Truck Loading Using an Autonomous End-Loader

Project Proposal

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I. Project Summary

The autonomous truck loading project will utilize an end-loader to locate and navigate to a load and scoop the load. It shall then proceed to locate and navigate to a truck and empty the bucket into the truck. This process will continue until it is deemed that the truck is filled. Encoders and beacons shall be utilized to determine end-loader position and motor drive requirements to achieve the desired destination. A Silicon Labs development board will be used for overall system control. The final goal of the project will be to have a functional autonomous system fill the truck as quickly and accurately as possible, while maintaining a low system cost.

II. Detailed System Description

The system will consist of a velocity sensor for the tracks, position sensors for the bucket arms, a bucket tilt sensor, truck and pile location sensors. A Silicon Labs development board shall be used for system control of the end-loader, motors for both tracks and individual motors for the bucket tilt and lift arms. The sensors will feed information about vehicle, truck, load, and bucket positions to the Silicon Labs development board, which will process the information and control the motors via pulse-width modulated signals appropriately. The Silicon Labs development board shall be mounted on the end-loader along with a power source. Figure 1 shows the overall system block diagram.

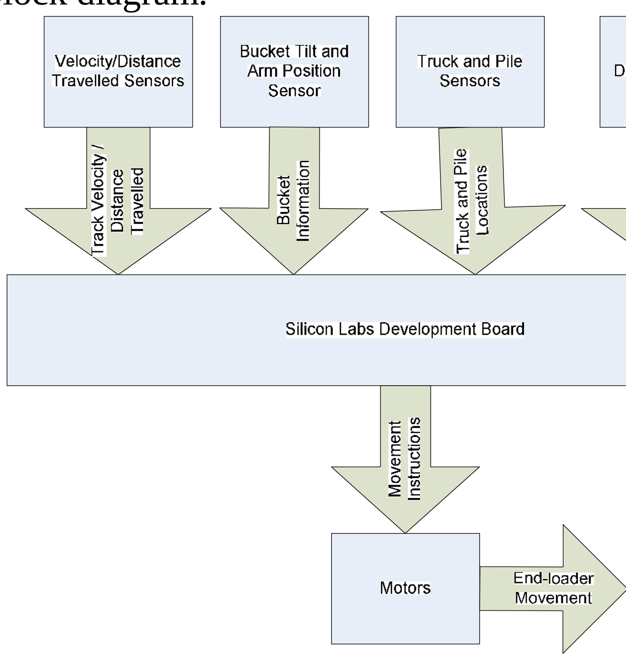

Figure 1: System Block Diagram

Subsystems

As figure 1 illustrates, there are six main subsystems. The subsystems are as follows: the velocity/distance sensors, the bucket tilt and arm position sensors, the truck and pile sensors, the distance sensor, the development board, and the motors.

1. Velocity/Distance Sensors: Encoders

Encoders will be used as a form of velocity and position determination. They will be attached to the drive shaft of the end-loader to determine how far the end-loader has moved based on the previous PWM in order to determine if a higher or lower PWM will be needed during the next timing cycle.

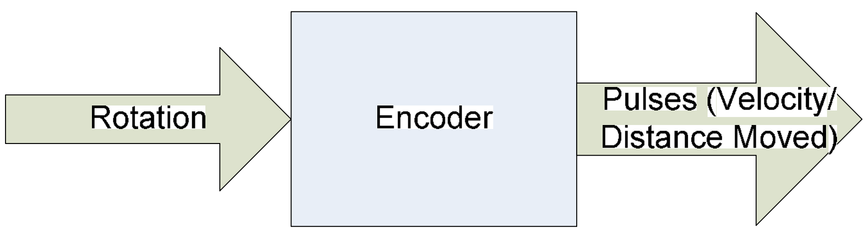

Figure 2: Encoder Subsystem Block Diagram

2. Bucket Tilt and Arm Position Sensors

It is crucial to be able to determine the bucket tilt and arm position during operation in order to scoop and dump the load. The Bobcat vehicle that we will be using has built-in sensors to determine the endpoints for tilt and arm position. While further investigation into these sensors remains, it appears likely that they will suffice.

