Implementing Development Status Scheme Based on Vehicle Ranging Technology

Chun-Yuan Ning[1], Jun-Jie Shang[1], Shi-Jie Jiang[1], Duc-Tinh Pham[2,3], Thi-Xuan-Huong Nguyen[4]

[1]Fujian Provincial Key Laboratory of Big Data Mining and Applications, Fujian University of Technology, Fujian Province 350118, China;
[2]Center of Information Technology, Hanoi University of Industry, Hanoi, Vietnam;
[3]Graduate University of Science and Technology, Vietnam Academy of Science and Technology, Vietnam;
[4]Haiphong University of Management and Technology, Haiphong, Vietnam

ningcy0606@163.com, 1215443831@qq.com, j530216317@qq.com, tinhpd@haui.edu.vn, huong_ntxh@hpu.edu.vn

Abstract. The intelligent vehicle system is the primary trend in the development of modern transportation. This paper introduces several kinds of ranging technology used in smart transportation, such as the existing ultrasonic ranging, millimeter-wave radar going, laser ranging, machine vision running, etc. Firstly, the development status is explained. Secondly, the principle is elaborated. Next, their performance is analyzed and compared. Finally, we introduce the development trend of vehicle ranging technology.

Keywords: Vehicle ranging; Laser ranging; Ultrasonic ranging; Radar ranging; Machine vision; Multi-sensor fusion

1 Introduction

Traffic incidents have become common with the rise in car ownership at home and abroad[1]. People paid extensive attention to technology for self-driving and helped to push technology. In comparison, the distance measurement technology can provide the self-driving system with precise and real-time decision-making, making the vehicle safer and more relaxed[2]. Many distance measurement technologies have been introduced and applied to different vehicle systems nowadays[3].

The intelligent vehicle system is the primary trend in the development of modern transportation[4]. This paper introduces several kinds of ranging technology used in smart transportation, such as the existing ultrasonic ranging, millimeter-wave radar going, laser ranging, machine vision running, etc. Firstly, the development status is explained. Secondly, the principle is elaborated. Next, their performance is analyzed and compared. Finally, we introduce the development trend of vehicle ranging technology.

2 Ultrasonic ranging

Ultrasonic ranging technology was born in the 21st century and has been widely studied and applied in robot obstacle avoidance, car reversing, and liquid level measurement. The main reasons, advantages, and disadvantages of the measurement error caused by ultrasonic ranging are analyzed in [5-6]. Ultrasonic ranging is a mechanical wave above 20 kHz generated by the transmitting end, which propagates along the probe's direction. When the ultrasonic wave encounters an object, it is reflected back and received by the ultrasonic receiving sensor [7]. From the time t from the start of the transmission to the end of the reception and the propagation speed of the ultrasonic wave in the current environment, the distance S to be measured is obtained, and the calculation formula is:

$$S = 1/2 \times v \times t \#(1)$$

Since the speed of sound of the ultrasonic wave is related to the temperature T, in order to improve the accuracy of the distance measurement, it can be further corrected by the method of temperature compensation. The approximate calculation formula of the ultrasonic propagation velocity v is：

$$v = 331.5 + 0.607 \times t \#(2)$$

3 Millimeter-wave Radar Ranging

The foreign-based millimeter-wave radar started in the 1960s. The research content mainly includes the recognition of Doppler and micro-Doppler features of moving targets, the recognition of features based on target time-frequency analysis, and the recognition of features based on target one-dimensional distance images[8-9].Millimeter-wave radar ranging uses Doppler radar technology to obtain the relative distance between the vehicle and the obstacle by processing the phase and frequency information between the transmitted signal and the recovered signal [10]. When the time difference between the signal sent by the sensor and the received signal is Δt, the distance is R, and the speed of light is c, the distance between the vehicle and the obstacle can be calculated according to the formula R=Δt/2.

