ISSN: 2664-9640

Application Review of Cloud Computing Technology in Autonomous Navigation

Taizhi Lv

School of Information Technology, Jiangsu Maritime Institute, Nanjing, 211170, China

lvtaizhi@163.com

Abstract

Many tasks in autonomous driving are computationally intensive, and the computing power and resources of autonomous driving vehicle cannot meet the needs of autonomous driving. The combination of autonomous driving technology and cloud computing technology solves the requirements of mass sensing data storage and mass data calculation and analysis in the process of autonomous driving. This paper summarizes the application research of cloud computing technology in the field of autonomous driving, especially the application of simultaneous localization and mapping (SLAM) and path planning.

Keywords

Mobile robot, Cloud computing, Cloud robot, Autonomous driving, Simultaneous localization and mapping (SLAM), Path planning, Edge-cloud collaboration.

1. Introduction

Autonomous driving technology refers to the cooperation of artificial intelligence, cloud computing, big data and other technologies. It perceptes the surrounding environment through inertial navigation, radar, positioning system, cameras and other technologies, and the automatic and safe operation of transportation tools under any human active operation based on SLAM, path planning, autonomous obstacle avoidance, autonomous decision-making and other technologies. In Disruptive technologies: Advances that will transform life, business, and the global economy released by McKinsey Global Institute [1] , the autonomous driving technology was among them. It is precisely because of the great role of autonomous driving in promoting economic and social development that countries all over the world attach great importance to the research of driverless technology and try to seize the commanding height of this cutting-edge technology.

Cloud computing is an intensive computing mode centered on data and processing capacity. It integrates multiple information and communications technology (ICT) and is the product of smooth evolution of traditional technologies. In recent years, cloud computing technology has provided strong support for unmanned driving related projects and research that requires strong computing and storage resources support, such as artificial intelligence, big data and the Internet of Things (IoT), and has strongly promoted the development of unmanned driving technology.

In the process of autonomous driving, unmanned vehicles continuously acquire surrouding environmental information through inertial navigation system (INS), laser radar, etc. Based on massive perceptual data, unmanned vehicles can realize decision-making and control such as positioning, map creation, target recognition, etc. The whole process involves the calculation and storage of massive data, which brings great challenges to autonomous driving technology. If some computing and storage tasks are migrated to the cloud, it will effectively improve the performance of unmanned vehicles and better support the rapid development of autonomous navigation technology. At the same time, computing in the cloud reduces the performance requirements of unmanned vehicles, which can unload some airborne equipment and improve the mobile portability of unmanned vehicles.

2. Application of cloud computing in robot field

After the concept of cloud robot was proposed in 2010, it aroused the interest of researchers, and became a new important direction in the robot field [2-3]. Cloud robot is the combination of cloud computing technology and robotics. It uses the powerful storage and computing capabilities of the cloud to improve robot capabilities and reduce the cost of robot local resources. The common cloud robot architecture is shown in Figure 1. The cloud robot is connected to the cloud through the network, and the cloud realizes the corresponding data storage and computing.

