An Autonomous Industrial Load Carrying Vehicle

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Abstract

The demand toward automation has changed the way that today’s warehouses and distribution centers operate. An ordinary industrial (or warehouse) human-operated forklift needs to be improved to achieve an efficient automated industrial task in the material handling process. With the rapid advances in sensor and computer technologies, the opportunities for developing an autonomous forklift are immense. I had gone through many articles in which a system configuration uses vision, laser ranger finder, sonar, etc. for autonomous navigation. Autonomous forklift handling systems is one of the most interesting researches in the last decades. In order to successfully demonstrate the working capability of unmanned autonomous forklift, the ability of it to detect and navigate objects autonomously becomes the critical part in research. In this paper, the development of an unmanned autonomous forklift is discussed. In which I am going to focus on the use of LPC 2138, LCD, motor to operate forklift, RF transceiver and different sensors such as position sensor, line detecting sensor and ultrasonic sensor for autonomous navigation and it material handling process.

\textbf{Keywords:} Autonomous forklift, LPC2138, motors, RF transceiver, Sensors.

1. Introduction

One long-standing goal of research in human-robot interaction is achieving safe and effective command and control mechanisms for mobile robots. This goal becomes
increasingly important as robots are deployed into human-occupied environments. We discuss our approach toward this goal in the context of robotic forklifts tasked with autonomously performing warehouse operations in an indoor environment. The process of loading, unloading and transporting of materials is one of the key issues for every production site and has a great impact on costs. The material flow within the product manufacturing cycle i.e. from the work benches to the storage, is very expensive and can be optimized in many companies, so that the efforts to find favorable and flexible systems continue to be of great importance. The demand toward a higher level of automation has changed the way that today's warehouses and distribution centers operate.

In recent years, there have been an increasing number of researches on the subject of unmanned vehicle navigation. Particularly, for the development of automatic industrial forklift, several research results can be found. The works presented in Garibotto et al. (1997) and Seelinger and Yoder (2006) describe the development of pallet engagement algorithm by using a vision system, while a different approach for localization and picking up the pallet by using a laser scanner is presented in Lecking et al. (2006). An extensive description for automating an industrial forklift together with a road following control algorithm by using a camera is presented in Rodriguez et al. (1998). This paper focuses on the development of a fully autonomous forklifter in which I will used ARM7 as a main controller, ultrasonic sensor for detecting obstacles and also for detecting empty space in rack, IR sensor used as a for line follower, LCD is used to display data. RF data transceiver is used to transmit the data to administration and receive the data from administration. Position sensor (limit switches) is used to sensed that whether the forklift keep load properly in the rack. There are two different motors used DC motor can operate forklift and bipolar stepper motor is used for forklift movement control.

2. Related Work
The development of the automatic industrial forklift [1,2,3,4,6,7]. The works presented in [3,7] describe the development of the pallet engagement algorithm by using vision system, while works in [6] present a different approach for localization and pick-up of the pallet by using a laser scanner. The optimization of the vision system for the navigation of autonomous forklift are presented in [2,7], while the works in [5] describe the development of a simulator for optimization of the multi-AGV operation in industrial environments. An extensive description for industrial forklift automation as well as a road-following control algorithm using a camera is presented in [4]. Fong et al. [8] address the problem of designing an interface that can be used to control a ground robot on uneven terrain with minimal user training. Their PdaDriver system uses images from a user-selectable camera for situational awareness, and allows the supervisor to teleoperate the vehicle with stylus gestures using either a twoaxis virtual joystick displayed on the screen or by specifying a desired trajectory segment by clicking waypoints on the image. Our interface also makes use of gestures drawn on images as a means of commanding the robot, though for tasks other than navigation.
Another similarity lies in the extension to the collaborative control paradigm [12], which emphasizes the importance of interaction between the robot and operator to facilitate situational awareness. Similar to the PdaDriver system, Keskinpala et al. [18] describe a PDA-based touch-screen interface for mobile robot control through which the user teleoperates a ground robot. In addition to providing views from a vehicle-mounted camera, the interface allows the user to view raw LIDAR (laserrange scanner) and sonar returns, either projected on the camera image or on a synthesized overhead view of the robot. The latter view is intended to facilitate teleoperation within cluttered environments, where a forward-facing camera image would provide insufficient situational awareness. Our approach is different, in that we render contextual knowledge at object level (e.g., pedestrian detections) as opposed to rendering raw sensor data, which subsequent user studies [17] have shown to add to the user’s workload during teleoperation. Sakamoto et al. [23] utilize gestures made on the world to command an indoor robot. Through a limited set of strokes, the user can give simple navigation directives by drawing on a bird’s-eye view of the robot’s environment displayed on a tablet computer. Originating from downward-facing cameras mounted to the ceiling, the interface requires significant environment preparation; this limits the vehicle’s operating region to the cameras’ field of view. Other investigators have also shown the utility of enabling a teleoperator to switch between first-person and third-person views of the workspace [11]. Existing research related to multimodal robot interaction [15] exploits a combination of vision and speech as input One important element of joint human-robot activity is the ability of individual agents to detect each others’ cues. Such cues are important aids in interpreting intent or other internal state; for example, eye contact has been shown to play an important role in pedestrian safety [14]. In autonomous vehicles, such cues are often missing by default. Matsumaru et. al. [20] explores several methods for communicating intended future motion of a mobile robot, including the use of synthetic eyes. The eyes indicate future motion, but not perceived objects of interest in the world

