Research Article

Research on Satisfaction of Driverless Function Based on the Artificial Intelligence Algorithm

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With the popularization of driverless technology, more and more vehicles have begun to apply this technology. Under these circumstances, user satisfaction with driverless function begins to have an increasing impact on car sales. This paper adopts the KANO model, a two-dimensional model, to analyze users' attitudes toward driverless functions. It is found that users have a high dependence on functions such as forward collision warning, autonomous emergency braking, and stated-speed sign recognition. Therefore, relevant enterprises should continue to develop these functions. Besides, users have high expectations for functions such as blind spot detection systems and rear cross-traffic alerts. Enterprises can achieve more support from users by optimizing these functions. Functions like lane-keeping assist, lane departure warning, parking distance control, and door open warning systems belong to indifferent attributes of driverless function, which are not cared about by users. There is no need for enterprises to optimize these functions. However, the lane change assist system has been criticized by users and should be improved by corresponding manufacturers.

1. Introduction

In recent years, the rapid development of the Internet and data science has brought profound changes to the automotive industry. Besides, the progress of high definition (HD) maps and the wide application of artificial intelligence have also promoted the maturity of intelligent driving technology. Under this circumstance, car driving is becoming simpler and smarter. As a direction for car driving development in the future, driverless technology has enjoyed considerable development in the latest years. Driverless cars, i.e., autonomous vehicles, are different from traditional cars. The latter needs to be driven by people, while the former perceives the surrounding environment through a sensor system inside the vehicle, including relevant intelligent software and various induction equipment. The driverless car can make its judgment according to perceived road information, vehicle position, and obstacle information to control the speed and steering so that it can be safe on the road. The driverless car breaks through the traditional driver-centered mode and improves safety and stability to a certain extent with the advantage of decreasing the incidence of traffic accidents, as well as reducing exhaust emissions and energy consumption. With high economic and social benefits, the driverless car is becoming an important part of the future development of smart cities.

The driverless car is a new technology and a new product. During the process of forming a new market, understanding and acceptance degree of consumers are unavoidable matters. According to a survey by relevant research institutions in the United States, 75% of drivers keep a cautious attitude toward the driverless car, and some of them are even skeptical [1]. Most people only have a simple understanding of the functions of the driverless car or view it as a novelty. The acceptance degree is still low. As the development direction of technology and product for auto enterprises in the future, whether driverless technology can satisfy users will play a key role in enhancing product attractiveness, thereby increasing sales of auto enterprises. Therefore, it is necessary to conduct research on user satisfaction with driverless

technology so as to provide suggestions for auto enterprises and driverless technology suppliers. The autonomous driving function studied in this paper belongs to the L2 level, which is not fully autonomous and requires the driver to maintain attention.

2. Introduction to Common Driverless Functions

Functions of driverless technology are still increasing, but they are mainly divided into two categories based on an existing framework. One is driverless technology that uses the camera as the data collection tool, and the other uses lidar [2]. However, mixed use of two technologies is the mainstream nowadays. Driverless functions provided mainly include adaptive cruise control, forward collision warning, autonomous emergency braking, lane-keeping assist, lane departure warning, stated-speed sign recognition, blind spot detection system, parking distance control system, rear cross-traffic alert, and door open warning system [2]. Among them, data are provided by cameras in the first six functions due to the visual field, while the data are provided by lidar in the remaining five functions [3].

The specific functions of automatic driving technology mainly have two sets of programs: one is pure visual perception and the other is laser radar. The supporters of the visual plan believe that humans can be qualified drivers through visual information with brain processing. So cameras and deep learning neural networks and computer hardware can achieve a similar effect. Representing companies of the visual plan include Tesla and Baidu.

The radar group uses mechanical radar, millimeter wave radar, ultrasonic radar, and multichannel cameras to achieve commercial production of L4. Representative enterprises include Robotaxi, BYD, and Nio.

The image sensor in the vision scheme can obtain complex environment information with a high frame rate and resolution, and the price is cheap. However, the image sensor is a passive sensor, which does not emit light itself. The imaging quality is greatly affected by the environmental brightness, and the difficulty of completing the perception task will be greatly increased in a harsh environment. However, data obtained by the visual scheme are more similar to the real world perceived by human eyes with characteristics of light hardware and heavy software. Due to the low price of the camera, the visual solution has an obvious cost advantage and is easier to pass the vehicle regulation test. In addition, the image data obtained by the camera are more similar to the real world perceived by human eyes, and the shape is most similar to human driving. The high resolution and high frame rate imaging technology also make the perceived environmental information richer. However, camera perception is limited in a dark environment, and accuracy and security are reduced. Moreover, its requirements for software are significantly increased because of presence of the visual scheme in the background of lower hardware requirements. So it needs to rely on powerful algorithms to ensure the efficiency of image processing, command delivery, and processing.

