ELEC 490 PROJECT BLUEPRINT DOCUMENT

Group 13
Monitor and Control of an Excavator Robot

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FOR
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Executive Summary

In the first two months of the project, important milestones were met and the project is on track to complete the original project requirements according to schedule.

The main hardware focus thus far has been to test all existing hardware, including sensors; current drivers; and wireless transceivers. Replacement parts were procured. A suitable excavator was chosen and ordered. An HC11 microprocessor was obtained from Tech Services and was tested to ensure all ports were functioning.

Software programming tasks were completed for both the graphical user interface and the HC11. For the user interface, a 3D model of the robot arm and bucket were developed, with the ability to rotate about the joints. HC11 assembly code was written to accept sensor inputs and communicate with the PC.

The main problem encountered so far was procuring a durable excavator. A suitable one was found from a British vendor but could not be shipped for this semester.

This setback will not impact the group's schedule or project goals, as other important components of the project were worked on during the first two months. All the goals on the initial timeline have been met, and the project is on schedule for completion.

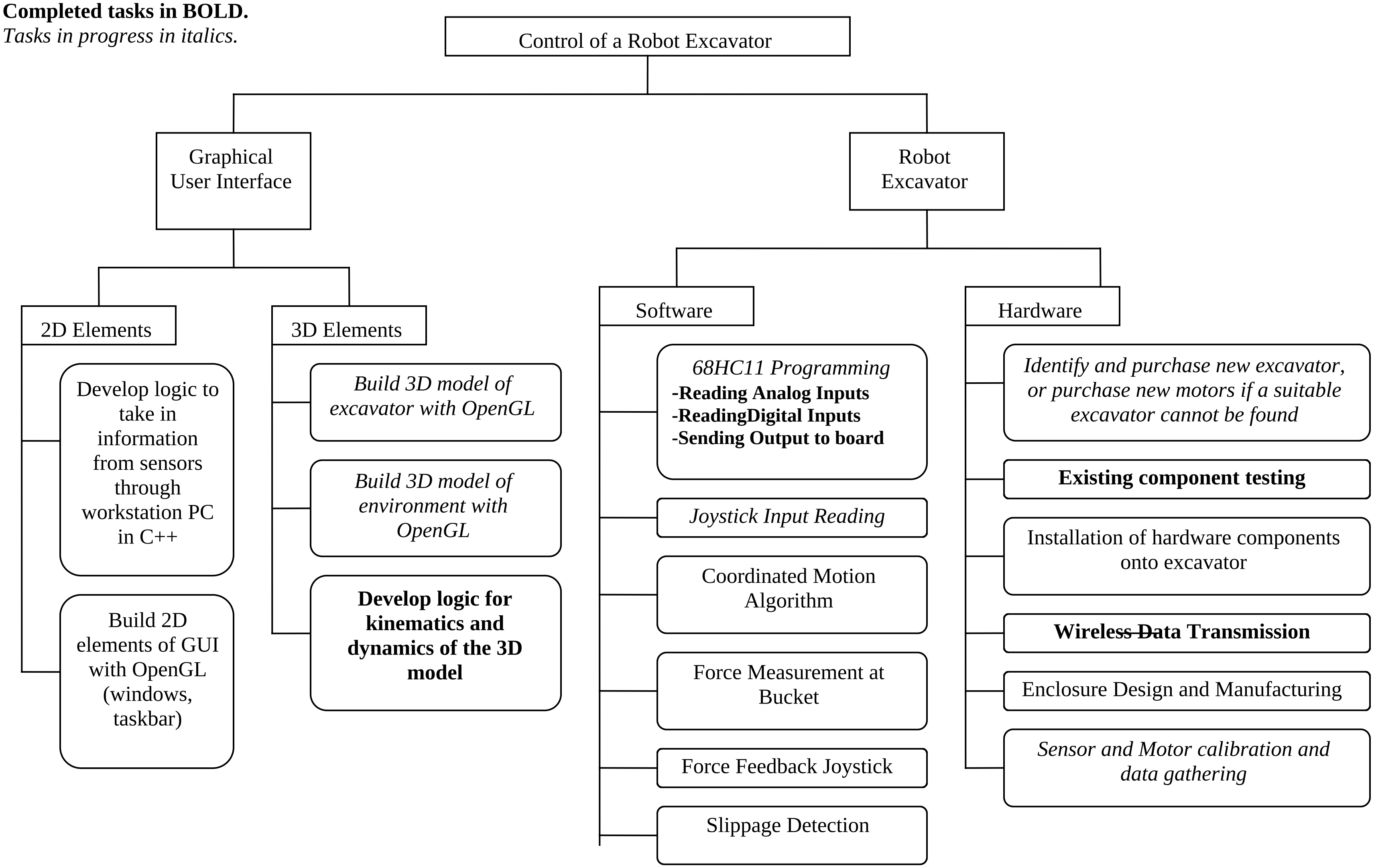
Table of Contents

1.0 - Introduction

This project blueprint is intended to present the progress to date, and outline the project strategy for the second semester. It contains a work breakdown, as well as a detailed budget as well as outlining potential problems and corresponding contingency plans. The intended audience is the course instructor, Dr. Michael Greenspan, and the faculty supervisor Dr. K. Hashtrudi-Zaad.

2.0 – Work Breakdown Structure

Completed tasks in BOLD.
Tasks in progress in italics.



TASK	PRIMARY Contact	SECONDARY Contact
Identify and purchase new excavator, or purchase new motors if a suitable	Ryan Murphy Vuk Zrnic	Alan Lo
Existing component testing	Ryan Murphy Vuk Zrnic	Alan Lo
Installation of hardware components onto excavator	Ryan Murphy Vuk Zrnic	Alan Lo
Wireless Data Transmission	Vuk Zrnic	Ryan Murphy
Enclosure Design and Manufacturing	Vuk Zrnic	Ryan Murphy
68HC11 Programming	Ryan Murphy	Vuk Zrnic
Sensor and Motor calibration and data gathering	Ryan Murphy Vuk Zrnic	Alan Lo
Joystick input reading	Ryan Murphy	Alan Lo
Coordinated Motion Algorithm	Ryan Murphy	Vuk Zrnic
