CASAM: A prototype system for computer-aided semantic annotation of multimedia

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Abstract. The CASAM project targets the concept of computer-aided semantic annotation of multimedia content. An integrated system comprised of multimedia analysis, reasoning and human-computer interaction research and technologies allows users to semantically annotate multimedia documents combining user input with system-initiated annotation. The CASAM prototype implementation has finished and the final system will be extensively evaluated over the next few months. This paper reports on the project objectives, underlying methodologies, features and modules involved in the system processes, as well as the future work planned for this research endeavor.

Keywords: Semantic annotation, multimedia, reasoning, ontology

1 Introduction

In a world of burgeoning multimedia resources we need evermore reactive and intelligent ways of annotating and retrieving large amounts of data according to semantic relations. The EU Framework 7 project CASAM[1] aims at bringing together leading research work on semantic annotation and analysis, with reasoning and human-computer interaction technologies developed for computer-aided semi-automatic annotation of multimedia for the ever-flowing streams of media produced by and processed in the news media world.

CASAM introduces the concept of computer-aided semantic annotation of multimedia content. Starting from the acknowledgement of the weak points of fully automatic annotation and the observed gap between manual and automated annotation approaches, the project pursues the new goal of combining the human and machine intelligence to maximize the performance and benefits in a semi-manual annotation scheme. The core idea is that instead of trying to substitute the human intelligence, the system will complement it.

The novelty of CASAM lies in the convergence of multimedia analysis, multimedia interpretation and optimized human-machine interaction with the ultimate target of minimizing human involvement in the annotation procedure. The chosen context for evaluation is the environment and green energy. The project case study is the large database of multimedia files containing relevant concepts, real-life multimedia documents used and managed by some of the largest news media agencies establishments in Europe, namely Deutsche Welle (DW), LUSA, and the European Journalism Centre (EJC).

In this paper, we present an overview of the CASAM project, the respective modules and report on the progress of the project, which is in its final year, expected to conclude in the first half of 2011.

2 CASAM project results

One of the tangible results of the CASAM project is the multimedia document annotation system. At present, the system's second, and final, prototype is being

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CASAM (Computer-aided semantic annotation of multimedia) is a project of the Information Societies Programme of the European Union, running from April 2008 to March 2011. The project's consortium consists of INTRASOFT International S.A. (Luxemburg, co-ordinator), NCSR Demokritos (Greece), the University of Birmingham (UK), Hamburg University of Technology (Germany), the Athens Technology Center (Greece), Deutsche Welle (Germany), Lusa: Agência de Notícias de Portugal (Portugal) and the European Journalism Centre (The Netherlands).

assembled. The components of the system are in their final stages of development and integration is under way. The first prototype has been successfully delivered and evaluated by the CASAM partner news media agencies. CASAM has advanced the state of the art in three main research areas: multimedia analysis, multimedia interpretation, and human-computer interaction. The CASAM project has delivered:

a. *A unifying representation for related knowledge*. The representation links domain-specific ontologies, in which concepts are represented by domain-specific terms, with multimedia interpretation knowledge expressed as taxonomy of concepts and relations. Both the domain ontology as well as the taxonomy are hand-crafted. The representation also includes a separate knowledge base that facilitates the maximization of information gain from the user's input. A domain-specific ontology for environment and energy related news has been developed.

b. *A methodology for knowledge-driven multimedia analysis*. The methodology provides ways to enhance multimedia analysis when knowledge is available about the context or the probability of presence of certain entities in the content. The context is high level information about the multimedia document, for example, that the document is about wind energy. The methodology also specifies how the knowledge represented in the multimedia semantic model can be used to achieve information extraction from various media (text, image, video and audio). The proposed multimedia analysis method exploits the information about the context in the analysed media to provide more relevant results.

c. *A methodology of reasoning for multimedia interpretation*. Intelligent methods that seek to acquire missing pieces of knowledge and disambiguate uncertain knowledge about multimedia documents. The algorithms developed produce queries that are forwarded to the multimedia analysis methods, as well as to the user. The purpose of the queries is to disambiguate aspects of the existing annotations of the multimedia document or acquire new information. The communication of the reasoning methods with both the knowledge-driven multimedia analysis module and the human-computer interface is bi-directional. The reasoning module provides the queries and the context and receives further knowledge and annotations about the multimedia document.

