Potential Benefits of Cooperative Shared Control

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Introduction

Advances in technology place ever increasing demands for effective interactions between humans and machines. Human-machine interaction (HMI) that incorporates shared control, in which the human and machines both simultaneously influence the outcome, may lead to a more natural interaction between people and machines [1]. This natural interaction could be particularly beneficial in assistive devices that are used to increase, maintain, or improve capabilities of individuals.

This research focuses on blended shared control, a form of control where human and machine simultaneously influence the outcome of a system [2]. This new form of shared control could lead to more natural interaction between humans and machines. This was investigated in two ways: cooperatively and competitively.

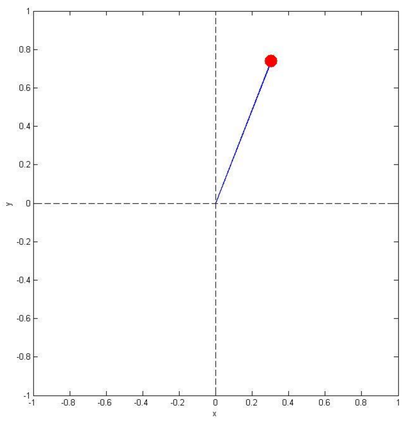
1. Cooperative Shared Control: In this scenario the human and the artificial controller work together to achieve the same goal.
2. Competitive Shared Control: In this scenario the controller and the human work together to achieve the primary goal, but a secondary goal is also present that only the human tries to achieve. This may results in conditions where the human may need to compete with the artificial controller to achieve the secondary goal.

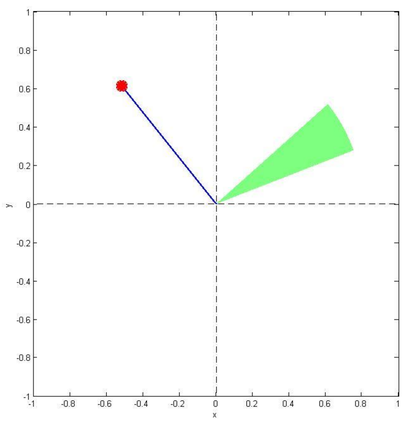
Methods

An interactive computer simulation of an inverted pendulum was developed using Matlab. The simulation uses input from a human and an artificial controller which work together to balance the pendulum. A proportional-derivative (PD) controller was used for the artificial controller. Input from a human operator was obtained using an Xbox 360 controller, with biofeedback provided by a flat panel display (lower right figure).

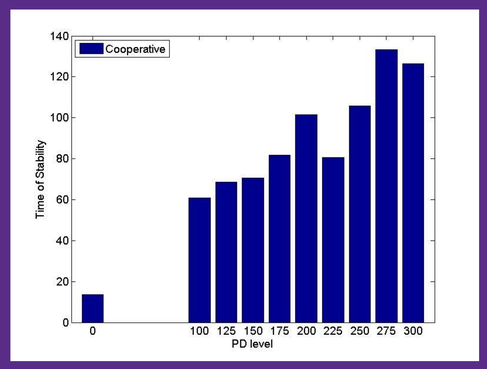
In the competitive shared control simulation, the primary goal was to balance the inverted pendulum. The secondary goal was to position the pendulum within a target region (green pie shaped area in the lower left figure).

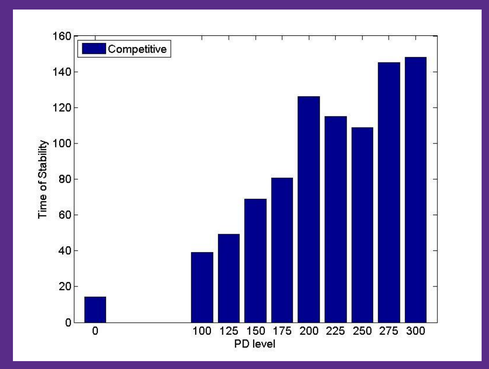
A total of 20 participants for the cooperative shared control and 12 participants for the competitive shared control were evaluated at 26 different testing conditions in a pseudo-randomized order. Each test condition was repeated three times for each participant and the result for each test condition was averaged.

