Autonomously Controlled Front Loader
Functional Description and Complete System Block Diagram

by

Steven Koopman and Jerred Peterson

Submitted to:

Dr. Schertz, Dr. Anakwa

EE 451 Senior Capstone Project

November 8, 2007

Introduction:

This paper discusses the project to be completed for EE 451. The goal of this project is to build a front loader from a hobby kit and modify it so that it will operate as an inexpensive autonomous vehicle. The specific goal for this project is that the front loader will determine between two objects, a truck and a pile of material. The front loader will start by find and navigate to the pile of material, and scoop up material. Once the bucket is loaded with material, it will locate and drive the front loader to the truck, and dump the material into the truck. Once the bucket is empty again, the process repeats and the front loader moves back to the material. The vehicle must complete at least three cycles of this without replacing the batteries.

Sensors will also need to be mounted on the front loader so that the vehicle can find the load and truck. The front loader must also be able to tell how far away some object is, so position sensors will be needed. This position sensor needs to work well down to 1-2 inches away, which complicates the choice of sensors. The distance traveled will need to be calculated with minimal error, so the tracks will need to be equipped with some sensor to measure track or wheel rotations. The front loader will also need to be able to determine if it has taken enough material to be considered nearly a full load or not. Sensors to detect the incline of the bucket arm and the tilt of the bucket will probably need to be added.

These are the primary goals of the project, and should provide a significant challenge. Interfacing a microprocessor with multiple sensors and using those sensors to guide the vehicle to the desired target without human intervention is a significant task. The remainder of this paper will talk about the system in more detail, by providing over-all system block diagrams, descriptions of each subsystem in the project, and the software functions that will be required to accomplish the goals of this project.

Overall System Block Diagram:

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:

- Silicon Labs Development Board
- Two rotary encoders, for measuring traveled distance
- Front end loader kit
- Distance sensor, for distance sensing
- Object sensor, for distinguishing between the truck and load
- Additional DC motor assembly, for independent bucket control
- Load material and toy truck to dump material into

These are the main components which will be required for this project to operate. Additional kits to modify the front loader to attach these additional components and mount the microprocessor will be needed as well, but these have mostly already been purchased for preliminary testing.

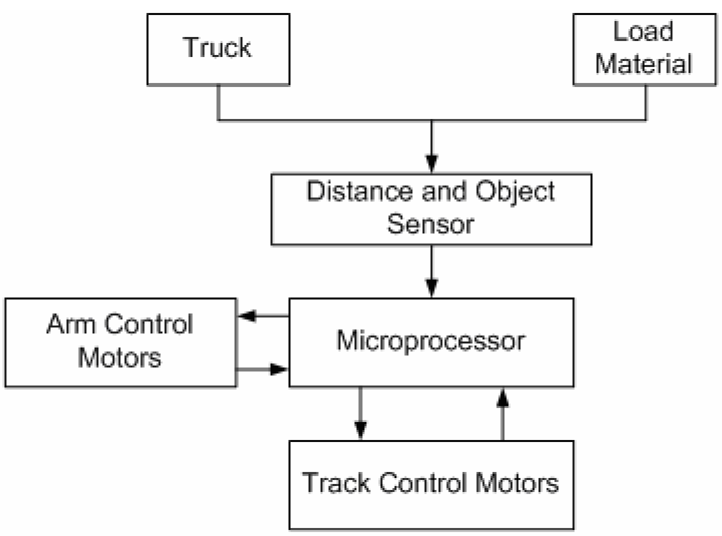

Figure 1: Overall system block diagram for the autonomous front loader project.

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 should send commands to the track control motors to make the target appear in front of the end loader, and orient the front loader immediately in front of the target. Once the end loader is close enough to the desired location, the arm control motors come into play. If the front loader is supposed to pick up material, then the arm and track control motors must be used to scoop up material into the front loader's bucket. If the front loader is supposed to empty the bucket into a truck, then the arm must be told to dump the material out. The bucket will have an independent motor mounted on it to control the tilting of the bucket. The front loader built from the kit would automatically begin dumping out material once it raised the arm to a certain height, which was not a desirable feature for the final project.

