Intelligent Service Robots with Emotional Intelligence as a Service

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Abstract

This study examines the needs for improved capabilities in future smart home settings for humanoid service robots to handle complex and intelligence-intensive tasks like home care and education for children. One important feature for a humanoid service robot to have in these applications is the capacity to participate in Distributed Collaboration and Continuous Learning (DCCL). To make the DCCL mechanism a reality, a new middleware platform is created based on cutting-edge Big Data Analytics tools that include distributed machine learning technologies as services. As a case study of the DCCL platform and methodology, we provide a user preference based children's toy suggestion application.

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

1 Introduction

Many have speculated about and investigated potential uses for human service robots as companions in the fields of entertainment, education, and healthcare, thanks to the fast advancements in the hardware and software capabilities of these robots in recent years. Because of their inherent autonomy, these service robots often rely entirely on locally installed software to carry out cognitive tasks and make decisions specific to their immediate environment.

A gap becomes apparent between the decision-making capability requirements of these applications and the localized intelligence capacity of humanoid service robots as they are extensively deployed and distributed as daily life companions into extremely complex and intelligence demanding application domains like children's education and an ageing society in smart home/school/campus environments.

An autonomous humanoid service robot is anticipated to bridge the gap in these emerging application areas by using external/remote intelligence resources and services during runtime and maybe even towork along with other service robots that mimic human behavior via public, external platforms. Despite the proliferation of cloud-based systems and platforms aimed at enhancing robot computation and collaboration capabilities in recent years, very little is known about efforts to empower humanoid service robots' intelligence and affection via the use of Big Data Analytics tools and distributed machine learning technologies.

This paper presents a new Distributed Collaboration and Continuous Learning (DCCL) middleware platform that supports collaborative humanoid service robots in these domains. The platform is built using a Big Data Analytics as a Service approach, which allows us to tackle the complex and intelligence demanding applications. The paper's primary findings are:

1.To do ever-increasingly intelligence-demanding tasks, including educating youngsters and assisting the elderly, a humanoid service robot companion must possess the Distributed Collaboration and Continuous Learning (DCCL) mechanism.

2.To back up the capabilities, it suggests and builds a DCCL middleware platform based on distributed machine learning technology and big data analytics tools.

3.It presents and suggests use cases for the DCCL platform and includes early experimental findings to support the platform's validity.

Here is how the remainder of the paper is structured. In Section II, we provide relevant research on robot cooperation based on cloud services. In Section III, we lay out the fundamentals of the model for emotional interactions between humans and HSRs, and we discuss the key obstacles in complex, intelligent situations;

to overcome these obstacles, we offer a paradigm called Distributed Collaboration and Continuous Learning (DCCL). In Section IV, we discuss the rationale and potential implementation of Big Data Analytics in bringing the DCCL model to life. To build the DCCL middleware platform, we use a Big Data Analytics as a Service strategy. In Section V, the article comes to a close and future studies are outlined.

2 Other Tasks

Connecting individual robots to cloud services to enable computation-intensive applications and arming them with increasingly complex social intercalation capabilities have been a development trend in recent years.An ecosystem software framework for cloud computing is being developed as part of the DAvinCi [1] project. For service robots operating in expansive settings, the architecture makes available the Cloud's scalability and parallelism. The messaging framework is ROS [7], and the framework is embedded on a Hadoop Cluster [6]. Automated information exchange and compute offloading are two goals of the RoboEarth project [2], which is building a platform based on cloud services. This platform allows robots to work together, share data, and complete tasks more efficiently. Service robots may access distributed computer resources and datasets using the Cloud Robotics project's thin-client paradigm [3]. They can also exchange training and labeling data for robot learning. Two recent articles published extensive surveys on the subject of robot integration with Cloud services [4] and [5].

While there is a common thread in these efforts about robots sharing information and outsourcing costly computing to the cloud, there is a noticeable lack of support for integrating a coherent world/context representation to enable sophisticated decision-making capabilities. Also, the primary focus and contribution of the article is the function of Big Data Analytics as a Service in creating the model and using it to implement a DCCL mechanism.