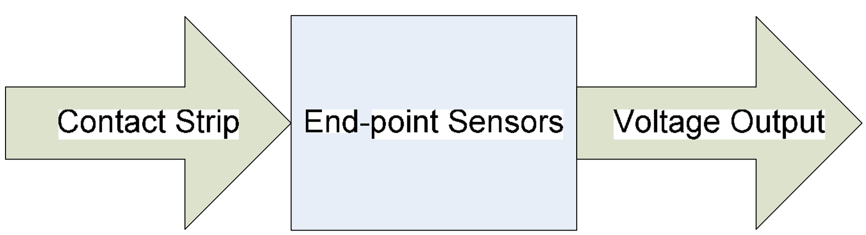

Figure 3: Bucket Tilt and Arm Position Sensors Block Diagram

3. Truck and Pile Sensors: Infrared Beacons

The infrared beacons will be used to determine the locations of the truck and the pile. A beacon will be attached to the pile and the truck. They will be run at different frequencies to differentiate between the pile and truck. The signal, when received by the photo-transistor will allow the vehicle to determine if the object is the pile or the truck.

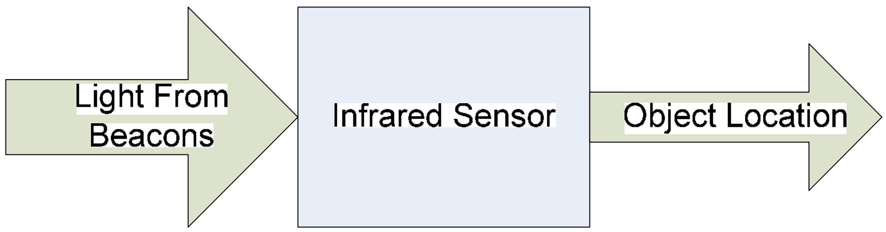

Figure 4: Infrared Subsystem Block Diagram

4. Distance Sensor

It is required that the vehicle be able to accurately determine its distance from the object it is navigating towards - either the truck or the load. Since the signal from the infrared beacons will vary slightly depending on the angle from the beacon, the infrared beacons cannot be used for distance data requiring high resolution. Due to these factors, an ultrasonic distance sensor will be utilized to determine the distance.

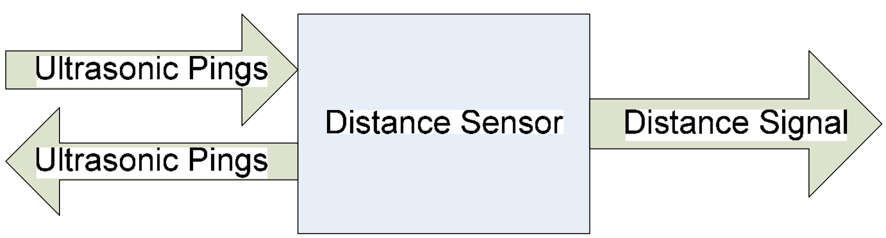

Figure 5: Distance Sensor Subsystem Block Diagram

5. Development Board

At present, a Silicon Labs development board will be used to provide vehicle control, but this will be further investigated to ensure that it will be adequate and allow for future expansion of the project. The board will use the inputs from the infrared beacons and the encoders to provide motor control and to determine the appropriate operation to be undertaken. The development board will navigate to the load or truck and then operate the bucket when needed.

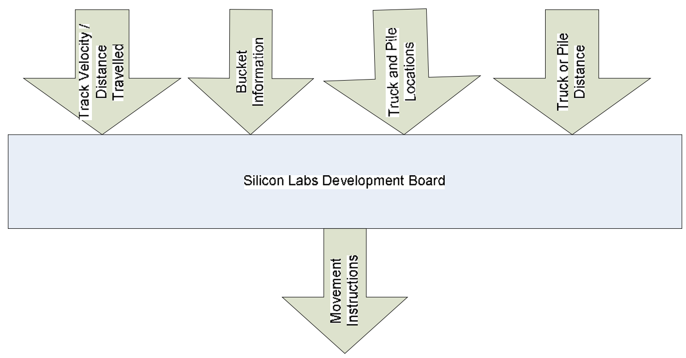

Figure 6: Development Board Subsystem Block Diagram

6. Motors

The motors will provide end-loader movement for navigating to the load and truck. There will be a separate motor to control the right and left tracks in order to provide turning. Both motors will also be able to operate in forward or reverse, independent of the other motor, giving a smaller turning radius as well as the ability to drive in either the forward or reverse directions.

