Autonomous System for Agricultural Task Automation

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ABSTRACT

Present work deals with the automation of a low cost commercial lawnmower to perform unmanned precision agriculture tasks such are the spraying of pesticides. To this aim the vehicle has been endowed with a set of additional subsystems and sensors to perform remote motion control and to obtain relative and absolute location in the field. The equipment integrated is composed of pneumatic cylinders, potentiometer and odometer sensors and a GPS receiver. The robot remote control and navigation system, have been tested in a close road circuit at the IAI-CSIC. Some results are displayed to show the precise lawnmower positioning in this well-known environment.

INTRODUCTION

Mobile Robotics is a field in great development, wherein mobile robots where initially constructed as automated guided vehicles (AGVs), but more and more this shift to self guided vehicles (SGVs) to be used in partially structured environments either for indoor or outdoor applications (Warren et al., 1999), (Cordesses et al., 1999). Elementary motion control, obstacle avoidance, pattern recognition and autonomous navigation are the key functions required for safe, reliable and accurate operation of a mobile agent.

In those applications where remote control of the robot is envisaged, the human operator has to design a high level control architecture able to control usual and unexpected inner and outer events so that the robot displays an intelligent behaviour in the assigned navigation tasks.

Robots have been employed in the indoors industrial domain in multiple applications as are high speed spot welding or load/unload of parcels. They now begin to be a reality in more complex and unstructured domains as are service in hospitals, cleaning or grass cutting in parks, spraying in agriculture, undersea inspection and maintenance, excavation in open-cut and underground mining, etc. (Stentz et al., 2000), (Rye et al., 2001).

Present work deals with the design of a physical system and an intelligent Agents architecture AMARA (García-Alegre et al., 1998) for a mobile robot that has to perform tasks in a partially known outdoor environment to deal with those tedious or hazardous tasks, which actually are accomplished by human beings.

THE ADVANCE MOTION: AN ELECTROPNEUMATIC FUZZY CONTROLLER

The automation of the steering and the speed is a challenge that will permit the increase of productivity in many agricultural tasks. Guidance of an agricultural vehicle requires driver attention becoming a tedious and tiring job especially in large field activities (Stoll et al., 1999). The vehicle used in present research, is a commercial low cost lawnmower devoted to investigate unmanned autonomous navigation strategies in outdoor environments. Its initial manual actuation system for steering and driving has been changed by an automatic one based upon two electropneumatic systems controlled by an onboard computer (Figure 1a). Each actuation system is composed of an

electrovalve, a pneumatic cylinder, and an actuator shaft coupled with the piston. The piston location determines the vehicle steering angle and the advance/stop drive, being measured by means of two potentiometric sensors. The difficulty to obtain an analytic model of the actuation system suggested the utilisation of a qualitative approach based upon the expert knowledge in the global actuation subsystem.

A Proportional-Derivative fuzzy controller for the robot steering is proposed. Inputs are current and former error of the piston location as measured by the pontentiometric sensor (García-Pérez et al., 2000). The time response of the piston in a complete cylinder run of 200mm, is about two hundred milliseconds.