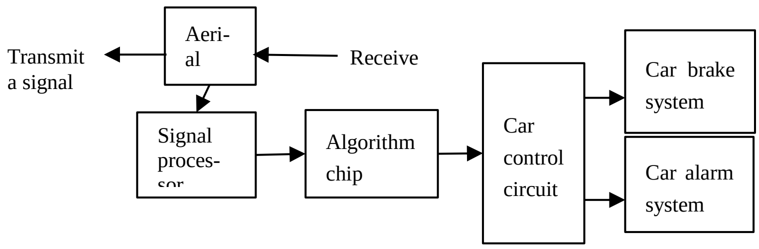

Fig. 1. Millimeter-wave radar work flow chart

4 Laser Ranging

In 1977, the United States took the lead in developing the world's first handheld small-scale laser range finder [11]. Its high brightness, strong directionality and penetrating power, simple structure, convenient installation and debugging, etc., were gradually widely used. To various industrial and civil fields [12-14].

Laser ranging is a method of determining the measuring distance by irradiating a laser beam onto a target and then passing back and forth the laser's information. It is mainly divided into two categories: pulsed laser ranging and continuous-wave phase laser ranging. Pulsed laser ranging technology is the time consumed between pulsed light waves and the target to be measured. If the time required for the light to travel in the air at a speed c between the two points A and B is t, then the distance D between the two points A and B can be expressed as follows.

$$D = ct/2\#(3)$$

It can be seen from the above equation that the distance between A and B is actually to measure the time t of light propagation. The principle of continuous-wave phase laser ranging is to measure the measurement distance by irradiating the object to be measured with a constant laser beam and measuring the phase difference between the emitted light and the received light returned by the target [15].

The principle block diagram of the typical phase laser range finder is shown in Figure 2:

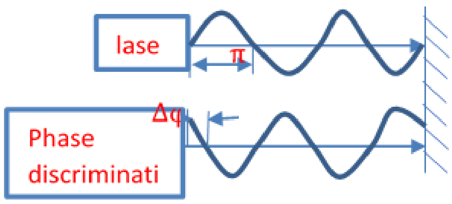

Fig. 2. Phase laser ranging schematic

As shown in the above figure, when T is the period of the transmitted signal, the phase difference between the transmitted and received signals is Δφ, and the distance between the transmitted and received signals is:

$$D = ct/2 = \frac{c}{2}\frac{\Delta\varphi}{2\pi}\frac{1}{f}\ \#(4)$$

5 Visual ranging

Visual ranging is the use of computer image processing technology to simulate the human eye to perceive information changes through information about the community vehicle's surrounding environment. Visual ranging has been widely used in lane state estimation, traffic sign signal recognition, license plate recognition, vehicle deviation from lane center estimation, etc. [16-20]. At present, visual ranging mainly includes monocular ranging and binocular ranging.

5.1 Monocular vision ranging

Monocular vision ranging uses a camera-based on a small hole imaging model. According to the viewing angle measurement principle, the ratio between the object size and the object distance remains unchanged, and the distance of the object is inversely proportional to the image size [21]. When the object's actual size and some camera parameters are known, the target can be obtained—the distance between.

5.2 Binocular vision ranging technology

Binocular vision ranging refers to the simultaneous use of two cameras to complete the ranging task. Binocular vision ranging is based on a triangulation method that achieves the perception of three-dimensional information by mimicking the way humans use binocular parallax to sense distance [22]. As shown in Fig. 3, the two cameras respectively image the same object from different positions and then recover the object's spatial three-dimensional information from the parallax image.