Laser radar is a kind of precise three-dimensional position sensor, which is essentially laser detection and ranging, and its principle is the precise rendering of the 3 d structure information of the target by transmitting and receiving laser detection and the distance between the target according to the target surface reflection energy, reflection spectrum amplitude, frequency and phase information. As an active sensor, radar can obtain the depth information of the target by emitting a pulse laser and detecting the scattering light characteristics of the target. It has the characteristics of high precision, large range, and strong anti-interference ability. However, the data obtained by radar are sparse and disordered, which are difficult to be directly used, and the monochromatic characteristics of a laser make it unable to obtain color and texture information. Although the ability of ranging description of the surrounding environment is outstanding, it has too fatal shortcomings, so it must be complementary with other sensors.

Adaptive cruise control mainly helps the driver to keep the same speed when the vehicle is in the front and the preset time headway [4]. The driver can set the desired speed and the time headway to the vehicle in the front. When the camera detects that the vehicle in the front is slowing down, the speed will also be automatically decelerated accordingly. If the traffic jam is relieved, the vehicle will steer at the selected speed again.

Forward collision warning warns the driver of pedestrians, bicycles, or vehicles in the front with visual and audible signals [5]. This function can prevent a car from colliding or reducing its speed when a collision happens. Besides, it can also help the driver if the car is at risk of colliding with pedestrians, cyclists, or other vehicles.

Autonomous emergency braking is a kind of auxiliary function, which can help the driver avoid collisions in traffic jams. For example, if the traffic becomes complex while at the same time, the driver is in the condition of low concentration, a collision may possibly happen in this situation [6]. When the vehicle is at imminent risk of collision, this function can assist the driver by automatically braking the vehicle or steering clear of the obstacles if the driver fails to act in time.

Lane-keeping assist aims at preventing the driver from accidental lane departure in certain situations on highways or arterial roads [7].

Lane departure warning uses audible and light signals to warn the driver when the vehicle departs from the lane. Stated-speed sign recognition can help the driver observe speed signs when the vehicle passes by [8]. The difference between a lane-keeping system and a lane departure warning is that one is a system for keeping a straight line, and the other is a system for warning of lane deviation.

The blind spot detection system is an auxiliary function for avoiding the blind spot vision of the driver. The warning lights are put on the outside rear mirror on both sides. It is not a substitute function but a complementary function for safe driving and outside rear mirror usage [6].

Parking distance control systems and door open warning systems use lidar to recognize obstacles so as to help users park or get on and off more safely.

The lane change assist system provides driving assistance when changing lanes to overtake, whether it is your vehicle or other vehicles.

The unmanned driving function introduced in this paper is a combination plan of pure vision and radar, which has no reference for the pure vision plan.

3. Satisfaction Research on Driverless Functions Based on the KANO Model

3.1. Basic Concept. A KANO model is a two-dimensional cognitive model that was established in 1984 by Noriaki Kano, a famous Japanese quality management expert [9]. He was inspired by Herzberg's dual-factor theory. The model is about the relationship between quality attributes and user satisfaction. It breaks the traditional single-dimensional cognition of quality and believes that even when product quality meets user cognition, users may not be satisfied. In this model, the relationship between product quality and user cognition is built, and quality attributes are divided into the following five categories. The first is an attractive quality. In this case, the quality attribute of products makes users feel surprised and user satisfaction will be greatly improved. Even when a certain quality attribute does not meet user cognition, users will not feel dissatisfied. The second is one-dimensional quality, which means when the quality attribute meets user cognition, users will feel satisfied. Otherwise, users will feel dissatisfied. The third is must-be quality. In this case, only when the quality attribute meets user cognition, users will feel satisfied. The fourth is indifferent quality, which means the quality attribute is not concerned by users and is unrelated to user satisfaction. The last is reversal quality. In this case, when the quality attribute meets user cognition, users may feel dissatisfied instead.

3.1.1. Attractive Demand. Attractive demand can be described as the attribute of surprise. Under this circumstance, customers will feel satisfied when their requirements are met; however, they will not feel dissatisfied even when their requirements are not met. For driverless functions, the key to achieving performance excellence and gaining a competitive advantage is to pay more attention to attractive attributes on the basis that the basic attribute is met. For attractive demand, customer satisfaction will rise sharply along with the increase of the satisfaction degree of customer expectation. Furthermore, once customer expectation is met, the customer may still feel very pleased even though the products or services are not that satisfying [10].

