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A Study for Moving Object Extraction Method of Intelligent Vehicle Omnidirectional Lidar

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Abstract. *Point cloud data can be obtained by vehicular laser radar, there are much noise, large amount of data and orderly data flow from its characteristics. This study has proposed a set of cloud data for the laser radar to process and efficiently extract the mobile target movement. The experimental results on range data show that the method can accurately and effectively identify the target in the radar scanning plane in a single frame based on the idea of dynamic programming. Simultaneously, to handle continuous frame data, and combine the results of each frame data by this method. When extracting the moving target information, the moving target can be continuously captured by an extremely low time complexity. The portability algorithm can adapt to a variety of processors, thus improving the use of laser radar to obtain the effect of moving targets.*
Keywords: dynamic programming, Lidar, range data, target detection

1. **Introduction.** Laser radar is a laser radar carrier, which is widely valued and studied in military, reconnaissance and surveying[1]. In the field of earth observation, the use of remote sensing image can obtain the information such as surface morphology and cover type (including Marine and underwater terrain), making topographic map, geographical drawings and various thematic map, meet the planning, decision making, forecasting and other needs, this not only requires to obtain all kinds of features of 3D coordinate information, and also requires to accurately determine the properties of all kinds of ground objects[2, 3]. The laser radar has extensive research on the target extraction of intelligent vehicles, especially in the field of laser radar data processing algorithm, and Chinese researchers have done a lot of works[4].

With the continuous development of the laser radar technology, and its technical characteristics such as much noise, large amount of data and orderly data flow which cause no a unified standard of data collection form. At the same time, the laser radar against a variety of occasions for secondary development makes the related algorithm of laser radar in transplantation in environmental awareness which becomes very complex[5, 6]. In order to guarantee the lidar data in a variety of convenient effectively with a variety of data fusion in the system, under the premise of considering time complexity, in a single frame data as the research sample, this study designs a set of high efficiency based on dynamic programming ideas moving target extraction method, the point cloud data of continuous frame data uses this method at the same time, more comprehensive feature extract relevant results, analysis of the moving target motion information. This method can be used in the application of intelligent vehicle and the smart car based on the lidar[7]. This

study firstly has carried on the detailed features of the lidar data analysis, according to the characteristics of the laser radar data, this study put forward the idea of the dynamic programming for the innovative point cloud data as a new method for analysis of moving object location, and the data processing, properly using the relevant methods in the experiment, it has obtained certain achievements, and this research adopts the method in the lidar point cloud data processing, an effective analysis of the effect of a moving object. Therefore, it is important to carry out the research on the extraction method of mobile target of intelligent vehicle for the lidar, moreover, there are great value for both technology and industrial application prospect[8].

2. **Laser radar data feature analysis.** Laser radar system mainly consists of laser transmitter, laser receiver, control system, information processing system and display device. The basic working principle of laser radar is launcha laser pulse signa for laser emissionl, then laser receiver collects echo signal generated by the laser scanning target. Finally, the system is processed to obtain the required information, displaying graphics through the display, and saving the relevant data[9]. When laser radar is working, laser transmitter firstly launches a series of laser pulses to the scanning space, which is illuminated by the scanning device and the optical transmitter system. The scanning device is controlled by control system, and laser beam scans in space according to the scanning mode[10]. When the laser pulse contacts the object, it will be reflected. Laser receiving system collects echo signals after these laser pulses are reflected by the target and pass through the optical receiving system, the data processing system is converted into the distance data, which is sent to the monitor to complete the final image display after processing[11, 12].

According to the measurement method of laser radar data signal, this study takes single-line and single-channel laser radar as the example, and it makes relevant analysis after using the laser radar to obtain the range data. Firstly, the propagation time of the measured signal is used. Secondly, the relative distance between the scanner and the image point is determined. Finally, the current environment is analyzed by the information in the echo signal. The radar uses the horizontal 360 degrees continuous rotation. The use of laser triangulation technology has obtained, and it is shown in Figure , lidar point cloud data with an included angle of 1 degree between each point of the laser radar scan.

