A Proposal On Robotics Using Cloud Computing

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***Abstract*—Technology advantage has opened a new research discipline for the robotic world. This paper aims to introduce the application and research of robots using cloud computing. The concept of networked robot is changing and opening a new field of research called cloud robot. The new machine to cloud communicating will enhance the efficiency and productivity of robots in industries. Currently Cloud Robotics is considered as one of the emerging research field under the mainstream research of robotics and artificial intelligence. The main focus of cloud robotics research is to explore the possibility of using existing cloud-computing infrastructure, which is based upon service oriented architecture. Further advancements in this field aim to establish a shared network resource for various robotics applications of future in order to make robots more scalable. Researchers strongly believe that this would also enable scalable, cheaper and much powerful robotic application with intelligent and self learning robots.**

***Keywords*—cloud computing, big data, networked robot**

I INTRODUCTION

Machine intelligent and robotic applications have brought significant impact to human life over the past few decades [1]. For example robots are used in industries to enhance productivity and for the successful completion of real time jobs. Many industries that use assembly line manufacturing process uses robots to get work don with in the dead line. Defense as well as the health care sector also uses robots for efficiency. A robot is a mechanical or virtual agent, usually an electro-mechanical machine that is guided by a computer program or electronic circuitry. Robots can be autonomous or semi-autonomous intelligent machine. Robotics is a wide and vast research field that is growing day by day. The research on robots has result in the new era of robots called cloud robots. The cloud robotic architecture leverages the combination of an ad-hoc cloud formed by machine-to-machine (M2M) communications among participating robots, and an infrastructure cloud enabled by machine-to-cloud (M2C) communications.

Unimate a digital programmable robot, was the first industrial robot, which worked on a General Motors assembly line at the Inland Fisher Guide Plant in Ewing Township, New Jersey, in 1961. It was invented by George Devol in 1954. Today, it is now possible to envisage human sized robots with the capacity for near human thoughts and movement. The preprogrammed digital robot has now evolved to networked and cloud robotics.

A networked robotic system refers to a group of robotic devices that are connected via a wired and/or wireless communication network . Networked robotics applications can be classified as either *tele-operated* robots or *multi-robot* systems. In the former case, a human operator controls or manipulates a robot at a distance by sending commands and receiving measurements via the communication network. Where the robots are controlled from distance using wireless connections like Bluetooth, Wi-Fi, Deep Space Network etc. Application examples include remote control of a planetary rover and remote medical surgery. In the latter case, a team of networked robots complete a task cooperatively in a distributed fashion by exchanging sensing data and information via the communication network. For example a group of robots engaged in rescue mission.

Networked robots, similar to standalone robots, faces inherent physical constraints as all computations are conducted onboard the robots, which have limited computing capabilities. Information access is also restricted to the collective storage of the network. With the rapid advancement of wireless communications and recent innovations in cloud computing technologies, some of these constraints can be overcome through the concept of *cloud robotics*.

In the cloud robotics the robots communicate with the cloud to share information and data. There are many architecture which explain the communication protocols. In the cloud system even the robots can communicate each other as in the case of networked robots. The data that are collected from individual robots or group of robots can be stored in the cloud or can be transferred from the cloud to a storage database where big data analysis can be used to obtain some information from the data. In this type of cloud interconnected robotic environment we use the new big data technology to collect and analysis huge data. The new technology growth take robotic research to a new level of environment where we can form an interconnected network of robots which can do useful work by sharing data and communicating with each other.

II CLOUD COMPUTING

Cloud computing is a terminology used to describe a computing environment in which information as well as application are shared to process data. It is a distributed environment in which not only network but also application, storage space, resources, etc. are shared to obtain a powerful

ISSN: 2278-0181

computing environment. In this architecture the Virtual machines are placed in the network place where it can communicate with each other without knowing the exact physical location.

In the 1960s, after the invention of computers, the need for computers as a public service was realized. It was not until 30 years later, with the creation of the Internet that allowed launching cloud computing to what it is today (Fig. 1). Cloud computing refers to sharing of computational resources over a network. Although seemingly a simple concept, it relieves remote devices from the burden of carrying out extensive computations and complex decision making procedures. It also allows even the simplest devices to have access to an unlimited supply of software resources .

