

Accepted Manuscript

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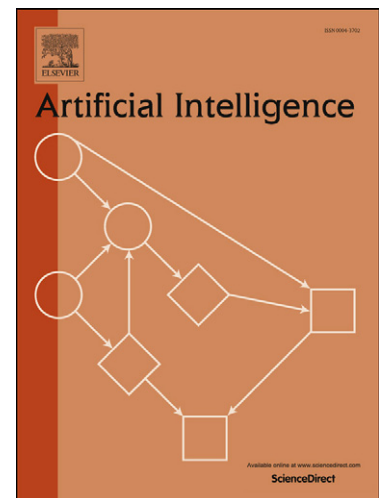
PII: S0004-3702(15)00132-0
DOI: <http://dx.doi.org/10.1016/j.artint.2015.08.009>
Reference: ARTINT 2881

To appear in: *Artificial Intelligence*

Revised date: 22 July 2015
Accepted date: 19 August 2015

Please cite this article in press as: K. Ramirez-Amaro et al., Transferring skills to humanoid robots by extracting semantic representations from observations of human activities, *Artificial Intelligence* (2015), <http://dx.doi.org/10.1016/j.artint.2015.08.009>

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Transferring Skills to Humanoid Robots by Extracting Semantic Representations from Observations of Human Activities

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Abstract

In this study, we present a framework that infers human activities from observations using semantic representations. The proposed framework can be utilized to address the difficult and challenging problem of transferring tasks and skills to humanoid robots. We propose a method that allows robots to obtain and determine a *higher-level* understanding of a demonstrator's behavior via semantic representations. This abstraction from observations captures the "essence" of the activity, thereby indicating which aspect of the demonstrator's actions should be executed in order to accomplish the required activity. Thus, a *meaningful semantic* description is obtained in terms of human motions and object properties. In addition, we validated the semantic rules obtained in different conditions, i.e., three different and complex kitchen activities: 1) making a pancake; 2) making a sandwich; and 3) setting the table. We present quantitative and qualitative results, which demonstrate that without any further training, our system can deal with time restrictions, different execution styles of the same task by several participants, and different labeling strategies. This means, the rules obtained from one scenario are still valid even for new situations, which demonstrates that the inferred representations do not depend on the task performed. The results show that our system correctly recognized human behaviors in *real-time* in around 87.44% of cases, which was even better than a random participant recognizing the behaviors of another human (about 76.68%). In particular, the semantic rules acquired can be used to effectively improve the dynamic growth of the ontology-base knowledge representation. Hence, this method can be used flexibly across different demonstrations and constraints to infer and achieve a similar goal to that observed. Furthermore, the inference capability introduced in this study was integrated into a joint space control loop for a humanoid robot, an iCub, for achieving similar goals to the human demonstrator *online*.

Keywords: Activity recognition, Human understanding, Knowledge-based, Semantic representation, Skill transfer.

1. Introduction

Transferring skills to humanoid robots based on observations of human activities is widely considered to be one of the most effective ways of increasing the capabilities of such systems [1, 2]. It is expected that semantic representations of human activities will play a key role in advancing these sophisticated systems beyond their current capabilities, which will enable these robots to obtain and determine *high level* understanding of human behavior. The ability to automatically recognize human behavior and react to them by generating the next probable motion or action according to human expectations will substantially enrich humanoid robots.

The main steps involved in inferring and reproducing the goal of the demonstrator's activity are [3]: 1) extracting the relevant aspects of the task; 2) processing the perceived information to infer the goal of the demonstrator; and 3) reproducing the best motion to achieve the inferred goal. Thus, in order to infer the desired goal, we first need a perception module that can determine which aspects of the activity are *important*. The most challenging aspect

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