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Big Data Analytics as a Service for Affective Humanoid Service Robots

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Abstract

This paper identifies and analyses the advanced capability requirements for humanoid service robots to serve in highly complicated and intelligence demanding applications, such as children education and home care, in future smart home environments. In particular, a Distributed Collaboration and Continuous Learning (DCCL) mechanism is identified as the key capability of a humanoid service robot to succeed in these applications. Based on the latest Big Data Analytics tools with distributed machine learning technologies integrated as services, a novel DCCL middleware platform is developed to facilitate the realisation of the DCCL mechanism. A user preference based children toy recommendation application is introduced as a use case study of the DCCL mechanism and platform.

Keywords: Affective Computing, Big Data Analytics, Continuous Learning, Distributed Collaboration, Humanoid, Service Robots

1 Introduction

As the rapid developments in the physical performance (i.e., hardware) and intelligent capability (i.e., software) of humanoid service robot technologies in recent years, the real-world applications of human service robots as companions in entertainment, education, and healthcare domains have been widely proposed and explored. As part of the autonomous nature, these humanoid service robots conventionally solely depend on the local built-in software to realise their intelligent capability and localised decision-makings.

However, as humanoid service robots are being widely deployed and distributed as daily life companions into highly complicated and intelligence demanding application domains, such as children education, ageing society in a smart home/school/campus environments, a gap emerges between the decision-making capability requirements of these applications and a humanoid service robot's localised intelligence capacity.

Facing these new application domains, an independent humanoid service robot is expected to fill the gap by accessing external/remote intelligence resources and services at runtime and even to

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collaborate with other humanoid service robots via an external open platforms. Although, in recent years, many Cloud computing technologies based systems or platforms have been designed and implemented to improve robot computation and collaboration abilities [1][2][3][4][5], the explorations on leveraging Big Data Analytics tools and distributed machine learning technologies and empowering both the intelligence and affection aspects of humanoid service robots were rarely reported.

In this paper, we tackle the highly complicated and intelligence demanding applications by using a Big Data Analytics as a Service approach, with which a novel Distributed Collaboration and Continuous Learning (DCCL) middleware platform is developed to support collaborative humanoid service robots in these domains. The main contributions of the paper are:

1. It identifies Distributed Collaboration and Continuous Learning (DCCL) mechanism as the key capability of a humanoid service robot companion to accomplish ever increasingly intelligence demanding applications such as children education and ageing society.
2. It proposes and develops a Big Data Analytics tools and distributed machine learning technologies based flexible and open DCCL middleware platform to support the capability.
3. It proposes and introduces use cases of the DCCL platform with preliminary experimental results to validate the platform.

The rest of the paper is organised as follows. Section II introduces related work on the Cloud services based collaborations of robots. Section III introduces the general model of affective interaction between humans and humanoid service robots and the main challenges in highly intelligent demanding scenarios; a Distributed Collaboration and Continuous Learning (DCCL) model is proposed to tackle the challenges. Section IV describes why and how Big Data Analytics could be used to realise the DCCL model and a Big Data Analytics as a Service approach is developed to construct a DCCL middleware platform. Finally, Section V concludes the paper and plans future works.

2 Related Work

In recent years, a development trend has merged in empowering an individual robot with more advanced social intercalation capabilities and connecting individual robots with Cloud services to facilitate computation intensive applications.

The DAvinCi [1] project develops a Cloud computing software framework for robotic ecosystem. The framework provides the scalability and parallelism advantages of Cloud computing for service robots in large environments. The framework is implemented on a Hadoop Cluster [6] with ROS (Robotic Operating system) [7] as the messaging framework. The RoboEarth project [2] develops a Cloud service based platform for sharing knowledge between robots and offloading computations into the Clouds. On this platform, robots are able to collaborate to exchange information and achieve a common task. The Cloud Robotics project [3] proposes a Cloud-based thin-client model for object recognition engine for service robots access to distributed computing resources and datasets and are able to share training and labelling data for robot learning. Two recent papers [4] and [5] conducted and reported comprehensive surveys on the topic of integration of robots with Cloud services.

Although these works exhibit a common theme of offloading intensive computation into the Cloud and sharing knowledge among robots, the support of fusing a coherent representation of world/context for facilitating advanced decision-making capabilities are largely missing. Moreover, the role of Big Data Analytics as a Service in the establishing of the representation and leveraging the representation for realising a DCCL mechanism is the main concern and contribution of the paper.