Autonomous Garbage Removal System

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Abstract

This paper reports on the design, construction and testing of an automated garbage removal system. This project was undertaken in the course of junior-level Electromechanical Design course at Wentworth Institute of Technology in Spring 2009 to create a system that will autonomously carry trash barrels to a residential curb on trash day. The system is comprised of a motorized cart and sensors which will allow it to navigate around obstacles and arrive at the specified location. While the prototype does not yet fully meet all the objectives specified, it has most of the functional requirements and will successfully drive and avoid obstacles. The prototype will be demonstrated.

Introduction

Current lifestyles have made certain home chores more of an inconvenience than they need to be. One such task is the taking of the garbage to the curb for pick up. The design is an autonomous vehicle which will automatically carry the household garbage bin from its storage location to the curbside and back once the garbage has been retrieved. A pictorial view of this system can be seen in Fig. 1 below. Current designs utilize systems which limit the functionality of the devices.[1], [2], [3] This design alleviates these limitations while serving the purpose in a more effective and efficient manner while being affordable to both the designer and consumer. The design will be of great assistance to those who are physically incapable of performing this otherwise common task. This includes the elderly, the handicapped, and those whose hectic lifestyle makes it impossible to accomplish the task. The project was to satisfy the requirements of Junior-level Electromechanical Design course, including the original design of a system having an electrical and mechanical component. The main objective of the design was to create a solution that would alleviate the unnecessary stress that such a simple task as taking the garbage out can cause. This robotic device can be programmed to the date and time when the trash is picked up at your address and the cart will drive your barrels out to the curb and wait to be emptied and then the cart will return the barrels to the storage location of as you choose. This whole system would be completely autonomous, and would require as little input as setting the date once, and ensuring the batteries are charged.

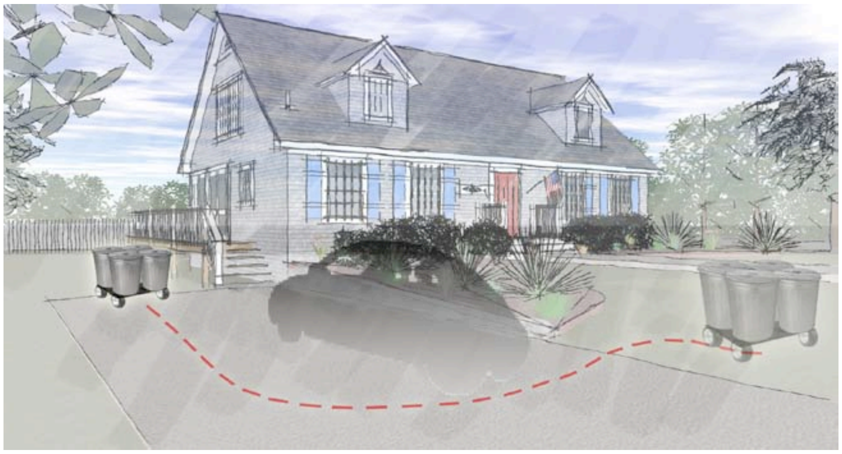

Fig.1: Design concept

Design:

In order to facilitate programming of the system a series of system block diagrams and program flow charts were created. Fig. 2 shown below is a block diagram of the overall system. The blocks with the slanted tops mean that there is a user input necessary for that step. This includes placing the trash in the barrels, and having the trash emptied from the trash barrel by the garbage man. The main idea is for the user to put trash in the bin, on the cart. Then on scheduled trash pickup day, moves out to the curb autonomously, then the trash is emptied by the garbage man, and then the cart would return to the house by itself.

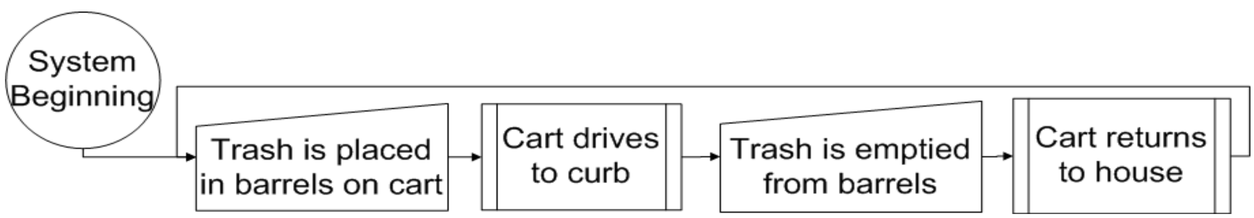

Fig. 2~System process block diagram

<u>Mechanical</u>:
The mechanical design of the system was first created with the assistance of 3-dimensional modeling software, a model has been developed which will be used to develop the prototype. This model can be seen below in Fig. 3.

