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Obstacle Avoidance Car based on Vision System

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Introduction

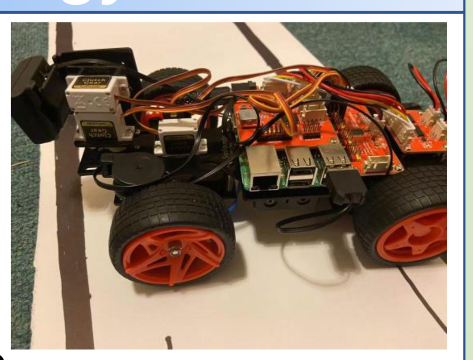
Autonomous driving technology is one of the popular technologies nowadays, which can capture environmental information and digital information to precisely sense what is around and react in time.
Autonomous driving technology requires the use of cameras as an input to information. Achieving lane following and obstacle location require cameras to read the road environment and information in real-time.

Aim

Detect and follow lanes, locate and avoid obstacles on lane based on Raspberry Pi 3B camera-equipped vehicle.

Methodology

Components:



1. Robot HATS
2. PCA9865
3. Motor Driver Module
4. USB Webcam
5. SunFounder SF006C Servo
6. DC Gear Motor

Lane-following:

- Image processing:

1. Blurring images by normalising box filters that can reduce the information system need to process. It can improve efficiency of processing image.
2. The image usually consists of three colour channels, namely red, green and blue. After blurring the image, the processor splits the colour image into separate some single-channel images. The separated red channel performed the best in the test environment because the test environment is simple and the road is white. Therefore, in the subsequent image analysis, the program will extract the red channel and ignore the other channels.
3. By setting a threshold to 255 for pixel values above the threshold and 0 for pixel values below the threshold that obtain an only black and white image.
4. Using the determination of pixel point coordinates, divide the camera capture image into the left area and right area. Identify the coordinate on the lane to calculate the distance from the x-coordinate to the image centre.

- Movement decision:

1. If both lane lines are detected, go straight ahead
2. If only one side of the lane line is detected and the coordinates on the lane line are near the centre of the screen, then turn to the other side and vice versa.

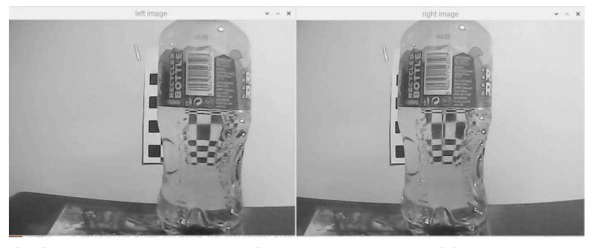
Methodology(Continued)

Obstacle avoidance:
The project uses a single camera to create a deep stereo image instead of a conventional binocular camera or a stereo RGB camera to create the world coordinates. Using a single camera is lower expenses than buying a powerful camera.

Procedure:

- Image processing:

1. Initialise the camera's position so that it is facing straight ahead. Subsequently, it deflected slightly to simulate human eyes. The camera builds a deep stereo image on the principle of mimicking the human eye.



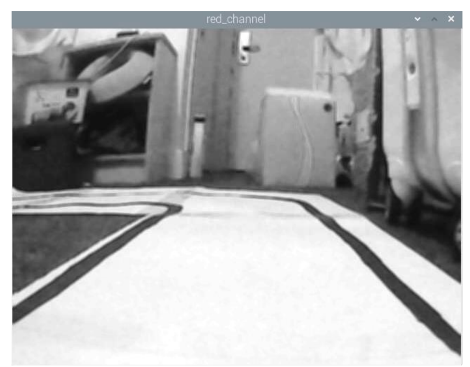
2. The critical step is to calibrate the camera parameters. The checkerboard offers a real-world coordinate of 3D points in calibration because of its known size and a square grid with distinctive colours. The pixel coordinates will be more accurate for more images captured and analysed. Then we can receive the internal parameters and external parameters of the camera. Simultaneously, we need to be aware of lens distortion, or distortion effect, in the camera. Distortion can be effectively removed by rotating the matrix and by some linear algebraic methods.
3. Combining two images of the simulated left eye and the eye with it to form a disparity map and transform it into depth map. OpenCV's Srereo_SBGM algorithm can efficiently process this step by improving visual disparity constraints by increasing the cost for wrong matches. This way can be analogous to the search method of least-cost estimation in artificial intelligence.
4. In the case of two images establishing a pixel coordinate system corresponding to the real world, the real-world coordinates of the camera form a ray with the coordinates of the object on the pixel coordinate system. When the camera captures the same object, the rays formed by two different camera angles through different pixel coordinate systems intersect at a point. Therefore, the known pixel coordinates of the object and the already calibrated camera parameters can find the object's depth.

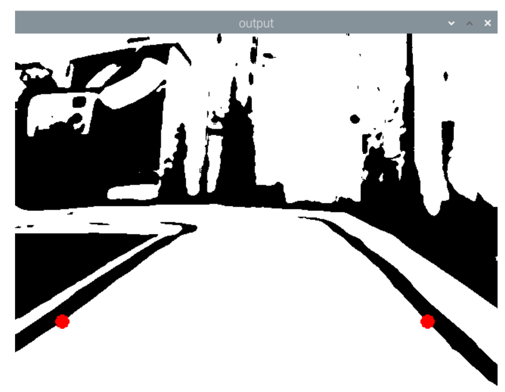
- Obstacle avoidance system:

1. Build depth map after processing images.
2. Identify a threshold which means safe distance. It will give an alarm if it detect the distance between camera and object.
3. Create a mask for range of interest to reduce the influence from corrupted environment.

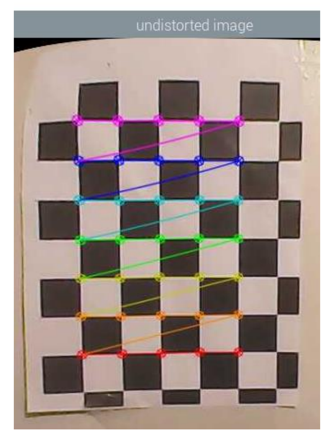
Result

The smart video car can follow the designed lane automatically and it's not just limited to following a straight lane. As the picture shows, there are two points on the lane which means the camera can detect both of lanes.





In the obstacle avoidance section, the internal parameters and external parameters of the single-camera was calibrated and rectified by analysing the checkerboard and it can print the distance and execute the decision for avoidance. The pictures show that the undistorted image and disparity image.



Conclusion

This project is generally complete and can be run successfully. Pixel dots are used in the lane following section to detect edge areas rather than the traditional Hough's theorem to detect straight lines. The reason for this is that Hough's theorem can detect lane lines very quickly and unambiguously when both lane lines are present, but when one of the lane lines disappears Hough's theorem cannot be calculated. The polar coordinates cannot be calculated because the coordinates of one of the lines are missing. For the obstacle avoidance system, it used a lot of linear algebra and was difficult to understand, but thanks to the advice of my supervisor I was able to reduce the cost of the project by replacing the stereo camera with a single camera.

Future Perspective

Regarding work on the future, I need to continue to update the lane following section to make it follow the lanes more smoothly. For the obstacle avoidance part, I would like to adopt a target detection algorithm to make the obstacle avoidance system more widely applicable and intelligent.

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