Autonomously Controlled Front Loader
Senior Project Proposal

by

Steven Koopman and Jerred Peterson

Submitted to:

Dr. Schertz, Dr. Anakwa

EE 451 Senior Capstone Project

December 13, 2007

Project Summary:

The overall goal of this project is to have a cheap autonomous vehicle that is capable of doing some task. This specific project took the task of controlling a front loader vehicle to scoop up some material from a bin, and dumping the material into a nearby truck. This project will take a pre-existing front loader vehicle, and add on a microprocessor and sensors deemed necessary to accomplish the task. This vehicle will not use an image processing system, although that will be one of the suggestions for further development.

Detailed Project Description:

This section discusses the various aspects of the project in more detail. First, it will provide a functional description and complete block diagram for hardware and software, and then move onto the requirements for the vehicle. Following this will be a mention of patents and standards that may be applicable to the design or final project, and then a summary of work that has been done on the project up to date.

Functional Description

This section lists the hardware components used, and introduces an overall system block diagram which shows the interaction between the major hardware components. The hardware expected to be used in this project is as follows:

- Microprocessor board, Silicon Labs C8051F34x-DK
- Two rotary encoders, HEF-16 or newer model
- Front end loader vehicle, Bobcat T190 RC Track Loader
- Distance sensor, ultrasonic sensor SRF05
- Object sensors, VectorT2X or similar digital compass, Infrared LED and Infrared transistor
- Load material and toy truck to dump material into

These are the main components which will be required for this project to operate. Modifications to attach sensors and microprocessor to the vehicle will have to be made, but unsure what will be required to accomplish this at this time.

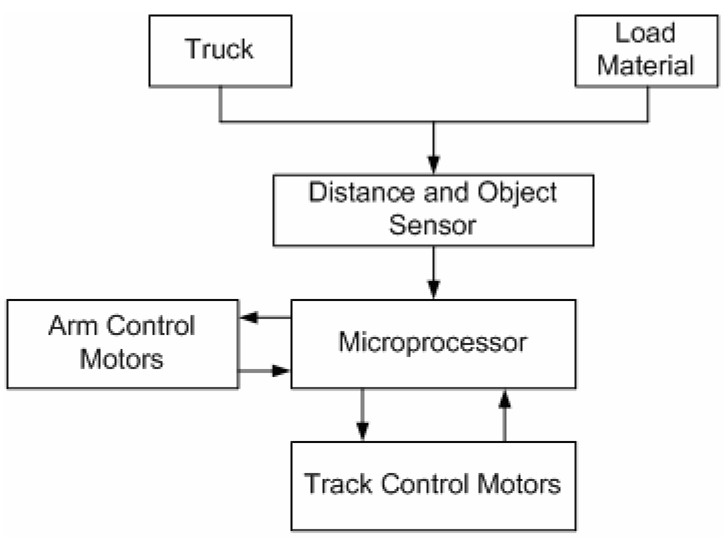

Figure 1: Overall system block diagram for the autonomous front loader project.

Moving on to how these components interact, Figure 1 shows a diagram of the interactions between the main components in this system. The primary object in this block diagram is the microprocessor block. The microprocessor receives information about where the truck and pile of materials is from the distance and object sensors. The object sensor is used to tell the truck apart from the material and background objects. Once the microprocessor knows where the load and truck is, the distance sensor will provide information to the microprocessor about how far the front loader must move.

With this information, the microprocessor will control the track control motors to move the end loader in front of the load. Feedback from the track rotary encoders will be used to make sure the vehicle is traveling in a straight line, or monitoring how much the vehicle turns. Once the end loader is close enough to the load, the arm control motors come into play, along with the track control motors. The arm and track control motors must be used to scoop up material into the front loader's bucket. Once the bucket is loaded, the front loader must navigate to the truck. When the front loader is supposed to empty the bucket into truck, then the arm must be told to dump the material out. The bucket needs an independent motor mounted on it to control the tilting of the bucket, which is included in the vehicle that will be used. This allows more realistic control of the front loader, since most actual front loaders have independent bucket tilt controls. The vehicle to be used also has basic sensors which can be used to tell when the bucket is tipped all the way forward or back, and when the arm is as high as it can go, or at ground level. Initially, these will be used as the feedback from the arm control motors block, but eventually they may be improved for more functionality.

