Realization of Unmanned Vehicle Navigation Considering Density and Pedestrian Flow with Cloud Information

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Abstract— **Gradually, unmanned vehicles are more popular and seen in some places, such as department stores or supermarkets with many people. In order to integrate into human daily life, they should be able to avoid crowd and follow pedestrian flow as human will do. It is not enough to only follow the shortest path for them.**

The purpose of this work is to implement a navigation algorithm in the real world that considers the flow and density of people. We use a cloud computer to receive fixed camera images, divide regions on the image, and then obtain pedestrian flow and density information through FairMOT[2] algorithm, and wirelessly transmit the information to the unmanned vehicle. Therefore, the unmanned vehicle can avoid high density or reverse flow, and better follow social etiquette.

In our implementation, flow directions are with different colors, and shown in our experiments. Furthermore, the flow and density information is passed through WiFi, and affects the cost of a new created cost map layer, called people flow and density layer. The density information affects the navigation reliably. Due to the same area may have different directions of people flow, the following flow algorithm is more challenging.

The fixed camera we used is a low-cost webcam, and the unmanned vehicle is with a single camera and a one-line lidar.

I. INTRODUCTION

In the current era of artificial intelligence, the world is actively developing artificial intelligence and robotics. Gradually, robots can be seen in some places, such as department stores or supermarkets, where there are many people. They are responsible for providing functions that serve people, such as customer guidance, cargo handling, etc. as shown in Fig. 1.

Fig. 1: A supermarket robot[1]

It can be found that robots have begun to be integrated into human daily life to help people solve problems, but we find that in human daily life, human beings actually have some subconscious social etiquette behaviors. For example, there are areas with many people or few people, and each area has its own main direction of flow of people. Generally, people will try to avoid crossing areas with many people, or areas in the opposite direction to their own walking direction, thereby reduce collisions and walk more comfortably.

However, convention robots don't understand such behaviors. The convention robots only consider how to reach the target in the shortest path. Therefore, the robots may pass through high-density or countercurrent areas, which will cause pressure on pedestrians, and may also cause the robots to lose their positioning due to surrounding crowd.

This paper proposes an algorithm to obtain the information of people flow and density, send the information to an unmanned vehicle, and enable the unmanned vehicle to navigate in the low-density area along the flow of people, which is a better path in terms of social etiquette.

II. RELATED WORK

Chang, et al. [4] proposes a hierarchical navigation considering density and human flow information, and divides its navigation into wide area navigation and narrow area navigation. The wide-area navigation considers the flow of people and density information to plan the appropriate global path, and then hands over the path to the narrow-area navigation to avoid obstacles in the venue and complete the navigation task.

They propose the concept and a simple verification of people flow and density detection. However, their implementation does not include sending information to the unmanned vehicle yet. We complete the detailed verification in the actual field including transmitting the information to the unmanned vehicle. We also design and implement the details of its navigation.

FairMOT [2] is a one-shot MOT (Multiple Object Tracking) model. We adopt the main framework for detecting crowd density. They change the anchor-based method commonly used in object detection to anchor-free, and the problem of sharing features between object detection and Re-ID is improved. Using low-dimensional Re-ID features, the One-shot MOT model not only has real-time computing speed, but also has good accuracy.

III. PROPOSED SYSTEM ARCHITECTURE

Our system architecture is shown in Fig. 2. The first step is to obtain the image through a fixed camera, and then use OpenCV [3] to perform pre-processing on the image to segment the area. The second step is to send the segmented image to the FairMOT algorithm, and determine the flow of people and density in the area. The third step is that the cloud computer uses Wifi to transmit the flow of people and density information in the area to the microprocessor Jetson Nano on the unmanned vehicle. Finally, the Jetson Nano will process the transmitted data to determine the area whether the flow and density of people are reverse flow or high-density areas, so that the unmanned vehicle avoids the unsmooth path.

