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Energy Condition Perception and Big Data Analysis for Industrial Cloud Robotics

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Abstract

Industrial cloud robotics (ICRs), which is proposed to integrate the distributed industrial robots (IRs) resources to provide ICRs services at any place, has been attracted great attention due to the characteristics of convenient access, cheaper computing cost, more convenient network resources, etc. Meanwhile, in manufacturing industry, the energy-efficient issue, which means minimize the amount of energy resources to achieve a given output level in manufacturing process, is also gradually paid great attention by academia, industry and government. Currently, ICRs plays a crucial role in production. The implementation of energy-efficient manufacturing for ICRs will significantly decrease the energy consumption on the premise of normal production process, and also have remarkable effect on energy-saving and emission-reduction in manufacturing industry. In this context, the energy condition perception and big data analysis of ICRs are the essential procedure to achieve the aforementioned goals. A novel system architecture which mainly focuses on distributed energy condition perception and big data analysis for ICRs is built. Based on the perceptive data of ICRs related to energy consumption, a big data analysis model combined with the manufacturing status of ICRs is proposed, and the relationship between the big data and the analysis model is presented. Through the data analysis model, we can analyze the energy consumption fluctuation characteristic of ICRs operating state, count the energy consumption of the product related to different production phases, predict the health status of ICRs, as well as the trend of energy consumption associated with their operations. A case study is implemented to demonstrate the effectiveness of the proposed system and approaches.

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Keywords: Industrial cloud robotics; energy-efficient manufacturing; distributed perception; big data analysis

1. Introduction

Cloud robotics (CRs), a new term which was introduced by James Kuffner at Google [1], is a new research field by combining the cloud computing technology with robotics. Due to the characteristics of massive parallel computation and real-time sharing of vast data resources, the robot can improve its capability when it accesses to the cloud, such as recognition functionalities, path planning, etc [2]. There are many IT companies and researchers which focus on the research field. Under this situation, due to the traditional industrial robots (IRs) are physically independent from each other, combining the IRs with CRs can significantly improve the internal communication and capacity extension of IRs, etc. Therefore, a new concept named Industrial Cloud Robotics (ICRs), which aims at integrating the distributed IRs resources to provide ICRs services at any place by convenient network resources and cheaper computing cost, is proposed [3]. When IRs are connected to the Cloud, they can be regarded as ICRs. Through the Cloud method, ICRs can share working knowledge, work at a lower cost by using a more open way than before.

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Currently, ICRs have been widely used in factories and take tedious and dangerous tasks, such as machining, assembly, painting, etc. However, when it comes to the energy consumption of ICRs, researches show that energy consumption of ICRs is approximately 8% of the total electrical energy consumed in manufacturing processes [4], and the energy consumed by manufacturing production is one of the main causes of global warming. With the public awareness of environmental protection enhanced and energy prices increased, enterprise and researchers have been engaged in the study about energy saving and energy efficiency improvement in manufacturing processing, such as the AREUS project, and one of the project target is to reduce the energy consumption of IRs by innovative hardware and software technology [5]. In this case, the energy efficient manufacturing is proposed, it is focused on improving manufacturing efficiency and reducing carbon emission during manufacturing processing [6]. Meanwhile, because ICRs are widely used in manufacturing process, the implementation of energy efficient manufacturing for ICRs will decrease the energy consumption on the premise of normal manufacturing process, and also gain economic benefits for industrial enterprises and environmental benefits for our society.

In order to carry out the energy efficient manufacturing for ICRs, we must find out the energy consumption characteristics of ICRs. Besides, because energy consumption of ICRs is multi-source, the distributed perception method to the energy consumption of ICRs is also essential, and this will facilitate us to understand the energy consumption of ICRs dynamically. Due to the perceptive data is large in size, the common data storage and analysis method may not be suitable for this situation. Thus, the big data technology and analysis method is adopted to convert the original perceptive data to valuable information, such as the trend of energy consumption for ICRs.

In the research fields of energy consumption distributed perception and big data analysis for ICRs, there are little literature mentioned directly. Liu *et al.*[3] presents a framework of ICR towards sustainable manufacturing and its enabling methodologies, Brossog *et al.* [4] described the power loss model and energy consumption factors of ICRs. Kehoe *et al.* [7] gives the recent development of Cloud robotics and some relevant technologies. Lee *et al.* [8] represents the case of the energy consumption management system of Omron company by combining the big data technology to reduce the energy consumption in the manufacturing process. Our current work will lay the foundation for the future scheduling, optimization work, such as Riazi et al. [9] realizes the energy optimization of IRs supported by current angular position information of IR's joints, etc. It will also provide the supporting information to the improvement of energy efficiency and implement of energy efficient manufacturing.

The rest of this paper is organized as follows. Firstly, the system architecture is presented in section II, and the relevant enabling approaches are also described in section III. Then, A case study to demonstrate the effectiveness of the proposed system is implemented and analyzed in section IV. Finally, the conclusion are made in section V.

2. System architecture

In order to obtain detailed energy consumption of ICRs in the manufacturing processes dynamically and dig out valuable information from the perceptive data by utilizing big data analysis method, a novel system architecture is built, just as shown in Fig. 1.

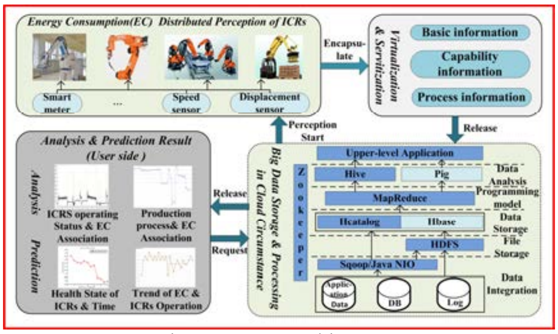

Fig. 1.System architecture

The system architecture contains four parts: the distributed perception, virtualization and servitization, big data storage and processing, analysis and prediction. Firstly, the distributed perception is focused on the analysis on energy consumption characteristics of ICRs and distributed energy condition perception method of ICRs. As we know, there are different types of ICRs and the energy consumption of ICRs which are made up of multiple parts, such as the energy consumed by motor or associated equipment, it is essential to analyze the mechanism of the energy consumption and obtain relative influence factors through the distributed sensing method, for instance, obtain the energy consumption data by the smart meter. As the user need to analyze the relevant energy consumption of ICRs, requests should be sent, and the authorized sensors installed on ICRs, which is also called condition perception. Secondly, in the virtualization and servitization, since ICRs are service-oriented, it's needed to build a virtualized description model to map the actual physics resources to virtual digital resources, and encapsulate it as a service. Then, in the big data storage and processing, considering that the perceived data of ICRs is big data, we need to integrate the receiving data, store and manage it in the database through the Hadoop technology. Finally, in the analysis and prediction, we need to extract and process the collected data through processing method such as DBSCAN clustering algorithm to identify the energy consumption patterns, RBF neural network to predict the trend of energy consumption, etc. By this way, we can analyze the energy consumption fluctuation characteristic of ICRs operating state, so as to measure the energy consumption of the product, which is related to different production phases, predict the health status of ICRs, as well as the trend of energy consumption associated with their operations. Analysis or prediction result will be send to the users according to the request.