AN INTEGRATED CONTROL SYSTEM FOR AN AUTOMATIC GUIDED VEHICLE (AGV)

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ABSTRACT

An immense amount of research is currently, being done on the development and use of Automatic Guided Vehicles (AGVs) in industry. An important component of this research often involves navigation and route-optimization of such AGVs. In this paper the design and control of an AGV, using a stationary control system and a GPS-like navigational system, is discussed. Substantial provision has also been made for the display of operational characteristics of the AGV on the stationary control unit.

Key words: Automatic guided vehicles, navigational system, route-optimisation.

1. INTRODUCTION

Automatic guided vehicles (AGVs) play an increasingly important role in the transport and management of material in industrial plants and such a system may be used to autonomously transfer components from one location and deliver it at the next [1]. The paper describes the development and assessment of an experimental AGV system. It is anticipated that this system will be upgradeable for use in a pseudo-industrial environment.

Section two of the paper describes the basic mechanical characteristics of the vehicle whilst sections three and four are descriptions of the control software and communication system that determine the operational characteristics of the vehicle. Section five contains a description of a system that identifies the position of the vehicle at any point in time. Section six and seven respectively includes results obtained thus far and anticipated future work to be done in this connection is described in section seven. The paper is concluded with a brief summary of the project.

2. AUTOMATIC GUIDED VEHICLE BASE

The AGV is a four-wheel drive, electrically powered vehicle, specially adapted to accommodate the control electronics on one level with a loading area in the form of a flat area directly above it.

A DC motor for forward and backward movement, with a servomotor for steering purposes, powers the vehicle. It is provided with a radio link for communication with a base station (the AGV Controller of the Drive Control System in figure 1). The receiver unit is the control unit of the car and transfers received commands to the traction motor and servomotor respectively.

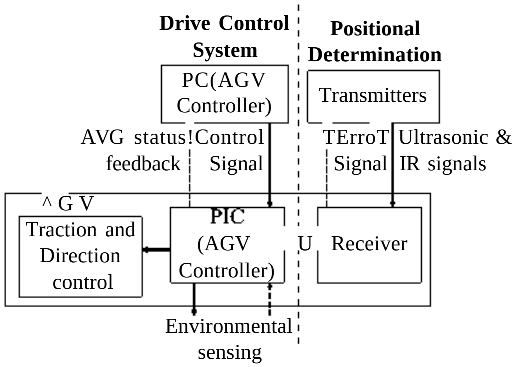

Figure 1: Block diagram of AGV system.

The DC traction motor is powered by means of an H-bridge circuit as shown in figure 2. The H-bridge circuit makes it possible to run the dc motor in both directions with only one power supply [2]. Pulse Width Modulation (PWM) controls the output voltage, and thus the speed of the vehicle.

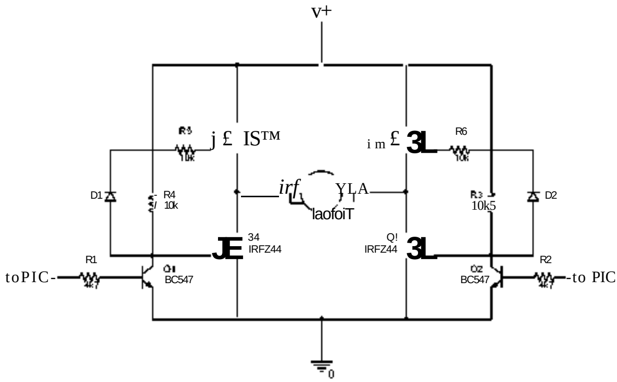

Figure 2: H-bridge traction control circuit.

Since communication between the control unit and the vehicle happens via a single serial data feed, it required an on-board controller to coordinate all the inputs and to supply appropriate control signals to the motors.

