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Cloud Robotics

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ABSTRACT

Cloud robotics has recently emerged as a collaborative technology between cloud computing and service robotics enabled through progress in wireless networking, large scale storage and communication technologies, and the ubiquitous presence of Internet resources over recent years. Cloud computing empowers robots by offering them faster and more powerful computational capabilities through massively parallel computation and higher data storage facilities. It also offers access to open-source, big datasets and software, cooperative learning capabilities through knowledge sharing, and human knowledge through crowd sourcing. The recent progress in cloud robotics hasled to active research in this area spanning from the development of cloud robotics architectures to its varied applications in different domains. In this survey paper, we review the recent works in the area of cloud robotics technologies as well as its applications. We draw insights about the current trends in cloud robotics and discuss the challenges and limitations in the current literature, open research questions and future research directions

Keywords: Cloud robotics, Collective robot learning, knowledge sharing

INTRODUCTION

Cloud robotics is an intersection between robotics, cloud computing, deep learning, big data, and internet of things and other emerging technologies. It is a field of robotics where robots rely on the internet network to implement their functions. More like, a robot whose sensing and computation are not integrated into a single system, thus robot having “an extended or a shared brain”, As a result, robots are getting not only smarter by connecting to the cloud, but also cheaper and smaller. Robotic systems have bought significant socioeconomic impacts to human lives over the past decades. For example, industrial robots have been widely deployed in factories to do tedious, repetitive, or dangerous tasks, such as assembly, painting, packaging, and welding. These pre-programmed robots have been very successful in industrial applications due to their high endurance, speed, and precision in structured factory environments. To extend the functional range of these robots or to deploy them in unstructured environments, robotic technologies are integrated with network technologies to foster the emergence of networked 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 teleoperated 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.

Robot cannot perform a task unless and until the task is pre-programmed into it. This limit can be exceeded by using cloud robots. When connected to the cloud, robots can benefit from the powerful computation, storage, and communication resources of modern data center in the cloud.

CHALLENGES IN NETWORKED ROBOTICS

Resource constraints:
Although a robot can share its computation workload with other units in the network, the overall effectiveness of the robotic network is limited by each robot’s resources, including onboard computers or embedded computing units, memories, and storage space. Physically, these onboard computing devices are restricted by the robots’ size, shape, power supply, motion mode, and working environment. Once the robots are designed, built and deployed, it is technically challenging to change or upgrade their resource configurations.

Information and learning constraints:
The amount of information a robot has access to is constrained by its processing power, storage space, and the number and type of sensors it carries. Networked robotics allows the sharing of information amongst robots connected by a communication network so that a global task can be solved or computed cooperatively using the whole network. However, networked robotics is constrained by the information observed or computed by robots in the network, and by the examples or scenarios that the network encounters, and hence limiting its ability to learn. A robotic team learning to navigate may perform very well in a static environment, where all obstacles can be mapped out with an increasing accuracy over time. On the other hand, the learning process has to be repeated once the environment changes or the robotic team is placed in a new unfamiliar environment.

Communication constraints :
Common protocols for machine-to-machine (M2M) communications include proactive routing, which involves the periodic exchange of messages so that routes to every possible destination in the network is maintained [3], and ad hoc routing, which forms a dynamic route to a destination node only when there is a message that needs to be sent [4]. Proactive routing incurs high computation and memory resources in the route discovery and

maintenance process. Ad hoc routing protocols suffer from high latency as a route has to be established before a message can be sent, and are not practical if the network topology is highly dynamic. These drawbacks are significant in mobile robotic networks, and may lead to severe performance degradation.

From networked robotics to cloud robotics:

Networked robotics can be considered as an evolutionary step towards cloud robotics, i.e., cloud-enabled networked robotics, which leverages emerging cloud computing technologies to transform networked robotics. The design objective is to overcome the limitations of networked robotics with elastic resources in a centralized cloud infrastructure. Cloud computing provides a natural venue to extend the capabilities of networked robotics. NIST [5] 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." Through its three service models (i.e., software, platform and infrastructure), it would enable tremendous flexibility in designing and implementing new applications for networked robotics.

CLOUD ROBOTICS ARCHITECTURE

The architecture is organized into two types: a machine-to-machine (M2M) level and a machine-to-cloud(M2C)level. The Cloud robotic architecture mainly consists of M2Mor/and M2C architecture.

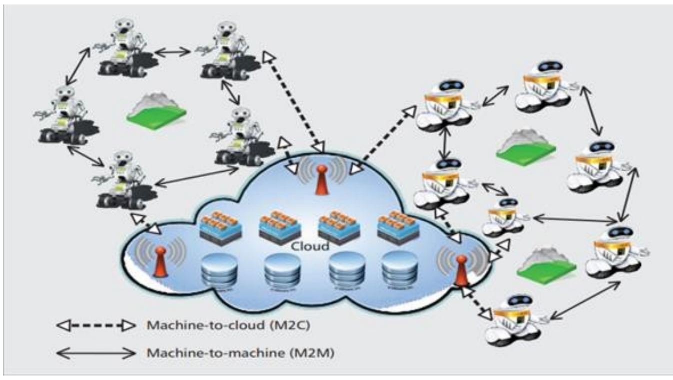

Figure 1: Cloud Robotics: Robots are interconnected via M2M/M2C communications [5]

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 virtualad-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.

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. The following are the three elastic computing models:

Clone-Based Model: Figure 2 shows the 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 modelallows for sporadic outage in the physical M2M network.

