Annotated Bibliography
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This document gives an overview of my research and publications. I have (had) a broad interest in computer science research and education and this is reflected in my publications. Most of my current work is on ontology engineering with focus on ontology development (introduction of Section 1), ontology alignment (Section 1.1) and ontology completion and debugging (Section 1.2). My aim is to develop methods based on a strong theoretical background that are then implemented in tools that can be used by knowledge engineers and domain experts in different fields such as materials science, life sciences and security. Further, I currently work on ontology-based database integration (Section 1.5), sports analytics (Section 6), and on education (Section 7).

1   Semantic Web, databases and ontologies

Researchers in various areas, e.g. medicine, agriculture and environmental sciences, use data sources and tools to answer different research questions or to solve various tasks, for instance, in drug discovery or in research on the influence of environmental factors on human health and diseases. Due to the recent explosion of the amount of on-line accessible data and tools, finding the relevant sources and retrieving the relevant information is not an easy task. Further, often information from different sources needs to be integrated. The vision of a Semantic Web [Lam14] alleviates these difficulties [Lam05]. A key technology for the Semantic Web are ontologies. Ontologies define the basic terms and relations comprising the vocabulary of a topic area, as well as the rules for combining terms and relations to define extensions to the vocabulary. They are used for communication between people and organizations by providing a common terminology over a domain. They provide the basis for interoperability between systems. They can be used for making the content in information sources explicit and serve as an index to a repository of information. Further, they can also be used as a basis for integration of information sources and as a query model for

information sources. An overview of the use of ontologies and ontology tools in bioinformatics and materials design can be found in the book chapters [Lam04, LTJS07] and [LADL18], respectively. The Semantic Web can be seen as an extension of the current Web in which information is given a well-defined meaning by annotating Web content with ontology terms.

We have looked at a number of issues in relation to the Semantic Web and developed tools, mainly within the BioTRIFU[1], SAMBO[2], KitAMO[3], KitEGA[4], RepOSE[5], and AlignmentCubes[6] projects.

Our tools have been **used in different domains** such as

- *materials science*: Data-driven computational materials design (DCMD) project at the Swedish e-Science Research Centre (SeRC)[7]: extension of NanoParticle Ontology and eNanoMapper [LAL19j], development of the Materials Design Ontology[8] (MDO) [LAL20];

- *animal health surveillance*: Animal Health Surveillance Ontology project: work on development of Animal Health Surveillance Ontology[9] (AHSO) [DFHLLBR19];

- *toxicology*: alignment of ToxOntology and MeSH for the Swedish National Food Agency [ILHL12];

- *crime investigation*: for the EU FP7 project VALCRI (Visual analytics for sense-making in criminal intelligence analysis, winner of the 2022 Security Innovation Award - Commercialisation of the European Commission) and the H2020 EU project SPIRIT (Scalable privacy preserving intelligence analysis for resolving identities);

- *sports*: development of an ontology for ice hockey [KLCCL19].

- *circular economy*: an overview of ontologies [LALLBL23].

Some of our work in this area was part of the EU Network of Excellence REWERSE (REasoning on the WEb with Rules and SEmantics) and

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[1] http://www.ida.liu.se/~patla00/research/BioTRIFU/
[2] http://www.ida.liu.se/~patla00/research/SAMBO/
[3] http://www.ida.liu.se/~patla00/research/KitAMO/
[4] http://www.ida.liu.se/~patla00/research/KitEGA/
[5] http://www.ida.liu.se/~patla00/research/RepOSE/
[6] http://www.ida.liu.se/~patla00/research/AlignmentCubes/
[7] https://e-science.se/
[8] https://w3id.org/mdo/1.0/
[9] http://bioportal.bioontology.org/ontologies/AHSO

in particular of the working group on a Semantic Web for bioinformatics (e.g. [Ba04, REWERSE-A2-D1, REWERSE-A2-D2, REWERSE-A2-D3, REWERSE-A2-D4]). Most of our recent work has been in the area of ontology engineering where we focused on ontology alignment[10], ontology completion[11], ontology debugging and ontology evolution.

Although ontology alignment, ontology completion, and ontology debugging have been studied in separate sub-fields of ontology engineering, I proposed an abductive framework for completion and debugging of ontologies and ontology networks in [Lam23] that covers these areas. Using the framework the state-of-the-art approaches are compared and challenges for future work are proposed.