3. Figures and Tables

![Fig. 1: Block diagram of autonomous forklift system.](image-url)
3.1 ARM7 Description
The LPC2131/2132/2138 microcontrollers are based on a 32/16 bit ARM7TDMI-S™ CPU with real-time emulation and embedded trace support, that combines the microcontroller with 32 kB, 64 kB and 512 kB of embedded high speed Flash memory. A 128-bit wide memory interface and a unique accelerator architecture enable 32-bit code execution at maximum clock rate. For critical code size applications, the alternative 16-bit Thumb® Mode reduces code by more than 30% with minimal performance penalty. Due to their tiny size and low power consumption, these microcontrollers are ideal for applications where miniaturization is a key requirement, such as access control and point-of-sale. With a wide range of serial communications interfaces and on-chip SRAM options of 8/16/32 kB, they are very well suited for communication gateways and protocol converters, soft modems, voice recognition and low end imaging, providing both large buffer size and high processing power. Various 32-bit timers, single or dual 10-bit 8 channel ADC(s), 10-bit DAC, PWM channels and 47 GPIO lines with up to nine edge or level sensitive external interrupt pins make these microcontrollers particularly suitable for industrial control and medical systems.

3.2 LCD Description
Whenever you come across a LCD that looks like it has 16 connectors it is most likely using a HD44780 controller. These devices provide the same pinouts making them relatively easy to work with. The LCD uses a parallel interface meaning that we will need many pins from our raspberry pi to control it. In this tutorial we will use 4 data pins (4-bit mode) and two control pins. The data pins are straightforward. They are sending data to the display (toggled high/low). We will only be using write mode and not reading any data. The register select pin has two uses. When pulled low it can send commands to the LCD (like position to move to, or clear the screen). This is referred to as writing to the instruction or command register. When toggled the other way the register select pin goes into a data mode and will be used to send data to the screen. The read/write pin will be pulled low (write only) as we only want to write to the LCD based on this setup. The enable pin will be toggled to write data to the registers. Display mode: FSTN / Negative / Transmissive, View direction: 6 O’clock, 5x8 dotes with cursor, 16 character*2 lines display, 4-bit or 8-bit MPU interface and Backlight: LED sidelight (white).

3.3 IR Sensors
Sensors are basically electronic devices which are used to sense the changes that occur in their surroundings. The change may be in color, temperature, moisture, sound, heat etc. They sense the change and work accordingly. In IR sensor the there is emitter and detector. Emitter emits the IR rays and detector detects it. The IR sensor basically consists of three components IR LED (emitter), Photodiode (detector), Op-Amp.
3.3.1 Working
We know that the white surface reflects all the radiations falls on it whereas the black color absorbs them. When the supply is given to IR sensor, LED starts emitting light radiations. If the surface is of white color then it reflects all the radiations. As these radiations starts falling on the photodiode which is connected in reverse bias, the resistance of the photodiode starts decreasing rapidly and the voltage drop across the diode also decreases. The voltage at Pin 3 starts increases, as it reaches just beyond the voltage of Pin 2 the comparator gives high output. In case of the black surface, LED emits light but it is not reflected by the surface, so the photodiode detects nothing and its resistance remains infinite. Hence the comparator gives low output. White surface– Comparator output is high. Black surface– Comparator output is low.

3.4 Ultrasonic sensor Transmitter and Receiver
Before transmit the ultrasonic wave, there is a part which is ultrasonic wave generator that function to generate ultrasonic wave. In that part, there is timing instruction means for generating an instruction signal for intermittently providing ultrasonic waves. This signal will send to an ultrasonic wave generator for generating ultrasonic waves based on the instruction signal from said timing instruction means (transform electrical energy into sound wave). After ultrasonic wave was produced, ultrasonic transmitter transmits the ultrasonic waves toward a road surface to find out the obstacle. The range that obstacle detected is depends on the range of ultrasonic sensors that used.