d. *Intelligent human-computer interaction methodology for maximizing information gain in multimedia annotation*. The human-computer interface can query the user to acquire specific information according to the needs of other components of the system. The interface methods can transform formal information requirements into adaptive dialogues with the user, with the objective of minimizing user effort while maximising benefit to the system as a whole. The quantity of information generated by the system and the number of requests for information can both be very high. Therefore, it is crucial to the success of the interaction that the HCI component explicitly reasons over these and determines what information to request and when and how to request it.

e. *An integrated system and tool-kit for computer-aided semantic annotation of multimedia content*. The system employs the synergy of all the developed methodologies towards the achievement of a novel annotation environment for the user. The system additionally supports multimedia document management, user roles, annotation result storage and management, and media streaming. A separate application has also been developed for semantic media search.

3 Multimedia content semantic annotation – the CASAM approach

The pivotal point in CASAM is the realization of the synergy of the human annotator with the CASAM system. The CASAM system exploits all the information that can be extracted from the multimedia document by the developed intelligent tools in order to minimize the human effort. The main components of the CASAM system are:

- Reasoning for Multimedia Interpretation (RMI)
- Knowledge-Driven Multimedia Analysis (KDMA)
- Human-Computer Interaction (HCI)

KDMA uses novel multimedia analysis techniques to extract useful information about the multimedia content (aka. document). This information is used to both jump-start the annotation process, as well as to guide the interaction with the human annotator. The management of the interaction with the human annotator is a coordinated effort of the reasoning from RMI module and the intelligent interaction optimizations from HCI. RMI's main objective is to reason about information that is needed to disambiguate aspects of the knowledge about the multimedia document, as well as to produce new annotations. This can produce a very large number of information requests. The HCI component's job is then to reason over the information requirements of the other components and decide what of this information to explicitly request from the user – and when and how this should be done.The best way to visualize the function of the CASAM system is by studying the information flow (system-user interaction loop), as illustrated in Figure 1:

1. KDMA analyzes the multimedia content (video, image, natural language, any existing annotation) and extracts the first information at the observation level. Namely, this information consists of basic image characteristics like key objects, presence and number of people, context identification etc., as well as speech recognition and concepts derived from text processing.
2. At the same time, the user enters a small number of tags or free text that describe the high-level concepts present in the multimedia content. Note that the tags do not belong to a predefined set. This is done in order to jump-start the annotation procedure since this high-level information can be utilized by KDMA and RMI to narrow the context.
3. RMI augments the KDMA-derived and user-provided information, instantiating appropriately the relevant ontology. Moreover, RMI infers new concept instances and reassesses the context and previous input from KDMA. Results are then fed back to the KDMA for multimedia analysis driven by the renewed information.

4. RMI reasons about what information is needed in order to add missing instances to the ontology or resolve any ambiguities that have arisen in the previous step. If the annotation target has been achieved the loop exits, otherwise the information requirements are fed to HCI.
5. HCI transforms the information requirements to input requests towards the user. HCI optimizes the user interaction using an effort-cost model, by using user modelling to adapt to user information input patterns. Furthermore, the user interface provides the user with the opportunity to alter the knowledge acquisition path devised by the system by possibly correcting the annotations that were produced by the automated multimedia analysis tools.
6. HCI input is passed to the RMI and the loop continues from step 3.

Note that the flow of information described above is only one of many possibilities, although the most typical one. The communication between the components is actually asynchronous. For example, KDMA has the potential to continuously fine-tune its knowledge-acquisition methods based on the guidance (context) that it receives from RMI.