1.1 Ontology alignment and merging

Within the SAMBO (*S*ystem for *A*ligning and *M*erging *B*iomedical *O*ntologies) project we have developed a **framework** for aligning and merging ontologies based on the computation of similarity values between terms in the source ontologies [LT05b]. Most current alignment systems can be seen as instances of our framework. We also showed how the framework can be used to experiment with different alignment strategies and their combinations. This is a first step towards defining a framework that can be used for comparative evaluations of alignment strategies. Further, we developed an alignment and merging **system**, SAMBO, based on this framework [LEMT03, LT05a, LT05b, LT06a, TJLAS06, WTWLS06, LTX08]. SAMBO uses linguistic strategies, structure-based strategies, strategies based on auxiliary knowledge and learning-based strategies. We have also evaluated existing tools (for ontology development [LHP03] and ontology alignment and merging [LE03, LT05a, LT06a]) for their use in bioinformatics as well as different strategies for alignment with a focus on biomedical ontologies. The evaluations in [LHP03, LE03] are to our knowledge the first evaluations of ontology tools using bio-ontologies. These evaluations were also among the largest evaluations of ontology tools (see survey in [KW04]). In these evaluations SAMBO shows good results regarding the quality of the alignment and often allows the task to be performed faster than the other tools. In 2007 and 2008 we participated in the Ontology Alignment Evaluation Initiative (OAEI[12]) where we focused on the anatomy task. SAMBO performed well in 2007 and won the track in 2008. SAMBO's successor, SAMBOdtf,

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[10]An overview of our work until 2012 is given in [LK12].
[11]An overview of our work until 2012 is given in [LID12].
[12]http://oaei.ontologymatching.org/

obtained second place in 2008 [TL07b, LTL08, LLT09d]. SAMBO is also discussed as one of the main ontology alignment systems in [SE13].

Based on our experience using and evaluating SAMBO, we developed a framework for **evaluating ontology alignment strategies** and their combinations [LT07a]. We also implemented a tool, KitAMO (Tool*Kit* for *A*ligning and *M*erging *O*ntologies), that is based on the framework and supports the study, evaluation and comparison of alignment strategies and their combinations based on their performance and the quality of their alignments on test cases. It also provides support for the analysis of the evaluation results. An overview of SAMBO and KitAMO is presented in [LT08]. In [IBPL17a, IBPL17b] we developed AlignmentCubes, an interactive environment for exploring and visualizing multiple alignments. One of the use cases is evaluation of ontology alignment strategies. The techniques are complementary to those of KitAMO. Alignment Cubes has been made availabe to the organizers of the OAEI and is currently being integrated in the MELT (Matching EvaLuation Toolkit) framework of the University of Mannheim.

We investigated several **techniques and methods** for ontology alignment. In [CTL06] we proposed a novel filtering mechanism to improve the alignment results of the strategies.

We investigated whether the use of partial reference alignments , i.e. part of the solution is given, could improve the results of alignment systems. Our study [LL09] was the first in its kind.

Further, we have developed a method that provides recommendations on alignment strategies for a given alignment problem. The method is based on the evaluation of the different available alignment strategies on several small selected pieces from the ontologies, and uses the evaluation results to provide recommendations. In [TL07a] we give the basic steps of the method, and then illustrate and discuss the method in the setting of an alignment problem with two well-known biomedical ontologies.

In [CDCL15] we investigated the use of clustering techniques to reduce the search space for ontology alignment algorithms.

In [Lam11, LK13, LK17] we introduced a framework for **session-based ontology alignment**. In contrast to the case of small ontologies, for large ontologies the computation of mapping suggestions can take a long time and therefore, we would like to be able to start the validation before every mapping suggestion is computed. Further, it is clear that for large ontologies, in general, there are too many mapping suggestions to validate in one time. Therefore, we want a system that allows to partially validate the mapping suggestions and resume the validation later. However, whenever validation decisions have been made, they increase our knowledge about the ontologies

and mappings and this knowledge can be used to provide better mapping suggestions. The proposed framework deals with this by introducing computation, validation and recommendation sessions. A session-based version of SAMBO was implemented that incorporated much of our earlier work.

In [IL14, ILA15] we proposed requirements for **user support** for large-scale ontology alignment and presented a literature study as well as an evaluation of the user interfaces of state-of-the-art systems with respect to these requirements. In [DILFJP16] we focused on system requirements for supporting the user validation step. The requirements were updated and a larger literature study and experiments covering several years of the OAEI Interactive track were presented in [LDFIJLP19]. A proposal for reporting on empirical studies in the Semantic Web is presented in [PILL18] and was used as a major inspiration for guidelines for the ISWC[13] reproducibility track[14] which started in 2020.