Build 3D model of excavator with OpenGL	Alan Lo	Ryan Murphy Vuk Zrnic
Build 3D model of environment with OpenGL	Alan Lo	Ryan Murphy Vuk Zrnic
Build 2D elements of GUI with OpenGL (windows, taskbar)	Alan Lo	Ryan Murphy Vuk Zrnic
Develop logic to take in information from sensors through workstation PC in C++	Alan Lo	Ryan Murphy Vuk Zrnic
Force Measurement at Bucket	Vuk Zrnic Ryan Murphy	Alan Lo
Force Feedback Joystick (Time Permitting)	Ryan Murphy Alan Lo	Vuk Zrnic
Slippage Detection (Time Permitting)	Vuk Zrnic Alan Lo	Ryan Murphy

Table 2.0.1 – Division of Labour

3.0 – Revised Project Timeline

The timeline has been revised due to the fact that the excavator will not be received until early January. It is shown in Appendix-II.

4.0 – Progress To Date

4.1 – Hardware

The first hardware task of the project was to obtain a larger, more durable excavator than last year's 18inch model. No suitable models could be found within Canada but a large model was found from a British vendor, the Ripmax Big RC Earth Mover. The excavator has been ordered and is scheduled to arrive in early January. Without the excavator in hand, component mounting was not possible as per the original timeline. Upon receiving the excavator, it will be equipped with hardware as shown in appendix illustrations A1 and A2.

The existing hardware components to be tested were: three digital encoders; two potentiometers; wireless transceivers; and the current driver board equipped with H-bridges and a voltage regulation circuit. The encoders were tested by applying 5V power to the encoders and viewing the two output waveforms on the oscilloscope as the knob was turned. One encoder had visibly burnt out and another had a damaged pin that had been soldered but still did not produce a clean square wave output. One replacement encoder was ordered. The potentiometers were tested by applying 5V DC source and monitoring the varying output voltage on the oscilloscope as the knob was rotated and thereby changing the internal resistance. Both potentiometers were working correctly but only one could be detached from the previous excavator so a replacement was ordered as well as a backup. The H-bridges were tested by powering them with a 12V DC voltage to the PCB board and applying a 0V or 5V voltage to the input of each individual H-bridge and monitoring the output pins. All H-bridges were functioning correctly and backups are available. The voltage regulation circuit was tested by applying 12V DC to the PCB board and the voltage at the output pins was 5V.