Software Description

There are several different steps that the software will have to go through. Figure 2 provides an overview of the process that the microprocessor will be expected to do. The first step is to configure all the timers and necessary registers on the microprocessor to operate correctly. Next, the microprocessor waits for the operator to tell it to begin loading the truck, probably with a push button of some type. Once this occurs, the front loader will use the object sensor to align itself in front of the load, and then use the distance sensor to tell how far to travel.

The microprocessor will control the drive motors with a Pulse Width Modulated (PWM) signal to control the speed, and wait for the front loader to arrive in front of the load. At this point, the bucket will lower and make contact with the ground, and the front loader will drive forward to load material into the bucket. When the bucket is filled, the arm will be lifted up so that the vehicle may then travel to the truck.

Once the bucket is off the ground, the vehicle will search for the truck using the object sensor, and then line up with the truck. The microprocessor will control the drive motors to move the vehicle to the truck, in a similar manner as mentioned before. The next step will tilt the bucket down and empty the material into the truck. The microprocessor will check how many times the truck had been loaded, and will repeat this process until it has been loaded at least three times. After the third loading, the truck will wait for the operator to empty the truck and press the button to resume operations.

The microprocessor will also need to run fixed period timers for PWM generation, and an external interrupt for an emergency stop feature. The emergency stop feature is beneficial to have; it allows the operator to halt operations that might end up damaging the vehicle. For example, the user might use it to stop the vehicle if it is about to run off the edge of a table, or about to run into a chair or wall.