Since 2013, our group organizes tracks of the **Ontology Alignment Evaluation Initiative (OAEI)** ([OAEI13, OAEI14, OAEI15, OAEI16, OAEI17, OAEI17.5, OAEI18, OAEI19, OAEI20, OAEI21, OAEI22] and [DILL17]). Since 2018 I am a steering committee member of the OAEI.

1.2 Ontology completion and debugging

Developing ontologies is not an easy task and often the resulting ontologies are not consistent nor complete. Such ontologies, although often useful, lead to problems when used in semantically-enabled applications. Wrong conclusions may be derived or valid conclusions may be missed. To deal with this problem we may want to repair the ontologies.

In [LLT09a, LLT09b, LLT09c] we presented a method and system for completing given missing is-a structure of taxonomies. This study was the first in its kind. In [LiL10a, LiL10b] the methods were extended for networked taxonomies. Further, in [LL11a, LL11b] we proposed an approach to deal with both missing and wrong is-a relations in networked taxonomies. In [IL12] we presented a system for debugging and completing dealing with missing and wrong is-a relations as well as missing and wrong mappings for networked taxonomies and it was used for debugging and completing a taxonomy for the Swedish National Food Agency [ILHL12]. This was extended to also deal with missing and wrong mappings [LI13]. We further extended this work to deal with ontologies represented in more expressive

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[13]International Semantic Web Conference, the main conference in the Semantic Web area.

[14]https://repro.semanticweb.org/ISWC2020/replicability-assessment-guide/

knowledge representation languages: the $\mathcal{EL}$ family [DLW14a, DLW14b, WDL14, LWD15] and $\mathcal{ALC}$ [LDI12]. In [DLL21] we described a plugin for Protégé that helps users to add new concepts to an ontology and introduces a completion step in that stage. The plugin is based on the algorithm for $\mathcal{EL}$ explained in [LWD15]. In [LWDI13] we formalized the repairing of missing is-a relations as a new kind of abduction problem. In [LL21] we introduced a combination of debugging, completion and axiom weakening to preserve as much knowledge as possible when repairing taxonomies.

Further, we integrated ontology alignment and ontology completion and debugging for taxonomies in [IL13a, IL13b, IL13c]. In [DLB15] we showed the advantages of integrating ontology debugging, completion and alignment into an ontology development methodology.

In [LL23a] we developed a framework for removing wrong axioms and mitigating the effect of thereby also removing correct knowledge by weakening and completing. We showed that there exist different ways of combining these operations and showed that current work only considered one of many possible combinations. A system based on the framework was presented in [LL23b].

In [LAL19, LAL19j] we developed a method for extending ontologies using topic models and formal topical concept analysis and showed an application to the nanotechnology domain. The method was used in [ALAL21a] to extend the materials design ontology proposed in [LAL20]. A tool for extending ontologies based on this method is described in [ALAL21b, ALAL23].

In 2012 we founded the International Workshop on Debugging Ontologies and Ontology Mappings - WoDOOM series and we co-chaired the three editions [LQH12, LQHP13, LQHP14]. The scope was extended in 2016 - International Workshop on Completing and Debugging the Semantic Web - CoDeS and we co-chaired that edition [PLSKHLP16].

1.3 Ontology evolution

In [LDIA16] we proposed requirements for user support and visualization for ontology evolution and presented a literature study as well as an evaluation of the user interfaces of state-of-the-art systems with respect to these requirements.

1.4 Literature search

Success in the life sciences depends on access to information in knowlegde bases and literature. Finding and extracting the relevant information de-

pends on a user's domain knowledge and the knowledge of the search technology. In [BLLKA09] we presented a system that helps users formulate queries and search the scientific literature. The system coordinates ontologies, knowledge representation, text mining and NLP techniques to generate relevant queries in response to keyword input from the user. Queries are presented in natural language, translated to formal query syntax and issued to a knowledge base of scientific literature, documents or aligned document segments.