4.2 – HC11 Programming

A minor modification has been made to the design approach. The dual chip version of the HC11 will be used to read the sensors and control the motors, instead of the originally intended HC12. The reason for this is because even though the HC12 is a faster chip, the HC11 PCB board is smaller. The overall system architecture remains unchanged.

The HC11 has been programmed to accept the digital encoder inputs on port A as well as port C. Two pulses from each encoder can be read at the same time. The digital inputs can be monitored with either a timing interrupt or by using an interrupt when the value has changed logic states. These two methods will be tested and compared for accuracy before the final method is chosen. Encoder readings (pulses) will be sent to the workstation, to be converted into displacement readings.

The HC11 has also been programmed to read a voltage between 0-5V on the A/D converter on port E. The A/D conversion is working correctly to read the analog potentiometer inputs. The A/D converter outputs were read on the appropriate 8 bit register. The 8 bit register provides 256 possible values while the potentiometer has a 295 degree range. This allows for readings accurate to within (295/256) 1.15 degrees. The A/D converter will also be used to read the voltage across a known resistance value to determine the magnitude of current outputted by the current drivers. The HC11 is capable of reading up to eight analog inputs and six analog readings will be needed for two potentiometers and four current drivers (H-bridges). Voltage readings from the potentiometers and current drivers will be sent to the workstation in order to calculate parameters dealing with the motion of the boom, stick, and bucket and external forces.

4.3 – GUI Programming

The GUI will be developed in C++ using the OpenGL API. OpenGL and a C++ editor/compiler have been installed on a laptop.

3D models of the boom and the stick have been developed. Each object has been built as a separate class, as part of a hierarchical model. The hierarchical design allows for each object to have its own local coordinate system. The benefit of using local coordinate systems is that when the entire excavator is translated in 3D space, the coordinates of each individual object do not have to be changed.

Since the excavator will not be received until early January, the model has been kept as a low detail wire-frame. The focus was shifted on kinematics of the 3D model. The boom and the stick can be rotated and translated in 3D space. The stick and boom can be rotated in the positive and negative direction along its rotation axis about the hinge joint. Clicking the left mouse button increases the angle of rotation in the positive direction by two degrees, and clicking the right mouse button increases the angle of rotation in the negative direction by two degrees. Similarly, the boom and stick can be translated using the left and right cursor keys to increase or decrease its x-axis position component. Eventually, the mouse and key presses will be replaced by sensor data.

5.0 – Budget

A $150 budget increase was requested and approved, in order to secure the desired excavator from the United Kingdom. All the required hardware has been purchased, and the project will be completed within the $550 budget. The budget appears below in Table 5.0.1.

Anticipated Expenses (Not Received)		
Description	**Cost ($CDN)**	**Vendor**
Excavator (1:12 scale, with batteries and charger)	$ 277.72	Seventh Avenue
Enclosure Materials	$ 50.00	Home Hardware
Wiring Materials (cables/connectors)	$ 50.00	DigiKey
Total Anticipated	**$ 377.72**	
Confirmed Expenses (Received by group 13)		
Description	**Cost ($CDN)**	**Vendor**
Joystick (Logitech, USB)	$ 34.49	Future Shop
Potentiometers (2 units)	$ 12.19	DigiKey
Battery Charger (with 10 NiMH batteries)	$ 47.75	Tiger Direct
Encoder (EC202V050A)	$ 47.00	DigiKey/DigiCan
Total Confirmed	**$ 141.43**	
Group Budget	**$ 550.00**	
Remaining Funds	***$ 30.85***	

Table 5.0.1: Project budget

6.0 – Potential Problems and Risk Mitigation

The potential problems and contingency plans are outlined in Table 6.0.1.

RISK	**LIKELIHOOD**	**MITIGATION STRATEGY**
Motor Burnout	MEDIUM	If motors cannot handle high voltage PWM signals, new step motors will be purchased
Wireless Interference (Wireless communication may become unreliable if excavator is not in close proximity to the workstation)	MEDIUM	Limitation will be imposed on excavator range
Missed pulse interrupts on HC11 leading to incorrect displacement calculation.	MEDIUM	The digital input from the encoders will be read by both a polling technique and also timing interrupts and compared for consistency.
Further excavator ordering delays	LOW	Further delays are available only if shipment gets lost. Replacement excavator can get to Kingston in 10 business days.

