A Framework for Situation Inference based on Belief Function Theory

Ladislav Beranek
Department of Applied Mathematics and Informatics, Faculty of Economics, University of South Bohemia, Ceske Budejovice, Czech Republic

Keywords: Information Extraction, Situation Recognition, Context Discovery, Belief Function Theory.

Abstract: The ability to identify the occurrence of a situation is the main function of context-aware systems. The process of identifying a situation is not easy due to the uncertain nature of the processed information. We use the belief function theory to detect specific situations on the basis of uncertain sensor data. In this paper, we propose a framework for situation awareness based on the belief function theory which is applied to determination of situation occurrence from uncertain sensor data. The framework consists of the situation sensors data processing (filtering, integration) and of situation detection based on alternative frames of discernment generation. The case study demonstrates that the proposed framework is effective and can be used to situation detection.

1 INTRODUCTION

Context-aware systems take into account the context of the user, i.e. data that characterizes the situation in which the user is currently finding himself. To determine such a situation, a number of sensors are required and the subsequent evaluation of data from those sensors has to be performed. By default, these sensors operate independently. The data they generate is then used to determine the situation in which the user is finding himself; for example, the user wakes up and gets up. The whole procedure of identifying the situation occurrence lies in the collection of reports and records of events from all sensors in a certain period of time, the integration of this data and its analyzing in order to obtain an overall overview of the situation. The aim is to assess the situation and also to predict future development of the situation. However, there are several problems in the processing of data from sensors and systems for obtaining such an overview of the situation:

- Large amounts of data and reports (here we call them evidence) are generated from different sensors.
- Data are variable in time, can be loaded with noise.
- It can be quite difficult to determine the relationships between data from different sensors; for example, from the perspective of time or the delay in data transmission over the network.

In order to determine the occurrence of a situation, various sensors are located in different places, for example in one household to monitor and to collect data to determine the situation. This data provides only symptomatic evidence and requires appropriate analysis of these symptomatic symptoms that can lead to a corresponding judgement about the situation (Beranek, 2012). The problem is how to combine and analyze these indicative evidences of such situation to determine the occurrence of a real situation.

In this paper, we propose an approach based on the use of belief functions. We use the theory of belief functions in two basic areas: to integrate the data from the respective sensors and to construct a frame of discernment which serves to the reasoning about the occurrence of situation. This method of construction of the frame of discernment is based on the work of Shubert (Shubert, 2012). The frame of discernment must consist of mutually exclusive elements. Often, also in context-aware systems using the belief function theory, the frame of discernment is chosen inappropriately (Daniel, 2010). A classic error is described in a paper presented by Zadeh (Zadeh, 1984). In his work three non-exclusive

Beranek L..
A Framework for Situation Inference based on Belief Function Theory.
DOI: 10.5220/0004143703580361
In *Proceedings of the International Conference on Knowledge Discovery and Information Retrieval* (KDIR-2012), pages 358-361
ISBN: 978-989-8565-29-7

diseases: meningitis (*M*), concussion (*C*) and brain tumor (*T*) are represented as elements of the frame of discernment $\Theta = \{M, C, T\}$. This is not in compliance with the requirements that the frame of discernment should include only exclusive elements. Such error can lead to misleading results which are described in Zadeh's paper. Haenni (Haenni, 2005) presented a correction of this error. He suggested to use, in this case, the other frame Ω created as a cross product of the mentioned elements-diseases:

$$\Omega = \{\{M,NM\}\times\{C,NC\}\times\{T,NT\}\},$$

where *NM* means no *M* and similarly *NC* means no *C* and *NT* means no *T*. The frame Ω will have eight elements. Haenni (Haenni, 2005) proved that the choosing of proper frame eliminates the problem. The conclusion differs substantially from the one presented by Zadeh (Zadeh, 1984).

In context-aware systems the situation inference is reliant on information from various sensors. But the information from these sensors may not be exclusive and even may display a high degree of conflict. We used the method of alternative frames of discernment generation based on the work Schubert (Schubert, 2012) in the phase of situation detection. This approach takes away the problems with possible non-exclusive data from sensors. This is important when this data is high conflicting. This approach is a new and effective application of belief functions in this area based on Schubert's work (Schubert, 2012).

The remainder of this paper is organized as follows: Section 2 gives a brief overview of related works in this area; Section 3 contains the methodology, a description of the proposed framework for obtaining of an overview of the situation based on processing data from sensors; Section 4 shows experiments and their results; Section 5 describes conclusion and further research plans.