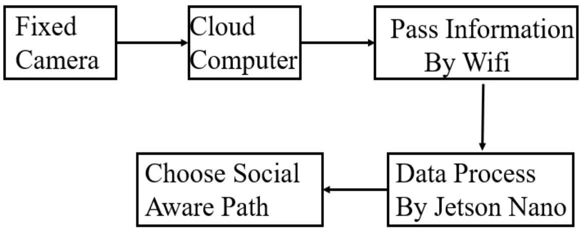


Fig. 2: System Architecture Flowchart

We detail the steps in the following. First, we use the cloud computer to divide the image into regions, which are divided according to the region of interest on the image, in order to later judge the flow and density information of the region, as shown in Fig. 3..

Fig. 3: Region Division

Then, the center coordinates of the lower edge of the target are obtained through the FairMOT target tracking algorithm. After processing each frame, we store the center coordinates of the lower edge of each object. Only up to 3 coordinates can be stored per target. When the fourth frame is reached, the coordinates stored in the first frame will be cleared, that is, the oldest coordinate information will be deleted, and the coordinates detected in the fourth frame will be added, that is, the latest coordinate information will be added. And so on until the last frame, it means that the coordinates of the detected objects are constantly updated to ensure that the information on the flow of people is also constantly updated, as shown in Fig. 4.

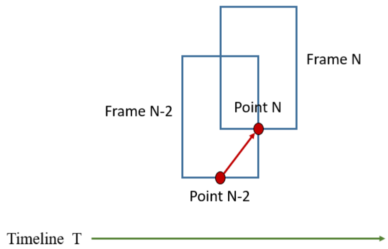
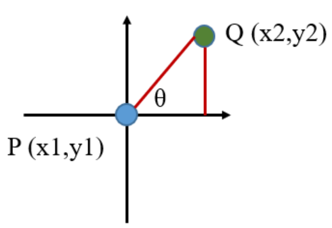


Fig. 4: Compare the coordinates of 2 different frames

The center coordinates of the lower edge detected in the current frame and the center coordinates of the lower edge detected in the previously stored second frame will be used to calculate an angle, θ. The angle calculation method is: use the currently detected coordinates (P) to establish a coordinate system, and then use the previously stored second frame coordinates (Q) to calculate the relative angle between the two points. The calculation method is shown in Fig. 5.



$$\theta = \arctan(\frac{y2 - y1}{x2 - x1})$$

Fig. 5: Relative angle calculation

In this experiment, we marked the direction of the flow of people with 6 different English letters, namely U, D, L, R, S or N. The meaning of each English letter is shown in Table 1.

Table 1: English Letter Table

English Letter	Sign Meaning	Angle Range
U	Upward Flow	$195^o \sim 345^o$
D	Downward Flow	$15^o \sim 165^o$
L	Leftward Flow	$164^o \sim 194^o$
R	Rightward Flow	$0^o \sim 15^o$ and $346^o \sim 360^o$
S	People Standing Still	None
N	None	None

Each English letter must have a corresponding relative angle range. The relative angle range specified in this experiment is adjusted according to the position of the fixed camera. In different fields, it may be different due to the placement of the camera. The human flow detection result in this experiment is shown in Fig. 6. and the colors will be explained later.

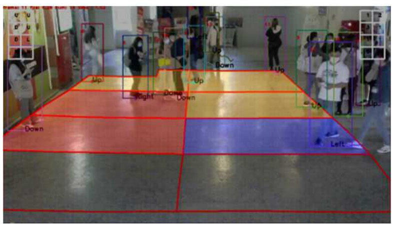


Fig. 6: People flow detector example

In judging the main flow of people, we will make each area have 5 values, corresponding to the number of people in each current flow state (U, D, L, R, S) of the area, and then only compare the 4 values. The number of people in the flow state S is not compared here. The largest value is the current main flow of people in the area, and different colors will be used on the image to represent the main flow of people in the area, which can visually identify the area more intuitively. The main flow of people in each direction with a different color is indicated in Fig. 7.