These are the major systems that come into play during the operation of the autonomous front loader. The microprocessor gets information about where the material and truck is, and sends signals to the track control motors to move to the material or truck. Once at the right location, the arm control motors are used to pick up the material, or dump the material into the truck. The next section will go into more detail about each of these subsystems.

Subsystem Details:

This section covers what each subsystem's responsibilities will be in more detail.

Microprocessor:

The primary subsystem of this project is the microprocessor subsystem, since the entire vehicle will be controlled from it. Refer to Figure 2 to see how the microprocessor interacts with other hardware components. The microprocessor uses information from the object and distance sensors to find the load material to scoop up, and then uses the drive motors to move over and load the material into the bucket. Once the material is in the bucket, the microprocessor will operate the arm lift and bucket tilt motors to secure the material in the bucket. The microprocessor will then find information about where the truck is and how far away it is with help from the object and distance sensors. Then the microprocessor will turn towards the truck and drive up next to it, and dump the material into it. The track motors will need to be controlled to a precise distance, so rotary encoder feedback will be added to each track.

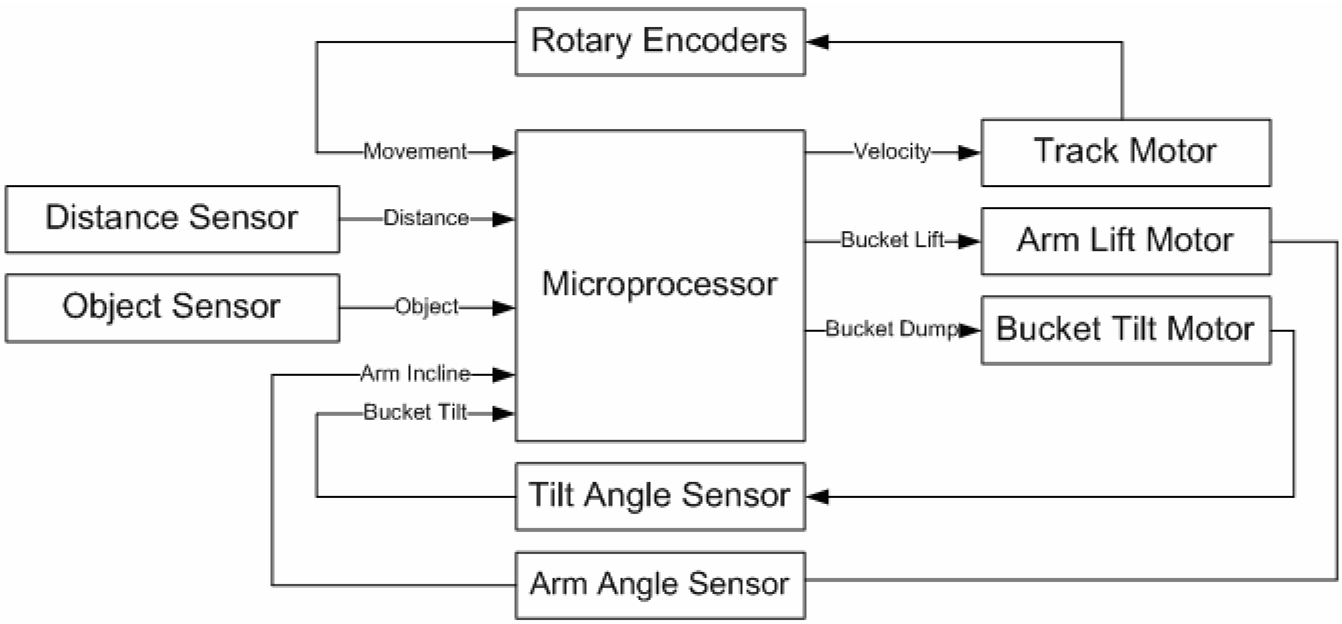

Figure 2: Microprocessor interaction with other hardware components.

