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Insect inspired odometry by flow measurements using optical mouse chips

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Introduction

Inspired by research on the waterstrider visual system we investigated precision limits for the estimation of self motion parameters from optic flow [1]. The result was that ego motion parameters can be extracted from flow to a surprisingly high precision if flow can be observed in image patches of opposite visual angle distributed over a large solid angle. Under these conditions only a few properly combined flow observations are necessary.

Since optical mouse chips are available we have cheap (2.5 €), light (0.5 g) and fast (response < 1msec) flow detectors at our hands. Here we present a hardware realization of an odometer driven solely by flow measurements in a few directions in space.

The device

The device (Fig. 1) contains eight optical mouse sensors (ADNS-2620, Avago) each provided with an adjustable plastic collimator lens (CAY045 Philips) of $f = 4.6$ mm focal length which images the environment onto the light sensitive area of the sensor. The mouse sensors sample the light intensity on their 1x1 mm array of 18x18 light sensitive diodes about 1500 times/sec. The focal length of the lens and the size of the diode array determine the angular size of the visual field of the sensors ($12.4^\circ \times 12.4^\circ$). A fast on-chip digital signal processor (DSP) correlates the patterns of two consecutive samplings and evaluates the displacement between them. In order to avoid too large displacements between two images the maximum allowed speed of the pattern on the chip's light sensitive surface is specified to 30 cm/sec. This limits the maximum rotation speed of the sensors to $(300 \times 180 / \pi) / f$ [$^\circ/\text{sec}$] (i.e. 3737 [$^\circ/\text{sec}$]). When the viewing distance to ground is D [cm] the maximum translational speed is $(300/f) \times D = 65.22 D$ [cm/sec] (i.e. about 980 [cm/sec] for our odometer model ($D \approx 15$ cm)).

Via two serial lines to each sensor a microprocessor (MP) (CY7C68013A-56P, Cypress) reads information continuously from all sensors in parallel. The information consists of three bytes : dY, dX, SQ in that order. dY, dX are the pattern displacements along each sensor's Y/X axis since the last reading, SQ is a 'quality' byte which indicates the 'number of features' detected in the sensor image while correlating. If SQ undergoes a selectable threshold dY, dX may be discarded. The MP is connected via USB to a PC. Reading the information from all sensors (strictly in parallel), transferring them via an USB bulk transfer to the PC costs less than 2 msec.

The odometer

We consider first the simple case of the odometer on a robot moving on flat contrasted ground. Motion is restricted to two degrees of freedom : rotation about the high axis (yaw) and translation along the long axis (but also sideways translation can easily be included). For each small time interval motion can be decomposed into yaw and translation. The response of all sensors to yaw was calibrated by performing a well defined pure rotation about the yaw axis and reading all sensors' response. The same was done for a pure forwards (sideways) translation. The 'response patterns' for yaw and translation depend on the arrangement of the sensors and the properties of the environment. In our case eight sensors with horizontal X-axis and the optical axis (Z-axis) oriented at 45° azimuth with respect to each other look down at 45° onto a flat ground with an irregular contrasted pattern. If we monitor motion combined of any yaw with any translation it is easy to extract each component from the accompanied ensemble of sensor responses. We simply calculate a best fit of the actual response to a linear combination of yaw and translation unit sensor responses. Monitoring the SQ byte allows to exclude sensors with poor contrast from ego motion estimates.

A more general ego motion estimate (more degrees of freedom, uneven ground etc.) with a device with 16 sensors is currently under research.

We would like to bring a prototype with us and show a hardware demonstration of our odometer at the conference.

References

- [1] H.J Dahmen et al (2000) : Extracting Egomotion from Optic Flow : Limits of Accuracy and Neural Matched Filters, in J.M Zanker, J. Zeil (eds) Motion Vision, Springer

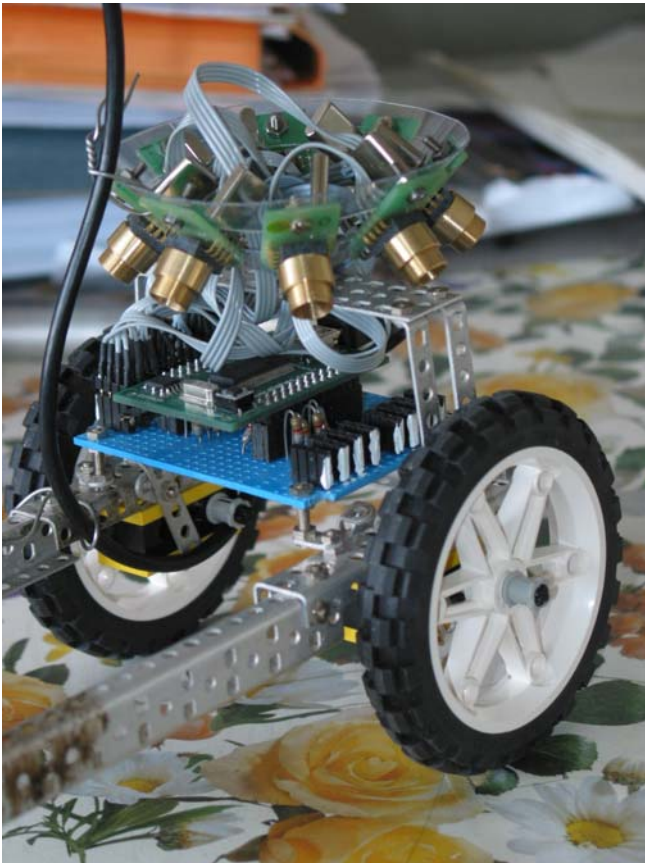


Fig 1

The odometer mounted on a two wheel chariot about 11cm above the contrasted flat ground.

Five of the eight sensors looking down to the floor can be seen.

Above the blue board there is the Cypress CY7C68013A-56P microprocessor installed.