1.5 Integration of data sources

In the BioTRIFU (*Bio- The Right Information For yoU*) project we tackled the problem of integrating biological data sources. We studied existing biological data sources regarding their content, data quality, updates, consistency, data models, semantic heterogeneity, and access and retrieval methods. Based on this we defined requirements for information integration systems in this area and discussed how existing systems conform to these requirements. We also developed the BioTRIFU system that addresses some of these requirements. In [LJ03] we proposed a base query language that contains operators that should be present in any query language for biological data sources and presented an architecture for a system supporting such a language. A first prototype was implemented [Jak05]. Further, we investigated the use of ontological information in data source integration. In [JL05] we identified the kinds of ontological knowledge that are publicly available in the field of bioinformatics and showed how these can be used for data source integration. The latter has been part of a tutorial at the 2006 Reasoning Web summer school [DJLSW06]. Some of the issues in information integration in the life sciences are also described in [LS07a] and the book chapter [LST09].

Since the early 2000s materials science has shifted towards its fourth paradigm, data-driven science. As data-driven techniques become widely used, big data challenges regarding volume, variety, variability and veracity and challenges in reproducing, sharing, and integrating data are growing at the same time. For instance, much interoperability software presently employs only syntactic interoperability in their linking software, which requires in-depth knowledge of the data content/format, severely limiting the reuse of software and data, especially outside the application domain. These problems relate to the FAIR principles introduced in 2016 which state that data should be Findable, Accessible, Interoperable, and Reusable, respectively (see, e.g. [LADL22]). In different areas research is on the way to conform

data management to these principles, including in the materials science domain. One of the recognized enablers for the principles are ontologies and ontology-based techniques. In this area we work together with the OPTIMADE[15] consortium that contains major materials database providers to introduce semantic and integrated access to materials databases. We use an ontology-based access approach where the ontology provides semantics as well as a global model for the integration. The vision of this approach is presented in [LAL20]. One of the necessary components in the approach is an ontology representing the domain knowledge in the materials databases regarding calculations. Therefore, we developed the Materials Design Ontology [LAL20, LALHAL23]. First results regarding extending this ontology using the approach in [LAL19j] are presented in [ALAL21a, LALHAL23]. Further, the approach was implemented in a proof-of-concept system using an RDF triple store (shown in [LAL20]) and another kind of implementation based on GraphQL [LALHAL23].

1.6   Representation and storage of biomedical data

In [SL05a, SL05b] we compared three proposed standards (SBML, PSI MI, BioPAX) and evaluated them with respect to their underlying models, information content and possibility for easy creation of tools. This evaluation was updated in [SJTL06] and extended towards other standards in [SHL07].

In [FSKL12] we evaluated the performance of XML databases for epidemiological queries in archetype-based electronic health records and in [FTWSKL16, SWFL17] we compared the performance for NoSQL approaches.

1.7   Similarity-based grouping of biological data

Similarity-based grouping of data entries in one or more data sources is a task underlying many different data management tasks, such as, structuring search results, removal of redundancy in databases and data integration. In [JRL06] we proposed a method for similarity-based grouping and show results from test cases. The main steps of the method are specification of grouping rules, pairwise grouping between entries, actual grouping of similar entries, and evaluation and analysis of the results. In [JL07] we presented a framework for evaluating similarity-based grouping strategies and an implemented tool, KitEGA (Tool*Kit* for *E*valuation *G*rouping *A*lgorithms), based on the framework. Users can plug in different data sources, grouping

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[15]https://www.optimade.org/

methods and classifications and the system supports the user in running the algorithms, and summarizing, analyzing and comparing the results.

2   Semantic Web and Workflows

The Semantic Web enables business-to-business in new ways. In this context, organizations need to make use of the new opportunities that the Semantic Web technology provides. However, this should be done without major requirements on the organization. To this aim we proposed in [ALS05] an agent-based model for integrating the usage of the Semantic Web (represented as Web services) into an organization's work routines (represented by Workflows). Further, we described a possible architecture for our approach, and briefly showed its feasibility with an implemented prototype. In [ALTS05] we described the central component of the model, sButler, which is a software agent that mediates between the organization and the Semantic Web. In [AALS06] we described a platform to evaluate service discovery technology (such as the sButler) in the Semantic Web.

3   Knowledge-Based Information Retrieval

Much information is stored electronically in document bases. Users retrieve information from these document bases by browsing and querying. While a large number of tools are available, not much work was done on tools that support queries involving all the characteristics of documents as well as the use of domain knowledge during the search for information. As part of our TRIFU (The Right Information For yoU) project we proposed a model for such a system [LS98, LS00]. We proposed a query language that allows for querying documents using content information, information about the logical structure of the documents as well as information about properties of the documents. Domain knowledge is taken into account during the search as well [LSJ99, LS00]. We also presented an architecture for a system supporting such a language and implemented a prototype [LS98, LS00]. In [LSÅ97] we concentrated on the structural information in the knowledge base and showed how the structural information of HTML documents can be extracted and represented automatically in a description logic for composite objects as defined in [Lam96, LP97]. This description logic was then used as internal representation language for the prototype.

