Location-based Concept in Activity Log Ontology for Activity Recognition in Smart Home Domain

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Abstract. Activity recognition plays an important role in several researches. Nevertheless, the existing researches suffer various kinds of problems when human has a different lifestyle. To address these shortcomings, this paper proposes the activity log in the context-aware infrastructure ontology in order to interlink the history user's context and current user's context. In this approach, the location-based concept is built into the activity log for producing the description logic (DL) rules. The relationship between activities in the same location is investigated for making the result of activity recognition more accurately. We also conduct the semantic ontology search (SOS) system for evaluating the effectiveness of our proposed ideas. The semantic data can be retrieved through SOS system, including, human activity and activity of daily living (ADL). The results from SOS system showed the advantage overcome the existing system when uses the location-based concept in activity log ontology.

Keywords: Activity recognition, Activity log, Location-based concept, Description logic rules, The semantic ontology search, Activity of daily living

1 Introduction

Nowadays, various kinds of healthcare systems have been proposed because people taking an interest in health is more increase continually. Numerous techniques are developed under Smart Home (SH) concept [1] to support the healthcare system more precisely. Activity recognition is a one of sub-system in the healthcare system. The results from the activity recognition are extremely useful because

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they can be used in many directions. For example, activity of daily living (ADL) is necessary information to know what human does in each day. Physician can use the ADL information to diagnose patient correctly.

Recently, the ontology concept has been developed in several activity recognition researches. The knowledge engineering is used to describe a semantic of context-aware infrastructure in the SH domain [2, 3]. Even though, the existing systems can recognize the human activity, they still need to improve recognition's ability in some ambiguous cases [4]. The main problem of the activity ambiguous problem is an input data. Mostly, snapshot data from the sensors is used as the input data for the activity recognition system. An interval time for receiving data from sensors is set depending on experimental environment. The system can identify the activity only when the interval time comes. However, the concept of snapshot information may not suitable for the activity recognition system. Since, It can be a lack of information for recognition in some cases.

According to the former problem, primary goal of this research is to classify the human activity more accurately. 13 activities of daily living are emphasized such as "Sleeping", "Cooking", "Watching TV", or "Eating or Drinking". There are three goals as following. First, we propose the activity log in the context-aware infrastructure ontology in the SH domain. The semantic of user's context can be obtained through this ontology. The activity log can also improve the ability of activity recognition. The reusability of knowledge is used to improve the generation for the new knowledge. Therefore, the relationship between activities is considered and leads to the hypothesis of this research, which is "activities in a specific location relate each other". Second, the location-based concept is developed in the activity log and DL rules. This concept makes the system knows what the activities were done by the user at the current user's location. It makes different result with the existing research [5]. For instance, the user does not need to do the "Drinking" activity after "Preparing drinking" activity immediately. It is possible that the user may do another activity before. We cannot use the recently activity for recognition in some cases. Finally, we demonstrate the advantage of proposed ideas through the semantic ontology search (SOS) system. We also present the ADL information, which gathers the activities in one day.

2 Proposed Ideas

2.1 Context-aware Infrastructure Ontology with Activity Log

Ontology model uses the knowledge engineering to define a semantic of context information, to explicit and formalize specification of a shared conceptualization. At present time, the ontology is adopted to various areas of researches, including the activity recognition. The context-aware information in SH domain has been introduced in several ontology models. [6] proposed a new user's context, which is human posture in the context-aware information to reduce the ambiguous case problem in the activity recognition system. Although the benefit of user's context is exhibited, it still needs to improve the relationship between semantic data. In

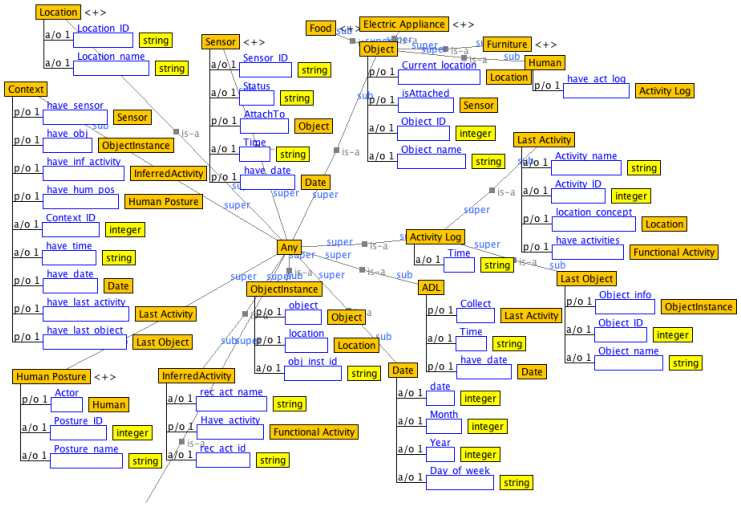


Fig. 1: Context-aware infrastructure ontology with activity log

this paper, we introduce the activity log to analyze the relationship between the current activity and last activity. The connection between current activated object and last activated object is also described for solving the "activity pattern ordering" problem.