To accomplish the elementary motions needed in any navigation task, two Agents have been generated, each one related to one of the two cylinders: 1) the ADVANCE Fuzzy Agent and 2) the START-STOP on/off Agent.
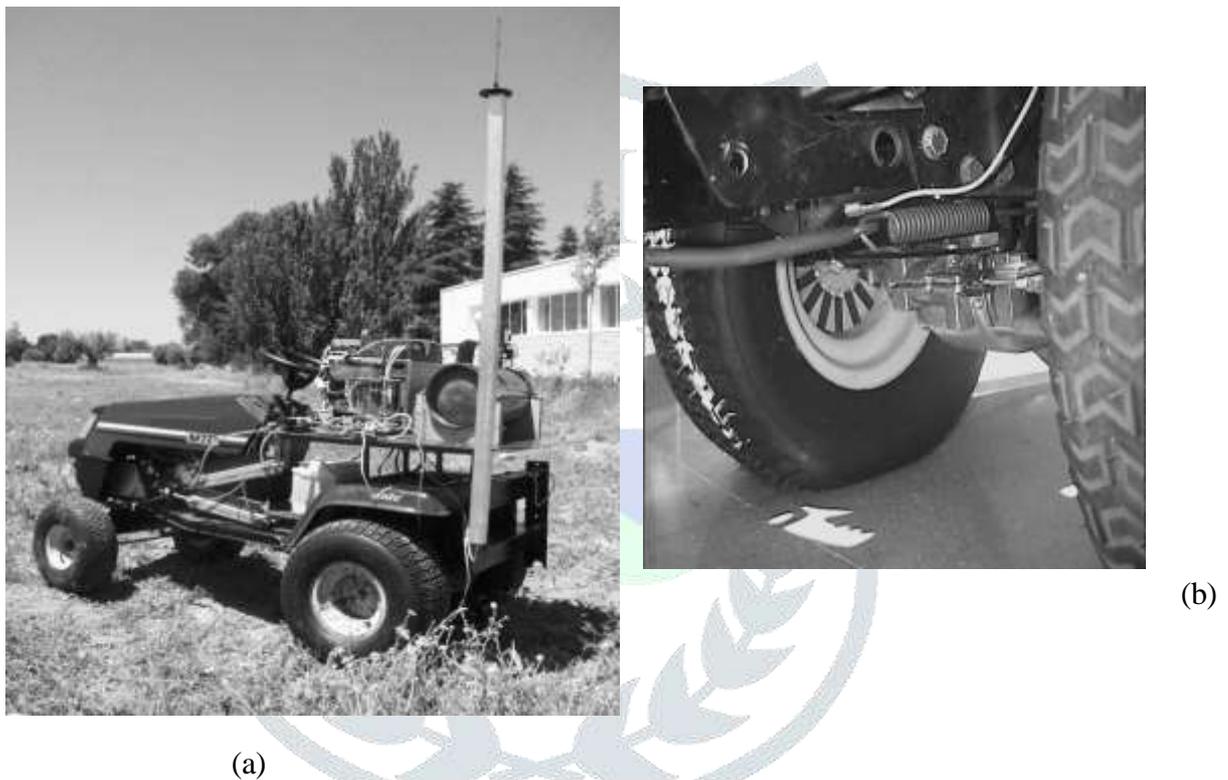

(a)

(b)

FIGURE 1. (a) Robot ROJO at the IAI-CSIC environment, (b) odometer magnetic strips installed in the inner face of the left front wheel

LOCAL AND GLOBAL POSITIONING: ODOMETERS AND GPS SENSORS

For the continous location of ROJO lawnmower two redundant sensors have been installed onboard: a GPS receiver and an odometric system.

The GPS system allows an absolute positioning of the vehicle in the field. But, GPS failures in the reception of the signals, even for high price dual_frequency survey grade GPS (Real Time Kinematic) receivers, lead us to the integration of an internal odometric system (Figure 1b). Failures are mainly due to obstacles, trees or buildings, or to electrical and meteorological disturbances.

Th GPS receiver is a DGPS submetric precision model receiving differential corrections through the Omnistar system. Omnistar employs a geostationary satellite to transmit the differential corrections, thus reducing multipath reflections. This system is extremely useful in mobile applications, since the differential correction decoder is placed onboard the robot, eliminating the need of a radio-link system. The DGPS provides the NMEA message that contains, among others, the global position of the vehicle and its Noth relative orientation.

The odometric system is composed of a magnetic Hall effect sensor that detects the variation of the magnetic field generated by 32 magnetic strips installed in the inner face of the front wheels (Figure 2). These sensors continuously deliver the position of the vehicle relative to its initial location, complementing the GPS "blindness" periods. They give an approximate location of the vehicle in the field that can be in turn conveniently corrected by different methods. Combination of odometric and DGPS signals provide the redundancy and complementarity required, as they obtain the instantaneous vehicle position by different methods at distinct frequencies. Dead reckoning operates

at 10 to100 Hz and GPS provides a new position at 5Hz.