4   Knowledge Representation

Most of my work in the area of knowledge representation has been concentrated in the field of description logics. Description logics are languages tailored for expressing knowledge about concepts and concept hierarchies representing the is-a relation. They are seen as core technology for the Semantic Web and are the basis for languages such as DAML+OIL and OWL. However, it is agreed upon that for many applications more complex additions such as temporal information and reasoning about the part-of relation, are needed. Further, given the fact that description logics present a clean object-centered model with a good understanding of the issues regarding types and classification, description logics provide a framework to investigate the issues which appear when we try to integrate classification and other kinds of reasoning.

4.1   Description Logics and Part-Of

In our largest project regarding description logics we extended description logics with part-of reasoning guided by applications. One of the first papers that was published in the area on work on part-of in combination with description logics was our paper [PL94]. In this paper we defined a simple description logic for composite objects and a specialized inference that allows for building new composite objects from already existing objects. The description logic allowed for representation of different kinds of part-whole relations, number and domain restrictions for part-whole relations and constraints between parts. A description logic system for composite objects was implemented, based on the CLASSIC description logic system. The framework was extended in [LP95a, LP95b] to deal with order information between parts and a restricted form of inheritance via part-of. Further, we defined a new inference that allows for finding out what is still missing, given a number of parts, to build an object of a particular kind. These extensions were motivated by a document management application [LP00]. In [LP96a, LP97] we used a description logic for composite objects to extend the description logic model for information retrieval. In our new model we can represent and query documents with respect to their contents as well as their structure. Another application is described in [LP96b, LP98] where we re-model the reaction control system of the space shuttle. We base our model on an existing implementation for which the domain knowledge base contains much hard-coded as well as implicit information about part-of and show the advantages of our model. In [LM96] we used our description logic

for composite objects to learn composite concepts. This work was extended and generalized in [LL98].

The work described above is included and some of it extended in my Ph.D. thesis [Lam96]. An extension of the work in the Ph.D. thesis together with some of the work on knowledge-based information retrieval is included in the book [Lam00].

In an overview article about part-of in object-centered systems [Ar*96] our approach is discussed as one of the main approaches in the area. Our framework has also been used by other researchers, e.g. in the CODY project at the University of Bielefeld as a basis for representation and reasoning in mechanical-object assembly tasks [CJW95, WJ96].

4.2 Description Logics and Time

Another interesting extension to description logics is the addition of temporal information. In [LR93] we defined a temporal description logic, T-LITE, which allows for representation of temporal concepts in two senses. First, objects can belong to a concept at one time and not at another time. Thus the extension of the concept is time-dependent. Further, we allow for concepts to be defined in terms of the development of objects.

4.3 Description Logics and Default Reasoning

In our lab much work has been done on extending description logics with default reasoning. In this area I have been advisor for Niclas Wahllöf. In his Licentiate thesis [Wah96] he describes a default extension to description logics that allows for computing whether it is plausible for an object to belong to a certain concept. He demonstrates the usefulness of his approach in a configuration application. The approach is also used in an application for search on the world-wide web [Wah96, LSW97, LSW98].

4.4 Temporal Reasoning for Traffic Accident Modeling

In [CSL04] we presented a temporal reasoning system for modeling and analyzing various types of traffic scenarios. The system is based on the event calculus. In the paper we described the system and provide a case study where we describe and analyze a rear-end accident scenario with and without communicating vehicles.

5   Agent Theory

Intentional agent systems are increasingly being used in a wide range of complex applications. Capabilities has been introduced into one of these systems as a software engineering mechanism to support modularity and reusability while still allowing meta-level reasoning. The paper [PL00] presented a formalization of capabilities within the framework of beliefs, goals and intentions (BDI) and indicates how capabilities can affect agent reasoning about its intentions. We defined a style of agent commitment which we refer to as a self-aware agent which allows an agent to modify its goals and intentions as its capabilities change. We also indicated which aspects of the specification of a BDI interpreter are affected by the introduction of capabilities and gave some indications of additional reasoning which could be incorporated into an agent system on the basis of both the theoretical analysis and the existing implementation. This work was extended in [PL05] where we defined different possible formalisations of capabilities within the framework of beliefs, goals and intentions. We defined an extension as well as an alternative for the framework in [PL00] and showed the consequences regarding agent commitment and BDI interpreter.

