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A Survey on Cloud Robotics and Automation

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Abstract: Nowadays, with the rapidly increasing use of cloud services, there are many opportunities and challenges faced in the industry. One of the trending domains is Cloud Robotics and Automation. Cloud Robotics deals with the cloud technologies such as Cloud Computing, Cloud Storage and Networking and other internet technologies. With the help of these cloud services, robots can be remotely controlled through the network. Also, Cloud Robotics and Automation makes it possible to build cost efficient and light-weight robots. Few of the challenges faced are developing a good knowledge base, establishing a proper communication network, effective load balancing, preventing data privacy and security and dealing with the ethical problems. The purpose of this study is to understand the scope of Cloud Robotics and Automation, how it can help to reduce human efforts in an effective way by overcoming the above-mentioned challenges. The study covers different types of technologies widely being used since 2015 that includes Cloud data storage, Networking, Cloud Computing, Artificial Intelligence, Deep Learning, Internet of Things. The study definitely answers the scope of the domain and gives precise examples of how it has helped in reducing human efforts by overcoming various challenges.
Keywords: Cloud storage, Robotics, Deep Learning, Automation, Networking

I. INTRODUCTION

Cloud Robotics is a field of robotics that uses several technologies out of which few include Cloud computing, Machine learning, Deep learning, Artificial intelligence, Big Data, Internet of Things [2][8]. Cloud Computing basically provides data storage and computing power over the internet without direct management by the user. An example of it is Google's Gmail. Artificial Intelligence is a concept where machines or systems behave in the exact manner as that of the humans while learning or problem solving. Machine Learning can be termed as an application of Artificial Intelligence with the help of which machines learn with their experiences and provides results without intervention of humans. Deep Learning is a subset of Machine Learning based on artificial neural networks. Learning can be supervised, semi-supervised or unsupervised.

There is a need for capable methods to be developed for intelligently utilizing the data that is generated through the increasing use of IoT devices [2]. With the help of using cloud services it is possible to fuse prior knowledge and build a cloud robotic navigation learning [3]. Also, in recent years, robotics or robot development has become one of the major subjects in the interest of the students. Humanoid robots have made great progress but are still facing some technical challenges [10]. The focus has always been to develop a design or an architecture to provide clear, concise interface to extend robotics using cloud services [7].

II. RELATED WORK

In the paper presented by Boyi Liu, Lujia Wang and Ming Liu [3], an architecture is proposed for navigation in cloud robotic system which allows robots to effectively use the shared knowledge that includes experiences uploaded by all the existing robots which use same cloud server. The paper addresses the problem of how to make robots learn efficiently in a new environment and extend their experiences so that they can use prior knowledge.

Paper presented by Kyu-Chul Lee and Yun-Hee Son [2] explains architecture of cloud of things based on the linked data. Topics such as device virtualization methods, device meshes, connectivity and awareness research based on machine learning to enhance intelligence and automation topics are discussed.

Smart Car Parking Management System proposed by Lomat Haider Chowdhury and team, developed a smart car parking system using local and remote cloud servers [11]. They made use of several hardware and software components such as Radio Frequency Identification cards, Camera, Database, Servers, Barrier gate, User interface, report generation etc. Response time is considered as the parameter for performance evaluation.

The proposed work in paper published by Nils Bore and team is a variant of Mobile Target Tracking (MTT) problem [1]. There are various techniques that have been proposed for MTT problem. In the method proposed in this paper, main objective is to track the jumping of the objects between the selected number of locations as well as their 2D positions which include obtaining association of

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measurements to targets. Before implementation of the above stated method, an assumption is made that the robot moves between finite number of locations in a closed environment. Also, no object enters or leaves the environment. Sampling based particle filters are used since requirement of high dimensional state space is not feasible. Kalman filters are used for tracking continuous positions. Also, Markov Chain Monte Carlo (MCMC) techniques are used for estimating the associations of several measurements. All the visual features of the object are first grouped in a cluster initially using STRANDS Robot. The proposed work provides improvement by incorporating motion and noise in their probabilistic model.

Also, the papers proposed by Yi Liu, Yuchun Xu [4] and Ben Kehoe and team [8], gives an overview of the cloud robotics field by describing about its related concepts, components, characteristics and presents four main beneficial aspects of cloud robotics that is Big data, Computing, Robot Learning and Human computation respectively.