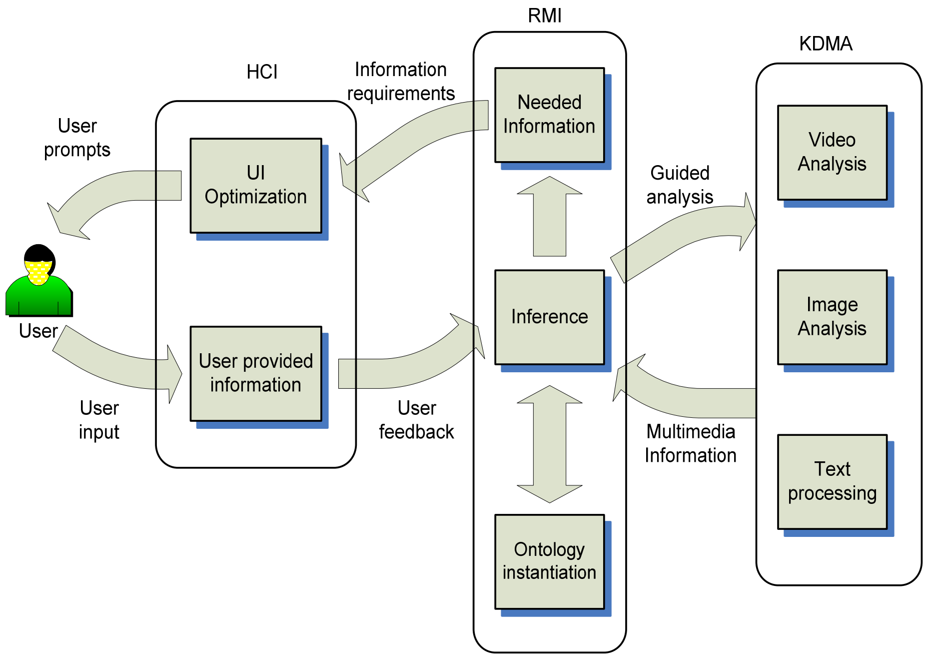

Figure 1: Information flow in the CASAM system

Consider the annotation of a news report about a man that created his own biofuel car. The news reporter that shot the scenes may have scribbled down a few words or labels (i.e. “biofuel car man”) when emailing the video to the channel. CASAM can import this information with an “auxiliary document” interface even before the annotation begins. The annotator, at the start of the annotation procedure, may also enter some words to quickly and further narrow down the contextual information. In the mean time, KDMA has already started analysing the document and the first results are fed to the RMI. All this information populates the ontology, increasing the knowledge about the multimedia document. Remember, also, that all communication is asynchronous. RMI now has enough information to produce more high-level information, further populating the ontology. For example, it is straightforward for RMI to infer that the video is about “renewable energy” from the fact that the video is about “biofuel”. “Renewable energy” is a parent of “biofuel” in the taxonomy. RMI can also fire the abduction rules in the abduction knowledge base. These rules produce possible interpretations. From the set of possible interpretations, RMI produces queries that are sent to both HCI and KDMA. Both of the modules try to answer the queries, KDMA by focusing its analysis on the query, and HCI by asking the user. HCI, receiving more than one query from RMI, optimizes the interaction by asking the queries in the appropriate time and context. For example, it would be very inefficient if the user was asked a question about a part of a video when he was watching a different part. When the user answers a question, this further increases the system knowledge about the multimedia document. The annotation procedure converges through this asynchronous interaction between the user, HCI, RMI and KDMA.

3.1 KDMA

The KDMA module is the back-end module of the CASAM annotation tool responsible for the low level analysis of multimedia content. It integrates methods that allow extracting information from audiovisual streams and texts, which can ultimately ease a user’s annotation task. The module works in cooperation with the RMI and the HCI modules, which utilize the extracted information and also provide back to the KDMA module knowledge that improves multimedia analysis through the knowledge-based adaptation of the KDMA information extraction methods.

Therefore, the key achievement of multimedia analysis methods is the ability to reassess the context and their results based on user feedback and new knowledge. The multimedia analysis procedure is able to refine its findings after positive or negative feedback resulting in a more robust approach and better handling of uncertainty.
The KDMA module is organized in a number of sub-modules:

- Knowledge-driven Audio Analysis (KDAA)
- Knowledge-driven Video Analysis (KDVA)
- Knowledge-driven Text Analysis (KDTA)
- Knowledge-driven Fusion Analysis (KDFA)

The above sub-modules are coordinated by the KDMA controller component. The controller component handles the flow of information between sub-modules and provides the interface with the rest of the CASAM architecture. KDAA, KDVA and KDTA modules are responsible for handling audio, video and text data respectively, while the KDFA module augments the extracted information by considering the information extracted by the other modules.

3.1.1 Text processing (KDTA)

The focus of text processing is on the exploitation of the ontology and the lexicons associated with it to support multilingual text processing, the combination of different learning methods, and the integration of textual information extracted from different types of documents (text derived from video/image OCR, speech transcriptions, images/video textual annotations) [1].
The KDTA module is responsible for the real time automatic semantic annotation of text, possibly highly noisy, with ontology concepts. KDTA has significantly contributed to the area of text analysis for multimedia interpretation with methods for automatic language identification, named entity handling and text translation. KDTA has also incorporated different semantic relatedness measures for the calculation of the distance between words in the input text and ontology concepts. Moreover, KDTA employs external information sources like Wikipedia and Wordnet for the task of semantic annotation. To improve annotation accuracy, a word sense disambiguation method for the identification of the proper meaning of the ontology concepts and the input words was developed. All text processing methods have been developed, implemented and comparatively evaluated in CASAM and with other benchmark corpora such as Genia [2] and OHSUMED [3].