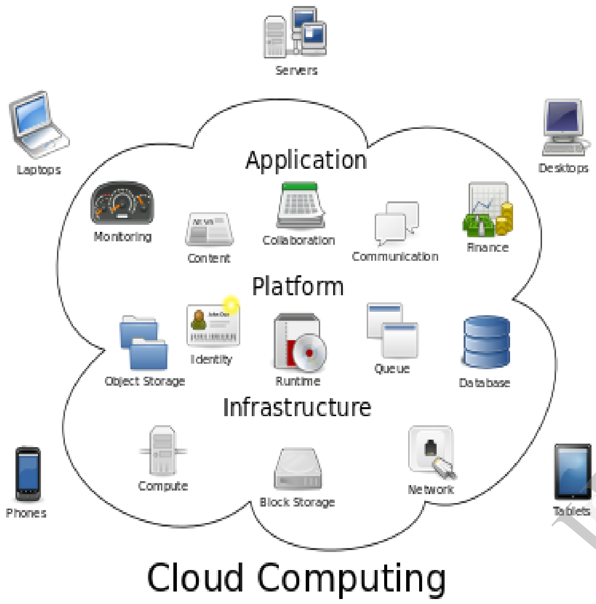

Fig 1: cloud computing

A. Cloud Service Model

Cloud computing providers offer their services according to several fundamental. Mainly there are three service models but we can generalize it as anything as a service. (XaaS) are described in a comprehensive taxonomy model published in 2009, such as Strategy-as-a-Service, Collaboration-as-a-Service, Business Process-as-a-Service, Database-as-a-Service. In 2012, network as a service (NaaS) and communication as a service (CaaS) were officially included by ITU (International Telecommunication Union) as part of the basic cloud computing models, recognized service categories of a telecommunication-centric cloud ecosystem.

Three basic cloud service models are Infrastructure as a service (IaaS), platform as a service (PaaS) and software as a service (SaaS). In the most basic cloud-service model, providers of IaaS offer computers, both in physical or logical and other services. In the PaaS models, cloud providers deliver a computing platform, typically including operating system, programming language execution environment, database, and web server. Application developers can develop and run their software solutions on a cloud platform without the cost and complexity of buying and managing the underlying hardware and software layers. In the business model using software as a service (SaaS), users are provided access to application software and databases. Cloud providers manage the infrastructure and platforms that run the applications. SaaS is sometimes referred to as "on-demand software" and is usually priced on a pay-per-use basis.

III CLOUD ROBOTICS

Our cloud robotics differentiates from existing solutions in that it leverages two complementary clouds (i.e., an ad-hoc cloud and an infrastructure cloud). The interconnected networked robot has changed to more advanced cloud robots. The networked robot results in machine to machine communication (M2M) to share information. This method has enhanced to the new model of communication i.e., machine to cloud (M2C). Cloud computing uses both M2M as well as M2C communication method to achieve maximum efficiency.

A. Network To Cloud Robot

Networked robot can be considered as a parent or an evolutionary step towards cloud robotics, i.e., cloud enabled networked robot which leveraged the emerging cloud technology to form cloud robot. The design objective is to overcome the limitations of networked robotics with flexible resources offered by a ubiquitous cloud infrastructure.

NIST defines cloud computing as “a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.” Cloud technology or cloud computing provide a natural platform to develop the networked robot.

Several research groups such as Google, Microsoft have started to explore the use of cloud technologies in robotic applications. Google have developed smart-phone driven robots that can learn from each other via the cloud [4]. The three main service model (i.e., software, platform and infrastructure), it enables tremendous flexibility in designing and implementing new applications for networked robotics.

IV SYSTEM ARCHITURE

The Cloud robotic architecture mainly consist of M2M or/and M2C architecture. On the M2M level, a group of robots communicate via wireless links to form a collaborative computing fabric (i.e., an ad-hoc cloud). The benefit of forming a collaborative computing fabric are many. First, the computing capability of individual robots can be pooled together to form a virtual ad-hoc cloud infrastructure. Next one is among the collaborative computing units, information can be exchanged for collaborative decision making in various robot-related applications. Finally, it allows robots that are not within communication range of a cloud access point to access information stored in the cloud infrastructure or send computational requests to the cloud.

On the other hand for M2C level the infrastructure cloud provides a pool of shared computation and storage resources that can be allocated elastically for real-time demand. This method allows individual robots as well as robotic group to offload computation task for a remote environment resulting in remote brain. By this method we can also exploit the new big data analysis for analyzing data to obtain useful information. This cloud method also helps to create scalable robots which can do multiple task by downloading the proper programs as well as library files from the cloud store.

A. Elastic Cloud Computing Architecture

The elastic cloud computing architecture can be viewed as hybrid model for cloud robotics. The proposed cloud robotics is built on the combination of an ad-hoc cloud formed by a group of networked robots and an infrastructure cloud. This unique combination offers us great flexibilities in designing computing models tailored for specific applications. We focus on the following three elastic computing models:

- Clone-Based Model: Each robot has a corresponding system level clone in the cloud. A task can be executed in the robot or in its clone. The set of robotic clones also form a peer-to-peer network with better connectivity than the physical ad-hoc M2M network. Moreover, this model allows for sporadic outage in the physical M2M network. Fig(2) shows clone-based model.