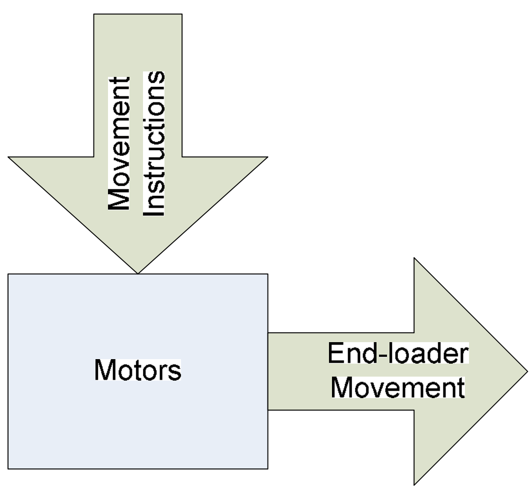

Figure 7: Motor Subsystem Block Diagram

Software Implementation

The overall software flowchart appears in Figure 8. After setting up the interrupts and performing required initialization, the system will wait until our main timer has overflowed and set a flag indicating that the main loop should proceed. This will be done to ensure that control operations are handled at a constant period in order to provide sufficient data from our velocity sensor to determine the PWM drive required to each drive motor to move towards the load or truck.

The microprocessor shall be programmed using assembly language. It shall generate a fixed period pulse-width modulated (PWM) signal for each of the motors. These will control the movement of the tracks, the bucket arm and the tilt of the bucket. A PWM signal will be used to control the amount speed of each motor so that they can be more accurately controlled. The software shall also be able to function independently of user input. Some provision shall also be given for human intervention in case of vehicle problems and for debugging purposes.

After the main loop begins, the software will check to determine if the truck is full, likely to be defined as a certain number of times the loader has emptied a load into it. If the truck is deemed full, the end-loader will stop and wait until a push button is pressed to indicate that the truck has been emptied and the end-loader can continue loading the truck.

If the truck is not full, the software will check the end-loader's position relative to the load and truck. It will also check how far the end-loader has moved based on the previous PWM in order to determine if a higher or lower PWM will be needed during the next timing cycle. If the bucket on the end-loader has already been filled with a load, the end-loader will need to navigate to the truck and empty the bucket into the truck once it arrives. If the bucket on the end-loader is not full, the end-loader will navigate towards the load and scoop up a load once it arrives there.