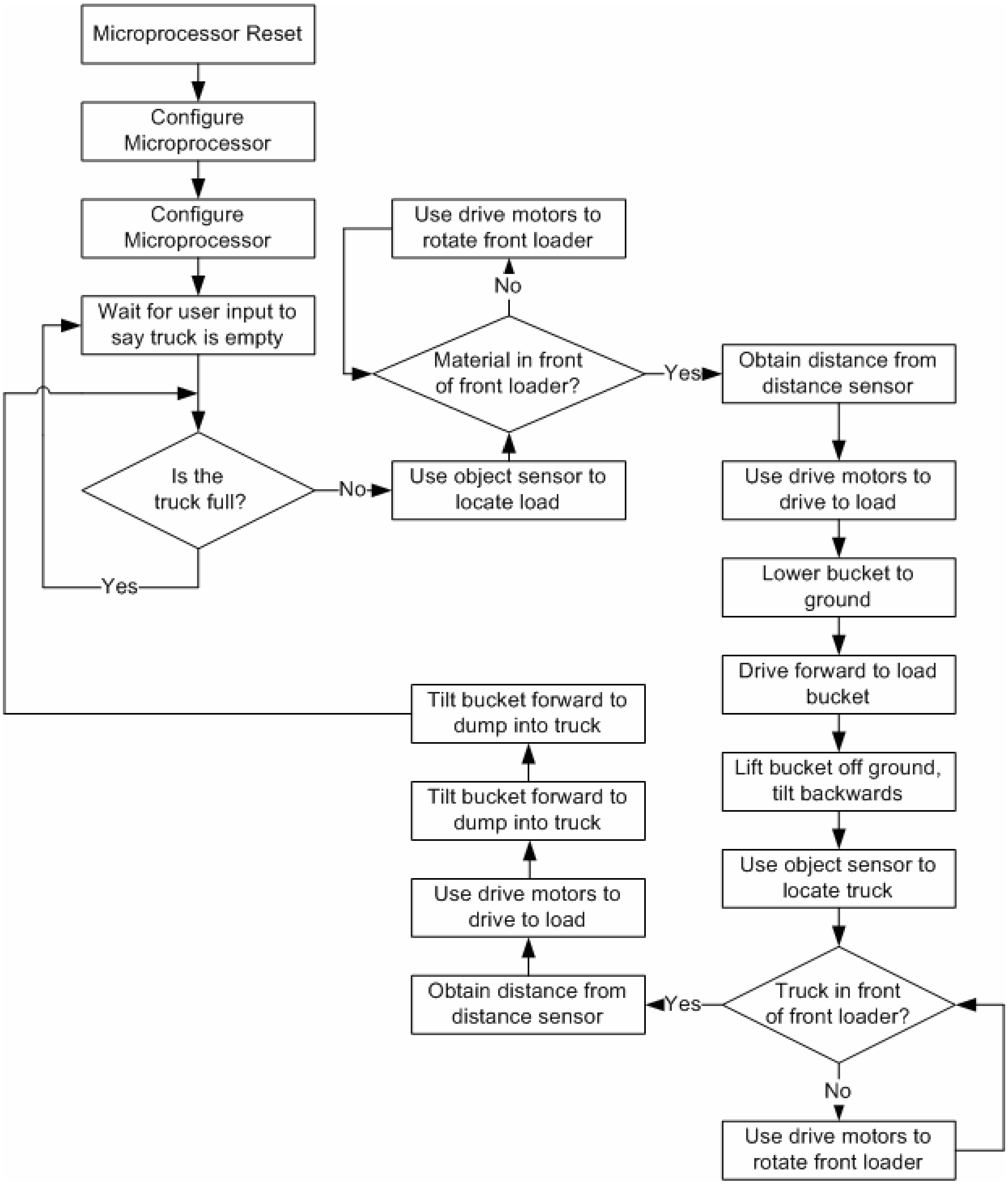

Figure 2: Software flowchart.

This is the primary process that the microprocessor system will have to go through. Important parts will be accessing the object sensor to locate the truck and load, reading the distance from objects, controlling the motors to move the front loader where it needs to be, and being able to load and empty the bucket. Additional software may be programmed to add extra features later, but this is what seems to be necessary at this point in time.

Vehicle Requirements

This section covers what the requirements of the entire project and each subsystem are. This will go into more detail about the microprocessor requirements, and the requirements for the other subsystems mentioned in the overall system block diagram. Some explanations about how the subsystem requirements are meant to help achieve the overall project requirements may also be included.

Autonomous Front Loader:

The first requirement of the vehicle is that it shall require no human information to load the truck with the desired load material. There will be some human input into the microprocessor, but this is primarily to allow the truck to be emptied safely, or to stop the vehicle if something goes wrong. Another requirement for the vehicle is that it shall be able to locate a nearby pile of material and a truck, and tell the two apart. The vehicle shall also be able to determine how far away the truck and material is. This will be used to drive the front loader to the truck and load, rather than assuming they are at constant positions, or accidentally driving too far or not far enough.

The front loader shall also be able to scoop the material into the bucket, and dump the material into the truck without having a significant amount of material falling out of the bucket. The vehicle shall be able to scoop up and dump at least 3 loads of material into the truck without the batteries needing to be replaced. This is a requirement came about from last year’s junior projects; the battery was not powerful enough to sustain the vehicle for significant periods of time, so higher power rechargeable batteries are to be used in this project.

Microprocessor:

The microprocessor has many tasks to do while it operates, since it is the device pulling together all of the sensor information and interpreting it. The microprocessor shall generate a fixed period PWM signal to control each motor on the vehicle. The device will use PWM signals since it is usually power efficient, and will simplify the motor drive electronic design. The period for the PWM signal will probably be around a few milliseconds, but a more appropriate period will be found once more information is known about the front loader. The microprocessor shall also accept a limited amount of user input, in addition to resetting of the microprocessor. The user input for the system will most likely be some input to start loading of the truck, and an emergency stop signal. Other input than this may be added later, but the microprocessor will at least accept this much input. The microprocessor shall also interface to all of the sensors on the vehicle, and interpret information received from the sensors. This is required if the project is going to have any chance of success. If the microprocessor cannot interface to the sensors correctly, it cannot get the information it needs to achieve its goals, and will not meet the requirements for the vehicle.