3.1.2. One-Dimensional Demand. One-dimensional demand is also called performance demand. It refers to the condition in which customer satisfaction is proportional to the satisfaction degree of customer needs. In this case, the more the customer needs are met, the more the customer will feel satisfied. The more the products or services provided by enterprises exceed customer expectations, the more satisfied customers are [11]. On the contrary, when such needs are not met, customer satisfaction may decrease significantly. Therefore, the driverless function should attach significance to this kind of attribute and meet one-dimensional demand to the greatest extent.

3.1.3. Must-Be Demand. Must-be demand is the essential quality requirements of certain products or services. It refers to the basic requirements of customers for the products or services provided by enterprises. Customers consider that the products must have a certain kind of attribute or function. According to Maslow's hierarchy of needs, when the quality attribute does not meet customer needs, customers feel dissatisfied. However, even when the quality attribute meets customer needs, customers may still feel dissatisfied [12]. Therefore, the driverless function should first meet must-be demand because it is the most basic requirement of users.

3.1.4. Indifferent Demand. Indifferent demand is the attribute of products or services that customers do not care about. Customers pay no attention to this attribute whether it is provided or not. The driverless function should not waste resources to meet the indifferent demand of customers because it will not lead to customer satisfaction or dissatisfaction [13].

3.1.5. Reversal Demand. Reversal demand is the quality attribute that customers dislike. It refers to the quality attributes that may cause strong dissatisfaction or low levels of satisfaction. The reason is that not all customers have similar preferences [14]. When customers' reversal demand is met, they may feel more dissatisfied. Suppliers of driverless technology should resolutely make such attributes disappear.

A successful product function can not only meet the basic needs of users but also meet user expectations. At the same time, such a product can even allow users to experience exciting feelings. In addition, indifferent demand is used to explore user requirements, and reversal demand should be avoided as much as possible. In designing products and functions, it is necessary to consider the five categories of demand. Structural partitions should be made to all functions in order to clearly understand the value and significance of each product function. Furthermore, from these five categories, product designers can know whether a product function is needed or not so as to find goals for product design and analysis. In this way, customers can be better served and product function can be improved.

3.2. Two-Dimensional Satisfaction Pattern. According to the two-dimensional satisfaction pattern, the opposite concept of "satisfied" is not "dissatisfied." "Satisfied" and "dissatisfied" should be regarded as two different and parallel concepts, which means that the opposite of "satisfied" is "not satisfied," while the opposite of "dissatisfied" is "not dissatisfied". Therefore, the relationship between "satisfied" and "dissatisfied" is not "either-or." For example, employees may

Table 1: Evaluation results of the KNAO model.

Function/Service		Dysfunctional				
		Dislike (1 point)	Live-with (2 points)	Neutral (3 points)	Must-be (4 points)	Like (5 points)
Functional	Dislike (1 point)	Q	R	R	R	R
	Live-with (2 points)	M	I	I	I	R
	Neutral (3 points)	M	I	I	I	R
	Must-be (4 points)	M	I	I	I	R
	Like (5 points)	O	A	A	A	Q

A: attractive, O: one-dimensional, M: must-be, I: indifferent, R: reversal, and Q: questionable.

not necessarily feel dissatisfied when satisfying factors are removed. Similarly, the removal of dissatisfying factors will not necessarily lead to employee satisfaction. Table 1 shows the relationship between the two-dimensional pattern of satisfaction and the attribute of the product defined by the KANO model.

We can see the relationship between functional requirements and satisfaction based on the KANO model (see Table 1).

Firstly, in the questionnaire, the questions of the same function or service will be asked in both positive (P) and negative (N) aspects.

Secondly, the positive question is like "if we can provide ** function or service, you feel. . . ." The negative question is like "if we cannot provide ** function or service, you feel. . . ."

Thirdly, we can get six attributes finally according to the answers.

Fourthly, attractive means that functions or services have exceeded user expectations. One-dimensional means certain functions or services may improve user satisfaction, and it will decrease without such functions or services. Must-be refers to the condition that certain functions or services will not improve user satisfaction, but it will decrease without such functions or services. Indifferent means that user satisfaction will remain the same with or without certain functions or services. Reversal refers to the condition that user satisfaction may increase without certain functions or services. Questionable means that users may not understand the questionnaire or give a wrong answer.