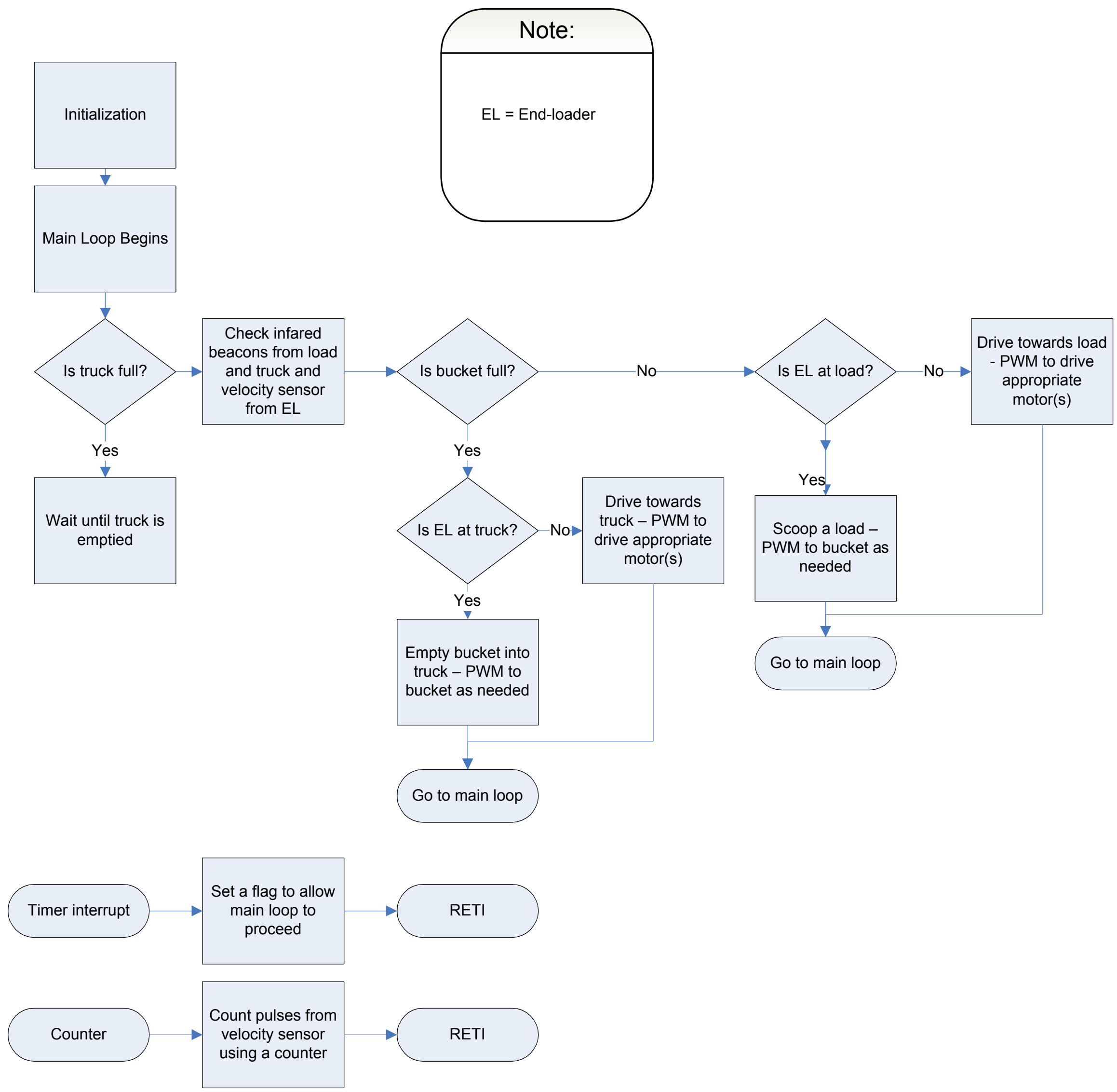

Figure 8: Overall Software Flowchart

The software shall utilize the sensor signals from the beacons to locate the target, either the truck or the pile. It shall also use these signals to determine how to perform the next action. The required action would be driving to the pile and scooping from the pile or driving to the truck and dumping the bucket in the truck. The software shall function in a manner that moves the vehicle and bucket smoothly, without spilling the load or running into the truck. After locating the truck and load, the vehicle shall be able to turn and continue to know where the truck and load are positioned by utilizing the rotary encoders for position data. The information from the rotary encoders will be fed into the microprocessor which shall track the vehicle movement.

The software shall be able to complete the entire loading and unloading process accurately and as quick as possible.

III. Vehicle Requirements

Initially, the vehicle sensors must be able to ascertain the bucket and arm positions. The initial positions of the bucket and arm are essential to determine how the bucket and arm should be moved in order to scoop up the load. The kit that is being used includes these sensors internally. Although further investigation is required, these sensors should be sufficient. Other vehicle sensors shall then be able to locate beacons on a pile of material and the truck that will be loaded, conveying the changing directions and distances to the microprocessor throughout operation. The microprocessor, discussed in greater detail momentarily, will interpret this information to navigate towards the material or truck as needed.

Sensors will be a critical part of the project. Currently these are still in the research phase with ongoing investigation as to the best type to use for each requirement. Mounted on the front of the vehicle, a position sensor shall determine the distance from an object. This information will be fed into the microprocessor which shall combine this data with the data from the beacons to accurately scoop the load or dump the load into the truck. The encoders shall be used to accurately turn and drive the vehicle, better gauging the vehicle movement throughout the process. Figure 9 below shows the location and purpose of each sensor. The vehicle track motors shall be able to sustain vehicle drive for a full or empty bucket.

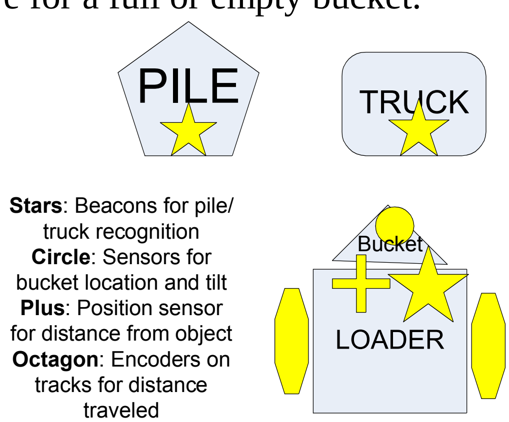

Figure 9: Sensor Locations and Purposes

Once the vehicle has arrived at the load, it shall be able to scoop the load into the bucket if the bucket is empty. After navigating to the truck, the vehicle shall be able to raise the arms and dump the full bucket into the truck. The arm motor shall be able to raise and lower the bucket and the bucket motor shall be able to alter the bucket tilt with both a full or empty bucket. The vehicle batteries shall be able to sustain operation until the truck has been fully loaded five times.

