Autonomously Controlled Front Loader
Functional Requirements List and Performance Specifications

by

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Submitted to:

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Introduction:

This paper discusses the requirements for the Autonomously Controlled Front Loader project to be completed for EE 451 and EE 452. The goal of this project is to build a front loader from a pre-existing vehicle or kit, and modify it so that it operates as a relatively inexpensive autonomous vehicle. The front loader will need to determine between two objects, a truck and a pile of material. The front loader will move to the pile of material and load the bucket with it. Once the bucket is loaded, the front loader will drive to the truck and dump the material into the truck. The front loader repeats this process until the truck is full. The vehicle should complete at least three cycles of this without replacing the batteries.

Sensors will need to be added to the front loader so that the vehicle can operate on its own. The front loader will need a sensor to determine how far away an object is, whether an object is of interest, and how far the tracks have moved when the vehicle is in motion. Currently, the project is in the investigation stages, which means the sensors that are going to be used have not been decided on yet, and additional sensors may still be needed. Because of this, requirements referring to sensors are left rather general, in agreement with the advisors advice.

The remainder of this paper will talk about the system in more detail, by providing over-all system block diagrams and requirements for each subsystem in the project. For a more detailed description of subsystems and software operation, please refer to the latest revision of the "Autonomously Controlled Front Loader Functional Description and Complete System Block Diagram" report.

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, as a microprocessor
- Two rotary encoders, for measuring traveled distance on both tracks of the vehicle
- Front end loader vehicle or kit
- Object distance sensor
- Object detection 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. Additional parts to modify the front loader may be needed eventually, but these are the minimum components needed for this to work.

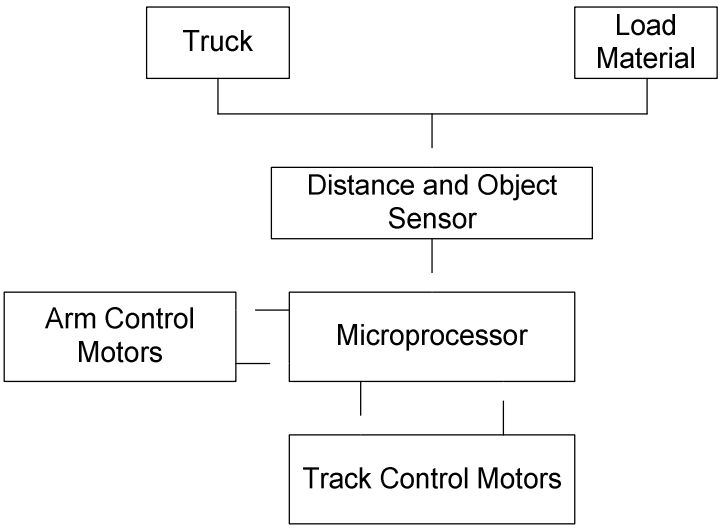

Figure 1 shows a diagram of the interactions between the main components in this system. The primary object in this block diagram is the microprocessor block. The microprocessor receives information about where the truck and pile of materials is from the distance and object sensors. The object sensor is used to tell the truck apart from the material, and both apart from the 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 can send commands to the track control motors to move the front loader to the load or truck. The rotary encoder from each track provides information back to the microprocessor, in order to keep the vehicle moving in the desired direction. 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 controlled 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 to control the tilting of the bucket, to make it more like a realistic system.

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.

Autonomous Front Loader:

This section details the requirements of the overall project, and the following subsections list requirements of each subsystem to allow the overall system requirements to be met. The overall vehicle has a lot of general requirements, so hopefully this format will aid understanding.

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 pulse width modulated (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 by the application of control theory 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 goal, 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, or make it level with the ground. 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 independently. 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.

Conclusion:

This document covered the goals for the Autonomously Controlled Front Loader, and went into details about requirements of the overall vehicle, and requirements of each subsystem. The exact requirements are difficult to pin down at this point in the project, since the project is still in the testing phase. More detailed requirements for sensors and interactions will most likely exist at a later time, but these are the general requirements for the system and subsystems.