2 RELATED WORK

The ability to determine the occurrence of a situation in which the user has found himself is an essential function for context-aware systems. This ability depends on the activities of the various sensors and the correct way to evaluate data from these sensors. Evaluation of data from the sensors, because of their nature, is not easy. Many reasoning techniques are used to evaluate and infer the current situation. Bayesian methods are quite popular, for example (Ulicny et al., 2011), (Ranganathan et al., 2004). Further techniques such as fuzzy logic (Furno et al., 2010), also in combination with semantic web (Ciaramella et al., 2020), or ontologies (Matheus et al., 2003) or hidden Markov models (van Kasteren et al., 2008) are used as well. However, these models usually require some preliminary information. Preferably, there is also belief functions theory used, see for example McKeever et al., 2009), (Liao et al., 2010). McKeever constructs sensor mass functions and uses theory of belief function primarily for combination of evidences. Liao tries to monitor human activities. He proposes a three-layer lattice structure. It is then used to combine the mass functions derived from sensors along with the sensor context and subsequently to infer occurrence of situation.

The use of the belief function theory is especially useful in situations in which we have no previous data (lack of training data), data is very inaccurate, and some data is missing. However, the proper application of the belief function theory has to deal with two problems. The first problem is the right application of Dempster's rule. To apply this rule correctly, input belief functions must be independent and reliable, i.e. obtained from reliable sources and correctly constructed in such a way that they reliably represent the corresponding source of evidence (Daniel, 2010). The second problem is that data from sensors is often non-exclusive. The construction of the frame of discernment must correspond to these conditions. The solution is presented in a paper by Schubert (Schubert, 2012). We will apply an approach suggested in this paper for construction frames of discernment in the situation detection phase.

3 BASIC CONCEPTS OF OUR FRAMEWORK

The framework for situation awareness proposed in this paper is based on the processing of the data and tabs from various sensors. It consists of two parts, as shown in figure 1:

1. In the first part, data from the sensors are processed by means of filtration and data integration;
2. In the second part, mass functions are derived, alternative frames of discernment are constructed, and the comparisons with adequate frames of discernment stored in the database are accomplished.

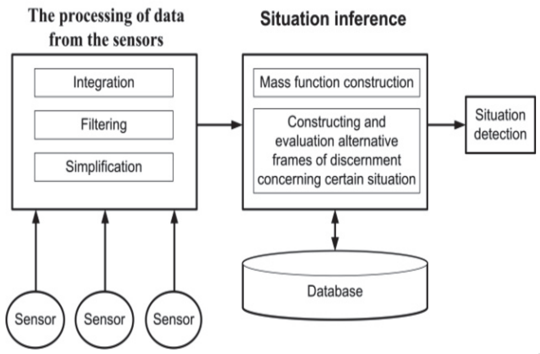

Figure 1: The framework for network security situation awareness consists of two parts, one is to process various events and construct the formal model of network security situation, the other is to acquire attack patterns through knowledge discovery and generate dynamically the network security situation graph.

3.1 Processing Data from Sensors

Data sources used for situation detection are very different, derived from various sensors (time sensor, water intake, position sensor, etc.). Therefore, in the first phase, it is necessary to convert all messages received on the situation observed in a standard format. In addition, these standardized records are filtered and integrated. The aim is to simplify and eliminate redundant records, to remove records that do not meet certain requirements. These requirements may be stored in the knowledge base in the form of attribute rules and be used according to the status of the situation. The record can be removed; for example, in the absence of a key attribute of the described events or when its value is out of range and thus not relevant for the analysis of the situation.

3.2 Construction of Alternative Frames of Discernment and Situation Inference

Mass functions are calculated at first. They can be derived from sensor reliability or can be quantified on the basis of inference rules. For example, in the home data set, a user "usually" uses the coffee maker when preparing breakfast and this is quantified as 90% of the time by examining sample occurrences of the "breakfast preparation" situation in the data. Therefore, a mass function value of 0.9 is applied on the basis of inference rule from the context value "coffee maker is used" to the situation of "breakfast preparation".

Now, we have some uncertainty about the different aspects of a situation. This information is expressed using established belief functions. We have no assumption that the atomic elements are sets of elements of the same frame, because they can relate to different aspects of the same phenomenon (the situation). Instead, we believe that they can be part of various homogeneous parts of frames whose Cartesian product will be a framework that represents all the possibilities of the problem. Even further, this may be revised whenever there is new information and framework may need to be expanded to include the possible outcomes that were not previously known (Shubert, 2012).

Since there may be several different alternative frameworks for each time point, we determine the most suitable framework for resolution. We define the fitness resolution framework to meet two different aspects simultaneously. Hence we construct the frames of discernment over the data obtained from the first phase. We then choose the most appropriate frame which has the lowest internal conflict.

We scan the data about the situation (first part) and, in the second part, construct alternative frames from which we chose the most appropriate one. We take this actual frame of discernment and process it. We compare it with the frames of discernment saved in the database (for example with the typical one when the user performs an activity - "breakfast preparation"). At the end, we deduce a description of the situation which corresponds to the actual user's activity.

Thus the function of the second part of our framework is as follows. We have two situation data sources available for actual situation detection: the belief functions generated from the first part on the basis of sensor data, and the set of historical situation descriptions. We have to determine and extract the knowledge from these pieces of information to perform the actual situation detection.