3.1.2 Video/ Image processing and VOCR (KDVA)

The KDVA module is responsible for analyzing the visual part of the multimedia input. Its functions include segmenting the visual part into shots and annotating each of them. Current functionality includes object detection and optical character recognition. Regarding object recognition, we introduced object detection functionality based on the Viola and Jones object detection framework [4]. We obtained a few preliminary evaluation results which are deemed satisfactory. Towards the end of the project the functionality of the module will be extended so as to enable shot classification (e.g. Indoor/outdoor , urban/vegetation), as well as grouping faces that belong to the same individual.

Regarding optical character recognition, the main progress concerns the spatial text detection system and consists of the highly discriminating feature set based on a new texture operator, and the incorporation of the refinement stage which is based on a sliding window, an SVM classifier and a saliency map [5, 6]. The later stage provides the capability of refining instead of just verifying the initial results like the previous hybrid approaches proposed. This means that while an image is refined, the machine learning algorithm can discard parts or the whole text image and split the image into different text lines.

3.1.3 Audio processing (KDAA)

The KDAA module serves two purposes. First, to extract information regarding audio events which may ultimately serve to detect the scene and/or particular recorded events of news feeds. Second, to extract as much information as possible from the speech content stemming from the speakers participating in the news feeds.
High processing and analysis speed is the most important objective of the module, in order to allow interactive communication with the CASAM end user. This priority for low execution time has resulted in novel audio analysis methods for feature extraction and classification.
Beside audio input, these methods also take into account user feedback, thus taking advantage of the synergistic approach of CASAM.
Furthermore, KDAA also features a novel methodology for speaker clustering in a LDA optimal reduced feature subspace, used to determine the number of people present in the audiovisual content [7].

3.1.4 Information fusion (KDFA)

This module serves the function of fusing information extracted from KDAA, KDVA and KDTA modules, thus providing further complementary information, that cannot be obtained by any of the other modules alone. At the same time, it improves, in a modality-independent way, synergy between KDMA multimedia analysis algorithms, which are in principle numerical, with higher-level logic-based reasoning, i.e. the RMI module.

The functionality of KDFA deals with an issue of special consideration in CASAM, which is a suitable probabilistic representation of temporal relations between audio and/or video events. Namely, a novel approach is proposed, which, through temporal relation probabilistic primitives, improves over the tradition Allen's relations, in that it handles noise in segment boundaries, inherent in all practical multimedia analysis results. All confidence indexes that quantify the temporal relations have a solid and sound probabilistic interpretation. This is the first approach allowing for evaluation of confidence values of temporal relations based on the duration of intervals, thus making reasoning with uncertain temporal relations practical.

In the context of KDFA, a method has been proposed for boosting the performance of the one medium analysis from analysis of the other media. The approach is particularly suited for improving audiovisual events recognition from information stemming from the automatic speech recognition and VOCR system and the text module. In particular, the method relies on estimating the concept priors for the video/audio part of the document given the concepts posteriors of the text part of the document, either given through auxiliary text files or from the speech and VOCR transcript. Then, these priors are used to evaluate video/audio concepts posteriors, by suitably adapting those provided by the original discriminative model for video or audio concepts, thus improving the overall classification performance.

3.2 HCI

The HCI module stands as the front-end of the whole CASAM system and, as such, is a critical component. The highly synergistic approach for the annotation process poses considerable challenges in the HCI design, such as:

- The internal (description logic based) representation needs to be translated into a human readable form.
- The quantity of information detected by the automated components can be very large and it is infeasible for the user to be expected to understand and either verify or reject all of it.
- The number of requests for information from the reasoning component can also be very high and, again, it is unrealistic to expect the user to be able to satisfy all of these.
- The automated components and their information requests to the user must work in conjunction with freely allowing the user to perform their usual annotation tasks, allowing the user to remain in control of the interface and their interactions.