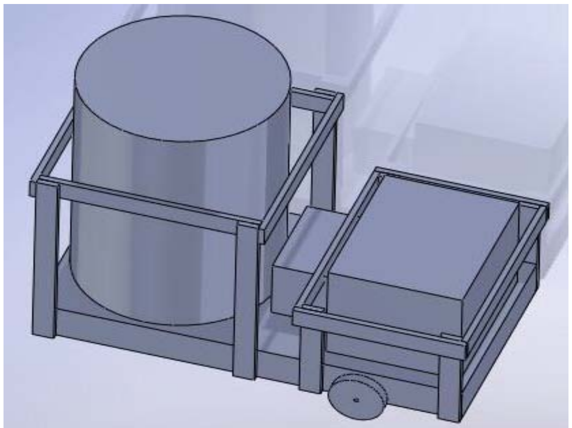

Fig. 3: SolidWorks model of Automated Trash System

Fig. 4: Prototype of cart

The model shown in Fig. 3 shows a model of the trash cart. This design would be one of several different designs meant to hold different quantities. This model shows a single trash barrel, and one recycling bin. Other models would include space for multiple trash bins, or multiple recycling bins. A scale prototype was then build on a 3/8 scale. All of the mechanical systems were then designed on this scale in order to create a working model. A series of calculations were preformed to identify the torque and rpm requirements for motors. Using these requirements motors were selected from Lynxmotion. The motors run on 7.2vdc and are geared 50:1 for a speed of 175 rpm and have a stall torque of 0.7 Nm. A picture of the completed prototype can be seen in Fig. 4. Once the cart was built the motors were tested using a bench power supply which outputs up to 2 amps. The cart was loaded with a 9 kg weight and the cart maneuvered successfully. The motors are rated up to 5 amps each which should mean that the cart can carry its rated load of 23kg.

Obstacle avoidance:

The obstacle detection system is shown in the system diagram in Fig. 5 and its function in Fig. 6. It includes a PING))) ultrasonic sensor from Parallax inc. [4]. This sensor outputs an ultrasound pulse, much like sonar, and receives the echo. Through this, it is able to determine the exact distance away that an object is up to 3 m. The simplicity of the sensor is in how it is interfaced with the microcontroller. The PING))) is designed to be highly compatible with the BASIC stamp line of microcontrollers. This led to the selection of a stamp as the central processor the design. Additionally, analog infrared sensors, seen in Fig. 5 and 6, were acquired to use as a secondary obstacle detection system, for object tracking once an obstacle has been detected. These analog sensors can range distances up to nearly a meter. Once interfaced with an analog to digital converter [5], the data from these sensors (the Sharp GP2D12 [6])can be read using the stamp. The last part of the obstacle avoidance system is a bumper sensor which is mounted on the front edge of the cart. This bumper sensor is comprised of two push button sensors in parallel. The pushbuttons are wired in series with a 220 Ω resistor and a 10k Ω pull down resistor. These two resistors allow the Stamp Microcontroller to interpret the signal and stop the cart when the bumper sensor is depressed.