To provide the best 2D-position estimation, a fusion algorithm has been proposed and proved (Pozo-Ruz et al., 2001), wherein the best position estimation is calculated as the maximum value of the join probability function obtained from both position estimation of the onboard sensors (Pozo-Ruz et al.,2001), Equation **(1)**

$$\hat{Loc}_f(t) = \tilde{Loc}_{og}(t) + G(t)\,(\hat{Loc}_{GPS}(t) - \tilde{Loc}_{og}(t)) \quad \textbf{(1)}$$

$\hat{Loc}_f(t)$ Is the best position estimation obtained by the fusion algorithm. The term $G(t)$ in the expression **(1)** is very important, as it ponders the difference between the best position estimation obtained by both odometry and GPS, as well as the presence of noise in the GPS estimation

NAVIGATION: REMOTE CONTROL AND PATH PLANNING

A software environment has been designed to remotely control the lawnmower navigation, keeping a visual track of the performed trajectory according to the goals of the task to be accomplished: spraying, image acquisition, watering, fertilising or soil sampling. The path planned in a remote node as a sequence of intermediate position to be reached, is sent to the vehicle and executed onboard (García-Alegre et al., 1993). The performed run can be visualised at the remote node and the performance evaluated by a set of heuristics that measure the success in reaching the set of intermediate positions

that compose the full trajectory (Figure 2). Communication between the robot and the remote user nodes is performed via Radio-Ethernet through the aerial IAI intra-net.
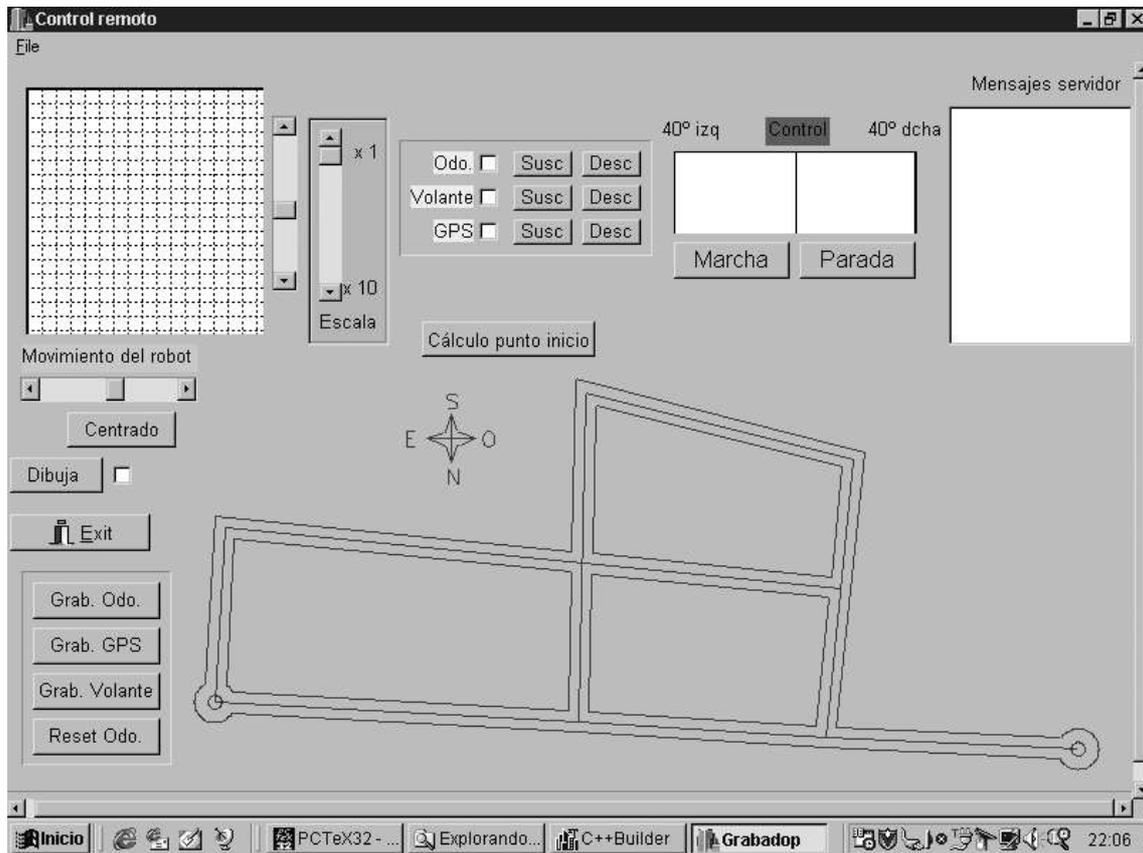
FIGURE 2. Client GOTOPOINT window.

