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Correct behavior identification system in a Tagged World

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ABSTRACT

This paper presents a system that is able to process the information provided by a Tagged World to identify user's behavior and to produce alarms in dangerous situations. The system inputs are signals from sensors, which are used to recognize correct behavior (action sequences) by Inductive Learning, using Data Mining techniques. The inference engine is a reasoning device that is implemented by means of Regular Grammars. It permits us to control user's behavior. As output, the system produces and sends alarms when a user action sequence is wrong, indicating the erroneous actions, forgotten future, and so on. To test our system, the Tagged World is supposed to be at a house, where we have used RFID technology to control the objects inside it.

1. Introduction

In the recent years, the computer technology has suffered a wonderful evolution to the small computer. This evolution was predicted by Weiser (1993) where he defined the ubiquitous computing as *the method of enhancing computer use by making many computers available throughout the physical environment, but making them effectively invisible to the user*. Following this principle, the devices are made tinier each time. Inside these devices, the hand-held ones and the sensors are emphasized upon.

Many traditional environmental applications base their operations in sensors, for this reason sensors are becoming more and more common in daily life.

There exists different types of sensors to collect information about very different magnitudes: temperature, electromagnetic waves, mechanical effects, some chemical products, radio-frequency signals, etc. Today, systems based on radio-frequency identification (RFID) technology are a key tool in helping to move Weiser's vision closer to reality (Want, 2004a, 2004b). A RFID System is always made up of two components (Finckenzeller, 2003):

- A tag (small silicon chip that contain identifying data and sometimes other information), which is located on the object to be identified.
- A reader which, depending upon the design and the technology used, may be a read or write/read device.

This type of sensors makes the creation of a Tagged World easy .

Definition 1 Koyama, Nakagawa, and Shimakawa (2006). A Tagged World is defined as a smart area that serves to recognize user's behavior by using information about their daily activity. This information is collected by sensors placed (embedded) in the environment.

In particular, RFID sensors allow us to collect information specifically about the different objects that user touches. This permits to develop a system that is able to detect the user actions from sensors information with the goal of finding mechanisms to identify the different actions with the specific activity carried out by the user.

It is obvious that there are a wide range of possibilities in designing this type of system, which result into many projects that propose different alternatives. For example, in Yamahara, Takada, and Shimakawa (2006) a Tagged World project is presented which uses RFID tags that are attached with all objects around the environment. A user brings a wearable computer equipped with a RFID reader to record the access logs to these tags. They use Bayesian networks methodology for the probability statistics in the recognition and the reasoning to provide personalized services to make a more safe and easy life by recognizing and reasoning about the human behavior.

In contrast, in Nakauchi, Noguchi, Sonwong, Matsubar, and Namatame (2003), a method that uses clustering techniques for the classification of the behavior is proposed, through the algorithm ID4.

The clustering techniques are also used in conjunction with a rule based system based (Isoda et al., 2004). A representation model that expresses both the spatial and the temporal relationships is proposed. Moreover, the system provides the user support by coupling the result with the aim of the model consisting of a set of states.

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In Philipose et al. (2004), a system to infer Activities of Daily Living (ADL) is proposed. A new paradigm for ADL inferencing leverages radio-frequency identification technology, data mining and probabilistic inference engine is presented to recognize ADLs based on the objects that people use. They use two kinds of sensors. The basic information is obtained by RFID technology, but other sensors are also introduced to fill in the gaps of information that RFID tags could generate. The system represents activities as linear sequences of activity stages, and annotates each stage with both the involved objects and the probability of their involvement.

In this paper, we propose a system to overcome some shortcomings (basically, the inability of generalization and adaptation to change) found in the earlier proposals. We use Data Mining techniques to identify correct behavior, and Regular Grammars to control the implementation of a sequence of actions.

The remainder of the paper is organized as follows: Section 2 is devoted to develop the theoretical basis of our proposal, introducing also the different tools that have been used. In Section 3, we specify the inductive learning process, and in Section 4 the Reasoning System is presented. We conclude by explaining the current architecture of our system and showing some examples about its operation. Finally, some consider the developed implementation and future proposals.

2. Our approach. Theoretical background

In this section, we present some concepts about Tagged World and related constructs which are necessary to know and to understand our approach. In addition, we present a system overview where we present the system structure.

