CAMERA-BASED LOCAL POSITIONING SYSTEM FOR MINIWORLD: A FLEET OF 25 SMALL AGV'S

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SUMMARY

A fleet of scaled-down Automatic Guided Vehicles (AGV's) is supervised and tracked as to position, heading and trajectory by a camera-based Local Positioning System® (LPS). LPS consists of one or more xyCatchers which together view the scene, where each xyCatcher® is a high-definition camera assembled with an embedded real-time image processor. This application is discussed after introducing some control characteristics of the AGV's. The MiniWorld system composed of AGV's and the LPS supervisor constitutes a captivating and mediagenic method of visualizing complex multi-actor simulations as a real-time tool for logistics development: actual rolling stock reveals more than display screens.

1. INTRODUCTION

The MiniWorld laboratory at the section Logistic Engineering/Transport Technology of the Faculty of Design, Construction, and Production of the Delft University of Technology, is a research facility in real-time logistics and technical automation. The core tool for running MiniWorld is a software framework called AgileFrames (Lindeijer 2000, Evers et al. 2000).
In MiniWorld, the physical simulation of the emulated logistic system consists of a fleet of 25 semi-autonomous intelligent AGV’s governed by overall traffic-control systems. On-board AGV controls as reviewed below run under embedded Linux on an AMD5x86 processor. Mechatronics is interfaced by a PLD (Programmable Logic Device). Each AGV as a node is linked by a Wireless-LAN (PCcard) to the traffic controller. Fig. 1 shows the assembled processing stack in the industry standard PC104 format. This paper emphasises the supervisory camera-based Local Positioning System, where fig. 1 already shows the high-contrast retroreflective optical targets, as well as one active marker. The active marker, a cluster of green LEDs, can be switched on for a brief initial identification, on wirelessLAN command from the supervisory tracking software part of LPS.

2. AGV’S: LOCAL AND REMOTE CONTROL

Under supervision of the traffic-controller (Evers et al. 2000), each vehicle finds its way through the scene autonomously, respecting the rules imposed by the scene’s design. Collisions are currently avoided through the use of guarded sections, which should not be entered by a vehicle until it receives clearance from the supervisor. As an expansion to these guarded sections, it is possible to allow multiple vehicles in a section by creating a virtual train, each vehicle driving at the same speed as the first, only centimetres apart. The vehicles do not have any proximity sensors to observe the presence of other vehicles or obstructions, but rely strictly on the traffic controller’s clearance to prevent collisions. In order to stay on its trajectory, each vehicle has to know its position and heading. Internally, the number of wheel-revolutions is counted by fractional odometry, and combined with the steering angles the vehicle’s onboard controller can compute its (incremental) position and heading. The steering angle is not measured, but -with the neglection of hysteresis- this is assumed to have a direct relation to the entered servo-setting of the 2 bogies.

Although the differences between the actual track and internally calculated track are not very big, they do accumulate over time, making it necessary to recalibrate or update the internal position regularly. Also, since each vehicle computes its position by adding a displacement to the previous position, the initial position and heading need to be obtained in another way.

3. LOCAL POSITIONING SYSTEM

For these two reasons, it was proposed and decided to apply an external supervisor and monitoring system, designated as the Local Positioning System® (LPS), with the added
requirement that it should be easily transportable and installable, to facilitate the deployment of MiniWorld at different locations for demonstration and on-site experimental validations.

This is where the LPS® composed of one or more xyCatcher® units usefully enters the stage of MiniWorld, as a contribution from the Faculty of Applied Physics (Delft University of Technology) to the inter-faculty cooperative DIOC/TRAIL project “Freight Transport Automation and Multimodality”.

The xyCatcher®, in a line of development from (Furnée 1967) through (Furnée et al. 1997), is based on optical detection of markers in an image, and is not designed to directly detect the object(s), the vehicle(s) in this application. Rather, a number of disc-shaped or spherical, retro-reflective passive targets or markers are attached on top of each vehicle, from which the vehicle's position and heading can be calculated, identified and tracked by additional software as reviewed below.

Each camera unit is equipped with an embedded image processor, which provides Ethernet output of the (x,y) coordinates of the markers. In real-time, the high-resolution marker coordinates are calculated as the individual geometric or intensity-weighted marker centroid. Marker data thus obtained feature a sub-pixel resolution of better than 1:20 of pixel dimensions.

The vehicles in MiniWorld only need the external LPS for calibrating their internal sensors, at most 5 times per second. As such there is no need for high-speed cameras, and the 15Hz Adimec MX12P with a sensor resolution of 1024 by 1024 pixels is used. With reference to the above: on a 5x5 m scene surface the xyCatcher/LPS system detects AGV displacements well below 0.2 mm.

The camera unit is equipped with a visible-light illuminator and matching color filter, the illuminator/flasher uses 100 powerful green LEDs, the flasher is synchronized to the electronic shutter of the camera to maximize the target contrast and ambient light suppression.

Based on the marker coordinates acquired on Ethernet, and the specific layout of the markers as shown in fig. 1, the software package for localising, identifying and tracking all individual AGV’s in real-time is an integral part of LPS as contributed and reported by Van Baarlen (2001).

The initial calibration of the camera parameters, both internal as an imager and external with reference to a 3D laboratory coordinate system, is a necessary but straightforward process using the Windows-rewrite (Van Baarlen, op.cit.) of pre-existing software. This allows the 2D reconstruction of a large viewing area as observed by multiple cameras with a limited overlap.
4. RESULTS

The current demo-scene within the available floor space (a crossing with two parallel, bi-directional lanes) allows only limited car-movements as depicted in fig. 2. The limited recording time of the trajectories run by these two vehicles accounts for the fact that for instance the track from (2000,-1100) to (-1400,200) is traversed by AGV13 only. The slight perturbations around the ideal tracks are ascribed to network delays between the tracking supervisor of LPS and the traffic controller of MiniWorld while, at the time of this intermediate test, the AGV’s had access only to a sub-optimal LINUX clock. Moreover, the AGV’s were not yet (as mentioned in the preceding section) equipped with the individual odometry for the fine-tuning of semi-autonomous motion between LPS updates. Standstill tests revealed the sub-mm resolution in terms of just-noticeable displacements.

![Tracks of AGV 12 and AGV13 during 4 minutes at MiniWorld Delft](image)

The much bigger scene of a container-terminal (shown below) with 6 ship-side cranes each with 4 AGV-parkings, and 12 shore-side stacking lanes, again each with 4 loading sites, will in an extended laboratory area allow the testing and visualisation of more advanced features.
4. CONCLUSION AND DISCUSSION

Implementing a camera-based Local Positioning System® (LPS) has established its potential as an essential remote supervisor of multiple semi-autonomous AGV’s, scaled-down within the concept of a large indoor MiniWorld laboratory.

With minimal changes in the AgileFrames concepts of individual and fleet control, the extension of the supervisory and localisation task in the real big world would indeed assume our LPS® substituted by the general free-field modalities offered by GPS, the satellite-based Global Positioning System.

In the real world, notably the public domain with a mix of non-systemrelated actors, the semi-autonomous vehicles could additional to GPS incorporate obstacle detection and ranging.

REFERENCES


