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Enhanced performance of delayed teleoperator systems operating within nondeterministic environments

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ENHANCED PERFORMANCE OF DELAYED TELEOPERATOR SYSTEMS OPERATING WITHIN NONDETERMINISTIC ENVIRONMENTS

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THESIS CERTIFICATION

I, Laurence Bate, declare that this thesis submitted in fulfilment of the requirements for the award of a Doctor of Philosophy in the School of Electrical, Computer and Telecommunications Engineering, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualification at any other academic institution.

Laurence Bate

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ABSTRACT

Bilateral force feedback teleoperation provides the operator with an enhanced real-time understanding of the remote slave environment. It is common for an uncompensated delay within a closed loop path to lead to system instability.

The control problem becomes significantly more complex when the delay conditions are not foreseeable. A good example of such conditions is when the feedback control loop includes the internet, as in remotely controlled teleoperators. Closed loop bilateral teleoperation via a communications path which has no clearly defined or predictable delay time presents difficulty in maintaining both robust stability and adequate system performance for all delay conditions.

In light of this researchers have developed a new transmission line based control law through the introduction of the 'Wave Variable' to enable stable teleoperator systems in the presence of network delays. However wave variables, by their inherent scattering design introduce reflections at the wave junctions. These reflections can prove very disorientating for the operator of a wave based teleoperator.

In this research the existing wave variable teleoperator architecture is augmented to establish stable robust bilateral teleoperator operation which minimizes the return wave based reflections, thus facilitating good teleoperator performance characteristics to allow operation in nonlinear environments.

The work presented in this thesis results in a new teleoperator architecture which: 1) improves wave based teleoperator transient response for the tasks of position tracking and contact stability without the need for prior knowledge of the remote environment wave reflections; 2) enhances force feedback fidelity, with particular focus on the ability to use the teleoperator in complex nonlinear environments such as stick-slip friction; 3) guarantees stable operation of the teleoperation without prior knowledge of the communications delay.

The new delayed bilateral teleoperator architecture is tested by simulations, and experimentally and comprehensively verified on two different teleoperator systems. One of these is a bilateral single degree of freedom teleoperator which consists of Master and Slave manipulators of identical characteristics; the other test bed consists of a Slave manipulator built specifically for non linear stick-slip control experiments.

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