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Learning and representation of event-discrete situations for individualized situation recognition using fuzzy Situation-Operator Modeling

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ABSTRACT

Knowledge representation and the ability to learn new knowledge define the success of situation recognition within cognitive systems. In this contribution, it is assumed that a complex environment in which a system is acting is modeled using an event-discrete approach. The modeling would be based on imprecise and uncertain knowledge about the environment, which is adapted by suitable learning abilities during the interaction between the system and environment.

The main contribution of this paper is developing an approximate reasoning approach driven by learning and reusing human-operator experiences to handle event-discrete situations in unknown dynamic environments. A new approach for modeling and learning the knowledge for situation recognition in human operator assistance systems is proposed. Situation recognition is individualized for humans by learning exclusive experiences of human operators in interaction with the environment. Individualization is caused by variety of human operators in definition of priorities and goals, generation of events, and different environmental characteristics importance in specification of situations. For modeling interaction-based knowledge structures, a fuzzy Situation-Operator Modeling approach is used and improved by applying a feature selection process. The corresponding approach is able to learn and represent new knowledge to improve the performance of individualized situation recognition for cognitive systems.

Here, the proposed approach is applied using a simulated driving environment and evaluated for different test drivers. Evaluation results highlight the ability and importance of the proposed approach for situation recognition in driving assistance systems.

1. Introduction

With the growing interest in using assistance systems for supervision of human operators, development of an advanced situation awareness got special attention at different application levels. In a dynamic environment, different factors such as the existence of blind-spot areas or high levels of acute stress may decrease awareness and actual understanding of the environment (Price et al., 2016). Situation awareness as a critical aspect of human decision-making (Endsley and Garland, 2000) could improve the decisions and actions of individual human operators.

In the past several years, significant steps have been made in the improvement of situation awareness in dynamic environments. Situation recognition for a system is defined as understanding the significance of the system state and its related environment. It plays a key role in situation awareness. Being aware of status, characteristics, and dynamics of relevant elements of the dynamic environment and understanding the significance of those elements by considering operator goals enhance situation awareness (Endsley, 1995).

The process of situation recognition in real-time plays an important role in situation awareness of human operators. Since humans usually characterize and interpret the situations according to their individual experiences and priorities (Singh and Jain, 2016), it may be argued that consideration of exclusive behaviors of human operators could improve individual situation awareness. The behaviors which could not be generalized and defined using rules, while closely depend on human experiences and preferences in different conditions are defined as exclusive behaviors of human operators.

Although different studies have focused on real-time situation recognition, but situation recognition process is still sluggish. On one hand, the term situation is still not suitably defined. Thus, there is a lack of knowledge representation approach for modeling the event-discrete knowledge about dynamic environment (Singh and Jain, 2016). On the

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other hand, less attention has been paid for individualization of situation recognition.

The main goal of this research is characterizing and relating the occurring situations through the events. Here an integrated approach for representation of event-discrete knowledge presented in Sarkheyli-Hägele and Söffker (2017) is used and developed for conceptual knowledge representation, data unification, real-time situation recognition, personalization, and action taking. The proposed knowledge representation approach is based on Situation-Operator modeling (SOM) approach proposed in Söffker (2001) and Fuzzy Logic (FL). In addition, the situation recognition is implemented using Case-Based Reasoning (CBR) approach which is modified to support multiple procedures for knowledge learning allowing individualization of situation recognition. The presented approach in Sarkheyli-Hägele and Söffker (2017) is improved by applying feature selection in learning procedure. The situation recognition and learning performance are measured by considering different evaluation metrics.

This paper is organized into several sections. In Section 2, an overview of the definition of situation, its formulation, and situation recognition procedure are given. In Section 3, the proposed approach for individualized situation recognition will be introduced. Two tasks of the proposed approach and their the related procedures are defined in Section 4. In Section 5, the proposed approach is implemented for lane-change situation recognition in a driving simulator. The performance of the implemented approach is evaluated with respect to the situation recognition and learning processes. Finally, the effects of online learning for individualized situation recognition assistance system are pointed out.

2. Situation recognition

The term situation recognition is used based on the definitions proposed in Nigro and Rombaut (2003) and (Fischer and Beyerer, 2012). According to Nigro and Rombaut (2003), recognition of the situations affected by a sequence of events or actions performed by operators is regarded as situation recognition. Moreover, situation recognition is addressed in Fischer and Beyerer (2012) as identification of the situations possibly leading to a specific situation pattern.