A microcontroller from Microchip (PIC18F242) is used to control the motors and steering of the AGV. To have enough PWM-control more than one PIC was needed. A master microcontroller with two slaves was used in this case. The communication between the different microcontrollers was done using an I^2C bus, as illustrated in Figure 3. The system worked very well and can be expanded as the project continues since one master can accommodate 256 slaves.

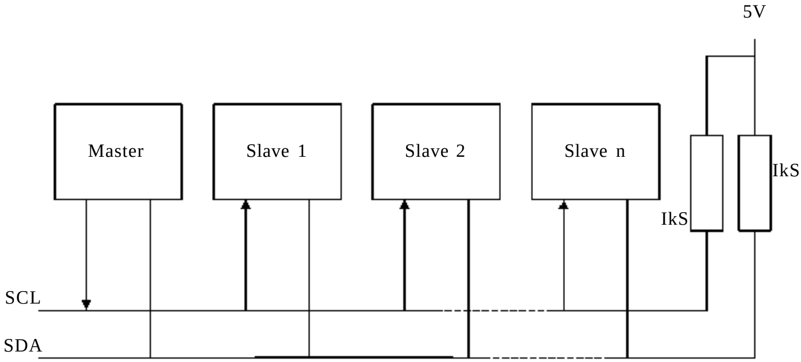

Figure 3: I^2C network

Initially the high transient current of the traction motor caused the PIC to reset on start-up thereof. Thus, it was necessary to use two separate sets of batteries; one to power the motor and H-bridge circuit and the other to power the control unit and the servo motor.

As has been stated, a servomotor, with built-in control circuitry, is used to direct the AGV. The angular position of the shaft of the servo is controlled by sending an appropriate control signal to the servo motor. The servomotor draws power proportional to the mechanical load exerted on it.

3. CONTROL SOFTWARE

A stationary PC, identified as the AGV Controller in Figure 1, controls the AGV. Commands are transferred from this unit to the AGV via a radio link, with feedback from the AGV provided in the same manner.

The control software provides for the programming of a sequence of actions to be taken by the AGV. Typically, this includes instructions in terms of:

- a sequence of directions to be followed for specified distances,
- at specified rates of acceleration,
- the speed to be maintained in each direction,
- changes in direction, and
- rates of deceleration.

The system makes provision for feedback regarding the motional functioning of the vehicle. In particular, feedback is provided in terms of the instantaneous speed of the vehicle, distances covered, corners taken and the actual acceleration and deceleration that took place. Consequently, it is possible to compare the actual functioning of the vehicle with the preferred, programmed values. A LabView interface (Figure 4) is used as the human interface for the project; all the measurements are displayed on the screen of the basestation PC.

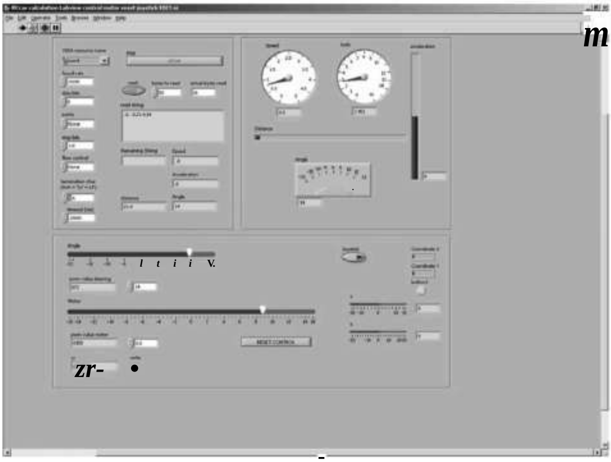

Figure 4: Labview interface.

Alternatively, it is possible to control the vehicle by means of a joystick. A joystick is interfaced to the control PC via the control software and the operation of the vehicle depends on the instantaneous position of the joystick.

4. NAVIGATION

4.1 Determination of position

In the study, a navigation system was developed such as to comply with the following specifications:

- The system had to be able to work indoors,
- The roof height would be known and would be approximately three meters,
- A positioning system with GPS characteristics was to be used.