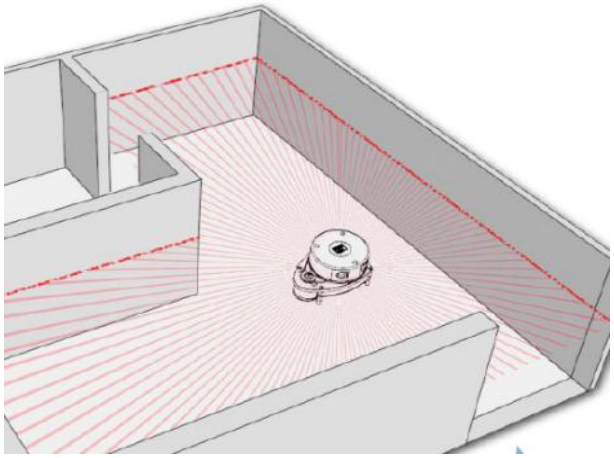


Figure 1. Laser radar operation mode diagram

There are large amount of data, much noise and local data too close features in the lidar data which can negatively affect the results. To ensure the accuracy of system sampling,

the multiple sampling is generally used to get similar information as reference of target input for the single objective, so the measured point cloud data needs to be processed each time up to hundreds of thousands to millions of data. At the same time, existence of more external interference, making the data stored in a large number of noise points, interference feature extraction, so the data needs to be processed as necessary. The "noise point" is the laser radar emits laser light while capturing a single target due to diffuse reflection, refraction and the range data fluctuation etc. For multiple single discrete "noise points", the value filtering algorithm can be solved very well. For a large number of "noise points" that exist in a large number of single discontinuous, small-scale continuous which are efficiently to be resolved in the extract real moving target information at the cost of minimal time complexity. It is of great significance to study the thoughts of dynamic programming.

3. **Dynamic programming algorithm and data fusions.**

3.1. **Dynamic planning ideas.** Dynamic programming algorithm is a mathematical method to optimize the decision-making process and has been widely used in many aspects since its inception. The algorithm is suitable for the relevant calculation under the premise of meeting the optimization and no post-efficiency problems[13].The optimization principle is the basis of dynamic programming, if the problem is not supported by the optimization principle, the dynamic programming algorithm will not be solved.

The basic idea of dynamic programming algorithm is to decompose problem into several interrelated stages. The sub-problems are arranged in a certain order in each stage, the sub-problems are firstly solved for a given stage state, and then the sub-problems are solved from original problem solution. For the recurring sub-problems, the solution is only solved on the first encounter, and resulting solution is saved to be used again in the subsequent state.

In the research of point cloud data of lidar, the longest non-descending sub-series thought is adopted to obtain the corresponding threshold function, so the dynamic transfer equation can be obtained. Because the large amount of cloud data obtained from the optimal strategy point, dynamic programming algorithm was chosen to analyze the extraction of laser radar moving targets in this study. This method not only saves the optimal sub-strategy, but also avoids the problem of repeated judgment. In this study, single laser radar data can quickly extract and analyze the moving objects, to satisfy the propose of quickly extracting and analyzing, the data of each frame must be processed by using dynamic programming algorithm which can process the data of each frame and extract object information, the integrated frame data analysis of the location of the moving object. Therefore, the algorithm has a lower time complexity, which makes the control system aware of the pretreatment of stage data can effectively improve the lag effect of pre-processing on the control system.

To address the issue of dynamic planning ideas, and considering the issue of each sub-problem is the stage of the process. Setting the state variable and taking the value of the variable as the state of each phase. The state constitutes a collection, the elements of collection are dependent on the stage k, so the initial state and the final state were x_k and X_k , the state sequence can be expressed as $\{x_1, x_2 \cdots, x_{\{k-1\}}, X_k\}$, so the whole process can be determined. Every stage $x_i(1 \leq i \leq k)$for the current condition, the optimal value of each phase, and after a state is determined according to the state $u(x_i)$ before the quantity based on the function that is for each phase $f_k(x_k)$ problem of the dynamic transfer equations, the core problem of dynamic programming can be solved by using the appropriate dynamic transfer equations. Making $f_k(x_k) = \max\limits_{[u_1,\cdots,u_k]} u_k(x_1, \cdots, x_k)$,

the dynamic transfer equation of the problem is used for each phase $f_k(x_k)$, and proper dynamic transfer equation is the core of the solution of dynamic programming problem.