3. Robots that Assist Humans Emotionally

3.1 **The Overarching Model of Emotional Interaction Between Humans and Robots**

The two-step process of recognition and response is typical for humanoid service robots when they engage in emotional interactions with human characters. In order for the robot to respond to a human character appropriately during a conversion, it must first be able to recognize the character's emotional state or overall mood through the processing of emotion-related stimuli, such as facial expressions, speeches, and gestures.The recognition step is represented by a model that combines individual classifications with overall data fusion. The robot is taught to recognize human emotions conveyed via facial expressions, voice, and gestures using separate supervised machine learning modules. The findings of each categorization are combined using a high-level information fusion module to determine an emotion state that is more accurate and realistic in general. When merging individual classification results, the information fusion module needs to be flexible and robust enough to accommodate the temporal and dynamic characteristics. This is because the overall judgment can be affected by the temporal features (coordination and correlation), such as the timing correlation of gesture changes and facial expression changes.Simulations of decision-making and high-level motor control processes constitute the response phase. Once a humanoid has identified a human character's facial emotion states, the second step in an affective interaction is for the humanoid to help the human character communicate with the character using synthesized emotional gestures, such as imitating body languages. During execution, a basic body language rule-based matching model of emotions and gestures will be consulted to choose one or more suitable gestures. In order to choose the right movements to portray different emotions, the model uses a series of conditional assertions. By favoring delicate motions over more forceful ones, these guidelines take into account certain temporal aspects of the contact process. As part of the responses to the 'contempt' emotion state shown by the human character, an example of this reaction phase is the choosing of an expressive gesture such as crossing arms in front of the chest. To create a synthetic gesture, the robot's fundamental arm, leg, and head motions are augmented by calling upon its body motion functions.

3.2 The Difficulties of Using a Humanoid Service Robot in Everyday Life

The two-step process of recognition and response is typical for humanoid service robots when they engage in emotional interactions with human characters. In order for the robot to respond to a human character appropriately during a conversion, it must first be able to recognize the character's emotional state or overall mood through the processing of emotion-related stimuli, such as facial expressions, speeches, and gestures.

In response to the increased demand for and rapid advancements in robotics over the last decade, there has been a recent uptick in research into and development of humanoid service robots (such as service and assistive robots) for use in everyday life [8][9][10][11][12][13][14]. There has been progress toward the goal of having humanoid service robots take part in human activities in the real world and improve people's quality of life. However, these robots are still designed to do simple, one-off mechanical and intelligent tasks, not accompany and serve humans for longer periods of time or with higher intelligence demands.

In these use cases, the humanoid service robot acts as a companion, hence it's important that it has certain capabilities:

1.Suggestion: Offer customized support and services.

2.Assistance with Decisions: Provide support for decision-making processes, including delegation.

3.Ability to read and respond to people's emotions and show some empathy is a sign of high emotional intelligence.

The fundamental information processing skills of a humanoid service robot, such vision, voice, and movement, may partially meet these needs. However, it is those sophisticated intellectual capabilities that allow a humanoid to really satisfy them. Any humanoid service robot worth its salt must have these high-tech features. Consequently, a team of robots will be able to work together more effectively in the actual world if their various observations and representations of it are combined into a single, coherent version. Broadly speaking, the presence of physical items is not always necessary for a world to exist; it may also be an abstract scenario or environment. One form of context that might pique the attention of several collaborative service robots is a person's emotional state or mood. In order for the robots to work together, it is necessary to create a real state of the surroundings by combining their observations from multiple perspectives across time.

3.3 The Importance of Being Able to Learn New Things and Collaborate Remotely

An autonomous humanoid service robot is anticipated to bridge the gap between the capabilities needed by these applications and its localized intelligence capacity. It will accomplish this by utilizing external/remote intelligence resources and services during operation and potentially collaborating with other such robots through an external open platform. Thus, a network of humanoid service robots working in tandem will need a method for Distributed Collaboration and Continuous Learning (DCCL). Service robots in a collaboration can be located anywhere in the world, but they must all work together to provide human users with the same view of the world and its context, and they must also learn from one another by imparting and receiving information and insights. Constantly referencing and updating the shared model that governs cooperation is how all the robots will learn.

