A disturbance emulation system for stability and recovery testing

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1. Motivation

The design and implementation of prosthetic and exoskeleton devices traditionally focuses on helping the subject walk normally on an even surface. However, as these devices become more sophisticated it will become necessary to shift to more dynamic walking situations. In real life, people are subjected to bumps, trips, and other disturbances while walking. By analyzing how people react and recover to these and other disturbances we can determine how to improve our devices for everyday situations and potentially prevent falls and other injuries.

2. Previous Approaches

Studies regarding stability and recovery during walking have been done previously using a variety of systems. The most common method has been to shift or translate the ground on which the subject is walking. For example, a subject unknowingly walks over a surface that moves quickly to the side to throw the subject off balance [1]. In addition, there have been experiments where forces are applied laterally to the subject's torso. The test subject wears a waist harness that is attached to a device capable of pushing or pulling the subject. This emulates the case of bumping into someone or something while walking [2, 3].

These methods are effective for simulating specific types of disturbances. A more universal system capable of creating a wide variety of disturbances would be useful in allowing for more diverse experiments with a single setup. When the system can only create one type of disturbance, the subject quickly becomes accustomed to the type of disturbance being tested. A less predictable system could yield better experimental results as the subject is less likely to change his/her gait to compensate for the anticipated disturbance.
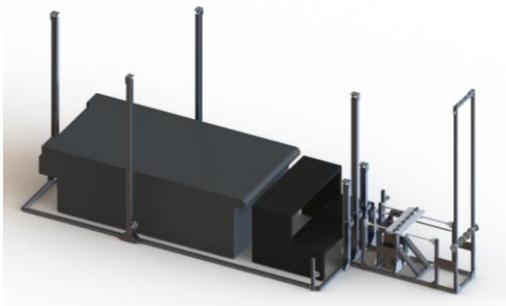
Figure 1: CAD model of the proposed system in place around an instrumented treadmill.

3. Novel Approach

We propose a multi-axis system for disturbance emulation. The system will be able to produce forces in multiple directions and apply those forces to several different locations on the subject. This will allow for greater flexibility in testing and the ability to emulate various types of disturbances with a single test setup.

4. Methods

We are developing a testing device for real-world disturbance emulation. The device consists of a rope and pulley system connected to the subject at one end and a motor-driven platform at the other. The ropes attach to a harness and straps at six points on the subject's body; the front, back, left, and right of the waist and the backs of both the ankles. The other ends of the ropes run through a novel actuated clamping system that allows the motorized platform to pull on one rope without disturbing the others. This allows for a single force to be applied to the subject at a time.

Pulling force on the active rope is measured online using strain gages. A precise pulling force can then be achieved through the use of feedback control, allowing the experimenter to create a variety of simulated scenarios.

5. Results

We have constructed a prototype disturbance emulator and begun benchtop testing. The system can reliably select, engage, displace, and release one of the six disturber ropes. The forces on the rope can be measured with an RMS error of about 3%. In addition, basic force control has been implemented and a desired force on the rope can be maintained.

6. Open Questions

We are still in the prototyping stage, and have not yet fully characterized the system's performance. In the coming months we expect to answer the questions: Can we reliably apply desired disturbance impulses despite the changing human dynamics on the end of the ropes? Will the system's bandwidth be high enough to apply forces at the desired point in the step cycle?

The scientific questions that can be answered using this system include: Do steady-state foot placement control strategies hold for large external disturbances? Can reflex-

like control strategies predict human responses to novel disturbances? Can active balance control with a robotic prosthesis reduce the effort of recovering from push disturbances?

References

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