HARVESTING TECHNICAL NOTE

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ROBOTICS FOR STEEP COUNTRY TREE FELLING

Summary

Unmanned machines will be felling trees in New Zealand forests in the future. Initially these machines will be "teleoperated" or remotely controlled with the operator situated either on site or possibly at a distant location. The mining industry has adopted teleoperation, and numerous examples can be found in military operations. One type of teleoperated forest harvester exists in Sweden, and more teleoperated devices are in development. Developers and manufacturers here can learn from the Scandinavian forestry experience and from military developments. We cannot rely solely on these overseas experts to develop a solution for our forests of large piece size wood on steep terrain.

Richard Parker, Scion

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Introduction

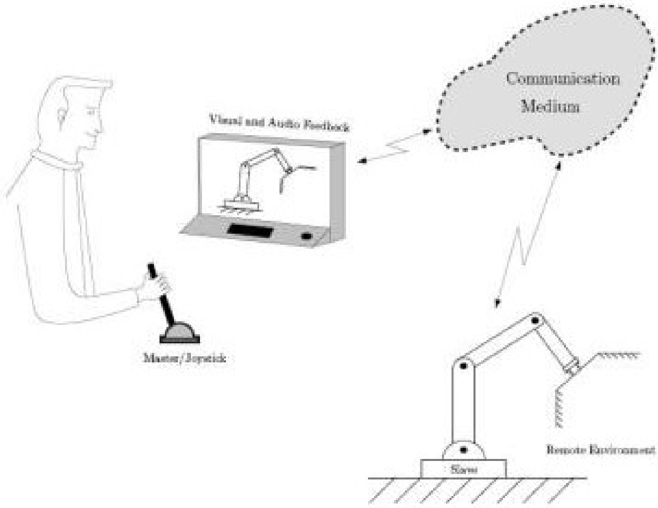
Interest in automation of forestry tasks dates back at least 20 years (e.g., Courteau, 1990). Autonomous and teleoperated off-road vehicles are currently being used in forestry and other industries internationally. In the future the New Zealand forest industry will benefit from the productivity and safety advantages offered by robotic technology.

Robots are currently used in mining, manufacturing and military activities, where they remove people from dangerous and difficult tasks and environments.

Robots used in repetitive and very controlled tasks such as car assembly are fully autonomous. They may be supervised by humans but they do not require regular human control. However robots which operate in less controlled environments such as forests, mines and battlefields currently need some level of human control. Remote control is at the low end of the automation scale. Robots for forestry would be, initially, under human control, called "teleoperation".

Teleoperation

Teleoperation, also called telerobotics, means "to operate at a distance". Teleoperation is the technical term for the remote control of a robot. In a telerobotic system, a human operator controls the movements of the robot from some distance away. Signals are sent to the robot to control it; other signals come back, telling the operator that the robot has followed the instructions. These control and return signals are called telemetry.



The concept of bilateral teleoperation (Hokayem & Spong, 2006).

Future Forests Research Ltd, PO Box 1127, Rotorua. Ph: 07 921 1883 Email: info@ffr.co.nz Web: www.ffr.co.nz

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In a more sophisticated form of teleoperation known as telepresence, the human operator has a sense of being on location, so that the experience resembles virtual reality. For example, a robot can be equipped with sensors that detect sensations of vision and sound, and in some cases pressure and texture. These sensations can then be reproduced at the operator location by means of specialised transducers. The fine motor skills many people take for granted are enormously complex manoeuvres for robots, where continuous, uninterrupted feedback between the machine and its operator are vital. A human may not think about how firmly they should grasp an object, but a robot doing a host of non-repetitive things needs instructions and constant feedback (Hokayem & Spong, 2006).