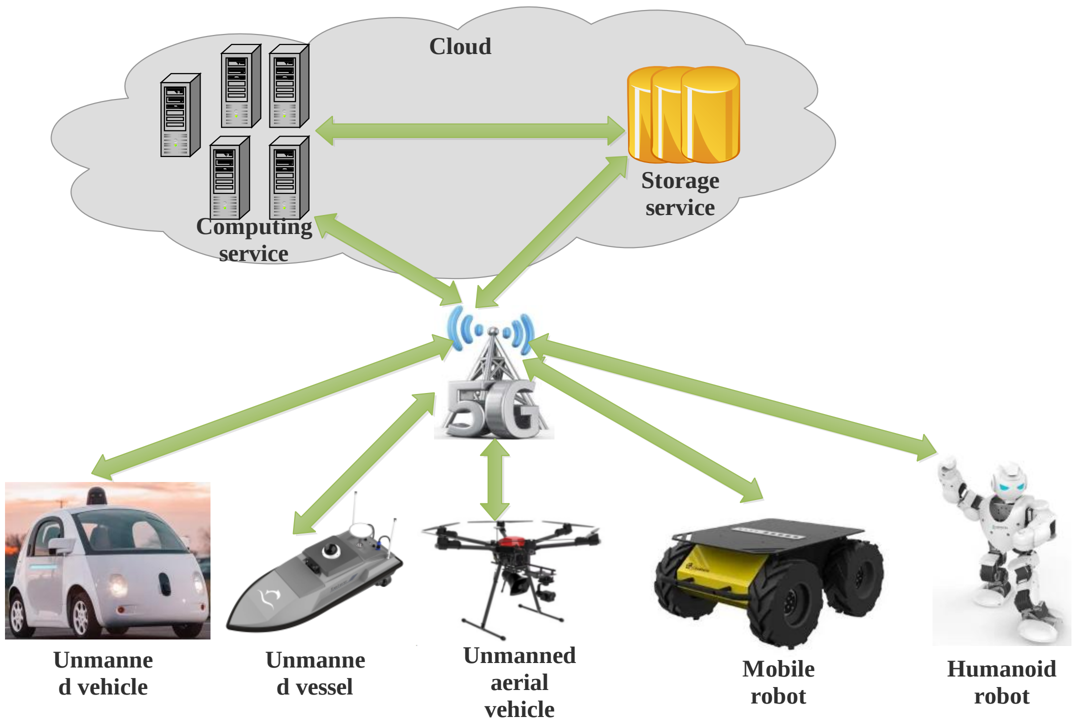

Figure 1: The cloud robot architecture

At present, there are roughly three types of cloud based robot service platforms: the cloud platforms based on network, the cloud platforms based on sensor network and the cloud platforms based on robot service network protocol. The cloud robot platforms based on network based mainly include DAvinCi, Rapyuta, RoboEarth, etc. Based on the idea of platform as a service, DAvinCi transfers the tasks from the robot ontology to the cloud [4]. In the reference [5], the Rapyuta robot is combined with the cloud platform, and put the robot brain into the cloud. It not only reduces the robot production cost, but also improves the computing power required for robot operation. RoboEarth uses cloud computing resources as data storage and integrates web services in the cloud environment [6]. Bouziane et al. [7] used NAO humanoid robots to perform interactive tasks such as voice recognition, face detection, video capture, etc., depending on cloud infrastructure. Sensor-cloud is a cloud robot platforms based on sensor network, which is used to process huge data, acquired data from sensor devices through the platform, and deploy robot applications in the cloud environment [8]. Google engineers have developed a robot software that allows smartphones to control robots such as LegoMindStorms, IRobot Create and Vex Pro. A children's hospital in Italy uses a humanoid robot developed by Aldebamn Robotics of France to realize voice recognition, face detection and video capture functions based on the cloud platform and enhance interaction with patients. Researchers from the University of California, Berkeley designed a fast object grabbing method based on the cloud platform and verified it with the PR2 robot of Willow Garage. PanDey P et al. use multiple underwater cloud robots to acquire and monitor ocean data and complete underwater tasks by sharing local and remote resources.

3. Application of cloud computing in autonomous navigations

SLAM and path planning are the key to realize autonomous navigation, regardless of unmanned ship, unmanned vehicle and unmanned aerial vehicle. There are important theoretical and application value for SLAM and pah planning. Path planning is to find the best path to avoid obstacles under certain indicators in the environment with obstacles. SLAM is the process of drawing the robot environment through the information collected by sensors, which is the basis of path planning and motion control. Figure 2 shows a typical autonomous navigation framework based on cloud computing, which includes a hardware platform and a software platform as a whole. The software platform helps mobile robots drive autonomously through edge-cloud collaboration.

