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Contents

A PROPOSAL FOR AN INSECT VISION INSPIRED CONTROL FOR AUTONOMOUS ROBOT BY AN OMNIDIRECTIONAL DEVICE

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Abstract

The paper presents a proposal for a navigation control system inspired by insect behaviour, in particular by the way social insects like ants, bees and wasps use visual information to navigate. The proposed system uses an omnidirectional perception subsystem, made by a conical reflecting surface, to simulate the insect's navigation in a corridor.

1. Introduction

Entomological studies about social insects have discovered some mechanism of visual navigation that can be useful in robotics [6] [7].

Experiments on bees have shown that navigating through a corridor they tend to fly along its center. To find the center of the corridor they cannot use stereo vision, they can only use a divergent vision system with separated lateral visual information. To obtain the exact position of the center during the flight, bees compare the two lateral optical flows, thus comparing the apparent velocity perceived by the left and right eye [8]. If the bee is in the center of the corridor, the two lateral apparent velocities are the same. If one side is closer, the apparent velocity perceived from this side is higher. From this information the bee knows that the flight direction has to turn towards the other side.

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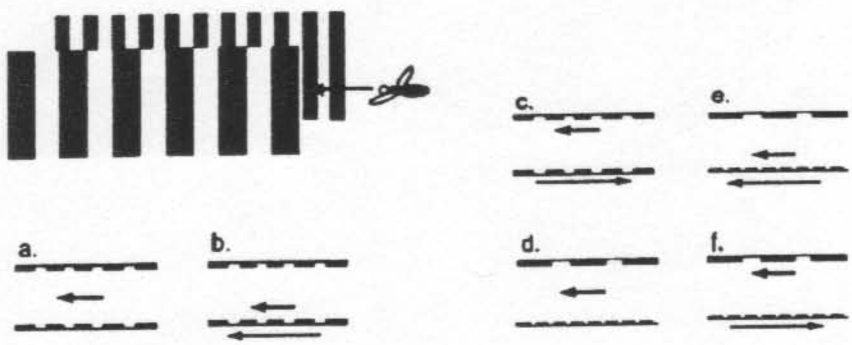

Figure 1 - Bee corridor flight experiments [8].

In the experiment shown in Figure 1, made by Srinivasan [8], the bee passes through a black and white striped corridor. Six different conditions have been tested (a-f) with different strips frequencies at the corridor sides and also with moving sides. The arrow in the centre of the corridor represents the bee flight; it can be in the centre (a, d) or near one side (b, c, e, f) of the corridor. The arrow outside the corridor represent the shift direction of the moving side: the side movement increases its apparent velocity changing the bee's flight direction. The analysis of the six experiments confirm the bee flight strategy above described. The centring mechanism is not affected by differences of the strip frequency (d), but is affected by their apparent velocity (b) regardless the moving pattern at each side (c, e, f).

2. The visual perception system

The aim of the proposed system is to drive an autonomous robot through the center of a path. It is a reactive navigation that does not need any a-priori knowledge of the environment.

The system is composed of the omnidirectional perception subsystem, the visual data preprocessing subsystem and the control subsystem. The perception subsystem is a CCD camera facing upwards (Figure 2), which records the image from a cone-shaped mirror. The mirror is placed at a known distance, coaxially to the camera lens. The resulting image is an omnidirectional view of a horizontal section of the environment around the robot.

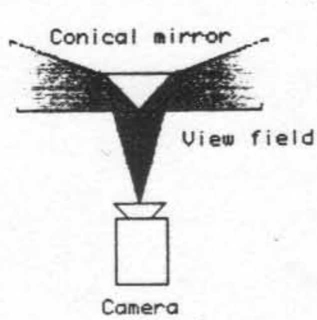

Figure 2 - The omnidirectional perception device.

The omnidirectional visual perception device has been derived from the Conic Omnidirectional Projection Image Sensor system (COPIS) [10] [11] and from the POLLICINO system [2] [3]. It produces color images of the surrounding environment with a typical circular structure like in Figure 3.

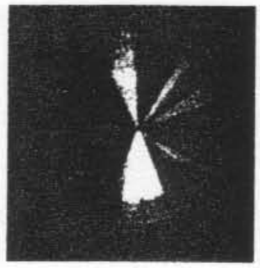

Figure 3 - A color image from the perception device.

