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LULEÅ TURBO TURTLE (LTT)

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Abstract. The navigation system onboard our test vehicle, LTT, measures angles to vertical reflector tape stripes attached to walls etc. The reflector identity is determined for each angle and then the angle is used together with odometery to update the state variables describing the vehicle motion. The video will contain a test run showing the accuracy and speed of our system. A pen is mounted on the LTT so the actual track can be seen on the floor. The design speed of the LTT is 1 m/s and the estimated maximum position error is 10 mm at low speed.

INTRODUCTION

The field of autonomous vehicles has received increased research interest during this decade [1,2,3,4,5]. The most important ability for an autonomous vehicle is to navigate. It can be done with increasing difficulty in a known, partly known or unknown surrounding. Developing methods to navigate in an unknown surrounding is a rather expensive and difficult research topic, because you are forced to use vision and very powerful computers to get reasonable speed in your vehicle [6]. The only navigation system already on the market, known to the author, is of the kind with a known surrounding [7]. Our system uses a partly known surrounding because our beacons are all identical so the system has to solve an association problem.

Research on a new navigation system for autonomous vehicles started in 1984 at our university. The system uses a low power laser and a rotating mirror to create a horizontal 360 degree scan of the surrounding of the vehicle. Vertical stripes of retro-reflective tape glued to the walls of our lab serve as beacons. When the laser beam hits such a beacon enough energy is reflected back to the receiving optics of the navigation system to be detected by a sensitive photo-detector. The rotation angle of the mirror is recorded and used to update the position and heading of the vehicle.

Our first approach was static in the meaning that we assumed to have three angles available, measured from one position of the vehicle, to geometrically calculate position and heading of the vehicle. As the vehicle is continuously moving this is of course not true. The trick was to drive slow enough that we could approximate the three positions when the angles were measured to be the same. The vehicle was described and some of our results was reported in [8].

The next approach was to include a model of the vehicle motion and a position estimator which uses both measured angles and wheel motions as inputs. Important work was also done on the control algorithms [9,10,11,12].

We are now close to finishing our third generation of the Luleå Turbo Turtle. The performance goal we have put up is a safe driving speed of at least 1 m/s and a maximum position error of 10 mm at low speed. In the next two sections the new hardware and software will briefly be described. As the system is not completely integrated at the time of writing we only have some preliminary results to report. The video will show the hardware of LTT and some runs demonstrating its speed and accuracy.

HARDWARE

The most important part of the hardware is the anglemeter which measures the directional angles to the beacons in sight. The illuminating laser is of the same type as used in CD-players. Its wavelength and maximum power is 820 nm and 12.5 mW respectively. It has internal correcting optics to produce a well collimated beam with a diameter of 5 mm.

The optical path of the angle meter goes through the hollow axes of the rotating mirror. This gives the anglemeter a 360 degree field of view. The rotation angle of the mirror is measured with an incremental encoder which gives an error less than 1 mradian. The collecting optics is a diamond-turned parabolic mirror with an aperture of 22 mm. The photo-detector has a square active area with an edge length of 0.1 mm.

The current pulses coming from the photo-detector are converted to voltage pulses and amplified in a pre-amplifier close to the detector. Another amplifier further increases the gain and shapes the pulses to maximize the signal to noise ratio.

The anglemeter is controlled by a micro-controller which with the aid of some additional electronics measures both the angle to a beacon and the peak of the received pulse. The data is then transmitted over a high speed serial link to the main computer in LTT.

The main computer is built around the MC68020 chip with an attached MC68882 floating point coprocessor. The main computer communicates over a radio link with a base station implemented in a personal computer of the IBM PC/AT-type. Two, almost completely digital, servos control the steering angle and rotation speed of the front wheel of our tricycle vehicle.

SOFTWARE

To make the software development as easy as possible and to make a clean design of the data flow possible, a multiprocess approach was chosen. The software is split into different processes that each handles a specific task, i.e. storing maps, calculating positions etc. The main processes are:

Radio (communication)

Driver (control)

Map (storage)

Path (storage)

Position (calculation)

Anglemeter (communication)

During the design of the software special considerations has been taken to make it tolerant to hardware errors and to avoid deadlock.

The cycle of calculating set points to the servos is divided into the following steps.

A realtime clock tells the Driver to start the calculations.

The Driver asks the Position process to give the current position and heading of the vehicle.

The Position process asks the Anglemeter process for the latest data from the anglemeter.

When Position has made its calculations it returns the position and heading values to Driver which calculates new set points and writes them to the servos.

These steps are repeated every cycle. The storage and communication processes are running asyncronously and can receive messages and act according to them during the calculation of new set points.

This approach has proven to be very flexible and fail-safe. The software was written in Modula-2, some device drivers in assembly language. To handle the processes and the communication between them a realtime kernel developed at our department was used.

PRELIMINARY RESULTS

As mentioned above we are in the middle of the integration of the various parts of LTT so no final results are available now. The parts have been tested separately and seem to function properly. Some of the bugs which have appeared after integration have been found, some have not.

The anglemeter performance looks very promising. The design goal was to be able to detect a beacon 10 mm wide at 10 m distance with a rotation speed of the mirror of at least 5 revolution/s. The first tests shows that the anglemeter can detect a beacon 5 mm wide at 30 m distance and at 20 revolution/s. Probably this can be improved further because the response of the pre-amplifier in the anglemeter is non-linear and the shift of the quiescent point due to stray-light from the laser was larger than expected. This changed the transient response rather much from the calculated. Work will continue on this subject.

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