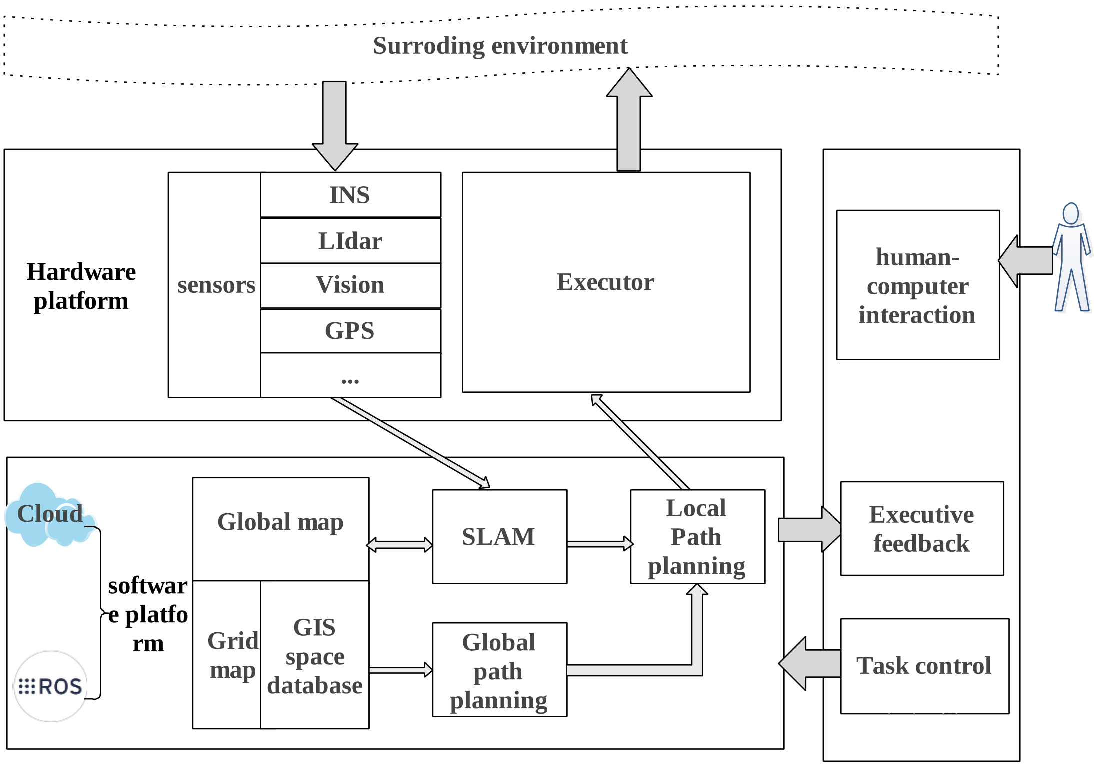

Figure 2: The autonomous navigations architecture based on cloud computing

3.1. Application of cloud computing in SLAM

With the application of 5G network, the SLAM solution of edge-cloud collaboration appears. This solution divides the SLAM process into two stages: edge acquisition and cloud computing. The edge is responsible for acquiring sensor data, and the SLAM computing intensive task is put into the cloud for execution. Based on DAvinCi platform, Arumugam et al. used Hadoop distributed system architecture Map/Reduce cluster to implement SLAM algorithm, which improve the efficiency of map construction and execution, and share data with other robots through software as a service (SaaS) model [4]. Because Hadoop is disk level computing with poor real-time performance, it is more suitable for batch processing, which limits the application of DAvinCi platform in real-time SLAM environment. At the same time, this method transfers messages through ROS message mechanism, constraining the scalability of the platform, and the server receiving ROS messages also becomes the bottleneck of the system. Kamburugamuve et al. implemented the GMapping algorithm on the IoTCloud platform using a distributed processing framework [9]. The lidar and inertial sensor data were sent to the cloud as stream events. The cloud carried out SLAM processing, and returned the positioning and map results to the robot. C2TAM framework is based on RoboEarth cloud platform and uses parallel tracking and mapping (PTAM) algorithm to achieve multi robot collaborative tracking and map creation tasks [10]. The advantage of C2TAM architecture is to make full use of the advantages of the cloud and use the PTAM method in 3D mapping to propose a more successful cloud+robot architecture.

3.2. Application of cloud computing in path planning

Traditional path planning methods rely on the computing resources carried by robots. Limited computing power makes path planning difficult to meet real-time requirements. Due to the high data rate, high concurrency and low latency of 5G mobile and wireless communication technologies in data transmission, cloud computing technology has been applied to path planning applications. Song et al. proposed a path planning algorithm based on cloud computing. The algorithm consists of path planning, obstacle avoidance and navigation control modules, which can be used for path planning of multiple robots to prevent collisions between robots and obstacles and between robots [11]. Lam et al. proposed that path planning is a service, realizing path planning of mobile robots in the cloud, and providing services in the form of interfaces [12]. The service is divided into three layers: cloud server layer, cloud engine layer, and client robot layer. The cloud service layer is implemented based on Hadoop and stores the path planning database. The cloud engine layer provides path planning services based on Rapyuta. The unmanned vehicle terminal acquries data and calls the PPaas service to obtain path planning results. In order to solve the problem of heavy data load, mobile edge computing and base stations are also widely used in path planning. The edge acquires data as the side end, and the base station, as the edge computing node, can quickly acquire the data and plan the path in real time. The cloud receives the processing results and further evaluates them to ensure the reliability of path planning [13].