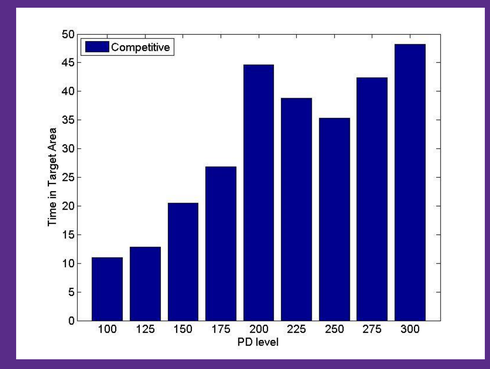


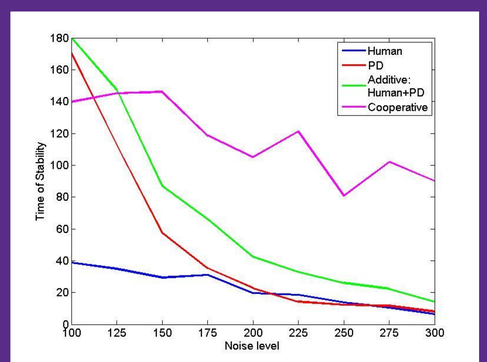


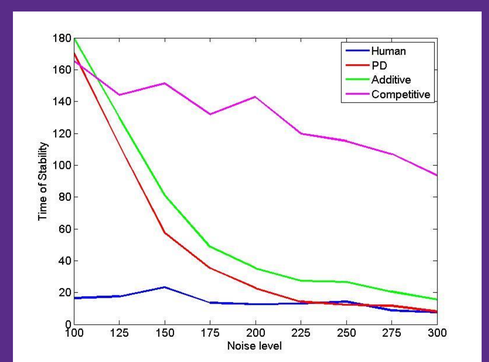
Results

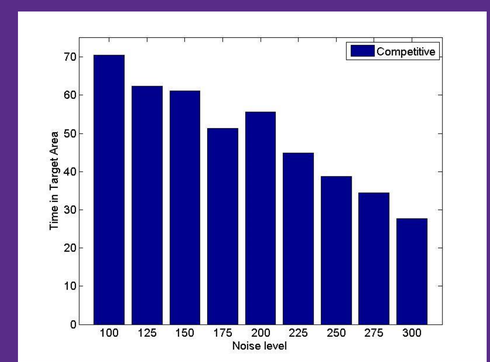












Cooperative Study

Goal:

Balance pendulum for as long as possible.

Performance measured by time above x-axis

Results:

Performance increases as PD level increases **(top)**.

Overall cooperative performance is better than PD alone **(top)**.

Overall cooperative performance is better than the sum of a human working alone and PD alone **(bottom)**.

Competitive : Primary Goal

Primary goal:

Balance pendulum for as long as possible.

Performance measured by time above x-axis

Results:

Performance increases as PD level increases **(top)**.

Overall competitive performance is better than PD alone **(top)**.

Overall competitive performance is better than the sum of a human working alone and PD alone **(bottom)**.

Competitive : Secondary Goal

Secondary goal:

Keep pendulum within target region for as long as possible.

Performance measured by total time in target region

Results:

Performance increases as PD level increases **(top)**.

Overall competitive performance is better than PD alone **(top)**.

Overall competitive performance is better than the sum of a human working alone and PD alone **(bottom)**.

Conclusion

The results from both the cooperative and competitive shared control testing were very promising. The results showed that blended shared control can outperform a human and that higher performance can be achieved by increasing the PD level. Blended shared control can also perform better than an artificial PD controller alone when the difficulty increases beyond the controller's capabilities. This same observation can be made when comparing blended shared control to additive performance. Competitive testing was also able to show that giving the human a secondary task to complete did not interfere with primary task completion. By lightening the load of a primary task, blended shared control could enable someone to perform additional tasks or allow them to perform them better than on their own.

References

[1] A. C. Lopes, G. Pires, L. Vaz, and U. Nunes, "Wheelchair navigation assisted by human-machine shared-control and a p300-based brain computer interface," in *Intelligent Robots and Systems (IROS), 2011* IEEE/RSJ *International Conference on,* 2011, pp. 2438 - 2444.

[2] A. Enes and W. Book, "Blended shared control of zermelo's navigation problem," in *American Control Conference (ACC), 2010*, 2010, pp. 4307 - 4312.