A Practical Activity Recognition Approach Based on the Generic Activity Framework

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ABSTRACT

In spite of the obvious importance of activity recognition technology for human centric applications, state-of-the-art activity recognition technology is not practical enough for real world deployments because of the insufficient accuracy and lack of support for programmability. The authors introduce a generic activity framework to address these issues. The generic activity framework is a refined hierarchical composition structure of the traditional activity theory. New activity recognition algorithms that can cooperate with the proposed activity framework and model are proposed. To be practical, activity recognition technology should also be programmable. The hierarchical aspects of our generic activity framework help to improve activity recognition programmability. The generic activity framework decouples the observation subsystem (i.e., the sensor set) from the rest of the activity model. The authors demonstrate the value of this decoupling by experimentally comparing the level of user effort needed in making sensor changes and the ramifications of such changes on model updates. They compare the level of effort required by the authors’ model to the requirements of previously reported approaches.

Keywords: Activity Model, Activity Recognition, Activity Theory, Generic Activity Framework, Multi Layer Neural Network

1. INTRODUCTION

Activity recognition (AR) technology can significantly empower many human centric applications in a variety of areas including healthcare and elder care (Helal, 2009, 2010). These applications are very critical for enhancing the quality of human life. For instance, telehealth systems can utilize activity recognition to empower caregivers with critical information beyond the patient’s vitals. The consistent and reliable service provided by such telehealth systems is especially critical for patients needing long-term care. For this and many other reasons, activity recognition technology has received significant attention from researchers in the past decade. Yet, current AR technology is not practical enough for real world applications due to its inadequate accuracy and difficult programmability.

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1.1. Inaccuracies in Activity Recognition

To be practical, activity recognition technology must guarantee the level of accuracy required by applications that utilize it. A lot of activity recognition (AR) research is focused on finding AR algorithms with improved accuracy using several techniques such as machine learning or artificial intelligence. However, recognizing human activities accurately is very challenging due to the diverse characteristics of human activities (Kim, 2010b). Among the many sources of inaccuracies, we found that the accuracy of the activity model affects the performance of other AR subsystems significantly. This is because the activity model is designed in an early stage of the AR system development process and other subsystems such as activity observation subsystem or activity recognition algorithm are developed based on the activity model. Currently, there are two popular activity-modeling techniques: activity theory based technique and probability-based technique. However, neither technique provides the high accuracy required by real-world applications.

Activity theory has been frequently used as a framework for activity model (Lingras, 2007; Surie, 2007; Lefrere, 2009). Even though activity theory is well known and is often used in activity modeling, it is not sufficient for real world activity recognition applications because of several limitations such as ambiguity and inaccuracy (Constantine, 2009; Kuutti, 1996). Moreover, activity theory was created and developed by psychologists so that it could aid in the understanding of human activities by other humans who have both high cognitive and understanding abilities. Modern activity recognition techniques are however being employed to understand human activities by intelligent computing systems. Since cognition by a computing system is very different from cognition by a human, it is necessary to revise conventional activity theory, or at least develop a new activity framework to extend this theory, to better support computer-based activity recognition systems.

In probabilistic activity recognition, it is assumed that human activities are continuously performed and each activity is a sequential composition of activity components such as motions, operations or actions according to a temporal sequence (Kim, 2010b). Among many probabilistic approaches, Hidden Markov Model (HMM) and Conditional Random Field (CRF) are popular modeling techniques. However, it is difficult to create models for complex activities using HMM or CRF. HMM determines the hidden state sequence (human activities) that corresponds to the observed sequence (sensor observation) and previously determined hidden state. HMM recognizes activities from both sensor observation and the previous activity in accordance with the first order Markov chain. The HMM is a generative, directed graph model (Rabiner, 1990) that should find all possible sequences of observations. Many activities may be performed in any order. Therefore, enumerating all possible observation cases and orders is difficult for a practical system. Furthermore, missing an observation or an order will cause the HMM to produce errors in the model.

Conditional Random Field (CRF) is more flexible than HMM because it relaxes the strict order constraint of HMM (Kim, 2010b). Similar to HMM, CRF also determines a hidden state transition from observation sequences. However, a CRF is a discriminative and an undirected acyclic graph, flexibly capturing any relation between an observation variable and a hidden state (Sutton, 2006). Because CRF does not account for the temporal order of the activities, it considers only relationships between observations and activities or relationships between past activities and future activities. Even though CRF removes order constraint from an activity model, it has been shown to be capable of outperforming HMM (Kasteren, 2008). However, CRF requires finding all possible relationships between activities. This is not practical because human activities may not always be in accordance with the typical relationships. To illustrate, “eating” usually follows “cooking,” but this rule may not always hold and other activities may be performed after “cooking.” If an activity model...
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