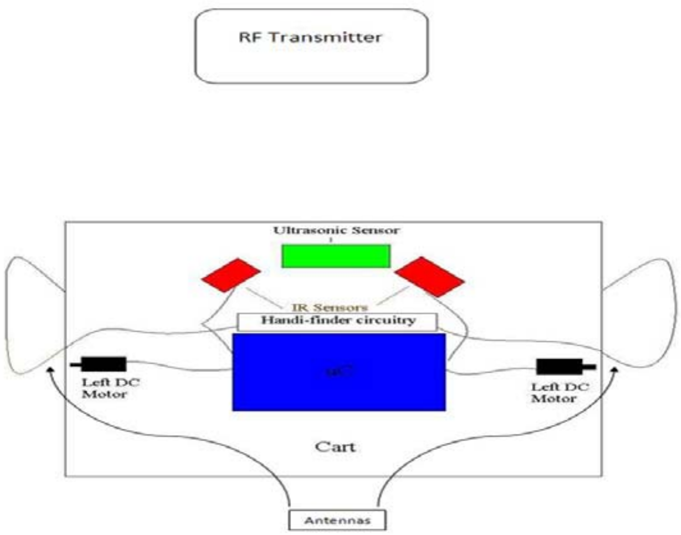

Fig. 5: System diagram

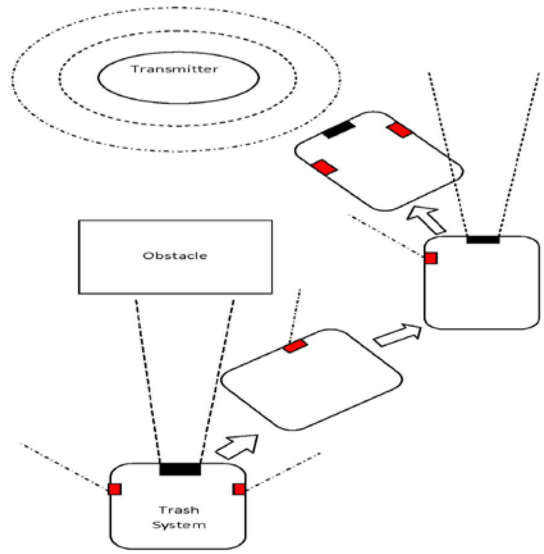

Fig. 6: Obstacle avoidance system

<u>RF module</u>:
The system uses two antennas separated by a 17 inch gap. These antennas output a differential voltage depending on the angle relative to the transmitter. This voltage is inputted into the microcontroller to allow the device to navigate. Two transmitters of different frequencies are used, one is placed at the curb and one at the house. When the “go to curb” or “go to house” subroutine is called by the program the receiver will lock onto the appropriate frequency and begin to return directions to the microcontroller. The directional antenna system that was used for this project was the Handi-Finder [7] directional antenna. The output of the Handi-Finder was connected to a receiver which is tuned to the same frequency of the transmitter. This combination of the Handi-Finder and receiver will interpret the direction of the signal and create an output that the microcontroller can use to navigate to the curb. The Handi-Finder was interfaced to the microcontroller through an ADC. A potentiometer was used to create a 2.55V reference voltage across pins 5 and 3 of the ADC. Working with a matched Radiotronix transmitter and receiver [8], [9] the team ran many laboratory tests to understand the relationship and the requirements of the system. The transmitter needs 3 volts power and a square wave signal in order to transmit correctly. Two AA batteries and a 555 timer chip [10] were used to power the transmitter. The 555 timer was used to generate a square wave. The receiver also is powered by a 3 volt supply; similarly the team used two AA batteries to power the receiver. The data out pin of the receiver is connected to the microcontroller through an ADC [5]. The digital signal will then be interpreted by the microcontroller to control the direction of the cart. The receiver circuitry was placed in a shielded box and all the external connections were made with shielded coaxial cables.

<u>Programming</u>:
The programming for this design was done using a Basic Stamp 2 microcontroller. Figs. 7 and 8 show how the main concepts of the design can be broken down into some more specific details about how it will complete its task. Once the block diagrams have been made, the programming has to be done with the microcontroller. Flow charts are created for the program and subroutines to break down exactly how the system monitors its several sensors, and what the priority of the system will be. They show how the feedback loops work, and which system overrides other systems. To help visualize the obstacle avoidance subroutine works, the diagram of Fig 6 above was made.