Hozo application is used to build the ontology in this research. Fig. 1 illustrates the context-aware infrastructure ontology with the activity log. Based on our ontology modeling is centered on *Context* class, which relates to location information and surrounding entities such as sensor, object, and human posture. The data from *Context* class is operated as an input data in this research because it can link to all of the semantic data. *Activity log* class, moreover, is proposed to aggregate a sequence of history of activities and object activations. It is necessary for collecting the log data because it is difficult to guarantee the accuracy when we used only data at a specific time point. To reach the benefit of the activity log, the location-based concept is presented to make the activity recognition system more accurately. *ADL* class is also presented to express what activities human does in each day.

2.2 Location-based Concept in Activity Log and DL Rules

The location information in the *Activity log* class can be referred through two properties: "location_concept" and "Object_info". In the *last activity* class, the "location_concept" property refers to the activities, which user performed in the current user's location. For example, if the user is doing some activities in the kitchen, the activities that user performed in the kitchen will be considered in the activity log for classifying the current activity. The relationship between activities in the same place is investigated. For example, "Wash dishes" activity

will happen if and only if the "Cooking" and "Eating and Drinking" activities occurred before. Hence, we can ignore the activities, which are performed out of the current user's location. As described from the ontology in Fig 1, we can construct various kinds of semantic data from *last object* class, including the location information. It is reasonable to use the "Object_info" property to monitor the object, which has dynamic location. For example, user can use the "Broom" object to sweep the floor in any rooms. In addition, the "last object" can figure out the lack of data problem because the snapshot data at the specific time point maybe not enough for recognition. For example, the system perceives that the "Cupboard" object is being used. It cannot refer to any activities. However, if we know the object used by user before such as refrigerator, the system may recognize the current activity as "Making a cold drink".

The idea to create the DL rules is available at this stage. The existing researches have been proposed the basic DL rules for recognition the current human activity, described in the introduction section. Normally, the ontology concept does not support the temporal reasoning, so it is not an easy task to analyze the relationship between the recent activity and the current activity. In this paper, the external program is implemented to capture the temporal reasoning. The DL rules are established based on the location-based concept and used the external program to link with the temporal reasoning. The example below indicates the DL rule for "Wash dishes" activity. The example rule used the relationship between activities in the same location through "LastActivity.Kitchen Activity" property.

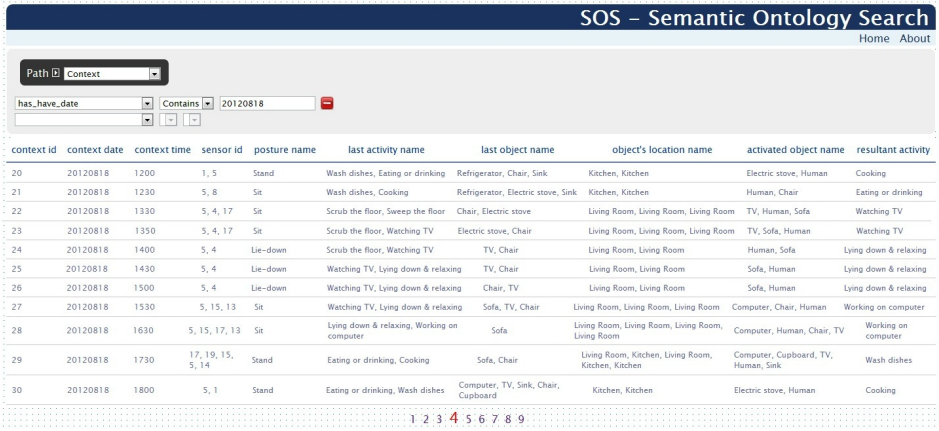
$$
\begin{aligned}
&Wash\ dishes \sqsubseteq Functional\ Activity \\
&\sqcap\ use(Object.Furniture(Sink)) \\
&\sqcap\ Object.Human.Current\_location(kitchen) \\
&\sqcap\ HumanPosture(Stand) \\
&\sqcap\ LastActivity.Kitchen\ Activity(Eating\ or\ drinking)
\end{aligned}
$$

3 Experiments and Results

In order to validate our approach, we have implemented the SOS system, with NECTECs ontology search framework [7], to recognize the human activity in the SH domain. For setting up the input data, the context-aware information in one day is fed into the system. We have also developed the external Java application to capture the temporal reasoning.

Figure 2 shows example results of the SOS system on 18th Aug 2012. We obtain good results when we use the reusability knowledge to promote the new knowledge. Context_id 29 is an outstanding example to explain the strong point of our proposed ideas. In this section, we will describe the usefulness of proposed ideas in two directions.