4. Big Data Analytics for Collaborative Learning and Distributed Systems

4.1 A Big Data Analytics as a Service Methodology

The term "Big Data Analytics" refers to a way of gathering and analysing information from large amounts of unrelated data. The three defining features of Big Data are volume, velocity, and diversity, and to analyse it, researchers use scalable data processing platforms like the cloud, together with specialised data mining and machine learning methods. Big Data Analytics, with its distributed and scalable data processing and intelligent analysis ability, is a flexible and efficient method to support incremental data collection, storage, and knowledge modeling. It is particularly well-suited to the case of DCCL of service robots in smart home/school/campus applications, where the heterogeneous data sources and distributed nature of the service make it ideal. Our work lays the groundwork for service coordination and continuous learning among these robots by designing and implementing a DCCL middleware platform that corresponds to the DCCL concept.An emotional service robot and its human user may have more fruitful interactions with the help of this platform's distributed cooperation and continuous learning mechanisms. OnOne hand, distributed collaboration allows robots to work together and share resources and information amongst themselves;

another hand, continuous learning allows autonomous robots to pick up new skills from their peers by absorbing the information they share. Through a remote intelligence interface, humanoid robots can access advanced capabilities like recommendation, decision support, and emotional intelligence. These capabilities are built on top of Big Data Analytics' classification, recommendation, and clustering services hosted in the cloud. The service robots can access both the advanced capabilities and Big Data Analytics' services, which enhance their basic vision, speech, and mobility capabilities.

4.2 DCCL Platform Design Guidelines

The DCCL middleware platform is built on a scalable and flexible messaging system. It integrates a team of robots with the Big Data Analytics facilities located in the Cloud. The DCCL middleware platform's architecture perspective is shown in Figure 1. Key data creation and processing algorithms are implemented on the service robot side and the Cloud based Big Data Analytics Service side, respectively, inside the DCCL platform's messaging system. A facial emotion identification system on the side of the humanoid service robot can identify seven fundamental emotions and neutral expressions using a combination of unsupervised automated facial point detection, regression-based intensity estimate for facial action units (AU), and emotion grouping. Publications such as [16][17] provide in-depth explanations of face expression recognition. An method for updating world and context representations that links a person's emotional state to the interaction setting. In the world presentation, human character is a sort of item that has been predefined. Attributes such as ID, Name, and face expression state describe an individual human character, which is an object of the persons type. An algorithm for data fusion integrates information sent by the several robots involved in the interaction scenario to create a combined representation of the context on the side of the cloud-based Big Data Analytics Service. Using the consensus operator established in binary subjective logic, all of the robots' views are combined to determine the human character's emotional state [18]. Intelligent and appreciative decision-making based on the query to fused context representation is generated by a user preference based recommendation algorithm.

4.3 Implementing the DCCL Platform Prototype

Aldebaran NAO, a humanoid robot, and Apache Ecosystem's Big Data Analytics technologies are integrated to build the DCCL middleware platform [15]. The Aldebaran NAO is a humanoid robot that is controlled and operated via the NAOqi software framework. Advanced robot applications may be easily created with the help of the NAOqi framework's extensive library of programming resources. Apache HBase and Apache Hive provide the infrastructure for storing Big Data data. Built on top of the Apache Hadoop framework, Apache Mahout is a collection of scalable machine learning and data mining modules that facilitate Big Data analytics applications. The primary machine learning methods used by the Mahout libraries are recommendation, clustering, and classification. There are three primary components to the design, as shown in Figure 1. Component A consists of the functional modules inside a NAO robot. Component B is the basic messaging system. Component C is the data repository and Big Data Analytics Service on the Cloud.

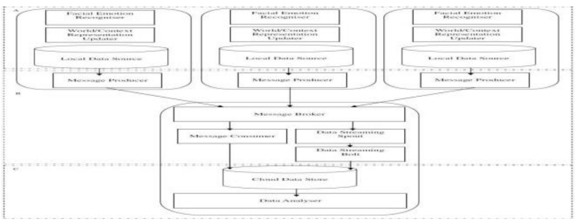

Figure1BigDataAnalyticsbasedDistributedCollaborationandContinuousLearningMiddleware Platform.