The research adopts airborne lidar point cloud data after laser radar processor sample, laser returned after extracting the distance information obtained as a specific point cloud data in every angle. The definition of every 360o data is one frame data, and the environmental perception related needs should be obtained based on multiple frame data. In this study, a single frame of data as a sample, the establishment of dynamic transfer equation, and finally compare the global optimal value of multi-frame, and then analyzing the signal of each group of mutation information, the moving objects are analyzed in point cloud data from a comprehensive perspective.

3.2. **The establishment of threshold functions.** Based on the sampling angle $i(1 \leq i \leq 360)$of the laser radar, the lower scalar was chosen as the stage information, and the input value of each angle distance is the laser radar. The $x_i(1 \leq i \leq 360)$ is defined as the distance between 1 degree and 360, the unit is millimeter. In the case of a laboratory without moving objects was chosen as a test sample, the continuous point cloud information is shown in figure 2, using the obtained single frame data as an example. Known point A cloud information for some condition, point B is for the unmanned condition point cloud information, when the environment changes, moving object into the detection range, point cloud data to the previous frame has a larger mutation, due to the laser diffuse reflection in the air are easily to be a variety of factors interference, so the data returned in a constant environment under the condition of adjacent frame will still have smaller mutations, in order to ensure the moving object information mutations, it could be the algorithm of point cloud data acquisition due to the interference generated by the environment itself can be more effective filtering, reducing the disturbance to the subsequent control, at the same time to facilitate the establishment of dynamic transfer equations in the initialization process of the dynamic programming, the algorithm is set up corresponding threshold function which is indispensable. Threshold function is created according to the specific point cloud information integrated dynamic programming algorithm of optimal substructure and the global optimal, to set this feature in this study and combine with the experiment on the basis of considering the engineering practice that is used to judge the continuous decline in sequence for each phase, it is not produced by the moving object itself into from the local information mutations, or due to the environmental and other factors which may lead to a small range mutations of point cloud data, resulting in the longest non-drop subsequence changes. According to the requirements, the only moving object into a distance information generated mutations is the valuable information, moving objects can be used to identify the information, and other situations should be as far as possible in the process of recursive elimination, it cannot be regarded as continuous objects, thus interference is really moving object extraction work. For each frame data, the threshold function in the current frame should be based on its all data.

The threshold functions to define an array w_i as the threshold array, the array subscript i for single frame point cloud data of each phase angle. To define a variable q based on point cloud data of each frame of the specific volume, the variable q is defined as formula

$$q = \frac{\sum_{i=2}^{360}(\left|x_i - x_{(i-1)}\right|)}{180} \tag{1}$$

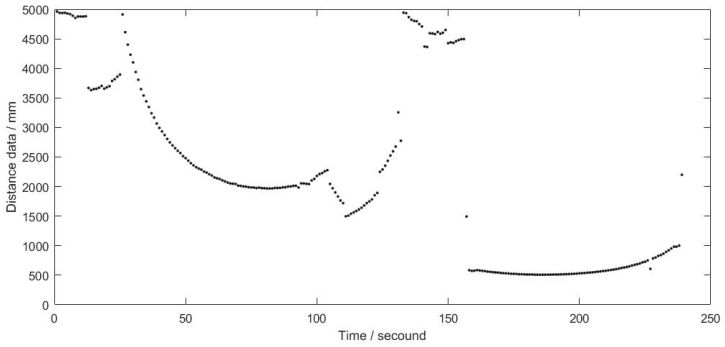
The pseudo-code in the program is expressed as:

```
w[1]=1
For i=2 to n
     If ABS(x[i]-x[i-1])>q then
```

