Artificial marker-based navigation using Aurora and OpenCV

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Abstract

This report serves as documentation for the source code developed. Two new plugins were added to the Aurora framework, which allow the use of a camera for a marker-based navigation system. The first plugin, used by the MarkerFollowing component, sets the new target of the robot's trajectory based on proximity to the marker, and ensures the robot does not change of target until it has completely arrived to the center point of the marker. The second plugin, used by the MarkerDetection component, detects the marker in the camera image and calculates the distance and orientation between the robot and the marker. The type of marker used is an arrow of an specific colour. OpenCV library was used to implement the image processing algorithms.

Marker detection

Introduction

The aim is to develop an artificial marker-based navigation using arrows of a certain colour to guide the mobile robot's trajectory. The robot is equipped with a stereoscopic camera that is used to detect arrows in the floor, and obtain for each one of them: distance to the robot, dimensions, center point, orientation.

The key assumptions will be:

- Any type of arrow can be detected.
- The robot only detects arrows of a specific colour that is defined in the configuration file of the component.

Finally, from all the arrows seen in the frame, the robot chooses as a target the one that is closest, and moves towards it until it is completely on top of its center point.

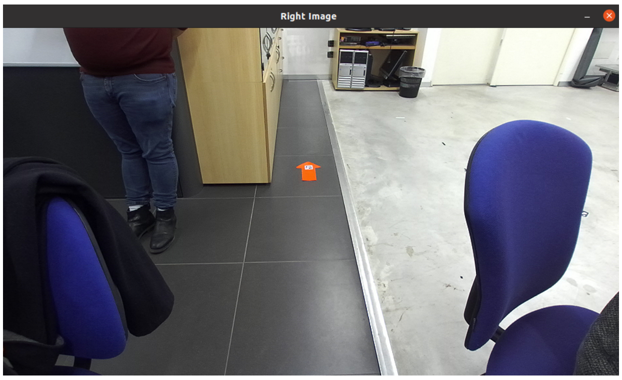

Figure 1: *Frame retrieved by the camera without processing*

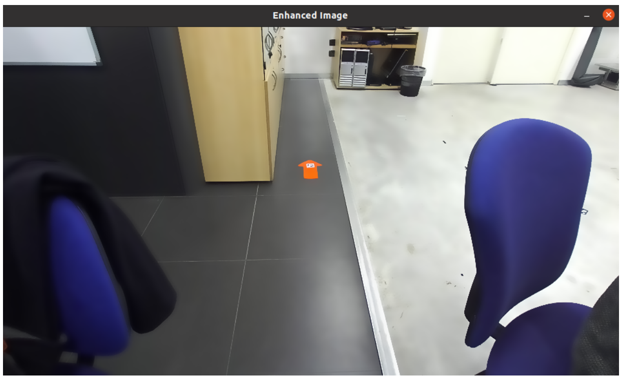

Figure 2: *Frame after applying bilateralFilter*

Image preprocessing

Enhance image quality The aim of this step is to reduce noise by smoothing colours, but without blurring the edges. For this we use the cv::bilateralFilter from OpenCV. A previous transformation of the colour codification is required in order to be able to use the method from the library.

Apply colour filter In this step we eliminate all the colors of the image except from the arrow's one. As we will be only detecting arrows of a specific colour. We will define a mask (cv::Mat) that consists of a binary matrix of the same dimensions of the frame.

Cells set to 1 will correspond to those within a color range (where the color of the arrow will be, plus some tolerance due to changes in the illumination).

Then, we will simply define another matrix of the same dimensions of the frame, where each cell will store white colour (255, 255, 255) in BGR codification.

We multiply (bitwise_and operation) both of them and the result will be a pure black and white matrix, where the background will be black (0, 0, 0) and the arrow white.

Figure 3: *Pure black and white image after applying the mask*

Figure 4: *Contours calculated out of edge detection*

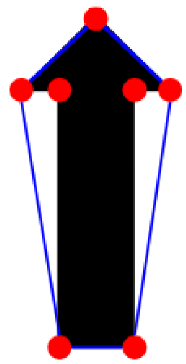

Figure 5: *Key points and convex hull of 1st type of arrow*

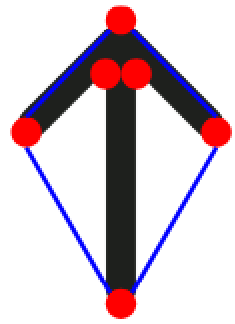

Figure 6: *Key points and convex hull of 2nd type of arrow*

Algorithm for detecting arrows

The algorithm for arrow detection in the frames can be decomposed in the following steps:

1. Detect the edges with Canny out of the pure black and white filtered image (Figure 4).
2. Find the contours of the arrows based on the retrieved edges from the previous step. Taking only the external ones in order to avoid detecting more than once the same arrow (RETR_EXTERNAL). Parameter CHAIN_APPROX_SIMPLE compresses horizontal, vertical, and diagonal segments and leaves only their end points.
3. From this step onwards each contour will be processed as a potential arrow…
4. Out of the contour (vector of 2D coordinates) we calculate the approximate polygon containing all its key points (corners of the arrows).
5. The convex hull is obtained out of the approximate polygon, as a list of the indexes that form the convex hull.
6. 1st ARROW CONDITION CHECK (Figures 4 and 5): convex hull contains 5 points (for the first type of arrow), or convex hull contains 4 points (for the second type of arrow). Also, the approximated polygon must have exactly two more points than the convex hull, as is a condition that is always verified for all types of arrows.
7. Identify the indexes of the two inner points of the arrow (those excluded from the convex hull) in the vector of points that form the approximated polygon.
8. Find the tip of the arrow / 2nd ARROW CONDITION CHECK: once we have the indexes of the two inner points, and based on the fact that both of them will be at distance 2 from the tip (inside the vector of points that form the approximated polygon), we can do the following checking to compute the tip:

   8.1. Sum 2 to the index of the first of the two points; subtract 2 from the index of the second point. If the index is the same, then it will be the index of the tip.