Truck and Material:

There aren't any real requirements for these subsystems. There are only two requirements that are really a matter of convenience rather than requirements. The user shall keep the material in a pile, rather than letting it get too spread out to be able to be picked up. The user shall also keep the truck from being over-full as well. These requirements are for convenience of the project, since there will not be a camera on the front loader. Adding a camera would exceed the capabilities of the microprocessor, along with increasing the difficulty of the project too far beyond a senior project. If the front loader had to pile the material together, the task would be very difficult without a camera. Also, if the truck filled up and the vehicle was still trying to fill it, dumping further loads into the truck would create a mess.

Distance and object sensors:

The distance and object sensors allow the microprocessor to get information about the real world. Since they are so important, there are fairly strict requirements for them. The object sensor shall determine between the truck and the load. The object sensor shall also provide information to the microprocessor to allow the object to be lined up in front of the front loader. The distance sensor shall provide information to the microprocessor about how far away the nearest object in front of the front loader is. This information shall be accurate down to the range of a few inches, as well as up to a few feet away.

Arm Control Motors:

There are two independent motors in the arm control motor subsystem. The first motor, the arm lift motor, is responsible for lifting the bucket up or down off of the ground, and the second motor, the bucket tilt motor, is responsible for tipping the bucket forward or backwards, or holding it steady while the arm moves. The arm motor shall be able to lower the bucket to the ground, and raise the bucket up high enough to dump into the truck with a full bucket of material. The bucket tilt motor shall be able to tilt the bucket forward or backwards. This is required for the scooping of material, the moving of material to the truck, and emptying the bucket into the truck.

Track Control Motors:

The track control motors are the devices that allow the vehicle to move around in the world. The track motors shall be able to move the vehicle forwards, backwards, or rotate it under the vehicles expected weight. This means that the motors have to be high enough power to move the vehicle, or else the project would be a failure. Each track shall be able to be driven either forward or backwards, independent of what the other track is doing. Each track shall have a rotary encoder on it to provide distance traveled information to the microprocessor. Independent control of each motor will be critical for moving the vehicle forward or backwards in a nearly straight line. Also, in order to look for the load and truck if they are not near the vehicle, it will need to rotate around nearly in place to see if it can find them. This means the motors have to be able to be driven at different speeds and in different directions at the same time. The rotary encoder provides distance traveled information, which will help compensate for variances between two similar dc motors, the variance in inertia of each gearbox, track, and each side of the vehicle.

Patents and Standards

This section contains a list of patents and standards that may be applicable to the design of the final product, or the finished autonomous front loader itself. Patents that apply directly to this project are difficult to locate, as most of the autonomous vehicle patents appear to be targeted to very specific goals, rather than general autonomous vehicles. Table 1 lists some of the patents and standards that may be applicable to this project, but most of the project should not be directly covered by patents, and only broadly covered by standards.

Table 1: Related Patents and Standards

Patent/Standard Number	Patent/Standard Name
6151539	Autonomous vehicle arrangement and method for controlling an autonomous vehicle
5111401	Navigational control system for an autonomous vehicle
5999865	Autonomous vehicle guidance system
6454036	Autonomous vehicle navigation system and method
ISO 10218-1:2006	Robots for industrial environments – Safety requirements - Part 1: Robot

Completed Work

So far, the lab work has been applied mostly towards finding a suitable front loader vehicle. The first few weeks, a hobby kit front loader was constructed and tested, but since it was lacking independent bucket control and the lifting arm could not hold much weight, it was abandoned. Investigation into the usefulness of the Bobcat T190 RC track loader followed this to see if it would be suitable for this project. It has an independent bucket tilt motor, and basic feedback sensors for the bucket tilt and the arm lift motors. The drive circuitry inside the vehicle is being investigated at this time, since datasheets were not provided with the toy vehicle. More investigation on the drive circuitry will be needed to see if it can be controlled by the microprocessor or not. This vehicle is also strong enough to pick up the desired load material. Modifications will need to be made to add rotary encoders to the tracks, and to mount the object and distance sensor, but it exceeds the minimum requirements for the vehicle body, so it will most likely be the one used for this project.