Truck and Material:

The truck and material subsystem are physical objects and targets for where the front loader wants to move to. The material will be placed in its own bin in order to ease difficulties in loading the bucket. The truck and load material may be getting some form of beacon, probably an infrared beacon, to distinguish between them.

Distance and Object sensors:

The object and distance sensor provide information to the microprocessor which allows it to figure out which way to move, and how far to go. Refer to Figure 3 for more information on the object and distance sensors. The object sensor will be responsible for picking out the desired object and giving the microprocessor information to center it in front of the front loader. Once this is accomplished, the distance sensor is then used to determine how far the front loader must travel to reach the object. Once the front loader is at the edge of the desired object, the position and recognition sensor will be ignored by the microprocessor until the front loader must move to another object.

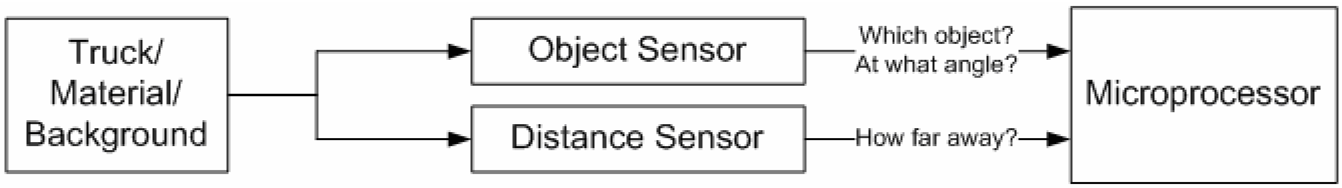

Figure 3: Distance and object sensor interaction with other hardware components.

Arm Control Motors:

The arm control motor subsystem is responsible for raising or lowering the bucket, and tilting the bucket backwards or forwards. If there is material to be picked up, the bucket will need to be set on the ground, and tilted level to the ground. If the bucket is full, the arm must be raised from the ground and tilted backwards to secure the material. Once the bucket is desired to be emptied, the tilt control motor must tilt the bucket forward to empty out the material inside of it. It should be noted that the arm lift motor and bucket tilt motor operate independently of each other. While the arm raises or lowers the bucket, the bucket will maintain nearly a constant incline, unless the tilt motor is being operated at the same time. This allows the bucket to be dumped out at almost any height, rather than at a constant height as the original kit was built for.

Track Control Motors:

The track control motor subsystem is responsible for moving the front loader around. It will need to move the front loader forward, backwards and rotate it left and right. Due to a high required precision on the exact distance traveled, some form of rotary encoder or optical encoder will need to be installed on each of the tracks. This information would then be fed back to the microcontroller in order to determine how far the front loader has traveled, and how much further is needed to be traveled. Another feedback system may come from the track control motors to determine how much extra of a load has been added to the end loader to determine if enough material has been picked up or not.

These are all of the primary subsystem blocks in this system. The next section will discuss the expected software functions that will be needed for the project.

Software Functions:

There are several different steps that the software will have to go through. Figure 4 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 to be straight 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 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 slowly to load the bucket. Once the bucket is loaded, the arm control motor will be told to raise up, and the bucket will be tilted backwards to secure the load.

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 drive motors will be controlled with another PWM signal to arrive at the truck. At this point, the bucket will be tilted down and emptied 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.