A receiver, receiving signals from a number of transmitters mounted at regular intervals on the ceiling, was mounted on the AGV. The AGV scans continuously for signals from the different transmitters.

Ultrasonic and infrared (IR) pulses are sent simultaneously from a specific transmitter. The transmitters send similar signals in a fixed sequence. The infrared light beam travels at the speed of light whereas the ultrasonic signal travels at the much slower speed of sound. The distance from the particular transmitter is calculated by using the time difference between the received IR and ultrasonic signals.

Since the transmitters are placed at predetermined locations, it is possible to calculate the distance of the AGV from each of the different transmitters or landmarks. The relative distances from at least three transmitters are calculated and, through a process of triangulation, taking into account the height of the transmitters, the position of the AGV is determined.

If signals from less than three transmitters are received, it indicates that the AGV has traveled out of its maximum range. The AGV should recognize the problem and return to its last known position within the area of reception.

Thus, the AGVs navigational system functions on a similar principle to that of a GPS system, but indoors. This is similar to a principle described by Baumann [3].

4.2 Obstacle Avoidance

In addition to position determination capabilities, the AGV has been provided with substantial obstacle-avoidance ability.

Sharp GP2D12 Infrared sensors are used for determining the distance of the AGV from an obstruction. A schematic representation of the sensor is shown in figure 5 [4]. Power and ground are supplied to the sensor, and an output voltage *(Vout),* proportional to the distance from an obstruction, is provided as an output. The sensor is connected to the control microprocessor through an analogue-to-digital converter (ADC).

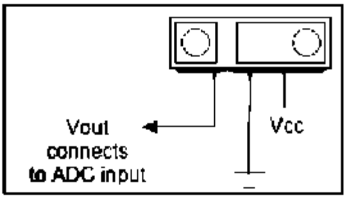

Figure 5: GP2D12 Infrared sensor

This range finder is one of the most commonly used in robotic applications since it is low in cost, compact and lightweight. The functioning of the GP2D12 is based on the triangulation principle with an IR LED for transmission and a Position Sensing Device (PSD) for the receiver [5]. It can measure distances between 10 and 80 cm.

The following characteristics of figure 6 should be considered [4]:

- The sensor output is logarithmic between 10 and 80 cm;
- Any distance closer than 10 cm might cause confusion and the sensor might erroneously signal that it is farther from an object than it really is. The easiest way to avoid this is to mount the sensors in such a way that the first 10 cm falls on the length or width of the AGV where there will be no object to recognise. This is illustrated in Figure 7 [6].

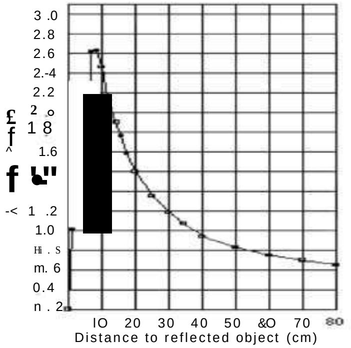

Figure 6: Sharp GP2D12 output characteristics

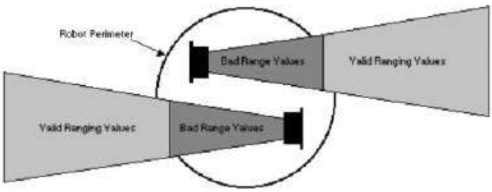

Figure 7: Example of cross-firing sensors to avoid range errors.

4.3 Monitoring of AGV Motion

Hall-effect sensors are used to measure the AGVs speed and the distance it has travelled. Ten little magnets are mounted on the inside rim of the wheel for the determination of the speed of the vehicle. The number of rotations of the wheel can also be determined - and thus the total distance travelled.

To measure the angle of the front wheels, a rotational precision potentiometer has been mounted on the steering mechanism. The potentiometer's output is an analogue voltage between 2.4 and 2.8 V from fully left-turned to fully right-turned. A PIC18F242 microcontroller, set up as the master, and two more PIC18F242 microcontrollers, set up as the slaves, are used to collect the motional data as described.