An Agent, GOTOPOINT has been developed based upon former ADVANCE and START/STOP Agents. Any navigation strategy can be performed based upon this module, by sending a sequence of consecutive positions.

A map of the working area is initially recorded and a visibility graph is derived to plan paths with minimum number of turns, from any initial to final position.

From the lawnmower initial position, the robot first approaches the central path-lane. Then, the robot drives to the closest planned node in the advance direction within a loop that ends when at final destination. Once the final position is reached with an error of about one-meter the STOP Agent is activated. At this moment, the lawnmower waits for a command to proceed with a new target.

To reach a location the ADVANCE Agent is activated, the START/STOP Agent is activated only to start or to end navigation from any current position. The best location obtained by means of the fusion algorithm, Equation **(1)**, every two seconds is used to drive the robot to the next intermediate or final location, by the activation and execution of the ADVANCE Agent.

RESULTS

Some results are presented to show the performance of the proposed sensor fusion technique. Odometry provides relative position, with respect to an initial location, and DGPS provides an absolute position. Thus, to fuse both position estimations it is necessary to initially determine the correspondence between odometric and DGPS positions (Pozo-Ruz et al., 2001). The robot locations given up by the odometers, DGPS, and position fusion algorithm, are shown in Figure 3 (a). The vehicle speed being 0.4m/s.