4 EXPERIMENTAL RESULTS

To verify the proposed framework for the situation inference, we created simulated home environment with six various sensors. In the first phase, we focused ourselves on the kitchen activities. We selected consecutive time slices describing the "prepare breakfast" activity (see table 1).

Looking at Table 1, the situation "preparing breakfast" is supposed to be occurring at 7.10. The same situation continues till 7.15. The sensor tells us that the coffee maker is in operation at 7.15. Here, the frame of discernment Ω = {eating, preparing

Table 1: Example of data processed within the framework.

Time	Sensor events	Generated frame of discernment	Resulting identified situation
7.10	foodstuffs, fridge, cook-stove,	{preparing breakfast}	preparing breakfast
7.15	foodstuffs, fridge, cook-stove,	{preparing breakfast}	preparing breakfast
7.20	coffee maker	{eating, preparing coffee, {eating prep. coffee}}	eating and at the same time preparing coffee
7.25	dishwasher, coffee maker	{eating, get coffee}	eating

coffee, {eating preparing coffee}} with relevant values of mass belief function is constructed. After processing this data together with the data from the database, we obtain the specification of the actual situation with the highest value of belief function. We are describing this process very briefly here and on a simple example.

Our approach incorporates the context quality information into sensor evidence by using the construction of alternative frames of discernment concerning situation. We also provide a mechanism to accumulate evidence for time-distributed situations. We demonstrate here our approach on a simple case study. Our approach enables situation inference with uncertain information with limited or no need for training data.

5 DISCUSSION AND CONCLUSION

In this paper, we propose a framework intended for situation identification. This framework is mainly based on the use of the belief function theory which reflects better the uncertain character of the process of situation detection. We describe here some results of our initial study. In our future activities, we want to analyze these procedures more deeply. We are preparing more experiments with the aim to especially improve the procedures concerning the resulting description of the situation, i.e. procedures pertaining to the extraction of the knowledge from processed data from sensors and from data stored in the database.

REFERENCES

Beranek, L., Knizek, J., 2012. The Usage of Contextual Discounting and Opposition in Determining the Trustfulness of Users in Online Auctions. *Journal of Theoretical and Applied Electronic Commerce Research*, vol. 7, No. 1, pp. 34–50.

Ciaramella A., Cimino M., Marcelloni F., Straccia U., 2010. *DEXA'10 Proceedings of the 21st international conference on Database and expert systems applications*. Berlin: Springer, pp. 31-45.

Daniel, M., 2010. Several Notes on Belief Combination. In *Proceedings of the Theory of Belief Functions Workshop*. Brest: ENSIETA, 2010. pp. 1-5.

Furno D., Loia V., Veniero M., 2010. A fuzzy cognitive situation awareness for airport security. *Control and Cybernetics*, vol. 39, No. 4, pp. 959–982.

Haenni, R., 2005. Shedding new light on Zadeh's criticism of Dempster's rule of combination. In *Proceedings of the Eighth Int. Conf. on Information Fusion*, Philadelphia, IEEE, pp. 879–884.

Liao J., Bi X., Nugent Ch., 2010. Activity Recognition for Smart Homes Using Dempster-Shafer Theory of Evidence Based on a Revised Lattice Structure. In Proceeding of the 2010 Sixth Int. Conf. on Intelligent Environments. Washington IEEE, pp. 46–51.

van Kasteren T., Noulas A., Englebienne G., Krose B., 2008. Accurate activity recognition in a home setting. In *Proceedings of 10th International Conference on Ubiquitous Computing*, South Korea, pp. 1–9.

Matheus C. J., Kokar M. M., Baclawski K., 2003. A Core Ontology for Situation Awareness. In *Proceedings of Sixth International Conference on Information Fusion*. Cairns, Australia, pp. 545–552

McKeever S., Ye J., Coyle L., Dobson S., 2009. Using Dempster-Shafer Theory of Evidence for Situation Inference. In *Proceedingd of the Fourth European Conference Smart Sensing and Context*. Lecture Notes in Computer Science 5741, pp. 149-162

Ranganathan, A. et al., 2004. Reasoning about uncertain contexts in pervasive computing environments. Pervasive Computing, IEEE , 3(2):62–70, 2004.

Shafer, G., 1975. *A mathematical theory of evidence*. Princeton University Press, Princeton, NJ.

Shubert, J., 2012. Constructing and reasoning about frames of discernment, *International Journal of Approximate Reasoning*, vol. 53, no. 1, pp. 176-189.

Ulicny, B. et al., 2011. Augmenting the Analyst via Situation-Dependent Reasoning with Trust-Annotated Facts. In *Int. Conf. on Cognitive Methods in Situation Awareness*. Miami Beach: IEEE, pp. 17–24.

Zadeh, L. A., 1984. Review of a mathematical theory of evidence, *AI Magazine*, vol. 5, pp. 81–83.