Design of an Excavator Testbed to Evaluate Operator Efficiency for Novel Human Machine Interfaces

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Mobile, multi-degree of freedom, hydraulic equipment commonly used in construction, agriculture, mining, and forestry have non-intuitive kinematics that require extensive operator training and experience to perfect. Industry studies show that even experienced operators continually make small errors when operating such equipment because of the large cognitive load. By reducing the number of operator errors, more intuitive human machine interfaces (HMIs) can boost operator efficiency, or in other words, allow the operator to complete the same task in less time. This causes greater productivity and fuel efficiency.

Coordinated control and other methods have been applied to multi-DOF systems, fluid-powered or otherwise, and have been shown to increase operator control and efficiency. However, no in-depth research has been done on what underlying control principles are best used to maximize operator efficiency specifically for mobile hydraulic equipment. The poster shows a testbed developed to study human-machine interfaces for such multi-DOF machines in order to research what control laws and feedback are best suited for off-road hydraulic equipment to maximize operator efficiency.

To test HMIs, the standard and new interfaces must be tested against one another on machines doing the same task in the same environment. Changing the controls on a real machine is time consuming and can be expensive. In order to bypass these difficulties, simulators are constructed so that different HMIs can easily be switched in and out for testing purposes. Simulation also allows the environment to be standardized for all tests. The simulator show on this poster is a Bobcat 435 mini-excavator. A realistic graphical interface, complete with sound, has been written that exceeds the quality of current academic simulators. The graphical interface is placed together with dynamic models of the excavator's hydraulic and mechanical systems developed from manufacturer data, into the cab of the mini-excavator. A new soil model was created to incorporate all possible motions of the bucket through the soil in order to realistically reflect the dynamics of the bucket-soil interaction.

Two coordinated control schemes are shown along with results from preliminary tests run to measure increases in operator effectiveness and machine fuel efficiency.