Investigation into sensors has also been started. It is probable that the distance sensor will be an ultrasonic sensor. Ryan Leman and Kevin Hurley collected some data about the sensed distance versus actual distance, and the minimum resolution of the sensor appeared to be adequate for the project. Also, infrared diodes and transistors are being investigated for object detection sensors. If the infrared diodes are used, they will be mounted on the load and truck, and flashed at different rates. The front loader will look for a signal from one of the diodes, and determine if it is the truck or the load. More powerful infrared LED's than are available in the lab stock room will be required, because the ones in the stock room only work up to about 8 inches at most. Leman and Hurley tested out some higher power ones that worked well, but couldn't provide enough directionality to ensure that the front loader was lined up with the load or truck.

One alternative to solve this is to also mount a digital compass on the vehicle. The digital compass will give directional information to allow the front loader to be lined up head-on with the load material and truck. The VectorT2X compass appeared to provide ample resolution for directionality concerns, but it has a relatively slow update speed upon turning. A cheaper version of this compass may be used, upon discussion with our advisor.

Schedule:

This section discusses the schedule intended for the spring semester of EE 452. Refer to Table 2 for the tentative schedule for the spring.

Table 2: Spring 2008 Schedule for EE 452.

Week #	Description of Activities
1	Modify front loader to include object and distance sensors Test modified front loader for functionality
2	Design motor power electronics, or determine if old ones are useable Finish attaching sensors to front loader, attach microprocessor Test microprocessor interface to sensors and motor power electronics
3	Continue testing sensor/power electronics interface to microprocessor Complete tasks that might have been delayed from week 1 or 2
4	Begin programming microprocessor to do individual tasks Probable order of tasks: Get vehicle to drive straight and turn, Load bucket when vehicle is in front of load, Dump bucket when vehicle is in front of truck, Get vehicle to differentiate between truck and load, Have vehicle drive up to load and truck.
5-6	Continue to develop software on microprocessor to achieve individual tasks
7-9	Combine routines together to achieve project goals Test project with simple layout (truck and load in a straight line, with front loader facing the material) and gradually increase the difficulty.
10-13	Wrap up software development, formalize results. Begin writing final report and presentation

The primary concern in the beginning will be to build up the hardware and verify it works. After that is completed, software can begin being written for the vehicle, and subroutines can be tested. Technically most of the work on this project will be a critical work path. The microprocessor cannot be tested without some working sensors and power electronics, and certain sensors cannot be tested on the vehicle at the same time as other ones.

Equipment List:

The final equipment list still needs to be formalized, but the basic one was mentioned earlier. The components that will be needed are as follows:

- Microprocessor board, Silicon Labs C8051F34x-DK
- Two rotary encoders, HEF-16 or newer model
- Front end loader vehicle, Bobcat T190 RC Track Loader
- Distance sensor, ultrasonic sensor SRF05
- Object sensors, VectorT2X or similar digital compass, Infrared LED and Infrared transistor
- Load material and toy truck to dump material into

Which rotary encoder that will be mounted to the vehicle has to be decided on, since the ones investigated in lab appear to no longer be purchasable. The front loader vehicle has been decided upon, and the distance and object sensor will most likely be an ultrasonic sensor and an infrared transmitter/receiver with a digital compass. The load material will most likely be corn, and the toy truck is not really a concern to find.

Bibliography:

Dr. Schertz. Personal interview. October 23rd through December 11th 2007.

Hobby Engineering. "Hobby Engineering: Sensor Section". December 7, 2007.
<http://www.hobbyengineering.com/SectionS.html>