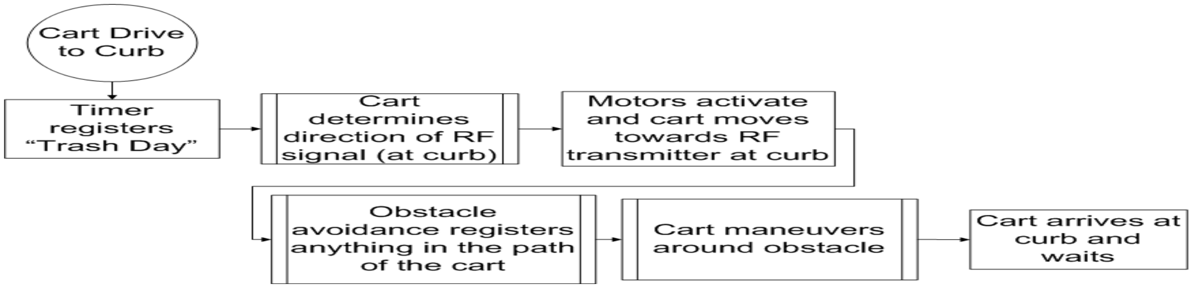

Fig. 7: Initial trip logic

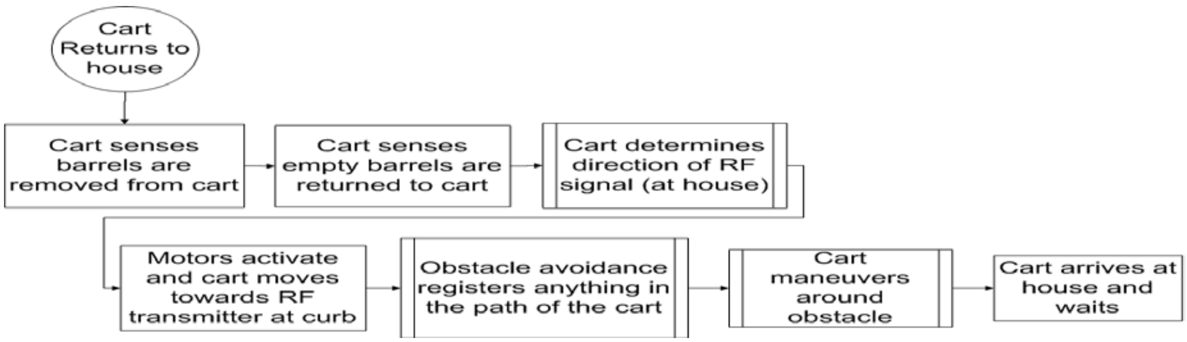

Fig. 8: Returning trip logic

A major design parameter of the Autonomous Garbage Removal System is the idea of "setting and forgetting it". This way the time of pickup is put into the system, and nothing else has to be done by the operator. This requires some sort of timer to keep track of when exactly to initiate the program to start the operation of taking out the trash. A "SLEEP" function in the microcontroller [11] allows for the system to go into a stand-by mode for a specified amount of time. This function was used to sleep for a whole week (168 hours) then it would turn on and initiate the sequence on trash day. The motors were interfaced with the Microcontroller with a Pololu Low-Voltage Dual Serial Motor Controller [12]. This device runs two motors independently with 128 speed in forward and reverse. The motor controller can supply up to 7 volts and 5 amps per motor.

<u>Batteries</u>:
An integral part of the entire system is the power. The selected motors run from a 6.0 volt source and at maximum load and speed would draw 5 amperes of current from this power source. Due to cost effectiveness, the batteries selected were 7 volts at full charge and have a 1000 mAh capacity. Assuming maximum current draw, the run time for the system was calculated and found to be 12 minutes. The cart's motors are powered from a 6 volt, 1000mAh battery. The system also needs a 9 volt battery for the microcontroller and RF receiver power as well as a 3 volt battery pack for the Handi-Finder. Finally the transponders need their own separate power sources in the form of a 3 volt battery pack.

<u>Budget</u>:
As seen in Table 1 below, the team was successfully able to stay close to out estimated budget. The team was able to save a considerable amount of money by using donated parts, such as the transmitter and receiver. Also the team built the model of the cart primarily out of scrap

materials which helped keep the team on budget. The estimated budget initially was $385.00. The actual budget was $386.52.

Discussion:

Mechanical: The mechanical design of the system worked well. The first problem encountered in the design of the cart was a difficulty connecting the motor shaft to the drive wheels. This problem was resolved with the use of a lathe to remake the axles, so that they were true and didn't turn in an eccentric fashion. The second problem encountered was the rear swivel caster wheel. This problem became apparent when testing of the cart began, the cart would have the tendency to turn slightly in one direction or the other. After some testing, this problem was solved by replacing swivel caster with one with less drag force which leads to better tracking. If there is and lingering problems with the tracking of the cart it can be adjusted in the programming by making one of the motors turn slightly faster than the other.