As said before our system tries to solve various problems arising in the task of to recognize user's behavior in Tagged Worlds. We have mentioned the word "behavior" several times before, but without stating precisely its meaning, which is needed as this word has a very general and context dependent semantics. To do this we chose the formal representation introduced in Koyama et al. (2006): *a behavior is composed by actions*. Therefore, we will understand a behavior as an action sequence ordered on time

Definition 2. Let $A = \{a_1, a_2, \ldots, a_n\}$ be the set of possible user's actions in some situation or domain. A user behavior is a finite set of actions:

$$\beta = \{\alpha_1, \alpha_2, \ldots, \alpha_{p(\beta)}\}$$

with $\alpha_j \in A \forall j$, where α_j is performed before α_k if, and only if $j \leqslant k$.

Let us observe that this definition of action does not consider the concrete instant time in which an action is performed. However there are problems in which the information about concrete time is to be relevant. For them a definition of action is needed to consider that time. As we indicated previously we will assume that RFID tags are the only sensors to collect the user information. This allows us to associate each action from the above definition with some specific object. So, we will denote each action with the corresponding object name.

Example 3. If we want to control the behavior `to go out home`, the user has the following possible actions: `to take the mobile phone`, `to take the keys` and `to close the door`. Then, these actions will be represented in our system as: `mobile phone keys door`.

The set of possible actions is always finite but its length depends on the context or domain. Similarly different behaviors may involve a different number of actions.

According to our objectives the system we propose is to be designed to carry out the following tasks:

- *To detect the "key" actions that correspond to a normal behavior.* For this only the actions that are common in any performance of a specific behavior are to be considered. For example, when we study the behavior `to go out home`, we know the user, normally, `to take the keys and to close the door`. However, if he takes a bag or a scarf, it will not be a common action in this behavior. These common actions are to be considered "key" actions and they specifies a behavior, that is, the definition of a behavior is a skeleton one, which is only composed of key actions.
- *To determine whether a sequence of actions as performed by the user is correct or not.* When a sequence of actions arrives to the system, it should indicate whether the sequence is right or wrong with regard to the previously studied and controlled behaviors. Thus, if the user is `to go out home`, and in general, `to take the phone`, `to take the keys`, `to close the door` and `to call the elevator`, the system has to detect any forgotten or wrong action: forgetfulness of the keys or the mobile phone, not closing the door...
- *To generate and send alarms when the sequence of actions is incorrect.* While from a theoretical point of view the main aim of the system is to identify user behavior, from a practical point of view it is very useful to provide a service able to generate and send alarms for the user when the sequence of actions is incorrect.

Besides these tasks, there exists another interesting goal: the Knowledge Mobilization. The aim of this idea is to allow the use of hand-held devices to communicate the alarms to the user (after processing signals on a server to identify the correct behavior).

When we talk about behavior, the user concept is not the same as the concept of the research. This different perception of the behavior could be a problem if we want the system would be used by *anybody*. For this reason, we think that it is convenient to use a simple and obvious behavior concept that would be controlled by the system.

Our objective is to design and implement a system that is able to generate and send alarms when a user omits some key action in a behavior. Thus, "right/correct behaviors" are to be identified, but to do this task we need to take into account different aspects of user's conducts:

- *A user does not carry out the behavior actions in the same order every time*. When a user goes out home, we know that he has to take the mobile phone, to take the keys, to close the door; but it is possible that he has to take the keys, to take the mobile phone, to close the door too.
- *To identify a behavior it is needed for the user to make all the behavior actions.* When a user takes the mobile phone, he could be carrying out various behaviors: to go out home, to speak, to tidy up, etc.
- *A user may carry out intermediate (non key) actions that have not been considered in the skeletal definition of a behavior.* As we have commented before the definition of a behavior is a skeleton one, which is only composed of key actions. However a user may perform some additional non key actions keeping the rightness of the behavior. When a user goes out home, we know that he has to take the mobile phone, to take the keys, to close the door. However, when the user takes the mobile phone, it is possible that he takes the bag before the keys.
- *A user may start a behavior without finishing a previous one.* When a user takes the key and the mobile phone, we could believe that he is going out home. Nevertheless, he could realize that he forgot to make the bed.