6   Sports Analytics

Sports analytics deals with using data related to sports events to obtain insights about the sport and its surroundings.

One of the important topics in sport analytics is the valuation of player performance. In [NLC18] we compare and contrast which attributes and skills best predict the success of individual players in their positions in five European top football leagues. Further, we evaluate different machine learning algorithms regarding prediction performance. A similar study regarding ice hockey and several NHL seasons is presented in [LKCL20]. In [SCL19] we extend earlier work for evaluating the performance of players in ice hockey and show relationships with traditional performance measures and salary. In [LCL18] we extend this work to the related problem of evaluating the performance of player pairs. We experiment with data from seven NHL seasons, discuss the top pairs, and present analyses and insights. New goal-based performance measures for ice hockey based on the fact that not all goals are equally important for winning a game are presented in [VSJCL21, LC22, SCL23a]. In [SSCL23] we investigate the importance of special teams in ice hockey. In [SCL23b] we identify different player roles for

ice hockey and compare player salaries and investigate in team composition.

Predicting game or season outcomes is important for clubs as well as for the betting industry. Understanding the critical factors of winning games and championships gives clubs a competitive advantage when selecting players for the team and implementing winning strategies. In [GWCL21] we tackle this probem for basketball. We work with NBA data from 10 seasons and show that our approach has a similar performance as the odds from betting companies and does better than ELO.

In [LJCL19] we present the implementation and evaluation of an imitation learning method using recurrent neural networks, which allows us to learn individual player behaviors and perform rollouts of player movements on previously unseen play sequences. The method is evaluated using a 2019 dataset from the top-tier soccer league in Sweden (Allsvenskan).

In [KLCCL19] we develop an ontology for ice hockey.

7 Computer Science Education

Yearly, our group teaches basic database courses to about two to four hundred engineering students with different backgrounds and different requirements. We also have a limited amount of teacher resources. To deal with this situation we have organized our course topics in the form of modules. A database course is then defined by a number of modules together with a mini-project. In [LS07b] we discussed this organization and give an evaluation.

In [LK98] we described a view of teaching where computer science is integrated with a number of other areas. This view is used in the Information Technology curriculum at Linköping University. The teaching philosophy in this curriculum is problem-based learning. We describe a particular term in the curriculum as an example of the approach and the integration of computer science teaching with teaching of other disciplines. In [LGK97] we described a particular theme in the term in more detail.

Within the same curriculum a term has been developed where the civil engineering students work and study together with students from the psychology and economics education programs. The aim of the term is to give the students experience in cooperation with project group members, clients and experts from other professions. The information technology and economics students build companies together and perform a project. The psychology students act as consultants for the different companies. The project includes the design and building of a mobile robot, an analysis of

the necessary calculations for the control of a robot arm, the development and implementation of a prototype of a stock administration program, as well as an economic analysis of the system and a market analysis with respect to their product. Subjects from six departments are integrated in the project. We followed the term during development, running, evaluation and updating as part of the NyIng project. NyIng (Förnyelse av ingenjörs- och civilingenjörsutbildningarna) was a project under the auspices of the Swedish government with as goal to evaluate the engineering education in Sweden and suggest ways to improve this education. Our observations are described in [Lam98, LO99a].

In [SÅL00] we described a specialization in media technology where both subject learning and personal development are in focus. We illustrated the teaching methodology with a course where projects are used to obtain the subject learning and personal development goals. A key factor in the approach is student responsibility.

[HLTK01] described a mid-term evaluation method based on 'Muddy Cards' that allows us to obtain comments about courses during the running of the courses. The main advantage is that there is still time to make changes to the courses that affect the students who participated in the evaluation. Another advantage is that when changes cannot be made, there is a chance to inform the students about the reasons.