4. Conclusion

With the rapid development of 5G technology and cloud computing technology, mobile robots have expanded their computing capabilities and improved their portability through cloud computing technology. This paper first outlines the application status of cloud computing technology in the field of mobile robots. Cloud robots use the powerful storage and computing capabilities of the cloud to enhance robot capabilities and reduce the cost of robot local resources. SLAM and path planning are the key technologies to realize unmanned driving. Cloud computing solves the problem of insufficient edge computing power in the process of unmanned driving, and effectively promotes the development of unmanned driving technology. The trend of cloud computing in the field of autonomous navigation is edge-cloud collaboration. Through edge and cloud complementing each other, autonomous driving is more accurate and reliable.

Acknowledgements

This work was financially supported by the Natural Science Foundation of the Jiangsu Higher Education Institutions of China (21KJB580007), the Excellent Scientific and Technological

ISSN: 2664-9640

Innovation Team of the Jiangsu Higher Education Institutions of China (Maritime Big Data Team), the Young Academic Leaders for QingLan Project of the Jiangsu Higher Education Institutions of China.

References

[1] Manyika J., M. Chui, J. Bughin, R. Dobbs and P. Peter, "Disruptive technologies: Advances that will transform life, business, and the global economy," McKinsey Global Institute, 2013.

[2] Kuffner J., "Cloud-enabled robots," in Proc. IEEE-RAS Int. Conf. Humanoid Robot., Nashville, TN, USA, 2010.

[3] Kehoe, Ben, et al. "A survey of research on cloud robotics and automation." IEEE Transactions on automation science and engineering 12.2 (2015): 398-409.

[4] Arumugam, Rajesh, et al. "DAvinCi: A cloud computing framework for service robots." 2010 IEEE international conference on robotics and automation. IEEE, 2010: 3084-3089.

[5] Mohanarajah, Gajamohan, et al. "Rapyuta: A cloud robotics platform." IEEE Transactions on Automation Science and Engineering 12.2 (2014): 481-493.

[6] Waibel, Markus, et al. "Roboearth." IEEE Robotics & Automation Magazine 18.2 (2011): 69-82.

[7] Bouziane, Radhia, et al. "A web services based solution for the NAO robot in cloud robotics environment." 2017 4th International Conference on Control, Decision and Information Technologies (CoDIT). IEEE, 2017: 809-814.

[8] Yuriyama, Madoka, and Takayuki Kushida. "Sensor-cloud infrastructure-physical sensor management with virtualized sensors on cloud computing." 2010 13th international conference on network-based information systems. IEEE, 2010:1-8.

[9] Kamburugamuve, Supun, et al. "Cloud-based parallel implementation of slam for mobile robots." Proceedings of the International Conference on Internet of things and Cloud Computing. 2016: 1-7.

[10] Riazuelo, Luis, Javier Civera, and JM Martınez Montiel. "C2tam: A cloud framework for cooperative tracking and mapping." Robotics and Autonomous Systems 62.4 (2014): 401-413.

[11] Song, Kai-Tai, and Yu-Xuan Sun. "Coordinating multiple mobile robots for obstacle avoidance using cloud computing." Asian Journal of Control 23.3 (2021): 1225-1236.

[12] Lam, M. L. , and K. Y. Lam . "Path planning as a service PPaaS: Cloud-based robotic path planning." 2014 IEEE International Conference on Robotics and Biomimetics, IEEE ROBIO 2014 IEEE, 2014：1839-1844.

[13] Wan, Shuo, et al. "Toward big data processing in IoT: Path planning and resource management of UAV base stations in mobile-edge computing system." IEEE Internet of Things Journal 7.7 (2019): 5995-6009.