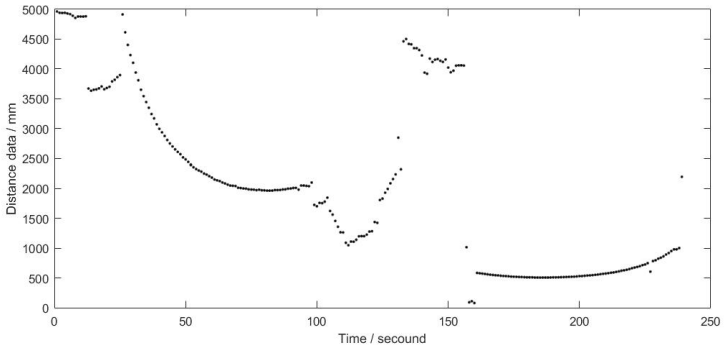
```
        w[i]=w[i-1]+1
        Else
        w[i]=1
  EndIF
 EndFor
```

3.3. **The establishment of dynamic transfer equation and algorithm process.** In the case of a single frame of data analysis, reach frame data has a function f_i , representatives from radar scanning initial position to the current rotation angle i for the cases, the process from the data in a continuous rise or fall which is used to ensure the current rotation angle i for the degree, and it is based on the current degrees maximum range from the value of time, the long-range data from continuous variation was obtained as the result of the current stage of the optimum. When all the data according to the equation of the iteration is completed, all traversal functions f_i as a result, before the save R_i to the array, in which the data to be obtained, comparing with the current function f_i, selecting different variation range of the angle, it can obtain the moving target relative to the target movement information. Conclusion array T used to store the function calculation results, the array is defined as an array , the laser radar sampling to the center of the moving target is under the present tense and the $f_i = \max\{x_1, x_2, \cdots, f_{i-1}\} \times w_i + 1$ polar coordinates of the location in which the laser radar information in the current state. The formula of the dynamic transfer equation is shown in the following equation:

In the process of solving the problem, the transfer equation still stores the continuous noise point in the optimal value result of a stage, but for obvious moving targets, the laser radar range from data information is still greater than the possession of the mutations



(A) Unattended rdnge information coordinate system



(B) Some people state distance information coordinate system

FIGURE 2. USingle-frame laser radar range coordinate system

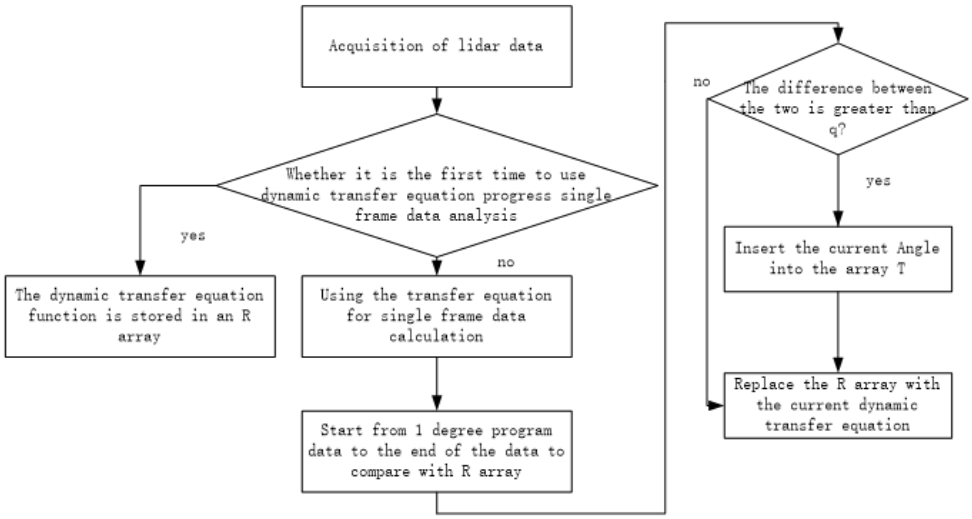


FIGURE 3. Flowchart of dynamic programming

which is caused by the instrument itself, the measuring principle and the environmental problems of "noise" in the process from data continuously present situation, according to adopt the analysis process of the algorithm can filter out the noise points related to impact, the algorithm was used in the implementation flow chart, and the flow chart is as follows:

4. **Experimental results and discussions.** The study mart car with laser radar as an example, the physical and detection environment, it is shown in figure 4 to carry out the laser radar mart car real figure. In laboratory environment for the testing environment, the laser radar mart car using laser radar to detect the laboratory environment, extracting the laboratory process information from the data. To take this study algorithm, the single moving target (mobile laboratory personnel) sampling analysis, and it is concluded that is the continuity of moving target mobile information.