Due to accumulative errors in positioning, the odometers can not be used for long distance runs. This is way, the proposed algorithm continously updates the position obtained by the odometry with the one provided by the DGPS (Figure 4 a, 4 b).
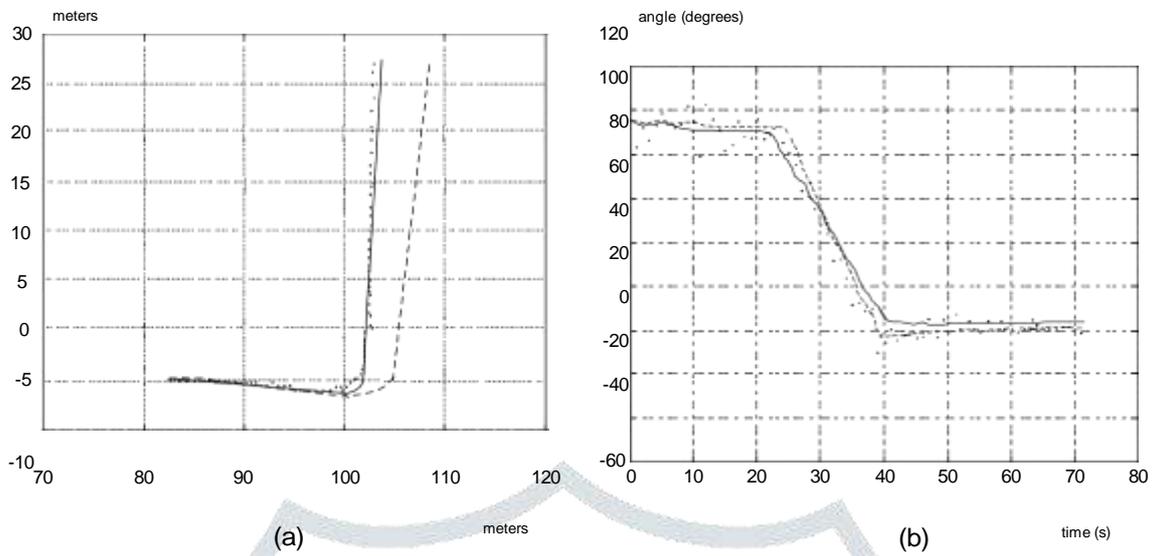
FIGURE 3. (a) Robot 2D-positions: Odometer (dashed line), DGPS (doted line) and fusion algorithm (continuous line), (b) Robot North relative orientation
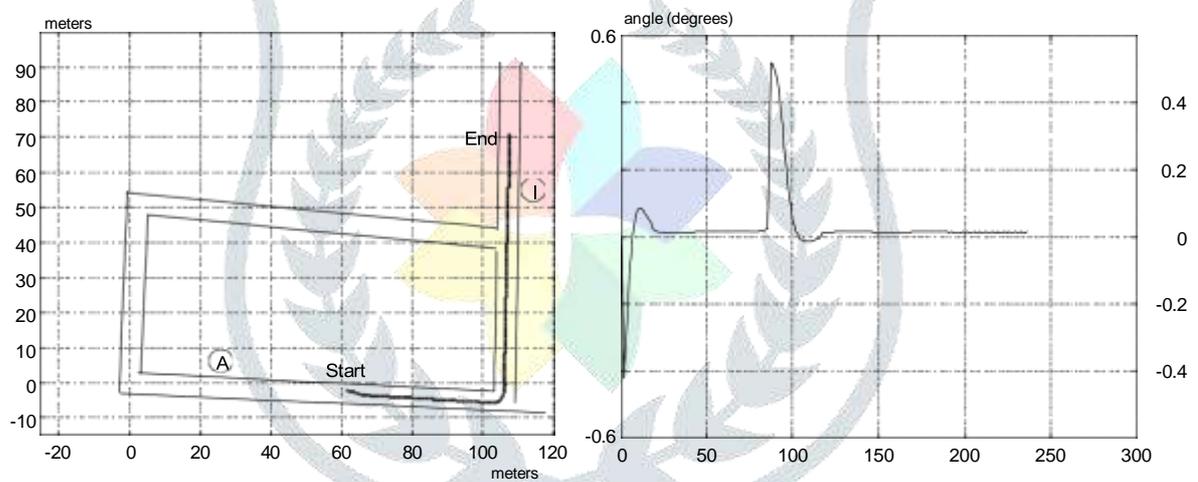

FIGURE 4. (a) Robot trajectory, (b) Wheels direction changes

CONCLUSIONS

The lawnmower automation has been achieved with a low cost, moderate power and moderate precision electropneumatic actuation system. Gasoline is the only source of energy, since the pressurised air reservoir is filled with an air pump powered by the vehicle motor. The fuzzy controller offers a smooth steering behaviour all over the range of the state space.

The proposed data fusion algorithm offers a continuous positioning. This point is one of the major issues of current work, as DGPS based location can not warranty continuity in real time location. By integrating an internal positioning system that updates its value at each DGPS reading through the fusion algorithm, it is possible to rely in the odometers position estimations whenever DGPS signals are absent. This lack of signals occurs independently of the cost of the DGPS system.

The proposed architecture, based upon the MultiAgent AMARA model already proved in office environment, offers a dynamic framework to ease develop new navigation strategies, through the combination of former elementary Agents ADVANCE, START/STOP and GOTOPOINT.

For the remote operation, it has been initially assumed that no humans would be present in the immediate vicinity of the robot in wide areas. However, to accomplish the requirements of safe navigation a laser sensor is now being integrated in ROJO lawnmower.

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