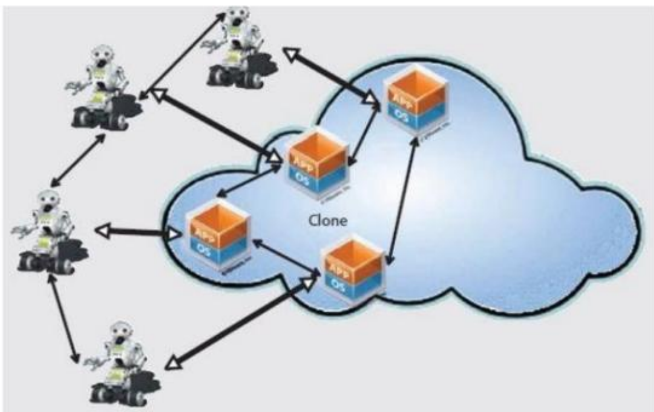

Figure 2: Clone-Based model[5]

Peer-Based Model:Figure 3 Shows the 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.

Figure 3 Peer-Based Model [5]

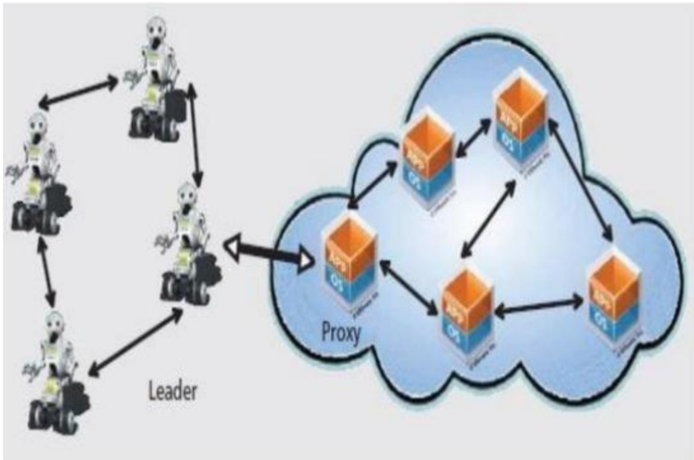

Figure 4: Proxy-Based Model

Proxy-Based Model: Figure 4 Shows the 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.

EMPOWERING CLOUDCOMPUTING IN ROBOTICS:

Digital Transformation:

That digital transformation is assisting a robot in automating a task while also giving vital data back to help you run your organization more efficiently," Barga explains. "When people think about robots and automation, they don't usually consider that story. They understand that it will need a long-term strategy for the services to ingest the data and the analytics they'll access to create around it to run their business more efficiently. Things start to become extremely intriguing after that."

Innovations in Cloud Robotics:

Cloud Robotics Innovations discovered that cloud robotics would lead to intelligent robots with higher computing efficiency and lower power consumption. These characteristics will lower manufacturing costs because there will be less hardware, as well as lower emissions.

Cloud robotics innovation has gained traction due to initiatives by large corporations such as Google and IBM and the participation of research institutes in some ongoing projects worldwide. The need to develop robots with high performance and accessibility has been the primary focus of research activities.

Supervised Autonomy:

These robots' heads may be in the clouds, but that doesn't rule out the presence of a brain. The robots are all self-contained, intelligent units.
Mobile robots, particularly those used in intralogistics, must securely navigate warehouses, factories, and distribution centers while avoiding workers, forklifts, and other equipment.

Faster Deployment:

The only autonomous mobile robot (AMR) option for material handling and data gathering that deploys in hours rather than weeks and does not require instant integration to demonstrate values is the cloud robotics platform. On-demand automation is the term for it. A cloud software platform effectively runs a fleet of cart-carrying autonomous mobility robots at a third-party logistics warehouse for an automotive company.

ADVANTAGES

- Back up and restore data: Once the data is stored in the cloud, it is easier to get back-up and restore that data using the cloud. The fact that data can be stored in the cloud without capacity constrains also helps with backup and restore purposes.
- Improved collaboration: Cloud applications improve collaborations by allowing groups of people to quickly and easily share information in the cloud via shared storage.
- Low maintenance cost: Cloud computing reduces both hardware and software maintenance costs for organizations.
- Unlimited storage capacity: Cloud offers a huge amount of storage capacity for storing important data such as documents, images, audio, video, etc,. in one place.
- Big data: Access to updated libraries of images, maps, and object/product data.
- Collective learning: Robots and systems sharing trajectories, control policies, and outcomes.
- Human Computation: Use of crowd sourcing to tap human skills for analyzing images and video,classification, learning, and error recovery.
- High speed-Quick deployment: The ability to spin up new cloud computing instances in a matter of seconds reshaped the agility and speed of software development. Developers can easily test new ideas and design application architecture without the dependency on on-site hardware limitations or slow procurement processes.

APPLICATIONS

- Big Data: access to updated libraries of images, maps, and object/product data
- Cloud Computing: access to parallel grid computing on demand for statistical analysis, learning, and motion planning.
- Collective Learning: robots and systems sharing trajectories, control policies, and outcomes.
- Human Computation: use of crowd sourcing to tap human skills for analyzing images and video, classification, learning, and error recovery.

CONCLUSION

Cloud robotics is the use of remote computing resources to enable greater memory, computational power, collective learning, and interconnectivity for robotics applications. It allows robots to benefit from the powerful computational, storage, and communications resources of modern data centers. Logistics, security and surveillance, personal assistance and care, guidance and education, entertainment, and companionship are some of the emerging sectors, which are witnessing the rise in the adoption of cloud robotics. Increasing utilization of cloud-based technologies and cloud-based artificial intelligence robotics technology has brought about creating cloud robotics, therefore increasing demand in the global cloud robotics markett.

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