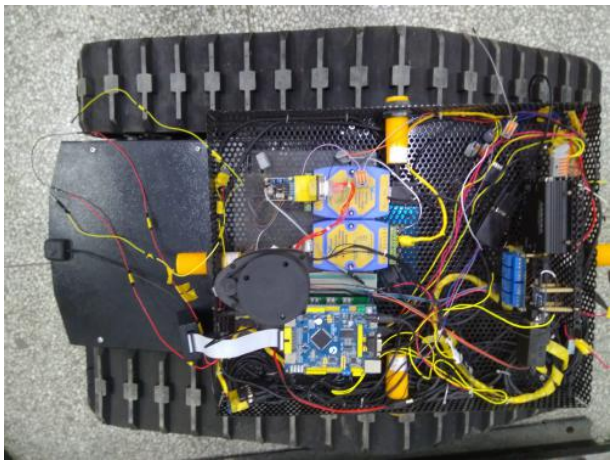


FIGURE 4. Experimental physical map

In this paper, the experimental hardware for the algorithm : dual-core Core i7 processor, graphics card of NVIDIA GeForce GTX independent display, hardware memory of 4GB. In each frame of memory after the data is imported,, ten samples are taken as samples. The statistics are as follows:

Table 1. Memory usage in the experiment

Frequency	1	2	3	4	5	6	7	8	9	10
Memory(MB)	15.54	11.96	13.01	12.69	13.05	12.86	12.88	12.00	12.68	13.08

It can be seen from Table 1 that the laser radar returns data each time, the number of iterations is different due to the different number of data generated by different data in each frame, resulting in a different degree of iterations, making the use of program memory appear to a certain degree. Fluctuations. With the corresponding number of experiments, the time statistics for each treatment are as follows:

Table 2. program running time

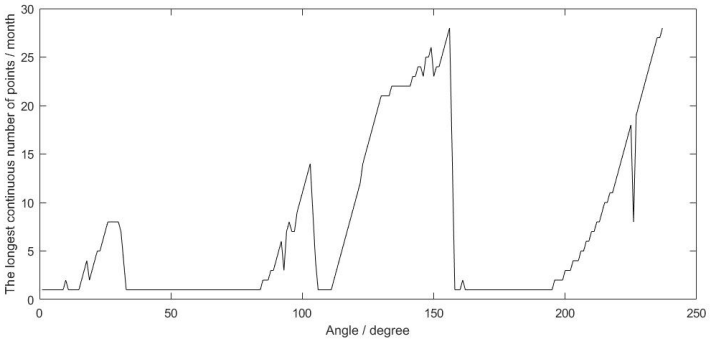
Frequency	1	2	3	4	5	6	7	8	9	10
Time(ms)	3.22	2.52	4.01	3.56	4.21	3.96	3.85	3.65	3.45	4.25

It can be seen from Table 2 that the time used for the point cloud data of each frame under this hardware configuration is within 5ms, so it can meet the current control frequency requirements of the control system and can be calculated within a short time. The central position of the target has a corresponding practical significance.