First, we compare between the systems that use activity log and does not use activity log. In general, "Sink" object in the kitchen can be activated in several purposes such as "Wash hands" activity, or "Wash dishes" activity. Thus, the



context id	context date	context time	sensor id	posture name	last activity name	last object name	object's location name	activated object name	resultant activity
20	20120818	1200	1, 5	Stand	Wash dishes, Eating or drinking	Refrigerator, Chair, Sink	Kitchen, Kitchen	Electric stove, Human	Cooking
21	20120818	1230	5, 8	Sit	Wash dishes, Cooking	Refrigerator, Electric stove, Sink	Kitchen, Kitchen	Human, Chair	Eating or drinking
22	20120818	1330	5, 4, 17	Sit	Scrub the floor, Sweep the floor	Chair, Electric stove	Living Room, Living Room, Living Room	TV, Human, Sofa	Watching TV
23	20120818	1350	5, 4, 17	Sit	Scrub the floor, Watching TV	Electric stove, Chair	Living Room, Living Room, Living Room	TV, Sofa, Human	Watching TV
24	20120818	1400	5, 4	Lie-down	Scrub the floor, Watching TV	TV, Chair	Living Room, Living Room	Human, Sofa	Lying down & relaxing
25	20120818	1430	5, 4	Lie-down	Watching TV, Lying down & relaxing	TV, Chair	Living Room, Living Room	Sofa, Human	Lying down & relaxing
26	20120818	1500	5, 4	Lie-down	Watching TV, Lying down & relaxing	Chair, TV	Living Room, Living Room	Sofa, Human	Lying down & relaxing
27	20120818	1530	5, 15, 13	Sit	Watching TV, Lying down & relaxing	Sofa, TV, Chair	Living Room, Living Room, Living Room	Computer, Chair, Human	Working on computer
28	20120818	1630	5, 15, 17, 13	Sit	Lying down & relaxing, Working on computer	Sofa	Living Room, Living Room, Living Room, Living Room	Computer, Human, Chair, TV	Working on computer
29	20120818	1730	17, 19, 15, 5, 14	Stand	Eating or drinking, Cooking	Sofa, Chair	Living Room, Kitchen, Living Room, Kitchen, Kitchen	Computer, Cupboard, TV, Human, Sink	Wash dishes
30	20120818	1800	5, 1	Stand	Eating or drinking, Wash dishes	Computer, TV, Sink, Chair, Cupboard	Kitchen, Kitchen	Electric stove, Human	Cooking

1 2 3 4 5 6 7 8 9

Fig. 2: Result of SOS system at 18th August 2012

system, which does not have the activity log, cannot get any supported ideas to ensure the resultant activity. On the other hand, the system with activity log considers the relationship between activities to achieve the correct resultant activity. For example, the "Eating or drinking" activity follows the "Cooking" activity. "Wash dishes" activity comes after "Eating or drinking" or "Cooking" activity. Furthermore, the system, which uses the activity log, also solves the "activity pattern ordering" problem. Since, each human has own lifestyle to complete the task, even the same task. The aggregated data from the history of activated objects can make the reasonable information, although the user has different ordering. Nonetheless, the sequence of activities may not be always arranged in the same order. It is depended on the human behavior.

Second, we compare the performance of two methods. One of them uses only the activity log to classify the activity, whereas another one method applies both the location-based concept and the activity log. The challenging point of the activity log is that it is difficult to keep track of activities, which one should consider with current activity, in some cases. The experimental results in Fig. 2 indicate the advantageous of the location-based concept in the activity log. If we consider in a column "last activity name" in context_id 28 carefully, the last activities are "Working on computer" and "Lying down & relaxing" activities. It is difficult to connect the relationship between these two activities and the user's context in context_id 29. Thus, the system uses the location-based concept and retrieves the last activities that user performed in the current location (context_id 20 = "Cooking" and context_id 21 ="Eating or drinking") to classify the resultant activity of this context. Truly, the resultant activity in context_id 29 can be other activities, but the "Wash dishes" is a high probability that the user may be performing because we have the supported conditions as "Cooking" and "Eating or drinking" to verify this result.

4 Conclusion and Future Works

We have proposed the technique to improve the ability of activity recognition in the SH domain. In this paper, we presented the activity log in context-aware infrastructure ontology to interconnect between history user's context and current user's context. The result shows the advantage overcome the existing systems when we add the activity log into the ontology. Furthermore, we also enhanced the activity log by including the location-based concept. The activities, which performed in the same location, are considered to decide the current activity. The experimental results also indicate how the importance of location-based concept is. With location information, system will scan the recent activities only in the interesting area. It makes the system classify the human activity more reasonable. In this paper, the SOS system has also introduced to evaluate the proposed ideas. In this system, various kinds of semantic data can be searched through the proposed ontology. The ADL information is recorded and formed in term of last activity – separated each ADL by date as shown in Fig. 1. Hence, we can retrieve the ADL information from SOS system for further processing.

The future directions of this research can be developed in many ways. For example, it can be established more specific rules to cover more activities in the SH domain or analyzed the human activity in each day, ADL, in order to perceive the human behavior. Then, analyze the human behavior to provide various kinds of services such as healthcare service, household appliances service, or entertainment service.

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