Many experiments are conducted on service robots, multiple humanoid robots are built and knowledge exchange between these robots is implemented and achieved with the help of effective software architectures developed [5], [6], [10]. New platform is developed for overcoming the access control over service robots and tested through various parameters for accuracy [6.] Cloud application is used for implementing an interface between robots and architecture is designed for having effective communication between robots [5], [10].

There are various software architecture solutions available nowadays for Cloud Robotics. One of which is proposed in the paper published in IEEE 2016 WAC Journal by Seyed Ali Miratabzadeh and team [7]. The method proposed describes following main components of cloud robotics: Computing, Storage and Networking. Similarly, the trends and challenges faced by cloud robotics architecture is well explained in the paper proposed by Huaxi (Yulin) Zhang, Lei Zhang [9]. It introduces about a domain specific language and explains how to use it for developing an architecture for Robotics.

Sr.No.	Title	Author	Algorithms/Techniques	Journal	Description
1	Detection and Tracking of General Movable Objects in Large Three-Dimensional Maps	Nils Bore, Johan Ekekrantz , Patric Jensfelt , and John Folkesson		IEEE 2018	Proposed a model for detection and tracking of moving objects typically in a closed environment, evaluated by point cloud data gathered autonomously.
2	Cloud of Things based on Linked Data	Yun-Hee Son, Kyu-Chul Lee		IEEE 2018 (ICOIN)	Proposed various device virtualization methods for Cloud of Things based on linked data.
3	Lifelong Federated Reinforcement Learning: A Learning Architecture for Navigation in Cloud Robotic Systems	Boyi Liu, Lujia Wang and Ming Liu		2019 IEEE/RSJ (IROS)	Proposed an architecture for navigation in cloud robotic system which allows robots to effectively use the shared knowledge that includes experiences uploaded by all the existing robots which use same cloud server.
4	Summary of Cloud Robot Research	Yi Liu, Yuchun Xu		IEEE 2019 (ICAC)	Describes the concepts, characteristics, architecture involved in the domain of Cloud Robotics and its applications.
5	The Exchange of Knowledge using Cloud Robotics	Asil Kaan Bozcuoglu, Gayane Kazhoyan, Yuki Furuta, Simon Stelter, Michael Beetz, Kei Okada, Masayuki Inaba		IEEE 2018 (ICRA)	Describes how robots can exchange their experiences like humans using openEASE as the cloud application.

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6	A Novel Cloud Platform for Service Robots	Jin Liu , Fengyu Zhou, Lei Yin , And Yugang Wang		IEEE 2019	Presents a new robot cloud platform termed as Cloud Robotics Intelligent Cloud Platform (CRICP) that can be used for the service robots and can have efficient results.
7	Cloud Robotics: A Software Architecture For Heterogeneous Large-Scale Autonomous Robots	Seyed Ali Miratabzadeh, Nicolas Gallardo, Nicholas Gamez, Karthikpai Haradi, Abhijith R Puthussery, Paul Rad, Mo Jamshidi		IEEE 2016 (WAC)	Proposes a software architecture for cloud robotics that involves technologies such as cloud computing, storage and networking.
8	A Survey of Research on Cloud Robotics and Automation	Ben Kehoe, Sachin Patil, Pieter Abbeel, and Ken Goldberg		IEEE 2015	Describes four main advantages of cloud that includes Big Data, Cloud Computing, Collective Robot Learning and Human Computation.
9	Cloud Robotics Architecture: Trends and Challenges	Huaxi (Yulin) Zhang, Lei Zhang		IEEE 2019 (SOSE)	Introduces CRALA – a domain specific language to design an architecture for cloud robotics.
10	Cloud-assisted Humanoid Robotics for Affective Interaction	Yujun Ma ,Yixue Hao, Yongfeng Qian, and Min Chen		IEEE 2016 (ICCAR)	Proposes humanoid robotics architecture for affective interaction using cloud computing.
11	Smart Car Parking Management System	Lomat Haider Chowdhury, Z.N.M Zarif Mahmud, Intishar-Ul Islam, Ishrat Jahan and Salekul Islam		IEEE 2019 (RAAICON)	Developed a smart car parking system using local and remote cloud servers.

III. CONCLUSION

Cloud computing services along with image processing and sampling techniques can be used to develop models that can help tracking various movable objects in a closed environment. Also, by doing advance research in the same field, there is a scope for identification and tracking of movable objects in an open environment. Cloud Robotics and Automation domain has endless applications in the industry which can be discovered through thorough research on respective problem areas.