- Peer-Based Model: Each virtual machine (VM) or robot in the cloud is considered as a computing unit. These robots and VMs form a fully distributed computing mesh. A task can be divided into smaller modules for execution over a subset of the nodes in the computing mesh. By this the computing load is distributed among the systems. Fig(3) shows peer-peer model.

- Proxy-Based Model: In the group of networked robots, where one unit functions as a group leader, communicating with a proxy to bridge the interaction between the robotic network and the cloud. The set of computing units are organized into a two-tier hierarchy. Fig(4) shows proxy model.

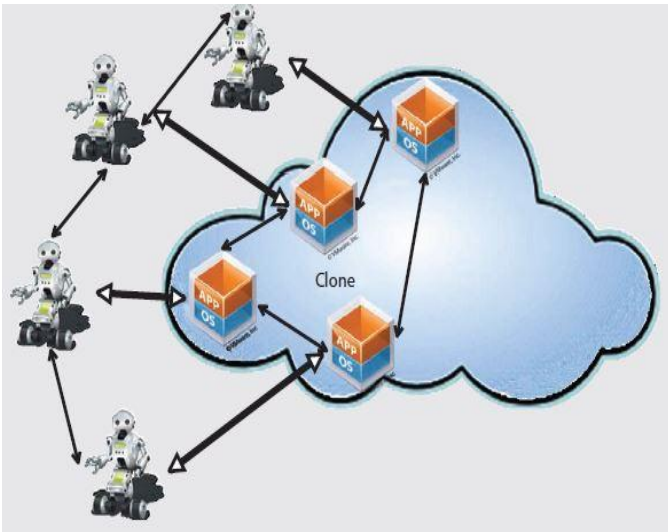

Fig 2: showing clone model

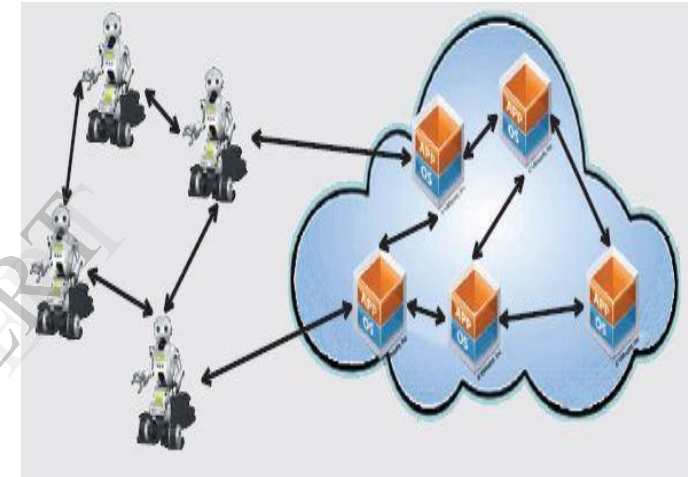

Fig3: showing peer to peer model

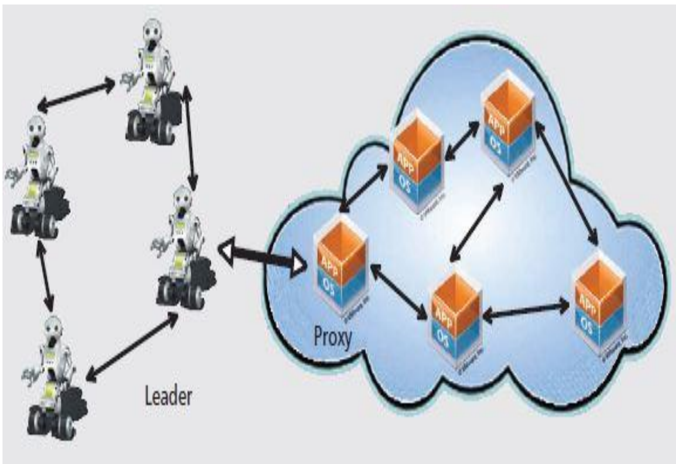

Fig4: showing proxy model

V APPLICATIONS AND ON GOING RESEARCH PROJECTS

Future robotic applications will benefit from cloud robotics, which provides the following advantages over traditional networked robots.

- Ability to offload computation-intensive tasks to the cloud.
- Access to vast amounts of data.
- Access to shared knowledge and new skills.