The user of CASAM typically has a very limited amount of time available (in some use cases only a few minutes). The aim of HCI is to extract the maximum value from this available resource. This means that the HCI component must reason over the information presented to the user and try to optimise the dialogue that takes place.

Whilst the information provided to the HCI component has measures of confidence and importance, this is not on its own sufficient to determine what to present to the user and when to present it. Moreover, the dialogue with the user has a cost (in terms of time but, more importantly, in terms of cognitive load) which is determined by, amongst other things, the difficulty that the user has in performing the task, as well as the current context of the user (inappropriate interruptions from a task place a much higher load on the user than contextually relevant ones) [9].

The requirements of the HCI component are, therefore, twofold:

- It should provide an effective user interface for the CASAM system

- It should manage the dialogue with the user in order to maximise the information gain for the system and minimise the cost to the users, both in terms of time spent and in terms of their cognitive load.

A key ingredient to developing a successful user interface is to utilise a user centred design approach where all aspects of the design are considered from the end-user perspective. To this end, an extensive effort was dedicated during the design process, and also during user requirement elicitation throughout user trials [8, 9].

The HCI component interacts with the rest of the CASAM system through a series of web service interfaces that implement an agreed contract. The HCI component itself is divided into two parts, front and back-end. The user interface, with which the user interacts, is implemented as an Adobe Flash client that executes on the end-user's machine. This communicates through web services to the HCI back-end which runs on a remote server and provides the interface to the rest of the CASAM system.

This division enables the portability of the application to any machine with a flash enabled browser. It provides for a highly responsive user interface by running the user interaction locally while off-loading any heavy processing task to a more capable server machine. Of course, for standalone applications both parts could be deployed to a single server.

Conceptually, the division can be considered as the back-end working strategically to determine *what* to display and the front-end playing a tactical role and deciding exactly *when* and *how* to interact with the user.

As well as the live system, the HCI component includes two simulation engines which are used as development tools (to provide predictable input and to test components before functionality is developed elsewhere) and to enable reliable user testing.

Figure 2: The HCI annotation module

Figure 2 illustrates the HCI module working with the user to annotate a multimedia document.

3.3 RMI

To speed up multimedia annotation processes, the CASAM project investigates the collaboration of machine intelligence and human annotators. The automatic part is based on Knowledge-Driven Media Analysis (KDMA) modules that compute basic observations from the raw data of a media document to be annotated. These observations are augmented using a Reasoning-based Media Interpretation (RMI) component.

In [10] the RMI system is defined as an agent that consumes observations it receives as (weighted) description logic assertions and builds high-level interpretations (additional assertions) for describing media content based on a background knowledge base. Resulting interpretations are ranked internally by a probabilistic scoring function, and the interpretation with the highest score is communicated to the Human Computer Interface (HCI), which displays the results.

RMI provides media interpretation services that work incrementally, i.e., they are able to consume new analysis results, or new input from a human annotator, and produce notifications for additional interpretation results or, in some cases, revision descriptions for the previously best interpretation. Incremental processing is non-trivial, and the communication of changes is realized using a specific difference operator such that notifications about additions and omissions can be computed in a semantically well-founded way (see [11]).

For the formalization of multimedia interpretation in RMI, a logically well-founded, abduction-based approach was pursued. Abduction is used to explain observation assertions using internal knowledge bases. Due to the incremental input it is natural that the abduction operator can return multiple explanations that have to be maintained on an agenda. Extending previous work, the order of agenda entries is controlled by probabilistic knowledge. Probabilistic reasoning is done in terms of Markov Logic Networks [12]. Initial research on optimization techniques for Markov Logic in combination with description logics has been published in [13].

Internally, a large set of tentative interpretations might be maintained as it is possible that additional observations change the scores of the interpretations on the agenda. Maintaining a huge agenda is a very resource-consuming task for the agent because it has to compute high-level interpretations for each of the possibilities on the agenda when new observations are received. Therefore, the agent has an interest to disambiguate interpretation alternatives and delete them from its agenda, especially when interpretations have similar (low) scores. For this reason, another facility provided by RMI is companion feedback, namely the generation of queries, which have the purpose of being able to disambiguate between interpretations that are considered to be possible (given the input provided by HCI and KDMA on the one hand and the interpretation knowledge of RMI on the other) [14]. Queries are communicated to HCI and feedback from the user, i.e. query answers sent back to RMI, is used to manage the internal agenda.