In [FHLMW15, FHLMW16] we described the introduction of an e-learning tool (OpenDSA) in a data structures and algorithms course. OpenDSA provides textbook quality text with links to a dictionary of important terms. It provides many code examples and step-by-step algorithm visualizations. Understanding of algorithms is supported by simulation exercises for the algorithms. After each section and each chapter, there are quizzes with multiple choice questions related to the main concepts of the section or chapter. Common to all examples, exercises and quizzes is that they are randomly generated instances of examples and exercises, thereby providing for a multitude of practise possibilities. As a help for doing the exercises and quizzes, students can obtain hints, and automated and immediate feedback is given. Further, OpenDSA automatically stores extensive log data about the interaction with the system. We analyzed the log data, used questionnaires and performed observation studies to investigate the influence of using this tool on student learning and attidutes.

8 Object-Centered Databases

The work in this area was part of the LINCKS project. LINCKS is an object-centered multi-user database system developed for complex information system applications where editing and browsing of information in the database is of paramount importance. Some of the interesting features of LINCKS are multiple users, a hypertext interface, support for composite objects, temporal information, alternative views of data, information sharing and parallel editing notification.

8.1 Version Management of Composite Objects

In [Lam92a] we defined two different kinds of composite objects. On one hand we have composite objects such as folders, where the composite object is considered to have changed only if things are added or removed from the composition. On the other hand we have composite objects such as documents where the composition itself (the document) is considered to have changed whenever one of its parts (e.g. a paragraph) changes internally. We described the relations connecting such compositions in the temporal logic LITE and developed synchronization rules which we have proved are capable of maintaining the desired relations as parts of the database change over time. The rules have been implemented in LINCKS.

In [Lam92b, Lam92c] we proposed a mechanism for version management of composite objects based on time slices. To maintain a consistent history of a composition, we maintain for the time slices information about which version of the composition root existed, what the hierarchical structure was together with information about the objects participating as components, information about the kind of binding between composition and component (static or dynamic) and for the dynamically bound components, which version existed. The update approach we implemented is a form of screening, i.e. a delayed update on need or demand.

The work found in [Lam92a, Lam92b, Lam92c] has been extended in my Licentiate thesis [Lam92d]. The work in [Lam92a] is also extended in [Lam97] where we discuss temporal properties of parts and wholes with respect to different categories of part-whole relations.

8.2 Combining Description Logics and Object-Centered Database Systems

Description logic systems are object-centered knowledge representation systems. The functionality provided by these systems is often complementary to the functionality provided by object-oriented database management systems. In [PLK95] we reported on combining the object-centered database system LINCKS with the description logic system CLASSIC.

9 Security

Key management schemes for multicast in 2003 provided either no resistance to collusion or perfect resistance to collusion. The resistance to collusion was achieved at the expense of efficiency in terms of the number of transmissions and the number of keys that are used. In [DSL03b] we introduced a hybrid key scheme that allows to balance resistance to collusion against efficiency. The resistance to collusion is defined by the number of multicast group members that maximally are allowed to collude. In [DSL03a] we argued that applications may have certain assumptions regarding the users and their access to the multicast channel that may be used to provide a larger choice for balancing efficiency against resistance to collusion. Starting from a user categorization, based on the accessibility to the multicast channel, we formalized the collusion requirement. Different user categorizations give different degrees of collusion resistance and we showed that the existing work has focused on special cases of user categorizations. Further, we proposed and evaluated a flexible key management strategy for the general case where the accessibility relation defines the order of exclusion of the categories. The theoretical and experimental results showed that our scheme has good performance regarding transmissions and keys per controller. A more efficient variant of the scheme regarding keys per user is found in [DSL04].

10 Debugging of Real-Time Systems

The work done in this area was part of the DARTS project (Debug Assistant for Real-Time Systems). The debug assistant is designed for real-time systems which are developed in a host-target environment. The host system is a Unix workstation and the targets are single-board computers on a VMEbus. The workstation and the targets are connected via ethernet.

The debugging is a two phase process. During the first phase the target

system is monitored and the execution history of the system is recorded. The second phase includes the actual debugging. The papers [TGL93a, TGL93b] described mainly this second phase. One part of the debugging tool is a visualizer which allows a user to visualize the system activities in a suspicious region. This region is identified by the other component of the system. This other component is a source code analyzer which matches trace data to source code and saves the result in a Prolog database. This database can then be queried to find the time window where the faulty behavior occurs.

11 Combining Learning and Planning

In my computer science undergraduate thesis [Lam90] we studied the combination of the concept learning system CLINT and a planner to learn preconditions of actions. This project was a first step in using CLINT as part of an autonomous agent [DeR91, DeR92]. In this project we assumed that the agent has a set of incompletely specified actions in the sense that the preconditions of the actions known to the agent may be incompletely or incorrectly specified. However, the agent does know what the result of his actions should be and decides using that knowledge when actions go wrong. Whenever an opportunity occurs the agent tries to learn a better specification of the preconditions of the actions.