If the ultrasonic wave detect the obstacle, its will produce a reflected wave. An ultrasonic receiver is used for receiving the ultrasonic waves reflected from the road surface to generate a reception signal. There is ultrasonic transducer that will transform back the sound wave to electrical energy. This signal amplified by an amplifier. The amplified signal is compared with reference signal to detect components in the amplified signal due to obstacles on the road surface. The magnitude of the reference signal or the amplification factor of the amplifier is controlled to maintain a constant ratio between the average of the reference signal and the average of the amplified signal. Minimum range 10 centimeters, Maximum range 400 centimeters (4 Meters), 5V DC Supply voltage, 15 mA , Modulated at 40 kHz.

3.5 DC motor
DC motors have many applications and used for multi-purpose applications. A machine that converts dc power into mechanical energy is known as dc motor. Its operation is based on the principle that when a current carrying conductor is placed in a magnetic field, the conductor experiences a mechanical force. The direction of the force is given by Fleming’s left hand rule. Parts of a DC Motor are a simple motor has six parts Armature/ Rotor, Commutator, Brushes, Axle, Permanent Magnet, DC Power supply.
3.6 Limit Switch
Limit Switch Features are Amp rating 0.1 A to 25 A, Circuitry SPDT, SPNO, SPNC, Operating force 0.7 oz max. to 14.6 oz max, Terminations quick connect, pc board, pcb straight angle left, Actuators/Levers pin plunger, straight, short flag, roller, sim. roller, curved tip, loop, paddle, Voltage 125 Vac, 250 Vac, 277 Vac, Approvals UL, CSA, ENEC, Operating temperature -40 °C to 82 °C [-40 ºF to 180 ºF], Contacts silver, silver cadmium oxide, gold and Housing material PCT polyester thermoplastic.

3.7 Bipolar Stepper motor Features
NEMA 17 Frame Size(42 x 42mm), 1.8° Step Angle, High Torque - Up to 70 oz-in, High Step Accuracy and Resolution, Low Vibration and Noise, Typical Applications of Nema 17 Stepper Motor: Inject printers, Dispense Robot, Analytical and Medical Instruments, Textile Equipment, Embroidery Machine, Precision Telescope Positioning Systems, Stage Lighting and Robotics, With the highest possible torque and also small dimensions (42 x 42 mm) the Nema 17 Stepper Motor series offers high resolution and is employed with economically priced drives for precision applications. These series Nema 17 Stepper Motor offer a great value without sacrificing quality and were designed to offer the highest possible torque while minimizing vibration and audible noise. A broad line of Stepper Motor windings and stack lengths are available off-the-shelf, or the Stepper Motor can be customized to fit your machine requirements. We can customize the Stepper Motor winding to perfectly match your voltage, current, and maximum operating speed for maximum flexibility. Technique parameter of Bipolar Stepper motor Step Angle Accuracy ±5%full step, no load, Resistance Accuracy ±10%, Inductance Accuracy ±20%, Temperature Rise 80 Max. (rated current, 2 phase on), Ambient Temperature -10 to +50, Insulation Resistance 100MΩ Min. 500VDC, Dielectric Strength 500VAC for one minute.

3.8 RF Transceiver Descriptions
The CC2500 is a low-cost 2.4 GHz transceiver designed for very low-power wireless applications. The circuit is intended for the 2400-2483.5 MHz ISM (Industrial, Scientific and Medical) and SRD (Short Range Device) frequency band. The RF transceiver is integrated with a highly configurable baseband modem. The modem supports various modulation formats and has a configurable data rate up to 500 kBaud. CC2500 provides extensive hardware support for packet handling, data buffering, burst transmissions, clear channel assessment, link quality indication, and wake-on-radio. The main operating parameters and the 64-byte transmit/receive FIFOs of CC2500 can be controlled via an SPI interface. In a typical system, the CC2500 will be used together with a microcontroller and a few additional passive components. Low power consumption, High sensitivity (type -104dBm), Programmable output power -20dBm-1dBm, Operation temperature range : -40++85 deg C, Operation voltage: 1.8~3.6 Volts, Available frequency at : 2.4~2.483 GHz.
4. Conclusion
While working on this project the expected result is well develop an autonomous forklift which will navigate autonomously having ability to avoid obstacle while moving forward. It will be able to control its speed and work on priority base. It will detect the empty space in the rack, keep the load at its assign place and if a product is not available in the stock it will inform to the administrator.

5. Acknowledgement
We take this opportunity to thank out Head of the Department Prof. Sheetal Bhandari for her guidance and providing necessary facilities, which were indispensable in the completion of this report. We are also thankful to our seminar guide Prof. Ganesh Rahate and Seminar coordinator Prof. Varsha Harpale and all the staff members of the Electronic and Telecommunication engineering department. We would like to thank the college for providing the required magazines, books and access to the internet for collecting the information related to the seminar. We thank our Principal, Dr. A. M. Fulambarkar, who is a constant source of motivation for us. Finally, we are also grateful to our friends for their valuable comments and suggestions.

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Journal Papers


Books