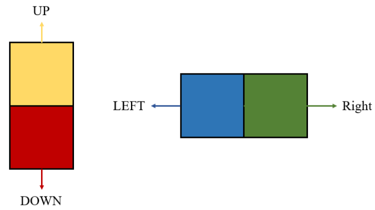


Fig. 7: Colors represent the flow of people

In terms of judging density, the five values of each area mentioned above are used to store the total number of people in different flow states, including five flow states of U, D, L, R, and S. Therefore, when judging the main flow of people, we can also get the number of people in each direction in each area. We can add the number of people in different directions in each area to get the total number of people in the area, that is, we get the number of people in the area, i.e., the density information.

We must transmit the information to the Jeston Nano on the unmanned vehicle through the Wifi wireless network for data processing in order to affect the navigation path of the unmanned vehicle. The schematic diagram of data transmission is as follows in Fig. 8.

Fig. 8: Data transfer

Finally, Jetson Nano data processing is required to change the navigation path planning. The procedure will be divided into three parts.

The first part: We use the lidar positioning system on the unmanned vehicle, convert the pixels required for each area on the image into real-world coordinates, and obtain the four required flow vectors, which are: U(0,-1), D(0,1), L(1,0), R(-1,0) four vectors, as shown in Fig. 9.

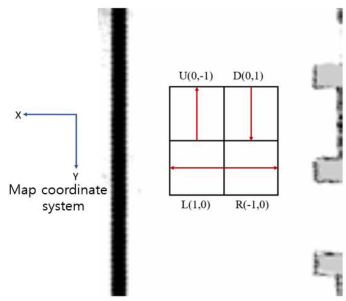


Fig. 9: Vector labeling example

The second part: The vector between the unmanned vehicle and the target point can be obtained through the function provided by ROS [5] itself, then the vector of the unmanned vehicle to the target point and the main flow vector of people in each area can be used to calculate the angle between the two vectors. After calculating the angle, we can set a threshold value for it. This threshold value is based on many experiments, and finally find a threshold value that is most suitable for this experiment. If the calculated angle between the flow of people in this area and the unmanned vehicle to the target point is less than or equal to the set threshold, it is defined as the area along the flow of people; otherwise, the calculated angle is greater than the set threshold, then we define the area as the reverse flow area. The angle calculation is shown in Fig. 10, and the threshold value set in this experiment is 45^{o} 。

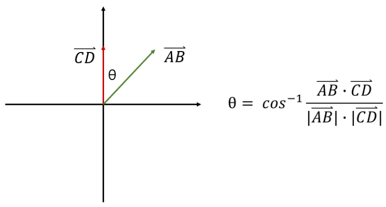


Fig. 10: Angle between vehicle and flow directions calculation

The third part: We will first calculate the cost of the flow status and density information for each area. As shown in Table 2, the forward flow is cost 0, the reverse flow is cost 50, and the density cost is 1 for one person. If there are N people, then it is cost N.

Table 2: Area Cost Table

Follow the flow of people	Against the flow of people	People Density
Cost 0	cost 50	1 cost/people

After calculating the cost of the status of each area, it is time to make the navigation of the unmanned vehicle avoid against the flow of people or high-density areas. The method is as follows, we can split the obtained cost map into raws for analysis, and use the above method to calculate the cost of the first raw first, as shown in Figure 11.

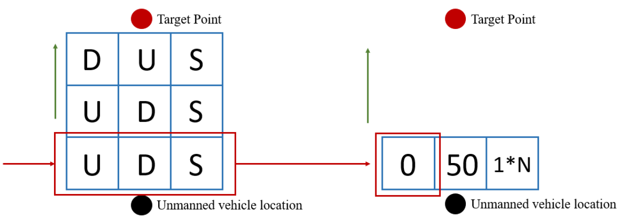


Fig. 11: The first raw of area analysis

After getting the costs of each area in the first raw, we will make the unmanned vehicle preferentially select the area with the lowest cost (details will be explained later), which is also the area with the flow of people, and then avoid the area with the opposite flow or high density. According to the method just described, the same analysis can also be performed on the second and third raws, and finally the best area is selected for each raw, and these areas are the areas where the unmanned vehicle will travel, as shown in Fig. 12.