12 Conference and Workshop Proceedings, Organization of Initiatives and Special issues

VOILA. The International Workshop on Visualizations and User Interfaces for Ontologies and Linked Data (2015) was organized by Valentina Ivanova, Patrick Lambrix, Steffen Lohman and Catia Pesquita in Bethlehem, PA, USA [ILLP15]. The Second International Workshop on Visualization and Interaction for Ontologies and Linked Data (2016) was organized by Valentina Ivanova, Patrick Lambrix, Steffen Lohman and Catia Pesquita in Kobe, Japan [ILLP16]. The Third International Workshop on Visualization and Interaction for Ontologies and Linked Data (2017) was organized by Valentina Ivanova, Patrick Lambrix, Steffen Lohman and Catia Pesquita in Vienna, Austria [ILLP17]. The Fourth International Workshop on Visualization and Interaction for Ontologies and Linked Data (2018) was organized by Valentina Ivanova, Patrick Lambrix, Steffen Lohman and Catia Pesquita in Monterey, CA, USA [ILLP18]. The Fifth International Workshop on Visualization and Interaction for Ontologies and Linked Data (2020) was or-

ganized by Valentina Ivanova, Patrick Lambrix, Catia Pesquita and Vitalis Wiens virtually, originally planned in Athens, Greece [ILPW20]. The Sixth International Workshop on Visualization and Interaction for Ontologies and Linked Data (2021) was organized by Patrick Lambrix, Catia Pesquita and Vitalis Wiens virtually [LPW21]. The Seventh International Workshop on Visualization and Interaction for Ontologies and Linked Data (2022) was organized by Bo Fu, Patrick Lambrix and Catia Pesquita virtually/Hangzhou, China [FLP22].

A special issue for the Journal of Web Semantics on visualization and interaction for ontologies and linked data was organized by Valentina Ivanova, Patrick Lambrix, Steffen Lohman and Catia Pesquita and published in 2018 [ILLP19si].

LINHAC. The first ice hockey analytics conference in Europe and largest in the world was organized as Linköping Hockey Analytics Conference in 2022 by Patrick Lambrix, Niklas Carlsson and Mikael Vernblom in Linköping [LCV22].

EKAW. The 19th International Conference on Knowledge Engineering and Knowledge Management (2014) was organized by general chairs Patrick Lambrix and Eero Hyvönen in Linköping, Sweden [JSLH14, LHBPQSDG15].

WoDOOM/CoDeS. The First International Workshop on Debugging Ontologies and Ontology Mappings (2012) was organized by Patrick Lambrix, Guilin Qi and Matthew Horridge in Galway, Ireland [LQH12]. The Second International Workshop on Debugging Ontologies and Ontology Mappings (2013) was organized by Patrick Lambrix, Guilin Qi, Matthew Horridge and Bijan Parsia in Montpellier, France [LQHP13]. The Third International Workshop on Debugging Ontologies and Ontology Mappings (2014) was organized by Patrick Lambrix, Guilin Qi, Matthew Horridge and Bijan Parsia in Anissaras/Hersonissou, Greece [LQHP14]. CoDeS is a broadening of the WoDOOM series. The First International Workshop on Completing and Debugging the Semantic Web (2016) was organized by Matthew Horridge, Patrick Lambrix, Bijan Parsia and Heiko Paulheim in Heraklion, Greece [PLSKHLP16].

DILS. The Seventh International Conference on Data Integration in the Life Sciences (2010) was organized by Patrick Lambrix and Graham Kemp in Göteborg, Sweden [LK10, KL10].

DL. The International Workshop on Description Logics (1999) was organized by Patrick Lambrix, Alex Borgida, Maurizio Lenzerini, Ralf Möller and Peter Patel-Schneider in Linköping, Sweden [LBLMP99].

OAEI. Our group organizes the Anatomy track (since 2013) and co-organizes the Interactive track (since 2015) of the Ontology Alignment Eval-

uation Initiative. [OAEI13, OAEI14, OAEI15, OAEI16, OAEI17, OAEI17.5, OAEI18, OAEI19, OAEI20, OAEI21, OAEI22] are summary papers for the different years of the OAEI. [DILL17] is an experience paper regarding the OAEI tracks using the Anatomy data set during 2007-2016.

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