4 Conclusions and further work

CASAM has combined research achievements from the areas of semantic analysis, machine learning, multimedia, and human-computer interaction to produce a semantic platform that works with the users for computer-aided semantic annotation of multimedia. A specialized ontology was also developed for the domain of environment and energy. However, the annotation process can be easily applied to other domains by employing the respective domain ontologies. The use of the disasters and accidents domain ontology from the European project MESH is currently used to showcase this flexibility of the CASAM system. Towards the end of the project, the current test results and user evaluation show that the integrated system successfully brought together the three major research areas to produce a novel approach to semantic annotation of multimedia content.

The work performed in CASAM has produced a significant amount of knew knowledge in the areas of probabilistic abductive reasoning and learning, multimedia analysis and intelligent user-machine interaction. The research carried out in CASAM is part of the prior and continuing work of the CASAM partners which, from the project onset, brought in significant experience and prior research achievements in their respective fields. The CASAM partners plan to enhance or expand the current methods and findings which are a core part of their research planning and strategy.

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References

1. Zavitsanos, E., Tsatsaronis, G., Varlamis, I. & Paliouras, G. Scalable Semantic Annotation of Text Using Lexical and Web Resources, Artificial Intelligence: Theories, Models and Applications, pages 287-296, 2010
2. Kim, J.D., Ohta, T., Tateisi, Y. & Tsujii, J. GENIA corpus—a semantically annotated corpus for bio-textmining, Bionformatics-Oxford, Vol.19, pp180-182, 2003
3. Hersh, W., Buckley, C. Leone, T.J. & Hickam, D. OHSUMED: an interactive retrieval evaluation and new large test collection for research, Proceedings of the 17th annual international ACM SIGIR conference on Research and development in information retrieval, pages 192-201, 19942.
4. Viola, P. & Jones, M. Robust real-time object detection. International Journal of Computer Vision, 57(2):137-154, 2004.
5. Anthimopoulos, M., Gatos, B. & Pratikakis, I. A two-stage scheme for text detection in video images, Image and Vision Computing, 28(9), pages 1413-1426, 2010
6. Anthimopoulos, M., Vlissidis, N. & Gatos, B. A Pixel-based Evaluation Method for Text Detection in Color Images, ICPR 2010
7. Petridis, S., Giannakopoulos, T. & Perantonis, S. A Multi-class Method for Detecting Audio Events in News Broadcasts, Artificial Intelligence: Theories, Models and Applications, pages 399-404, 2010
8. Creed, C., Lonsdale, P., Hendley, B. & Beale, R. Synergistic Annotation of Multimedia Content. In Proc of the 2010 Third International Conference on Advances in Computer-Human Interactions, (2010) 205-208.
9. Creed, C., Bowers, C.P., Hendley, R.J. & Beale, R. User Perception of Interruptions in Multimedia Annotations Tasks. To appear in Proc. NordiCHI 2010
10. Gries, O., Möller, O., Nafissi, A., Rosenfeld, M., Sokolski, K. & Wessel, M. A Probabilistic Abduction Engine for Media Interpretation. In J. Alferes, P. Hitzler, and Th. Lukasiewicz, editors, Proc. International Conference on Web Reasoning and Rule Systems (RR-2010), 2010.
11. Espinosa, S., Kaya, A. & Möller, R. Formalizing Multimedia Interpretation based on Abduction over Description Logic Aboxes. In Proc. of the 2009 International Workshop on Description Logics DL- 2009, 27-30 July 2009, Oxford, United Kingdom, 2009. CEUR Workshop Proceedings (Vol. 477).
12. Gries, O., Möller, R., Nafissi, A., Rosenfeld, M. & Sokolski, K. Basic reasoning engine: Report on optimization techniques for first-order probabilistic reasoning. CASAM Deliverable D3.2, Hamburg University of Technology, 2009.
13. Gries, O. & Möller, R. Gibbs Sampling in Probabilistic Description Logics with Deterministic Dependencies. In Thomas Lukasiewicz, Rafael Penaloza, and Anni-Yasmin

Turhan, editors, Proc. International Workshop on Uncertainty in Description Logics (UnIDL-2010), 2010.
14. Gries, O., Möller, R., Nafissi, A., Rosenfeld, M., Sokolski, K. and Wessel, M. Meta-level reasoning engine, Report on meta-level reasoning for disambiguation and preference elicitation. CASAM Deliverable D3.4. Hamburg University of Technology, 2010.