These components make up Part A of the NAO Humanoid Robot's Modules. A facial emotion recognizer triggers an event to update the database of environment and context representations whenever it detects an interested human character's facial expression. Updater for World/Context

Representation: ALWorldRepresentation is a NAOqi module that provides access to and updates data stored about generic objects over the long term. By subscribing to the database update event that the Facial Emotion Recognizer generates, the World/Context Representation Updater may update the World/Context Representation with the recognized emotion state encoded in the event payload. This is achieved using the API of the ALWorldRepresentation module. Using a C/C++ API library, the NAO robot has a local data source that stores permanent data in a SQLite database and allows for general searches with intelligent criteria. This library is wrapped by ALWorldRepresentation.These components make up Part B of the Messaging System's Modules. Although it is embedded on the robot side, the Local Data Source of Part A is also seen as part of the messaging system that connects the robot to the Big Data Analytics Service in the Cloud. This is from the perspective of the message source. The Apache Message Broker To facilitate communication between message producers, topics, and commuters, an open-source message broker called Kafka was developed. Message Producer: A Java application that accesses World Representation database data using the SQLite API and constructs and publishes well-formatted messages into a preset topic within the Kafka Message Broker using the Apache Kafka API. Java application Message Consumer, built on Apache Kafka API, subscribes to messages in the Kafka "FusedWorld" topic and stores them in the Cloud's Big Data Store. For applications involving the transmission of massive amounts of data, a Data Streaming Subsystem, in the form of a configurable plug-in, may be set up to import data from Kafka Producer into Apache Storm Spout. We will process this info immediately. Data from the Kafka "FusedWorld" message topic may be accessed using Apache Storm Spout. After Spout transmits data streams to Apache Storm Bolt, the latter analyzes the data and sends it to the cloud-based Big Data Store.

These components make up Part C of the Cloud-based Big Data Analytics Service's Modules. Mega Data Warehouse: Data is stored in tables generated using Apache Hive and Apache HBase.

the Data Streaming Subsystem that may be configured by the Message Consumer. A big data analyzer is a collection of data processing and analysis capabilities. It includes a high-level decision-support system based on Apache Mahout scalable data mining libraries and an information fusion process based on Subjective Logic Consensus Operator [18]. Since the DCCL platform integrates the NAO robot with the Apache Mahout recommendation library, a NAO service robot may consult a remote recommendation service located in the cloud.

Section 1.1: Designing the Case Study and Conducting Initial Simulation

An example use case for a recommendation app that takes user preferences into account is shown below. In this scenario, children's emotional states and actions will be used to choose which toys a humanoid service robot partner would find most suitable. The plan is to have these service robots that look like humans join a group of kids in a school setting so they can play. It is possible to deduce a child's emotional condition from their facial expressions when they play with a toy. Each robot companion records and shares the user's emotional state in order to fine-tune the recommendation decision-making process in real-time based on the user's preferences in relation to the toy suggestions. It is possible to deduce a child's toy choice based on the intensity of their emotional state and the rate at which it changes.

A common 'preferences' database table is used to hold the link between children's ID, toys' ID, and preferences as part of the context representation. In order to construct a recommendation model, the remote recommendation service utilizes a fused representation. Invoking a remote recommendation service, a humanoid service robot revises the preference values in response to identified changes in the child's emotions and makes a toy suggestion during runtime.

In an initial simulation investigation of the combined emotion detections by various robots over time, three humanoid robots are supposed to reach a final agreement based on the recognized facial expression state. In this 5-minute simulation, each of the three robots takes three photographs every one *second, for a total of 180 snapshots per minute; the goal is to find the consensus of a cheerful kind of facial emotion detections for a given facial emotion. The expectation of a detected type is a real number between 0 and 1 as a confidence value. Out of the 180 photos, each joyful type facial expression is utilized as positive evidence, while the other kinds, such as sad, surprised, neutral, etc., are all used as negative evidence. The Subjective Logic Consensus Operator [18] is the foundation for the interpretation of positive and negative evidence, as well as associated opinion consensus on the fused expectation calculation.*

2. Wrapping Up and Looking Ahead

***The paper's authors foresee that increasingly** complex (physically and intellectually demanding) application scenarios, such as smart homes, education for youngsters, and an aging population, would provide additional obstacles for humanoid service robot partners as they become more integrated into human civilization. Supporting increased capabilities of cooperative humanoid service robots that can conduct emotional interactions with human characters, a Distributed Collaboration and Continuous Learning middleware Platform is built using Big Data Analytics as a Service. Data transfers in a variety of settings are made possible by the DCCL middleware platform's versatile message producers, consumers, and subjects, all of which are made possible by the messaging system's reliability. Emotion stability characteristics, including arousal and valence, form a complex world representation, which may be used, for instance, to recognize a child's mood in the future. The platform allows for the collection and analysis of these characteristics throughout time. Instead of focusing on the short-term changes in the strength of a child's emotions when playing with a toy, the identification of mood allows us to infer that their choice for the item will shift over time.*

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