5. COMMUNICATION WITH AGV

Communication between the Base Station PC and the AGV takes place via a Bluetooth communication link. This channel is used for the transmission of control signals from the Base Station PC to the AGV Controller fitted on the AGV.

Similarly, the acquired actual motional data is sent to the Base Station PC from the AGV via a Bluetooth communication link. Last mentioned is shown as the AGV Status Feedback signal in Figure 1. This data is processed using

LabVIEW and displayed on the control computer. In addition, provision is made for the manual control of the AGV by means of a joystick - as mentioned above. These control signals are also conveyed via the Bluetooth communication system to the AGV.

Bluetooth is a wireless technology intended for short range wireless radio links. The primary features of Bluetooth can be summarized as:

- Voice and data capabilities
- Robustness
- Low complexity
- Low power consumption
- Low cost

Bluetooth operates in the range of 2.4 to 2.48 GHz. The advantage is that these frequencies are the same worldwide and any Bluetooth device can connect to any other Bluetooth device within range. Each Bluetooth device can communicate with up to seven other devices [7]. The fact that Bluetooth has low power consumption is unfortunately limiting its range. The only way to ensure low power consumption is to transmit weak signals, typically in the range of 1 mW. Although this level of signal is very weak it can still transmit through walls.

In this project, the following Bluetooth modules were used - as shown in figure 8:

- HPS-120Handywave Version 2
- MSI 6970 Bluetooth dongle

Figure 8: Bluetooth modules.

The HPS-120 is equipped with an antenna, resulting in an increase in ma-imum operational distance. T he HPS-120 is fi-ed to the AGV and communicates with the AGV via RS232 (USART) to give commands and provide feedback to the PC. The dongle is placed in the USB port of the PC. Distances of up to 30 m where obtained during practical testing in this study.

6. PRELIMINARY RESULTS

The unit as described was found to function according to expectations. Accurate control was maintained over the traction motors, whilst the system devised to monitor the instantaneous turning angle of the front wheels functioned satisfactory. However, a bigger swing in output voltage between the maximum left turn and maximum right turn conditions would have been preferable. The speed sensing was very satisfactory whilst acceleration and deceleration were determined mathematically from the rate of change in speed.

Even though the serial Bluetooth communication system is quite slow, it met the required data transfer rate of the AGV, both for control and feedback purposes.

7. FUTURE WORK

It was decided to use an adapted electric wheelchair chassis as an AGV in future. This system is powered by two direct current motors - which necessitate a substantial redesign of the control system. However, it would create a system with a much bigger maximum payload. In addition a two wheel driven system, with two free-running, trailing wheels will be much more maneuverable, requiring a less complicated navigational model.

Since there are a relatively large number of operational and environmental parameters on and around the AGV to monitor, a Controller Area Network (CAN-bus) system might eventually be utilized.

Similarly, the AGV might be optimized in the following ways:

- Object (obstacle) recognition and determination of the speed of the object by using a more elaborate system of sensors,
- Alternatively, an omni-directional camera can be added for object recognition and -avoidance.

8. SUMMARY

The paper describes an AGV developed for utilization in an industrial environment for material-handling applications. A stationary control unit, communicating via a Bluetooth communication link with the AGV, is used to program the movement of the vehicle. Similarly, feedback regarding the status of the AGV and its movements is provided to the base station.

The system uses a GPS-like positioning configuration with ceiling-mounted ultrasonic- and infrared transmitters. It was found that this system is particularly accurate within a predetermined area of operation of the AGV. An accuracy of approximately three centimeter was measured repeatedly. However, slight variations in accuracy were noted with differences in ambient temperatures and humidity.

As an alternative to programmed control of the AGV, it can be guided by means of a joystick connected to the control unit.

9. ACKNOWLEDGMENT

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10. REFERENCES

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