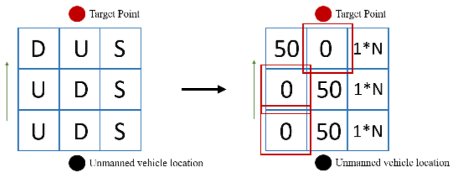


Fig. 12: Choose the best area example

Finally, the Costmap [6] function of ROS [5] will be used to actually avoid the reverse flow and high-density areas. The original Costmap has only three layers of static obstacle layer, dynamic obstacle layer and expansion layer. We add an additional layer of people flow with density layer to receive information about people flow and density. The function of this layer is to increase the cost value of each raw except the area with the lowest cost, and increase the cost value to 254. Thus, the navigation of the unmanned vehicle can avoid the counter-flow and high-density areas.

IV. EXPERIMENT

The fixed camera we used is a low-cost webcam, and the unmanned vehicle is with a single camera and a one-line lidar.

We chose to conduct the experiment in the hall on the first floor of the Electrical Information Building of our school. First, we will divide the image of the fixed camera into 3*3 areas, and then make all areas in the leftmost column generate the flow of people in the same direction as the unmanned vehicle, and make the area in the middle column have a flow of people in the opposite direction to the unmanned vehicle, and make the rightmost column have people standing and not moving significantly to affect the density information, as shown in Fig. 13. By doing so, we can demonstrate unmanned vehicle navigation that also considers crowd density information.

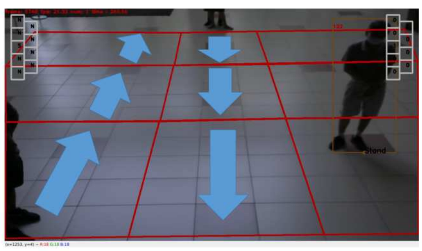


Fig. 13: Experimental flow example

The crowd flow status and density information of each area are obtained through the fixed camera, and the cost is calculated for the 9 areas, and the resulting navigation will avoid reverse crowd flow and high-density areas, as shown in Fig. 14.

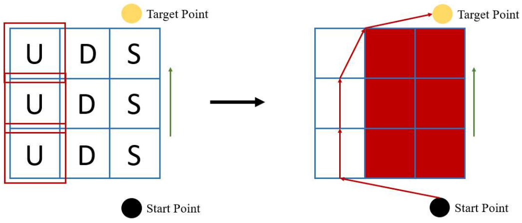


Fig. 14: Navigation path planning map considering the flow of people

Fig. 15 shows how we make the planned flows in Fig. 13 happen.

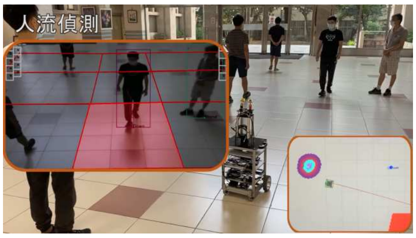


Fig. 15: People flow result (first)

According to Figure 15, the unmanned vehicle obtained the information on the flow and density of people in each area, so the unmanned vehicle can know which areas are the areas with or against the flow of people, and choose the area with the flow of people and avoid the area against the flow of people to reach the destination, shown in Fig. 16.

Fig. 16: People flow result (second and third)

V. RESULT AND CONCLUSION

We realize unmanned vehicle navigation in the real world that combines cloud information and considers people flow and density information. The density information affects the navigation reliably. Due to the same area may have different directions of people flow, the following flow algorithm is more challenging.

We hope the proposed navigation algorithm can be applied to unmanned vehicles serving department stores or large shopping malls. Whether it is a customer-guided robot or a cargo-handling robot, with our algorithm it can be better integrated into people's lives and improve service quality.

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