IV. FUTURE SCOPE

The cost for designing software architectures for cloud robotics and building various robots using different hardware components is still high in the market. Having mentioned the earlier point, more attention is still primarily given to the robustness of the model/system developed and its better performance. Thus, ongoing and future work related to various applications of cloud robotics and automation domain should be focused on the above points so that we can get cost efficient, less error prone, robust and effective solutions accordingly.

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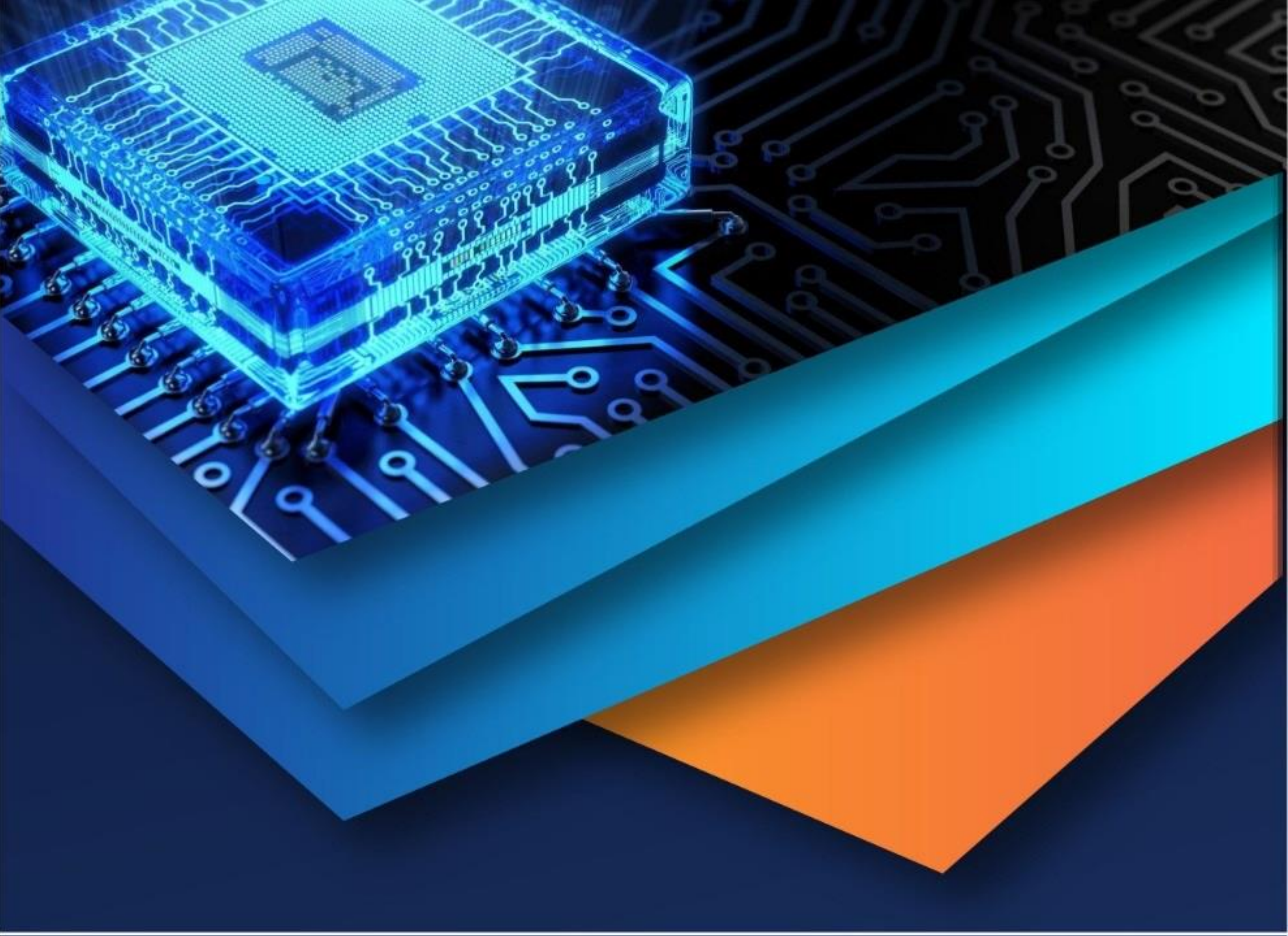

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