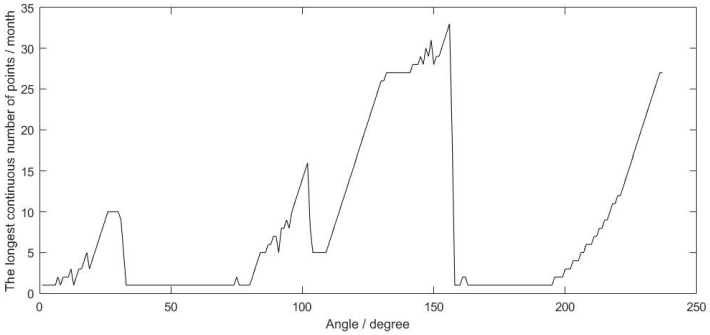
To start with the laser radar for the corresponding system pretreatment, then the point cloud data is obtained when the researchers at boot after laser radar at the front of a mart car with a constant speed after a certain distance, collecting information and sample analysis to a certain part of the frame data in the experiments. For example, running the related algorithm x in an array, this study obtained single frame dynamic transfer equations f_i with the angle, in the way of conformity multi-point cloud image capture three frames as shown in figure 5.

Figure5 (a) was plotted under the conditions without moving person status in the laboratory, there is only a state of moving object image in the environment, the image data is used as the basic reference data, when a person is surrounded in the tests, collecting the state image of the reference image can be seen from the figure5 (b), when the person does not move, because the person has a performance in the point cloud data, the data in the presence of someone, in a part of the larger mutation, thus the person has the integrity on the image system state changes, from figure 5 (b) and (c) in using the algorithm to deal with data with the smart car relative stationary state caused by environmental factors, moving object will tinily impact the final result. It can be seen from the figure 5 (c), when the person is moving the data areas of mutations will follow the movement in the constantly changing, so the continuous impact of the state image of smaller, but comparing with figure5 (a) the image still has great changes without movements. In the use of this algorithm is applied to analyze.

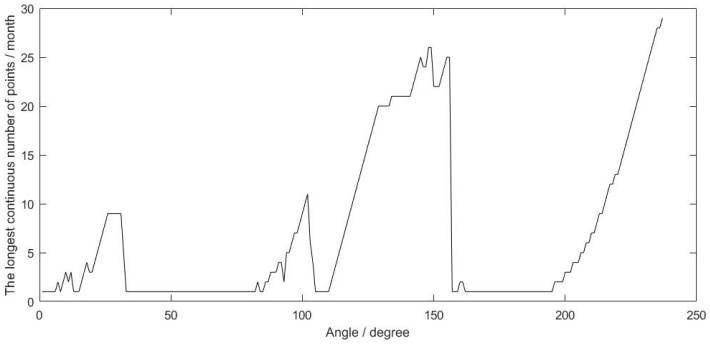
The lidar data of moving target extraction process, the first thing to process the environmental data under the general condition of extraction, according to the situation of different conditions as shown in figure 5 (a), when the person in a bearing mobile the smart car, this method adopts the dynamic transfer equations of each stage of the calculation of the optimal value, it has a clear effect. From the figure 5 (a), (b), (c) three frames, the personnel and the impact of the move when it was in a certain way which produces the corresponding impact on the state of the image are the information extraction, the angle can be obtained according to this research program T array. To select a sampling period of a situation, the situation is the data of three groups of samples after ten times as shown in table 3:



(A) Image without moving person status



(B) Moving person not moving state image



(C) Moving frame when moving a certain state images

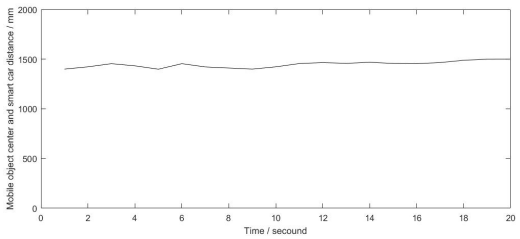
FIGURE 5. Dynamic transfer of equation results and angle relationships in many cases

TABLE 3. T Array Information

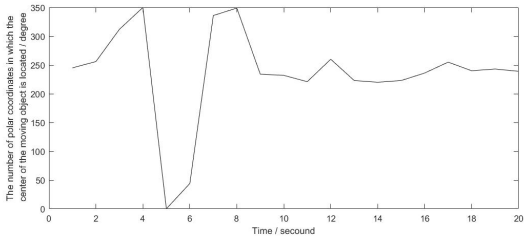
T array subscript	1	2	3	4	5	6	7	8	9	10
The first group(unit / degree)	234	244	236	237	238	237	233	240	238	237
The second group(unit / degree)	235	235	234	237	239	238	250	233	240	233
The third group (unit / degree)	235	233	236	234	231	233	235	236	237	234