4. Empirical Analysis

According to the previous introduction to driverless functions, we have developed a questionnaire. For the same function or service, we have prepared two aspects of questions, positive or negative. Each question can be chosen from 1 to 5, representing dislike, live with, neutral, must-be, and like, respectively. The survey was completed online, and a total of 181 valid questionnaires were returned. Judging from the demographic characteristics, the proportion of males and females is almost equal to 50%. People who participated in the survey are mostly aged 35 to 45 with nearly 30%. Besides, the majority of participants have driving experience for more than 2 years, and all questionnaire users have used the self-driving functions (see Table 2).

According to Table 2, functions such as blind spot detection systems and rear cross-traffic alerts belong to attractive attributes. Adaptive cruise control belongs to the one-dimensional attribute. Forward collision warning, autonomous emergency braking, and stated-speed sign recognition belong to must-be attributes. Lane-keeping assist, lane departure warning, parking distance control system, and door open warning system belong to indifferent attributes. The lane change assist system belongs to the reversal attribute. No functions belong to questionable attributes.

In summary, we can infer that users have expectations when a driverless function can improve driving ability in the blind spot and indirect field of vision. In other words, users hope that driverless technology can solve the problems of the

TABLE 2: Results based on the KANO model.

Function/Service	A	O	M	I	R	Q	Results	Better	Worse
adaptive cruise control (P) & adaptive cruise control (N)	27.07%	29.83%	19.89%	22.10%	0.55%	0.55%	One-dimensional	57.54%	-50.28%
forward collision warning (P) & forward collision warning (N)	0.55%	1.10%	63.54%	33.70%	0.55%	0.55%	Must-be	1.68%	-65.36%
autonomic emergency braking (P) & autonomic emergency braking (N)	3.31%	4.97%	43.65%	26.52%	8.84%	12.71%	Must-be	10.56%	-61.97%
lane keeping assist (P) & lane keeping assist (N)	0.55%	0.00%	2.21%	85.08%	3.87%	8.29%	Indifferent	0.63%	-2.52%
lane departure warning (P) & lane departure warning (N)	3.87%	0.00%	0.55%	91.71%	3.87%	0.00%	Indifferent	4.02%	-0.57%
stated-speed sign recognition (P) & stated-speed sign recognition (N)	18.23%	9.94%	44.75%	21.55%	5.52%	0.00%	Must-be	29.82%	-57.89%
blind spot detection system (P) & blind spot detection system (N)	60.22%	13.81%	2.21%	19.89%	3.87%	0.00%	Attractive	77.01%	-16.67%
parking distance control system (P) & parking distance control system (N)	1.10%	6.63%	14.36%	59.67%	16.57%	1.66%	Indifferent	9.46%	-25.68%
lane change assist system (P) & lane change assist system (N)	7.73%	3.87%	5.52%	33.70%	49.17%	0.00%	Reversal	22.83%	-18.48%
rear cross traffic alert (P) & rear cross traffic alert (N)	34.25%	22.10%	6.63%	32.60%	4.42%	0.00%	Attractive	58.96%	-30.06%
door open warning system (P) & door open warning system (N)	1.10%	12.71%	29.28%	54.70%	2.21%	0.00%	Indifferent	14.12%	-42.94%

A : attractive, O : one-dimensional, M : must-be, I : indifferent, R : reversal, and Q : questionable.

blind spot and indirect field of vision they face when driving. The more this function can meet user expectations, the higher user satisfaction will be. However, the user will not show obvious dissatisfaction even when the expectations are not met. The reason may be that users also have the ability to deal with problems of the blind spot and indirect field of vision when there is no driverless technology.

Adaptive cruise control is expected by users according to the questionnaire. That is to say, most users hope that driverless functions can help them free their hands and enjoy a more relaxed driving experience.

For forward collision warning, autonomous emergency braking, and stated-speed sign recognition, users consider that they belong to must-be attributes. In a driverless environment, the greatest concern of users is safety. Therefore, users think that driverless technology must be equipped with such functions as warning of road conditions ahead and emergency braking afterwards. In addition, users consider stated-speed sign recognition necessary because they are not willing to passively receive tickets for overspeeding in the case that cars are controlling the speed automatically. As a result, stated-speed sign recognition is also indispensable.

For lane-keeping assist and lane departure warning, users see no impact on their acceptance of driverless technology. After all, land departure is an obvious and easily perceived driving situation for most drivers. Besides, the parking distance control system and door open warning system are not attractive to users. It is mainly because there are not many accidents reported when parking and getting off the car without the driverless functions.