   8.2. If the indexes are not the same, we will subtract 2 to the index of the first of the two points; sum 2 to the index of the second point. If the index is the same, it will be the index of the tip.

   8.3. If none of the conditions are satisfied, it means that the figure is not an arrow.

9. We get the two bottom points of the arrow simply by adding 3 and 4 to the index of the tip in the approximated polygon list of points. Then,

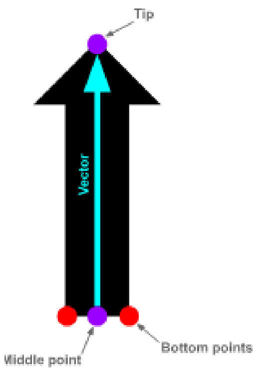

Figure 7: *Arrow vector and the two points that define it*

we calculate the middle point of them (for the case of the second type of arrow).

10. With all these calculations, we have obtained the coordinates of the tip and of the bottom of the arrow, so we can build a vector (figure 6) from which we can calculate the size of the arrow, its center and its orientation.

```
for (int i=0; i<iterations;i++)
{
do something
}
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Methodologies

Sample Sites & Processing

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[1] Example footnote text.

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Data Analysis

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Table 1: *Example single column table.*

Location		
East Distance	West Distance	Count
100km	200km	422
350km	1000km	1833
600km	1200km	890

Figure 8: *Anther of thale cress (Arabidopsis thaliana), fluorescence micrograph. Source: Heiti Paves, https://commons.wikimedia.org/wiki/File:Tolmukapea.jpg.*

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Results

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Links

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Discussion

This statement requires citation [1]. This statement requires multiple citations [1, 2]. This statement contains an in-text citation, for directly referring to a citation like so: Jones and Smith [2].

Subsection One

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Table 2: *Example two column table with fixed-width columns.*

Location		
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100km	200km	422
350km	1000km	1833
600km	1200km	890

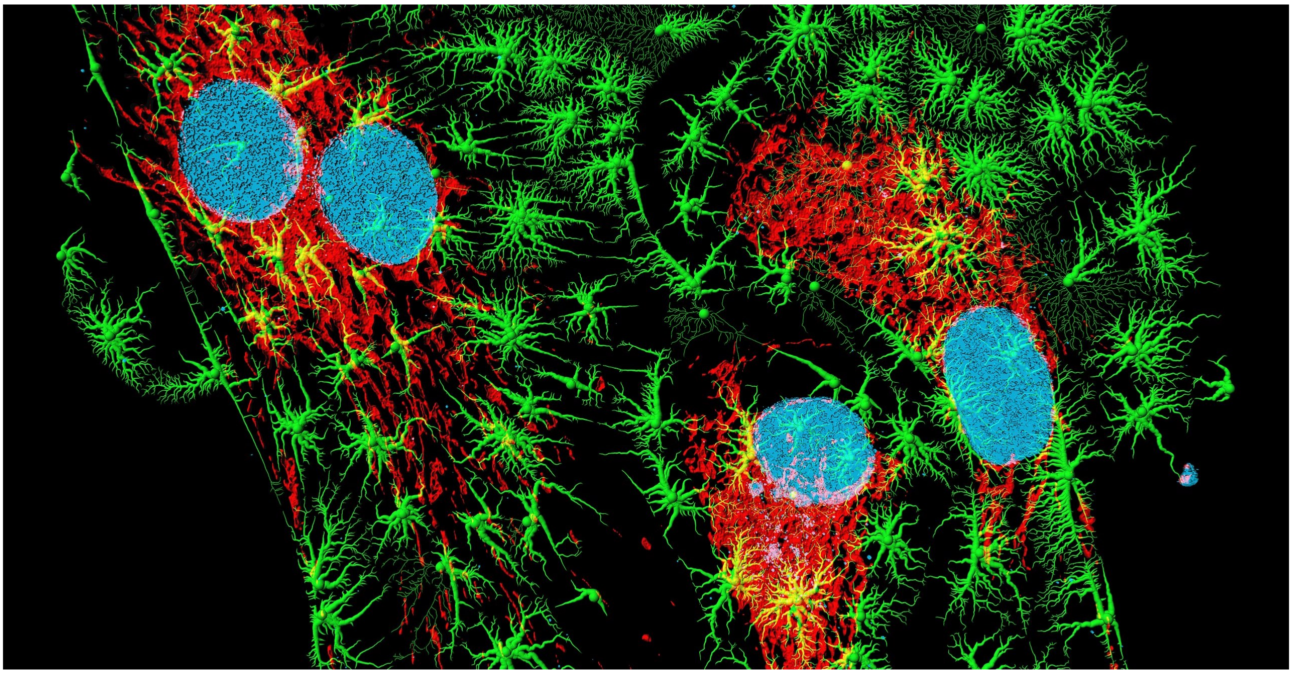

Figure 9: *Bovine pulmonary artery endothelial cells in culture. Blue: nuclei; red: mitochondria; green: microfilaments. Computer generated image from a 3D model based on a confocal laser scanning microscopy using fluorescent marker dyes. Source: Heiti Paves, https://commons.wikimedia.org/wiki/File:Fibroblastid.jpg.*

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Subsection Two

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References

[1] J. M. Smith and A. B. Jones. *Book Title*. 7th. Publisher, 2023.

[2] A. B. Jones and J. M. Smith. “Article Title”. In: *Journal title* 13.52 (Mar. 2024), pp. 123–456. DOI: `10.1038/s41586-021-03616-x`.