3. The pre-processing

The pre-processing system divides the perceived image into the three RGB chromatic components and splits each chromatic channel image into 360 sectors of 1 degree. For each sector the mean chromatic value is extracted (Figure 4).

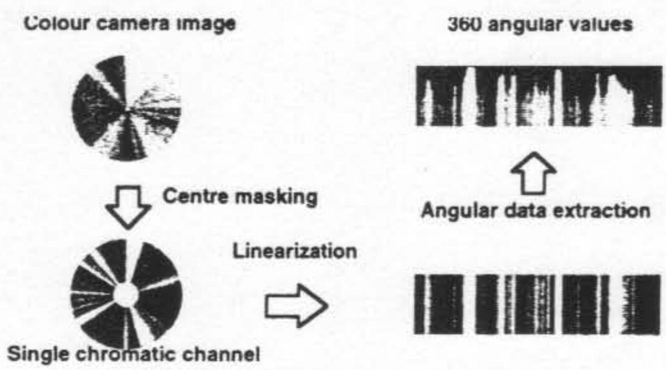

Figure 4 - The image pre-processing

Then the system divides the perceived information in two parts, extracting for each side only the useful data.

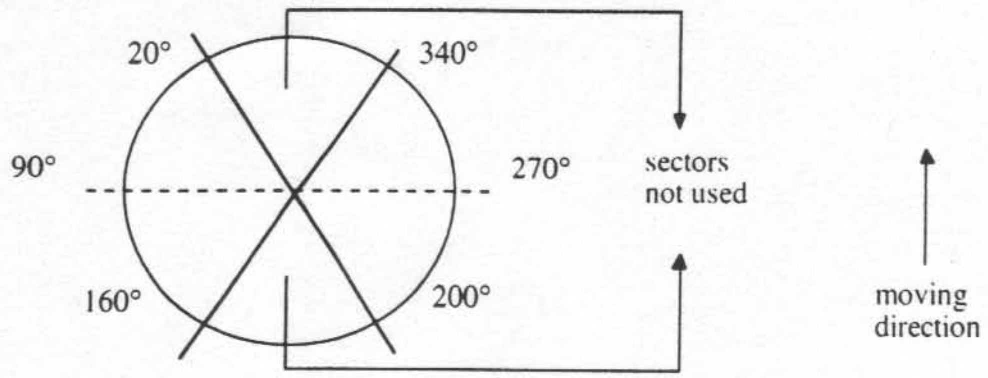

Figure 5 - Sectors involved in the control process

The system eliminates the front and the rear sectors to avoid errors due to parallax and robot skidding (Figure 5).
Then an estimate of the lateral optical flow between two time-sampled images is calculated in the following way:

$$\varphi_L(\tau) = \sum_k | x_n(k) - x_{n+1}(k+\tau) | \Big|_{k=20 \div 160-\tau,\ \tau=20 \div 90} \quad \text{. left side}$$

$$\varphi_R(\tau) = \sum_k | x_n(k) - x_{n+1}(k+\tau) | \Big|_{k=200 \div 340-\tau,\ \tau=200 \div 270} \quad \text{. right side}$$

$$\tau_L = \tau \mid \min [\varphi_L(\tau)]$$

$$\tau_R = \tau \mid \min [\varphi_R(\tau)]$$

Lateral movement estimation is computed as the lowest above defined correlation between two sequential acquired images $x(n)$ and $x(n+1)$.
The lateral movement difference is an approximation of the outcoming angle shifting.

$$\psi = \tau_L - \tau_R$$

The above formulas must be separately computed for each chromatic channel and the overall angle shifting is the average of the three results. This value is passed to a control system at regular time intervals in order to keep the robot navigation in the center of the corridor. The following control criteria can be applied to the system:

if (ψ==0) then "no change"

if (ψ <0) then "turn right"

otherwise "turn left"

The above control criteria is designed for a continuos corridor. In fact wide and sudden opening can force the robot to leave the corridor with quick turns towards the opening.

More complex navigations can be managed with an higher level control that allow the switching among different control systems.

The system described is being tested in different indoor environments.

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