Applications

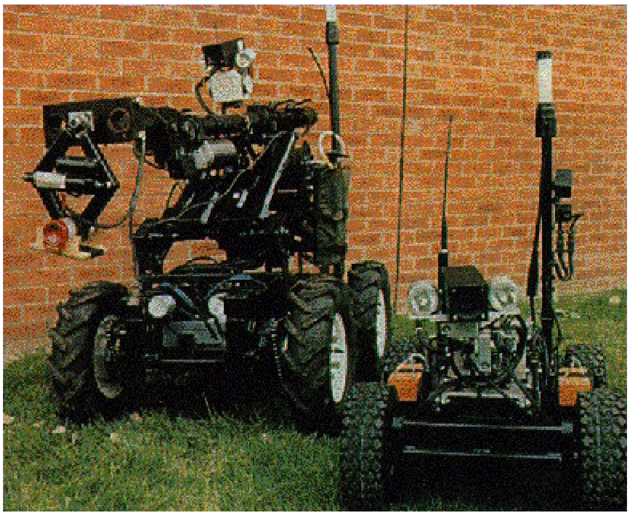
Bilateral teleoperation has been applied over the past 50 years in operations ranging from handling hazardous materials, commanding unmanned underwater vehicles, and operating robots in space, to manoeuvring mobile robots around obstacles.

Handling hazardous material

The earliest application of teleoperated manipulators was handling radioactive nuclear materials. The issues involved with such a task include motion scaling, visual feedback, workspace constraints, and force feedback (Clement *et al*., 1985).

Mobile robots

Once operating in a remote location, mobile robots send visual feedback to the human operator that allows her/him to assess the surroundings and issue a corrective command. However, this requires a high bandwidth to transmit real-time visual data to the operator, and the camera has a limited viewing angle.



Anti-terrorist application of teleoperated robots.

This led to the development of an interface that provides the operator with tactile feedback (known as a haptic interface), such as sending an extra force feedback signal to the operator allowing him to sense the surroundings of the mobile robot and reduce the need for high quality visual feedback. Haptic devices, such as seats that vibrate with the machine movements and hand controls that can feel the forces on the hydraulics help the operator control the robot (Diolaiti and Melchiorri, 2002).

Robots Working Today

An example of the extremes possible with a huge military budget is the MQ-9 unmanned air vehicle (UAV) known as the “Reaper”, which is flown by a crew on the ground situated anywhere in the world.

The Reaper is armed with bombs and missiles and a squadron is in service in Afghanistan.

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Armed MQ-9 robotic aircraft which is controlled by teleoperation.

An unarmed version has been flown as a long-duration observation platform to monitor forest fires in the United States.

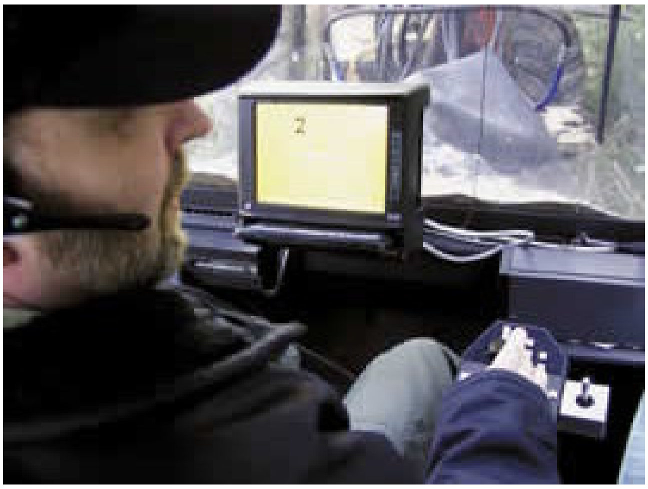
Pilot and sensor/weapons operator of the MQ-9 Reaper unmanned aircraft

Remote control has found some niche opportunities in forestry. An example of a teleoperated robot working in forestry is the Fiberpac AB "Besten", or Beast, developed in Sweden (Bergkvist *et al*., 2006).

The system is known as "Besten & Kuriren", which means the Beast and her Messengers. The system is designed for two forwarders to work with the harvester. Without a cab, the harvester consists of a chassis with six wheels and a boom fitted with a Votec 850 harvester head. Under this system, each forwarder driver takes turns to operate the harvester while still at the controls of their forwarder.

The "Beast" remote controlled harvester (Bergkvist et al., 2006).

The harvester is operated remotely from each forwarder: the measuring system, computer, screen and keypads are located in the forwarders.



Operator position in the forwarder working with the unmanned harvester

While the first forwarder is delivering its load to the roadside, the second operator fells and processes a load of logs directly into the bunk of his forwarder.