The essential problem of situation recognition is understanding the actual situation (internal state of the agent and its related environment including the state of entities) by considering a sequence of the actions, occurring or upcoming situations.

Situation recognition could be described as a process with three phases: (1) finding the similarity of the observed features, (2) finding the relation between the features, and (3) detecting the relation between the occurring situations (Ranathunga and Cranefield, 2012). Here, situation recognition is assumed as a pattern recognition problem to identify the actual situation by comparison with previously defined situation patterns. Features and relations between the features need to be associated with the values that can change over time (Baclawski et al., 2003).

A situation may not always be interpreted similarly for the human operators with different personal preferences and priorities. In addition, the current environmental situation may dynamically be captured based on different emotional states of human operators (Wendemuth and Biundo, 2012). This difference may result from differences between individual humans, different emotional states of one person considered etc. and may be in terms of characteristics importance in definition of a situation and linguistic modifiers applied for description of the situation. A variety of human operator goals and experiences cause these differences.

The situation recognition devoted to this work for a system, receives a stream of time-stamped status information of ego-system and its related environment as input. It performs a situation when an event occurs. It returns the identified situation patterns as the output by generating deducted situations according to the trigger actions.

3. Fuzzy situation-operator modeling-based case-based reasoning

In this contribution, a Fuzzy SOM-based CBR approach is introduced for the realization of individualized situation recognition. A first version of the approach is published in Sarkheyli and Söffker (2016b). The improvements are related to the knowledge base and knowledge learning process. In this section, the role of the knowledge representation and learning techniques integrated with CBR will be described.

3.1. Case-based reasoning

Case-Based Reasoning is a methodology to model human reasoning for solving cognitive problems such as decision-making. It has been successfully applied for problem-solving to a wide range of real-world applications (Perner, 2014). This reasoning approach applies previous experiences for solving new problems. An experience as a combination of a problem and its related solution, is organized as a case. The main four phases of CBR include retrieve, reuse, revise, and retain. A new case may be confirmed for a new experience of the problem, the solution, and its result. Accordingly, the confirmed case is learned and stored in the case base for further usages.

The term and construct situation is used to model a real world scene (Söffker, 2001). It expresses the internal structure of a considered system, as a part of the real world. A specific combination of sensor data and related combined characteristics is understood as a situation representing the actual state of the system and the related environment (Ahle and Söffker, 2008). A CBR approach applied for solving a special cognitive problem introduces a situation and the performed actions as "problem" and the executed upcoming situation as "solution". Case base as the main component of CBR plays an important role in situation recognition process. According to the Reyes et al. (2015), CBR suffers knowledge elicitation and case adaptation. To compensate these problems, CBR is integrated with SOM and FL approaches in this paper. An effective representation of cases could strongly affect CBR performance and improve the accuracy and computational time. In the next sections, the proposed approach for structuring and representing the cases is explained.

3.2. Situation-operator modeling

According to the different relationships between the situations introduced in Ye et al. (2012), the SOM technique is focusing on temporal sequence relationship which may be realized using actions.

The approach SOM defined in Söffker (2001) for the first time, is a technique for modeling event-discrete situations specially in dynamic environments with structural changes. Using this modeling technique, an event (a change in the environment) could be represented using a sequence of scenes, related causes (actions), and their effects. These concepts are modeled using two items, situation and operator, to represent scenes and actions alternatively. Accordingly, an event is defined as a sequence of initial situation, performed operator, and upcoming situation (Sarkheyli-Hägele and Söffker, 2017). Here, situation S_{i} is defined as a list of characteristics C with various hybrid data types and quantitative values, as well as relations R between the characteristics (for more information see Ahle and Söffker, 2008). The item operator O applies function f to transfer situation S_{i} to $S_{\mathrm{i+1}}$ with possibly a new set of characteristics' values and the relations. The operators considered by SOM are modeling the active actions.

By application of SOM for representation of event-discrete experiences in CBR, a sequence of events could be considered as a set of cases while each case is representing an event (for more information see (Sarkheyli-Hägele and Söffker, 2017)). The sequence may cause a specific situation pattern. Accordingly, the case $Case_{\mathrm{j}}$ where j is the case index, is defined using a 3-tuple $(S_{\mathrm{i}}, O, S_{\mathrm{i+1}})$. Assuming a closed and time-invariant arrangement (given system structure), S_{i} and $S_{\mathrm{i+1}}$ are two situations of an infinite set of situations, and O is an operator.