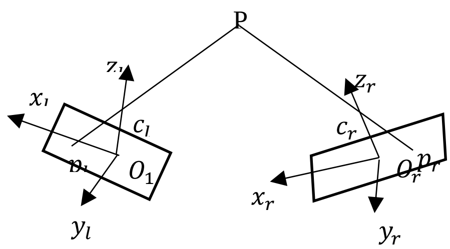

Fig. 3. Schematic diagram of binocular visual stereo imaging

6 Multi-sensor fusion

6.1 Comparison of traditional ranging techniques

Table 1. shows the technical indicators, advantages, and disadvantages of the traditional car ranging technology, and their respective uses are compared as follows:

Ranging type	Technical indicators	advantage	Disadvantage	use
Ultrasonic	Measuring range: 0.2-20m, optimal distance: 4-5 meters	Data processing is a simple, fast, low cost, easy to manufacture, and highly adaptable	Large beam angle, poor directionality, low resolution, short-acting distance	Close obstacle detection, car reversing collision

			and low precision	avoidance system
laser	Measuring range: 20-190mm, resolution: 0.5-10μm	Good directionality, small size, high precision, no electromagnetic interference, high measurement accuracy, long detection distance, relative distance measurement	It is difficult to make, the optical system needs to be kept clean, and the measurement performance is vulnerable to environmental interference.	Ranging and anti-collision during vehicle driving
Millimeter wave	Frequency band:2.4GHz、24GHz、60GHz、122GHz、245GHz	Long detection distance, reliable operation, penetrating rain, fog and dust, etc.	Lower resolution, more expensive	Distance measurement and speed measurement during vehicle travel
Machine vision	CCD, CMOS camera	Large amount of information, improved accuracy of judgment, low cost, small size, no pollution to the environment	Not suitable for heavy environments such as heavy rain and heavy fog, and has a large amount of calculation	Close obstacle detection, vehicle ranging, obstacle detection

6.2 Multi-sensor fusion

It can be seen by comparison of various ranging techniques. Multi-sensor information fusion technology is used to complement multiple sensor spatial and temporal multi-feature information, and synthesize (integrate and fuse) according to certain criteria to form a consistent description or interpretation of a certain feature of the environment, thereby overcoming the single sensor has the disadvantages of low reliability and small effective detection range. Therefore, in recent years, sensor information fusion technology has received more and more attention in the field of intelligent vehicle security research. As shown in Figure 4, the Audi self-driving car is equipped with up to 9 environmental detection sensors.

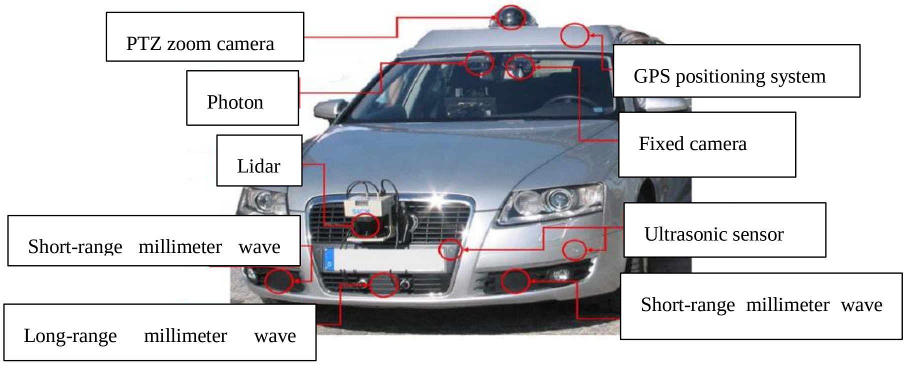

Fig. 4. Multi-sensor layout for context awareness

7 Conclusion

This paper primarily addressed the types of distance measuring instruments for vehicles with advantages. With the further advancement of science and technology, there will be more technical forms for distance measurement. The method implementation of single distance measurement had been combined with different methods of distance measurement. The multiple instruments are combined to complement each other and further increases system measurement accuracy and reliability. Each sensor's data collection, processing, and fusion algorithm can perform timely, accurate, reliable, and environmentally adaptive front vehicle detection, which is of great importance for preventing collision accidents in vehicles and improving driving safety.

