



Design of a Lab-based Development Platform for Teleoperation

Summary

Scion and the University of Canterbury Mechatronics Programme are working on a collaborative project to develop a prototype teleoperated excavator to harvest plantation forests on steep terrain. The first stage of the project is to build a lab-based development platform for the teleoperation system. This report presents the concept design of the development platform which includes a miniature hydraulic arm with three degrees of freedom and the corresponding control hardware. It will be used to develop a teleoperated system in a lab environment before retrofitting an excavator for teleoperation. A bill of materials with price estimates, overall dimensions and a layout diagram of the development platform are also presented.

Paul Milliken, Scion

Introduction

As part of the PGP Harvesting research programme, Future Forests Research engaged the University of Canterbury Mechatronics Programme and Scion to develop a teleoperated excavator for steep terrain harvesting. Some of the development of the teleoperation system will be accomplished most easily in a laboratory environment. Therefore a bench top miniature hydraulic arm has been proposed as a platform for much of the development.

The main advantages of this approach are:

- more convenient lab-based development of wireless communications, user interface, video and audio feedback, interlocks and semi-automation;
- much of the development can be done without requiring an excavator; and
- The lab-based development platform will also be useful for another FFR project known as Task B.

The main disadvantage of using a lab-based development platform is that it will not be able to be tested in a harvesting application.

The objective of this report is to present the detailed system design for a lab-based test bed that will be used for the development of the teleoperation system for an excavator. The

system will enable proof of concept and optimisation of the Future Forest Research teleoperation task prior to integration on a full scale machine.

The proposed scaled-down system is to allow testing of various new and novel control methods and monitoring concepts. The benefits stemming from the use of such an approach are that the work can be conducted thoroughly in a safe and cost effective way at the University of Canterbury, in conjunction with Scion.

Once proved, the appropriate techniques and technologies can be transferred to a hydraulically controlled felling machine and tested in situ, in a forest environment. Further developments can then be tested in the lab and later proved in the field, on an incremental basis.

Detailed Design of the Lab - based Development Platform

A. Arrangement of Components

Remote control of the system will initially be over a Wi-Fi connection (802.11g) to a single-board computer (SBC). The SBC will interface with the programmable automation controller (PAC) using the OptoMMP memory-mapped protocol for programming (Opto22, 2010). The PAC will, in turn, control the three hydraulic rams via solid-state relays and 0-10 volt analogue signals. The



solid state relays will control the rams' solenoids and the analogue signals will control the rate of flow of hydraulic fluid. The rams will be fitted to a robot arm with a similar geometry to an excavator arm. A diagram of the components of the lab-based development platform is shown in Figure 1.



Figure 1: Diagram of connections between components of lab-based development platform.

B. Options for the development of a hydraulic test-bed

Trinder Engineers of Nelson supplied two options for the construction of the hydraulic arm for the development platform for use in the University of Canterbury research laboratories.

Price estimates for both options were supplied by David Aitchison, Development Manager at Trinder Engineers in May 2012. The two design options for the hydraulic arm were either a purpose built 3-axis lab-based hydraulic

excavator front end attachment or a refurbished mini hydraulic excavator front end attachment.

1. Purpose built lab-based hydraulic excavator front end attachment

In this option the system would consist of a safety cage, a single phase powered hydraulic pump, proportional control valves and ancillary equipment. In addition there will be three actuators (two linear and one rotational) integrated into the lab-based excavator arm.



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Outline specification of the lab-based test bed;

- 1 x 1.1 kW single phase hydraulic power unit complete with triple pump, 3 station manifold with compensator and relief valves, 3 x proportional directional valves, filter, level gauge, filler breather, etc.
- 2 x hydraulic cylinders
- 1 x hydraulic motor
- 1 x safety cage with front opening doors and safety switch for interlocking purposes
- 1 x simple scale model of slew, dipper arm and boom arm mechanisms integrated with the hydraulic actuators to provide a scaled down excavator arm
- The recommended control valve option is for proportional valves with plug-in amplifiers (0 – 10V DC controlled, EHH-AMP-702-D-20)

Estimated system cost: \$23,964 + GST.

A cheaper valving alternative was available, but implementation would require additional effort from the research team to develop the basic servo-valve control requirements such as adjustable ramp time, gain, dead-band compensation and dither (PWM controlled, KDG4V3-S-2C-08N-MU-H5-60).

Using these valves would reduce the system cost by approximately \$3,200 on the estimate for the base three actuator system.

2. Refurbished mini hydraulic excavator front end attachment

In this option the system would comprise a safety cage, a single phase powered hydraulic pump, proportional control valves and ancillary equipment. The bucket and bucket actuator can be disconnected and replaced with an alternative device as required.

Outline specification of the mini excavator front end attachment:

- 1 x single phase hydraulic power unit complete with hydraulic manifold and proportional control valves (suitable for PLC

control), plus ancillary equipment

- 1 x mini excavator front end attachment (arm)
- 1 x safety cage with front opening doors and safety switch for interlocking purposes

In this option the proportional valves are not compensated by the pump, but this should not be an issue for this application.

Estimated system cost: \$15,000 + GST.

Estimated Cost and Bill of Materials

After consideration of the specifications and costs of both options, the second option was chosen.

The arm will consist of a modified and refurbished mini hydraulic excavator front end attachment. The next stage is to specify the exact dimensions of the arm. The miniature hydraulic arm will be completely contained in a cage with width, depth and height of 1300 mm x 1300 mm x 1750 mm respectively.

The total cost of the lab-scale development platform is estimated to be NZ\$31,500 plus GST, which includes a contingency of approximately 20%. A breakdown of the cost is shown in the bill of materials in Table 1.

Conclusions

- Much of the development of a teleoperated excavator for steep-terrain harvesting will be carried out on a lab-based development platform consisting of a hydraulic arm with three degrees of freedom and corresponding control hardware.
- A detailed design of the lab-based development platform was presented with a cost estimate of approximately NZ\$31,500 excluding GST.



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Reference

Opto22, 2010: "OptoMMP Protocol Guide". Manual 1465, 28 October 2010. Opto22 LLC, 43044 Business Park Drive, Temecula, CA 92590-3614.

Table 1: Bill of materials for lab-based development platform

Subsystem	Unit Cost	No. of	Manufacturer	Description
Single board computer in excavator PAC	300	1	Technologic Systems	TS-7558-BOX (Arm single-board computer)
	193	1	Opto22	SNAP-PAC-RCK8 (back pane)
	860	1	Opto22	SNAP-PAC-EB1 (brain module)
	243	2	Opto22	SNAP-AOV-25 (2-ch. 0-10V output)
	56	2	Opto22	SNAP-ODC5-i (Isolated 4-ch. 5-60VDC dig. output)
	233	1	Opto22	Delivery
	500	1	Scion	5, 24, 12V power supplies
Relays	18	6	Opto22	DC60S3 (solid-state relays)
Cabinet	800	1	Scion	Electronics cabinet, connectors, wire ways, wires etc.
Hydraulic arm	15,000	1	Trinder	Fabrication and assembly, two-way hydraulic rams (x3), hydraulic connections, pump and accumulator and proportional valves (x3)
Wifi	142	2	Gowifi	Two Ubiquiti M5 bullets
	32	2	Gowifi	Two rubber-ducky antennae
Remote PC	1,000	1	TalkTechNow	Desktop PC - remote side
Assembly/ testing of control hardware, delivery	6,400	1	Scion	Electrical fit out of cabinet with power-supplies, PAC etc., wiring and testing; transport/delivery of equipment.
Contingency	\$5,160	(~20%)		
TOTAL	\$31,500	(+GST)		