Table 6.0.1: Potential Problems and Risk Mitigation

7.0 – Conclusions

The group is on schedule to complete all original goals.

The excavator is scheduled to arrive early in the new year (before the end of the winter holidays).

Our ability to read and interpret sensor information was an important achieved milestone, which will allow the group to focus on motor control immediately after receiving the excavator and mounting all the hardware onto it.

Wireless capability has already been established. The biggest challenge facing the group is integrating all the systems into a functioning, autonomous package.

Full wireless control, coordinated motion, force feedback and real-time GUI will be implemented and demonstrated at the end of the winter term.

8.0 – References

[1] Vuk Zrnic, Alan Lo, Ryan Murphy, (2005). *ELEC490 Project – Remote Control of An Excavator Robot, Third Generation,*
Queen's University, Kingston, Canada.

[2] Shamir Charania, Noel Johnston, Tavis MacCallum, (2004-2005). *ELEC490 Project – Remote Control of An Excavator Robot, Second Generation,*
Queen's University, Kingston, Canada.

[3] Honeywell Sensing and Control Website
http://content.honeywell.com/sensing/products/resistors

[4] Discussions with Faculty Supervisor: Dr. Kevyan Hashtrudi-Zaad

[5] Weekly Progress Reports

Appendix 1 – Wiring Schematic