Microcontroller: BASIC Stamp 2 was selected as the microcontroller for its ease of use, high compatibility with the other components, and overall time savings so that there was little learning curve with the programming. The Stamp integrates well with the components used in the design, especially the PING ultrasonic sensor. Once the system neared completion, the limitation in this microprocessor became apparent. PBasic has limited commands, which translates to limited functionality. The controller processes every command in sequence, so at times, compensations needed to be made in the programming just to allow for the proper amount of time for the system to make the necessary decision. Essentially, this was done by adjusting the variable distance at which the sensors would indicate that the system was too close to an obstacle. A larger distance gave the microprocessor sufficient time to compute before an impact would occur. This microcontroller functioned well enough for this design, but the team feels that a more advanced processing unit would be necessary to get the desired functionality.

Motor Controller: The motor controller we used worked very well for this operation. At first the team had problems connecting the motor controller to the header because of the small size of the components. Once a header was connected a socket was created for easy installation to the wiring on the cart. When the motor controller was first tested using two diodes were placed between the negative terminals and ground, in an attempt to reduce voltage spikes generated by the motors where no power was applied, but the wheel was still turning. When power was applied the motor controller instantly began to smoke and the wheels began to turn slowly. Power was turned off and the motor controller was inspected and determined to be ruined. A second motor controller was purchased and the circuit was rewired. This new circuit was tested and preformed perfectly.

Stopping System: The design and testing stopping system of the cart was not completed. Due to the problem with the RF system the team ran out of time to work with the stopping system. The first concept that the team tested was using an inductor sensor mounted to the bottom, leading edge of the cart and a magnet located at the desired stopping location (at the curb, or house). When the inductor passes over the magnet the microcontroller would read a spike and use an interrupt to stop the program and wait for the return trip notification system to be activated. The results were inconclusive as to the feasibility of the concept. More research will be needed in order to determine if this system could be implemented in the future. Another problem with this concept is that the Basic Stamp 2 does not have an interrupt function so it would be difficult to stop the cart immediately when the inductor passed over the magnet.

Return trip notification: The return trip notification system is comprised of push buttons in the same fashion as the bumper sensors. The push buttons are located underneath the trash barrels and are normally in their depressed state when the trash barrels are located on the cart. When the trash barrels are removed at the curb the microcontroller will receive a digital zero which will reset the program and when the trash barrels are replaced the digital one will be sensed and the return trip program will activate.

RF system: In simple lab testing, a function generator was connected to the transmitter data port, and the receiver was connected to the oscilloscope. The oscilloscope easily read the signal that the transmitter was outputting. The transmitter and receiver could communicate without the use of any antenna which prevented the antennas from serving their intended function as a navigation tool. This problem was addressed by shielding with an aluminum box, and shielded coaxial cable running in and out of the box. The RF system was tested outdoors. The readings on the multimeter were very sporadic and seemed random. This RF system test turned out therefore to be inconclusive. This EMI could have been caused by poor shielding, malfunction in the Handi-finder circuitry, the crude antennas used, or the breadboard that was used for prototyping. Future plans would be to experiment with different types of antennas and replacing the breadboard with a printed circuit board.

Sensors: The distance sensors were carefully chosen. The ultrasonic sensor's large range affords time for the microprocessor to make decisions before any impact can occur. The infrared sensors were simple enough to convert from an analog differential voltage output to a digital signal that can be interpreted by a microcontroller. No issues were encountered with the sensors selected. The largest concern was more related to the microcontroller. Limitation in processor speed and the sequential manner in which the processor operates meant that the programmed distance had to be greater than initially thought, just to allow for processing time by the microcontroller.

Conclusions:

The general goal of this design was to develop a system which could autonomously navigate its way from one point to another. The main idea to make it unique was the navigational system was to be completely wireless. The idea here is there is no predetermined path whatsoever for the system to follow. It knows where it is supposed to be going, and it negotiates any obstacles in its way while it makes its way towards this set point. While the end product did not completely fulfill the goals that were initially set, a lot of knowledge was gained in striving to develop this system. Victories included creating a system that did successfully negotiate obstructions to its path without any input from the user. Through research, the team gained a wealth of information regarding how to specify electrical motors based upon application. Extensive research was conducted into radio-frequency tracking, and while the team feels that it found the solution for the system, limitations in experience and construction did not allow for the system to work effectively. There is no doubt that a working system that meets all of the design criteria that was set at the beginning of the semester is possible. The knowledge gained may allow us to actually finish this system. The team has absorbed a large amount of early experience in robotic and autonomous systems.

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