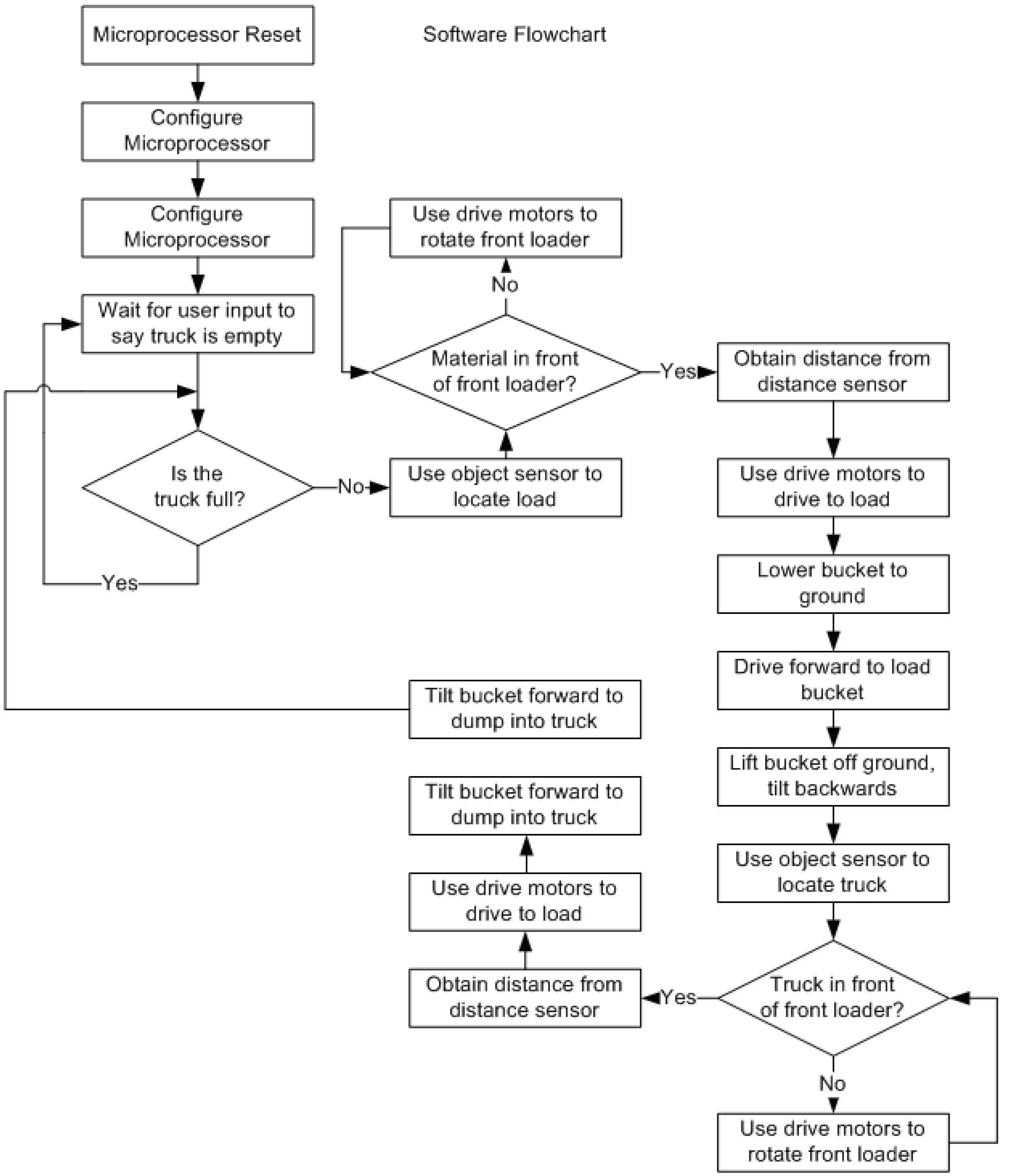

Figure 4: Software flowchart.

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.

These are the primary functions required to be in the microprocessor. There will be additional modules added for initialization of the microprocessor and whatnot, but those do not add detail about the project description.

Conclusion:

As was discussed in this document, the goal of the autonomous front end loader is to be able to control a front loader to do a basic task, load a truck from a pile of material, without human input. More specifics were given on the required hardware, and interaction between different pieces of hardware was clarified. A basic software process flowchart was also provided to give an idea of what the microprocessor will have to do.