For the lane change assist system, some users think it is unnecessary out of the distrust of the car changing lanes by itself.

TABLE 3: Summarized results based on the KANO model KANO (numerical).

Function/Service	A	O	M	I	R	Q	Results	Better	Worse
adaptive cruise control (P) & adaptive cruise control (N)	49	54	36	40	1	1	One-dimensional	57.54%	-50.28%
forward collision warning (P) & forward collision warning (N)	1	2	115	61	1	1	Must-be	1.68%	-65.36%
autonomic emergency braking (P) & autonomic emergency braking (N)	6	9	79	48	16	23	Must-be	10.56%	-61.97%
lane keeping assist (P) & lane keeping assist (N)	1	0	4	154	7	15	Indifferent	0.63%	-2.52%
lane departure warning (P) & lane departure warning (N)	7	0	1	166	7	0	Indifferent	4.02%	-0.57%
stated-speed sign recognition (P) & stated-speed sign recognition (N)	33	18	81	39	10	0	Must-be	29.82%	-57.89%
blind spot detection system (P) & blind spot detection system (N)	109	25	4	36	7	0	Attractive	77.01%	-16.67%
parking distance control system (P) & parking distance control system (N)	2	12	26	108	30	3	Indifferent	9.46%	-25.68%
lane change assist system (P) & lane change assist system (N)	14	7	10	61	89	0	Reversal	22.83%	-18.48%
rear cross traffic alert (P) & rear cross traffic alert (N)	62	40	12	59	8	0	Attractive	58.96%	-30.06%
door open warning system (P) & door open warning system (N)	2	23	53	99	4	0	Indifferent	14.12%	-42.94%

Except for discussing the attributes based on the KANO model, the better-worse coefficient can be calculated according to the percentage of each attribute. It indicates the degree of satisfaction increase or dissatisfaction removal by certain functions. After satisfaction increases, better = (A + O)/(A + O + M + I). After dissatisfaction removal, worse = −1 ∗ (O + M)/(A + O + M + I). The better coefficient can be interpreted as a coefficient after satisfaction increase. The value is commonly positive, representing that if a certain function is provided, user satisfaction will increase. The larger the positive value or the closer the value is to 1, the greater the impact on user satisfaction and the stronger the effect of satisfaction increase. In this case, user satisfaction will increase faster. The worse coefficient can be interpreted as a coefficient after dissatisfaction removal. The value is commonly negative, representing that if a certain function is not provided, user satisfaction will decrease. The larger the negative value or the closer the value is to −1, the greater the impact on user dissatisfaction and the stronger the effect of satisfaction decrease. In this case, user satisfaction will decrease faster. Therefore, functions or services should be considered first if the absolute value of the better-worse coefficient is higher.

After calculating better and worse coefficients, we can get the numerical results based on the KANO model (see Table 3).

According to Table 3, we find out that users are most satisfied with functions such as adaptive cruise control, blind spot detection system, and rear cross-traffic alert, which reflects that users are pursuing a more relaxed and safer driverless experience. On the contrary, users are least satisfied with functions like forward collision warning and autonomous emergency braking. However, these two functions are still considered essential by users, which shows that driverless technology should urgently improve these two functions to better satisfy users. There is a high worse coefficient in the door open warning system, indicating that users are in great need of this function. If this function is cancelled or poorly designed, users will have a bad experience with the whole driverless driving function.

5. Discussion and Conclusion

More newly produced cars are now equipped with driverless technology and user satisfaction with driverless technology is increasingly affecting their purchase choices. From the satisfaction research on driverless functions based on the KANO model, it is found that users are dependent on functions like forward collision warning, autonomous emergency braking, and stated-speed sign recognition, which are considered essential in driverless vehicles.

Therefore, car manufacturers or driverless technology suppliers should pay attention to the research and development of these technologies; otherwise, they will lose customers.

Secondly, users have high expectations for functions such as blind spot detection systems and rear cross-traffic alerts, but they are also very dissatisfied with these two functions. Car manufacturers and driverless technology suppliers should not only consider it a warning but also an opportunity. The better these two functions are, the more recognition can be obtained from users.

Lane-keeping assist, lane departure warning, parking distance control system, and door open warning system belong to indifferent attributes. Users are not too fond of these functions and consider them dispensable. Therefore, relevant enterprises should seek to improve these functions in order to improve user recognition, but the priority is not high.

The lane change assist system has been criticized by users, which is an unexpected situation. Therefore, relevant enterprises should investigate user requirements and feedback in time so as to improve this function.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest with respect to the research, authorship, and/or publication of this article.

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