomonides T. Semantic visualization of patient information. In: CBMS '08. 21st IEEE International Symposium. *Computer-Based Medical Systems*; 2008. p. 296–301.
29. Noy N, Fergerson R, Musen M. The knowledge model of protege-2000: Combining interoperability and flexibility. In: Dieng R, Corby O, eds. *Knowledge Engineering and Knowledge Management Methods, Models, and Tools. Lecture Notes in Computer Science* 2000; **1937**; p. 17–32.
30. Kriglstein S, Wallner G. Knoocks - a visualization approach for owl lite ontologies. In: *2010 IEEE International Conference Complex, Intelligent and Software Intensive Systems (CISIS),*2010. p. 950–955.
31. Fu B, Grammel L, Storey MAD. Biomixer: A web-based collaborative ontology visualization tool. In: *ICBO'12*; 2012.
32. Buntain C. 3d ontology visualization in semantic search. In: *Proceedings of the 46th Annual Southeast Regional Conference*. New York: ACM; 2008. p. 204–208.
33. Motta E, Mulholland P, Peroni S, d'Aquin M, Gomez-Perez JM, Mendez V, Zablith F. A novel approach to visualizing and navigating ontologies. In: Aroyo L, Welty C, Alani H, Taylor J, Bernstein A, Kagal L, Noy N, Blomqvist E, eds. *The Semantic Web at ISWC 2011. Lecture Notes in Computer Science* 2011; **7031;** pp. 470–486.
34. Lin H, Rushing JA, Berendes T, Stein C, Graves SJ. Visualizations for the spyglass ontology-based information analysis and retrieval system. In: Cunningham HC, Ruth P, Kraft NA, eds. *ACM Southeast Regional Conference*. ACM; **38**; 2010.
35. Sen S, Charlton H, Kerwin R, Lim J, Maus B, Miller N, Naminski MR, Schneeman A, Tran A, Nunes E, Sparling EI. Macademia: semantic visualization of research interests. In: *Proceedings of the 16th international conference on Intelligent user interfaces. IUI '11*. New York: ACM; 2011. p. 457–458.
36. Kboubi F, Chaibi AH, Ahmed MB. Semantic visualization and navigation in textual corpus. *International Journal of Information Sciences and Techniques* 2012; **2**(1): 53-63
37. Bertault F, Feng W, Krastins A, Yi L, Verza A. Shining light on complex RDF data through advanced data visualization. In: *Proceedings of the 2011 joint international conference on The Semantic Web*. JIST'11. Berlin Heidelberg: Springer-Verlag; 2012. p. 411–416.
38. Panchenko A, Romanov P, Morozova O, Naets H, Philippovich A, Romanov A, Fairon C. Serelex: Search and visualization of semantically related words. In: Serdyukov P, Braslavski P, Kuznetsov S, Kamps J, Roger S, Agichtein E, Segalovich I, Yilmaz E, eds. *Advances in Information Retrieval, Lecture Notes in Computer Science* 2013; **7814**; pp. 837–840.
39. Wu Y, Provan T, Wei F, Liu S, Ma KL. Semantic-preserving word clouds by seam carving. In: *Proceedings of the 13th Eurographics. IEEE - VGTC conference on Visualization*. EuroVis'11, Aire-la-Ville, Switzerland: Eurographics Association; 2011; pp. 741–750.
40. Chou JK, Yang CK. Papervis: literature review made easy. In: *Proceedings of the 13th Eurographics. IEEE - VGTC conference on Visualization*. EuroVis'11, Aire-la-Ville, Switzerland: Eurographics Association; 2011; pp. 721–730.
41. Schenk S, Saathoff C, Staab S, Scherp A. Semaplorer-interactive semantic exploration of data and media based on a federated cloud infrastructure. *Web Semantics: Science, Services and Agents on the World Wide Web* 2009; **7**(4): 298–304.
42. Ginters, E., Aizstrauts, A., Dreija, G., Ablazevica, M., Stepucev, S., Sakne, I., Baltruks, M., Piera Eroles, M.-A., Buil, R., Gusev, M., Velkoski, G. Skopje Bicycle Inter-modality Simulator – e-involvement through simulation and ticketing. In *Proceedings of 26th European Modelling & Simulation Symposium (EMSS 2014).* Bordeaux, France, pp. 557-563.
43. Nazemi K, Breyer M, Burkhardt D, Stab C, Kohlhammer J. SemaVis - A New Approach for Visualizing Semantic Information. In Wahlster W, Grallert H.-J, Wess S, Friedrich H, Widenka Th. Eds. *Towards the Internet of Services: The Theseus Program*, Springer; 2014; pp.191-202.
44. Ginters, E., Aizstrauts, A., Sakne, I., Piera Eroles, M.-A., Buil, R., Wang, B. . The Yantai Urban Economic Development Assessment Simulator. In Rocha, A., Correia, A.-M., Costanzo, S., Reis, L.-P. eds. *New Contributions in Information Systems and Technologies. Advances in Intelligent Systems and Computing* 2015; **353**, pp. 629-639.