IV. Patent Search

The search for patents and standards revealed little directly related to the project. Patent 6363632 is very similar to our application; however, patent 6363632 is for a larger vehicle – an application that ours would hopefully be able to develop into. The system in patent 6363632 utilizes a laser or radar scanning system whereas our system will likely use infrared beacons to determine positioning, so the systems do not significantly overlap.

Patent Number / Standard	**Brief Description**
6363632	System for autonomous excavation and truck loading
5546093	A system and method for providing navigation signals between first and second earthmoving or construction machines is provided.
6167336	Method and apparatus for determining an excavation strategy for a front-end loader
6151539	Autonomous vehicle arrangement and method for controlling an autonomous vehicle
ISO 10218-1:2006	Requirements and guidelines for the inherent safe design, protective measures, and information for use of industrial robots.
ISO 9283:1998	Manipulating industrial robots -- Performance criteria and related test methods

V. Current Progress

Thus far significant research into the proposed vehicle functionality has been completed. After assembling and significantly modifying the end-loader kit that was initially intended to be used, it was discovered that the initial vehicle had crippling disadvantages. The vehicle wasn't robust and lacked the adequate power to lift much of a load. It also required considerable modification to operate as needed, with no guarantees that it would be powerful enough to operate adequately with the added loads from the scoop, batteries, and processor board. After testing the initial vehicle with various motors and gearboxes intended for it and modifying the vehicle as would be required for future operation, it was decided to try a more durable Bobcat vehicle. The Bobcat vehicle also featured sensors to determine the endpoints of the bucket tilt and position. Significant time has been spent determining if the Bobcat would be an adequate replacement for the initial vehicle and understanding the motor connection circuit board. It was decided that the Bobcat vehicle will be a suitable replacement.

Work has also begun on the sensors that will be employed for vehicle operation. Needing to determine distance from the load and truck accurately, using ultrasonic sensors seemed a nearly ideal approach. It was found that the SRF05 was accurate to less than half of an inch, better than needed. After conceiving of various methods to determine the load and truck position, it was decided to try infrared beacons. To increase the range of the infrared beacons, a current to voltage converter followed by an amplifier with a low pass filter was used. Initial results showed a detection range of about 1 foot, not enough to navigate the vehicle. To increase the range further, a photo-transistor and infrared diode that were more closely matched in peak wavelength were ordered. A more powerful infrared diode, giving us a range of over 3 feet was then acquired. The final sensor that has been worked on is the rotary encoder. The HEF16 rotary encoder was tested to determine if it would be applicable to the project and it was found that with 16 pulses/rev, or 32 pulses/rev using an XOR of the two channels, it should provide enough accuracy.

VI. Lab Schedule

Lab Period	Overall Tasks/Goals	Kevin	Ryan
1/29	sensor mount and test	vehicle modification	vehicle modification
2/5	sensor mount and test	drive electronics	sensor installation
2/12	sensor mount and test	drive electronics	sensor installation
2/19	hardware	circuit board mounting	circuit board mounting
2/26	hardware	testing	testing
3/4	software	pwm generation	interpret sensor data

3/11	software	pwm generation	find truck or pile
3/25	software	navigate to pile or truck	navigate to pile or truck
4/1	software	scoop/dump	scoop/dump
4/8	debug/test	testing	testing
4/15	debug/test	debugging	debugging
4/22	debug/test	debugging	debugging
4/29	final presentation prep	Final Presentation and Report Preperation	
5/6	final presentation	Final Presentation	

VII. Parts List

Below is an initial parts list based on our research and experimentation to date. The Silicon chip will be determined by the advisor based on future expansion possibilities.

1	Bobcat Radio Controlled Bulldozer
1	Silicon Microcontroller (to be determined)
1	Ultrasonic SRF05 Pinger
2	QED123-ND High Power Infrared LED
1	L14C1 Phototransistor
2	LM741CN Opamp
5	.1uF capacitors
1	1Meg resistor
1	10k resistor
1	560k resistor
1	Vector V2X Compass
2	HEF16 Rotary Encoder

References

Dr. Schertz
http://www.google.com/patents?id=e-EJAAAAEBAJ&dq=6363632
http://www.google.com/patents?id=onsbAAAAEBAJ&dq=5546093
http://www.google.com/patents?id=350GAAAAEBAJ&dq=6167336
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