Change-over takes place when the first forwarder returns empty to the harvester, regardless of whether the second forwarder is fully loaded. The operators position their forwarders next to the harvester to cut logs directly onto the forwarder bunk. The forwarders are fitted with bolsters that can be folded 30 degrees outwards, and with a bunk that rotates through 360 degrees.

Under specific conditions of stand density and forwarding distance, this combination is less costly than a traditional harvester and forwarder system (Bergkvist *et al*., 2007).

Concept Forestry Robot

The Swedish forestry industry has a long-term goal of developing autonomous and semi-autonomous forestry machines. Some motivations are: reduced cost / increased productivity; reduced training time of operators; and improved working environment, such as reduced risk of repetitive strain injury (Westerberg *et al*. 2008).

A concept forest harvesting machine is being developed by the forest industry in northern Sweden, together with Umeå University and the Swedish University of Agricultural Sciences. They have launched a project entitled “Intelligent Off-Road Vehicle”. The shuttle is a logging machine that transports wood from where it has been felled to larger forest roads. A number of unmanned wood shuttles will be combined with a manned harvester.

The wood shuttle has several advantages. Since the shuttle is unmanned, companies reduce their labour costs. The shuttle is also several tonnes lighter due to the elimination of the heavy, reinforced cab for the operator. In addition, unmanned shuttles can use lighter, less fuel-hungry engines.

The wood shuttle will have two main functions: Path Recording and Path Tracking. In the Path Recording function, the operator remotely controls the shuttle along the desired route from the felling area to an access road in the forest. Positions and speed are then saved in the wood shuttle’s memory. When the information has been uploaded, the operator activates the Path Tracking function. The shuttle then operates automatically along its predetermined route.

Unmanned Wood Shuttle concept vehicle

For more information on this project click on this link:

http://www8.tfe.umu.se/forskning/Control_Systems/Set_Ups/Smart_Crane/index.html

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Robots for New Zealand Forests?

Engineering Factors

Terrain

Remote control also has advantages in situations where an on-the-machine operator might be exposed to hazards such as machine rollover. Currently the only working teleoperated forestry felling machine is the Beast. It is a wheeled machine fitted with band tracks, but there are no data available relating to it working on slopes. Presumably it will work on the same slopes as conventional harvesters and forwarders. Not having a cab would give it a lower centre of gravity, so it may be able to work on slopes steeper than conventional tracked forestry vehicles.

Tree Size

Larger tree size may not be a problem for the Beast. A Skogforsk study of the Beast reported it handling stems of an average volume of 0.94 m^3 (Bergkvist *et al*., 2006). The authors reported that the harvester may do better in larger piece size because there would be fewer pieces to handle to maintain productivity.

Human Factors

Unmanned vehicles still need human operators. The mining experience has shown that there are advantages to having experienced operators teleoperating machines. The mining industry even ensured the sounds from the controlled machine could be heard by the remote operators to improve their performance.

Issues that have been identified by military human factors and ergonomics specialists include:

- Limited field of view of the operator
- Orientation of robot in relation to terrain so operator can sense terrain
- Camera viewpoint so operator can understand where machine is
- Poor depth of field perception making it difficult to see hollows and rises in the terrain
- Time delay between operator control and robot movements
- Motion sickness of operator because his eyes see movement but his body is motionless (Chen *et al*., 2007).

Teleoperation provides potential for safe access for machines to areas that would be off limits to manned vehicles. The mining industry is adapting mine design so that safety criteria that are not acceptable for manned vehicles can be relaxed to standards that are acceptable for unmanned vehicles.

The automation of harvesting and forwarding will change the industry in the future. Some impressive developments in forest harvesters have been described, mainly targeted towards the easier terrain of the Scandinavian forests.

Before complete autonomous harvesting becomes possible, some of the robotics technology related to online simultaneous localization and mapping techniques must come to fruition.

In New Zealand forestry, Scion has developed some capability in teleoperation through a joint programme with Industrial Research Limited, developing force-feedback hand controllers for the meat industry robotics programme. The next stage of this project is to investigate the practicality of possible teleoperated forest machines for steep country tree felling.

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