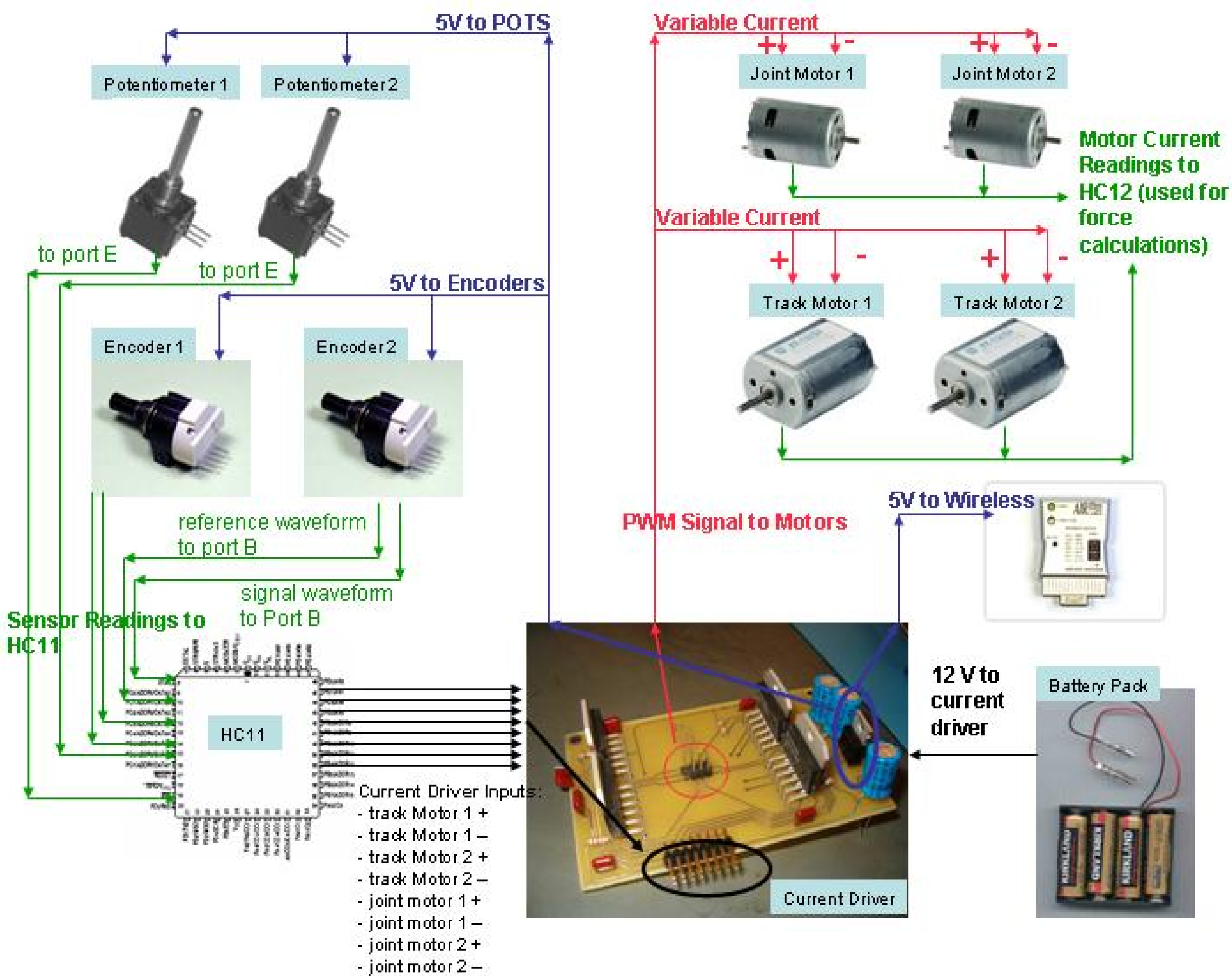


Figure A.3.1 – Wiring Schematic

Appendix 2 – Hardware Placement

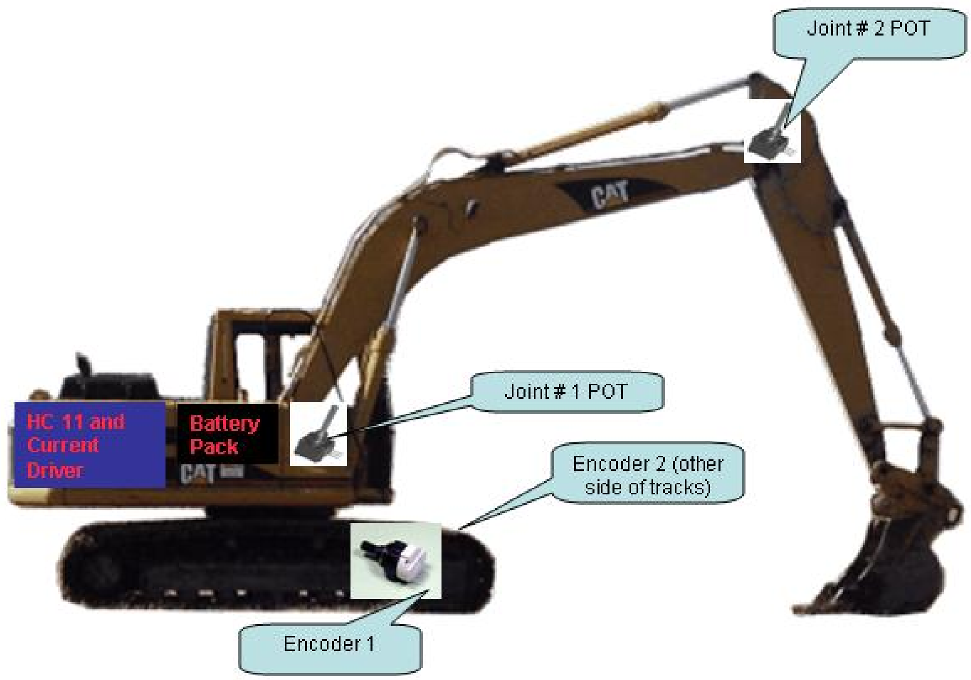


Figure A.2.1 – Hardware Placement

Appendix 3 – Project Timeline

Date	Graphical Interface	Hardware	Software
Oct-24	Build a 3D model of the excavator	Acquire 68HC11	
Nov-01		Purchase Excavator	Communication with Joystick
Nov-15		Test Sensors and PCB components. Order replacements	Calculate desired motor speeds based on joystick position
Dec-01	Build logic to move the excavator with proper physics, pertaining to velocity and displacement.	test PCB	Write HC11 logic to read sensor input
Dec-15		test wireless communications	Coordinated motion calculations coded
Jan-01			Write HC11 logic to drive motors
Jan-15	Build logic to move the boom and stick with proper physics, pertaining to position, angle and torque.	obtain excavator and preliminary wiring	Write HC11 logic to read motor loads
Feb-01		Mount Sensors and install motors	Joints angles and track displacement calculated from sensor outputs
Feb-15	Integrate with hardware	Test sensor accuracy	Wireless communication between HC11 and PC
Mar-01		HC11 and PCB mounted in enclosure	Bucket force calculations from motor loads
Mar-15			Force feedback joystick implemented
Mar-29	Complete All Goals		

Table A.3.1: Project Timeline