A. Cloud Robots In Assembly Line Production

Manufacturing industry is experiencing a large amount of drastic changes since the introduction of robots. The main advantage of robots are they can do hard dead line work which is much hazardous work. Industries that uses assembly line production is using networked robot which can share information and achieve the task in a remarkable manner. Robots which can do group task are also employed much in large scale.

Replacing these robots by cloud robot has many advantages. The scalable nature of cloud robots helps to keep very less resource within the robotic system. Keeping the resource and sharing the information and data will help to perform group task in much cooperative manner. Also the big data analysis can be used much to derive information which can be shared. In such a system the data from different robots are collected in the cloud and is then processed using a database server with big data analysis. So that the large amount of data can be used to get some useful information. And this data as well as the information can be shared to other group of networked robot.

For example the data collected by a robot which preforms pick and place can be used by robots that perform the assembling job. Even this information can be used by the robots which are working in the painting chamber. The collective cloud data can be analyzed using big data analysis to get some useful information that can be used by mechanics, who work in the local work station.

B. Cloud Robots In Aerospace Application

Compared to the automotive industry, the aerospace industry has been slow to introduce industrial robotics onto its assembly lines. Recently, however, there has been a general move towards automation in order to increase throughput and standardize processes. The slow introduction of industrial robots into the aerospace industry is largely due to the need for high accuracy over large structures. For example, holes have to be drilled within large structures with both high absolute and relative accuracy relative to other holes and features of the aircraft assembly. Airbus has been researching low cost, highly flexible automation for several years. However, tasks within rib bays and other low access areas found throughout aircraft structures have remained practically inaccessible to automation.

While robotics play an important function in the fabrication of aircraft engines, aerospace companies are increasingly investing in robots to perform drilling, painting and other tasks on airframes. Robot's ability to repeatedly position very large aerospace components with a high degree of precision ensures that flexible automation has potential market growth.
Comparing to other industries aerospace industries took much time to exploit the use of robots. But now they are also using robots in a large extend. For example, OC Robotics is working with Airbus UK and KUKA to develop aerospace robots to deliver end effector packages capable of inspection, drilling, sealing and swaging.
The new technology of cloud robot is opening a new research area for robots in aerospace industries. Since the work like drilling and the use of Snake-arm robot[5] can use the cloud robotic technology to achieve much higher efficiency.

C. Cloud Robots In Healthcare

Robots are widely used to assist humans in repetitive and physically demanding work or for things that need accuracy and precision in nearly every industry. Although currently healthcare robots are more widespread in professional clinical services, they can potentially become popular for personal use as well.
There is growing interest in healthcare robotics and several areas of innovation have been identified. A report by The European Foresight Monitoring Network identified main innovation themes: robotics for medical interventions, robotized technology, professional care support, robots assisted preventative therapy[8], diagnosis and rehabilitation treatment. Further six areas of support were announced by the European Commission Programme. They identified smart medical capsules, intelligent prosthetics, monitoring systems, robotized surgery, robotized motor coordination analysis systems and robot assisted cognitive and social therapies as particularly relevant based on the market, industrial and socio-economic potential.
The robotic assistance or robots used in medical field can be networked or clouded to enhance the use of knowledge. Each hospital or hospital group can be consider as a public or privet cloud group and each robot, i.e., cloud robot that is associated with it can share information. Research is focusing on implementing new architecture that can be scalable to enhance the use of cloud robots. By doing this even the robot itself can diagonals the disease and can prescribe medicine. Even the robots used in surgical area can share information with the cloud and can be scalable by downloading new library file for different application.

D. Ongoing Research Projects

There are number of research project ongoing in the field of 'Cloud Robotics'.

1) Roboearth

This is a European project lead by Eindhoven University of technology, Netherland. The project's main goal is to develop a 'Word Wide Web for robots', which could be seen as huge database over the network where robots can share information about objects, its environment and various other tasks.

2) Related work

Singapore's A-Star Social Robotics Laboratory (ASORO), have successfully built a cloud-computing infrastructure which helps robots to build 3-D maps of their environment at much faster speed than they could with onboard computers.

Google researchers and engineers have successfully developed and demonstrated Android based software which enables smartphones to control various robotics platform like Lego Mindstorms, iRobot etc.

Nao, a type of Humanoid Robot, which is used at children's hospital in Italy, rely on cloud infrastructure for some of its services like face detection, speech recognition and other tasks, which would improve their interaction with patients.

VI CONCLUSION

This paper aims to introduce basic architecture as well as some of the area of research where cloud robots can be incorporated. The wide application of cloud robots are already recognized by many research organizations worldwide. The new technology such as big data is also being discussed in the research environment. Incorporating the cloud as well as the big data analysis can further increase the application of the robots in the future world.

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