References

1. Pinto, D.: Traffic incidents processing system and method for sharing real time traffic information, (2008).
2. Dao, T.K., Pan, T.S., Pan, J.S.: A multi-objective optimal mobile robot path planning based on whale optimization algorithm. 2016 IEEE 13th Int. Conf. Signal Process. 337–342 (2016). https://doi.org/10.1109/ICSP.2016.7877851.
3. Shrivastava, A.K., Verma, A., Singh, S.P.: Distance measurement of an object or obstacle by ultrasound sensors using P89C51RD2. Int. J. Comput. Theory Eng. 2, 1793–8201 (2010).
4. Nguyen, T.-T., Pan, J.-S., Dao, T.-K.: A Novel Improved Bat Algorithm Based on Hybrid Parallel and Compact for Balancing an Energy Consumption Problem, (2019). https://doi.org/10.3390/info10060194.
5. Zhao Haiming,Bu Yingyong,Wang Jizhen,Zhou Zhijin.Study on a High Precision Ultrasonic Distance Measurement Method[J], Journal of Hunan University of Science and Technology, Natural Science Edition, 2006, 21(3): 35-38.
6. Wang Hongmei. Research on high resolution ultrasonic ranging method [D], Shandong University of Science and Technology, 2004.

7. Pan Kangfu. Research on reversing anti-collision alarm system based on ultrasonic ranging [D]. Nanjing University of Posts and Telecommunications, 2018.
8. Yang Lei,Wang Yong,Luo Dingli.Study on Classification Method of Moving Vehicle Based on Micro-Doppler Feature[J]. Fire control radar technology,2014,43(03):36-39+58.
9. Li Kaiming,Zhang Qun,Liang Bishuai,Luo Ying.Micro-Doppler Modeling and Feature Extraction of Truck Targets[J].Journal of Applied Sciences,2014,32(02):170-177.
10. Wu Rongzhen, Jin Dian, Zhong Shujiang, Dai Yuyu. Vehicle Ranging System Based on Millimeter Wave Radar[J].Automobile Practical Technology, (02):33-35, (2019.
11. ROSALES L A M, BADILLO I A, GRACIDAS C A H, et al. On-road obstacle detection video system for traffic accident prevention [J]. Journal of Intelligent& Fuzzy Systems, 2018, 35(1):
12. Yu Yanmei.Laser rangefinder and its development trend[J].Information Command Control System and Simulation Technology,2002(08):19-21.
13. Zheng Mingjie,Liu Xin.Development Status and Principle of Laser Ranging Technology at Home and Abroad[J].Science and Technology Innovation Review,2014(01):35.
14. Wang Li,Xu Antao,Wang Wei.Development of Laser and Method of Laser Ranging[J].Journal of Jiaozuo University,2007(04):55-56+71.
15. Jeng-Shyang Pan, Zhenyu Meng, Shu-Chuan Chu, Hua-Rong Xu. Monkey King Evolution: an enhanced ebb-tide-fish algorithm for global optimization and its ap-plication in vehicle navigation under wireless sensor network environment[J]. Tele-communication Systems, 2017, Vol.65 (3), pp.351-364
16. Jiang Gangyi,Yu Mei.Vision-based Lane State Estimation[J].Journal of Circuits and Systems,2001(03):6-10.
17. Liu Weichuan. Research on Target Discrimination Method of Vehicle Active Cruise System [D]. Liaoning University of Technology, 2017.
18. Huang Lin,Zhang Yousai.Traffic Sign Recognition Using Deep Convolutional Neural Networks[J].Modern Electronic Technique,2015,38(13):101-106.
19. Niu Jincai,Yu Jianli,Li Mengjun.Research and Implementation of Vehicle License Plate Recognition Algorithm[J].Electronic Measurement Technology,2018,41(06):45-49.
20. Liu Wei. Research on key technologies in lane departure warning system under monocular vision [D]. Nanjing University of Aeronautics and Astronautics, (2014).
21. Fang Guo, Lian Guofu, Zhang Ning. Analysis of three-dimensional target positioning accuracy of compound eyes[J]. Infrared and Laser Engineering,2014,43(12):4088-4093.
22. Fang Guo, WANG Keyi, WU Qing-lin. Development of multi-channel large field of view target locator[J]. Optical Precision Engineering, ,21(01):26-33 (2013)