The origin of the polar coordinates with the smart car location and direction is in a straight line as the starting point is zero, according to the algorithm for a moving target after the acquisition of point cloud image in table 1, after 40 frames calculation algorithm proposed by this study, after each time the interception of T as the polar

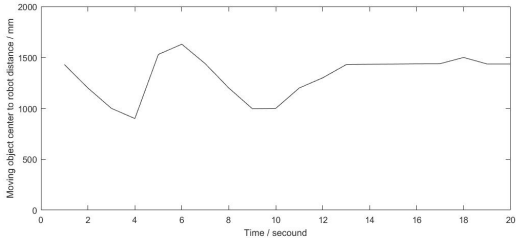
angle information is used in the analysis, based on the comprehensive selection by the system after the corresponding identification, the moving object with the smart cars in the relative position of azimuth information directly will then be obtained. Table 6 shows that the three periods of the three groups of data, and it provides the additive of subscript, data presentation which is very regular rising or falling, environmental awareness in the smart card system of point cloud data collected laser radar module. Finally, according to the way the end result can be obtained accurately judge the current time under the node position in the polar angle to the center of the target, this will spend longer time on the frame data comprehensive analysis which can get moving object movement. The relationship between the position and distance of the mobile object obtained in the mobile center which has been obtained by this research is shown in.



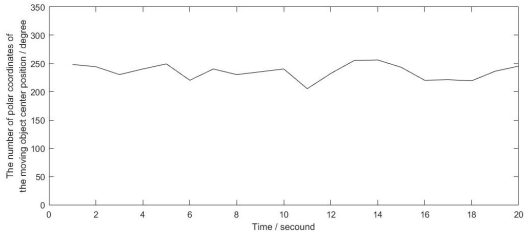
(D) The image of the position of the center of the staff and the orientation of the smart car in a stationary state



(E) The personnel center position and the distance relation image of the smart car



(F) The position of the personnel center and the position of the smart car



(G) The location of the personnel center and the distance of the smart car are the image

FIGURE 6. Relationship between the position of the moving target and the smart car position

The group of images is calculated using the scheme in this study for both the center of the moving target and its relative robot in both cases of the person standing or walking, and the obtained corresponding data is shown in figure 6. In the case of the standing motionless, laser radar accurately determines personnel rear mutation information generated in the personnel area and it shows the center location of the person in the figure 6 (d). Due to the person in the process of stationary or moving, so it is not strictly stationary target, after the completion of the data acquisition processing center position is not stable at a certain point of view, there is a certain error belongs to the normal phenomenon. The concept of empathy also exists in the distance detection image of figure 6(e). Because the lidar continuously updates the distance information of each angle from 0 to 360 degrees when the point cloud data is being collected, when the target moves to the initial angle of the sensor and it continues to move in the same clockwise direction, the data will be cleared from 0 degrees to re-measure, in the state of walking around the center of the

robot position in the 8s state when the polar angle directly into a 0 degree from Figure 6 (f),it can be judged the person is in a clockwise direction to continue. As the distance between the walking person and the moving person is undergoing a great change, the motion of the moving target in the current time can be judged according to the image, and the subsequent work of environmental awareness can be completed according to the corresponding status from the figure 6(g).

5. **Conclusion.** This study proposes a lidar point cloud data based on the dynamic programming applied method, the method of single frame number only about 129600 times, each calculation has no floating point arithmetic, if the relative accurate environmental awareness requirements need to be completed, just calculate frame data, then the comprehensive conclusions will be come out. This study aims on the single moving object by using the three computational analyses to more accurately represent the corresponding polar coordinate information. For the multi-objective research, we can refer to the single-objective approach in this study. According to the corresponding demand to increase the number of conclusions array, polar coordinates information of multi-moving target can be obtained at the same time. This algorithm has much practical significance as a part of laser radar point cloud data processing method.

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