Kiwii Platform: Using Kinect and Wii board to probe visual and postural effects on balance. Kahori Kita, John Rocamora, Yoshiyuki Sato, Frank Schumann, Scott Yang

To balance the human body upright in space, the nervous system integrates information provided by multiple modalities to control the multiple degrees-of-freedom provided by the body. Balance research often combines motion capture systems and multichannel devices to explore this task. Here we tested whether the Microsoft Kinect sensor and the Nintendo Wii Balance Board can offer a viable low-cost solution to probe visual and postural effects on balance.

We developed a platform to simultaneously record data from the Kinect sensor and the Wii Balance Board. We recorded the 3D joint positions from the skeleton inferred from the Kinect as well as the pressure from the 4 force sensors on the Balance Board (Fig 1). In a prototype experiment we asked the subject to perform a series of balancing tasks. The tasks are combinations of four conditions: 1) open/closed eyes vs. closed eyes, 2) one foot vs. two feet, 3) upper body constraints vs. free movement, 4) lower body constraint vs. free movement.

To validate the consistency between the Kinect and Wii balance board, we tested whether the trajectories of the center of mass from the Kinect and of the center of pressure from the Wii match. We first estimated the 3D center of mass by approximating the weight distribution of a typical human and then calculated the 2D center of pressure. The x-component of the center of mass and pressure trajectories match well for the two-feet standing posture (Fig. 2).

The absence of vision leads to larger and faster movements of the effectors in balancing. Hence, we tested whether lack of vision can be detected in the temporal dynamics of individual joint movements, in the center of pressure, and in the center of mass. Time-frequency analysis reveals faster oscillations in the center of pressure when balancing with eyes closed (Fig. 3).

We tested if some combinations of joints are more important for balancing without visual feedback. We used a linear SVM with cross-correlation coefficients between two different joints as input features and with eye-open or eye-closed conditions as output classes. The success rate of the SVM is 76%, suggesting that coordination between certain joints is more important to balance than others.

To investigate the effect of multiple sensory information, we constructed a simple optimal control model of balancing behavior by using an inverted pendulum model. The optimal controller estimates and controls the position of the center of mass with noisy visual and proprioceptive observations. By varying only visual-noise parameters, the model mimics qualitative differences between the center of pressure data under eye-closed and eye-open conditions. The result suggests that the balancing data of Kinect and Wii can be modeled as an optimal controller with multiple sensory inputs and can be used to evaluate the effects of sensory information on balancing.

In summary, the Microsoft Kinect and Nintendo Wii Balance Board provide a low-cost solution for investigating multisensory effects on human balancing behavior.

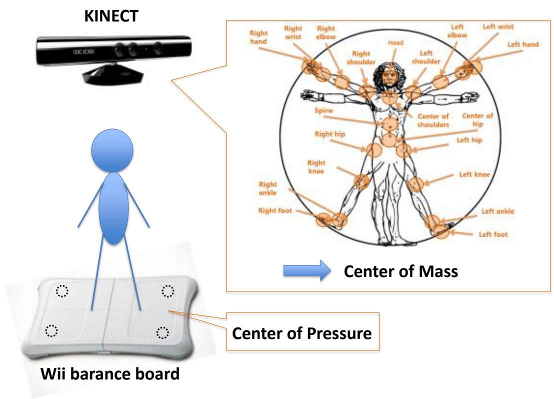

Fig 1: Setup. Combined Wii and Kinect.

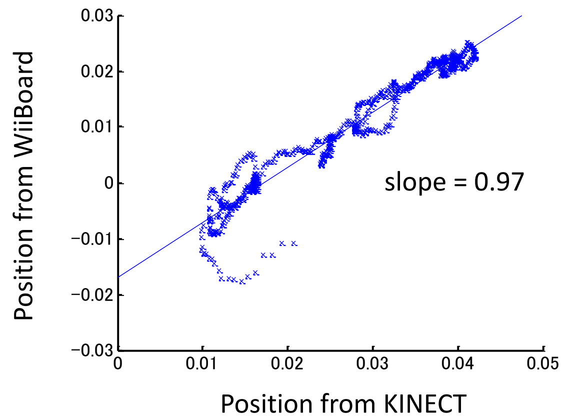

Fig 2: Calibration. Correlation between Center-of-Mass (Kinect) and Center-of-Pressue (Wii).

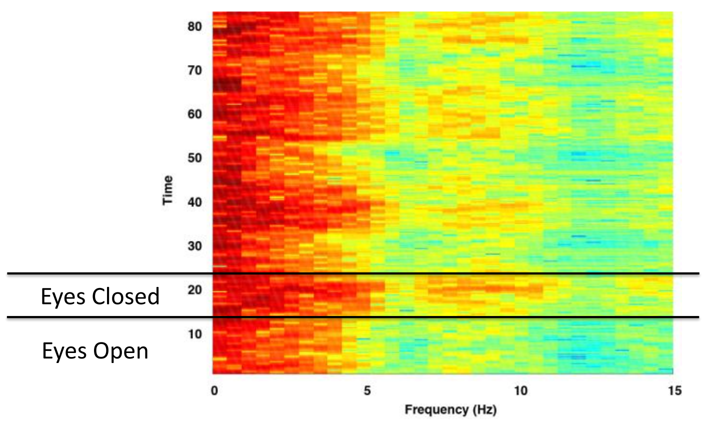

Fig 3: Time-Frequency Analysis. Closing the eyes evokes faster shifts in the Centre-of-Pressure.

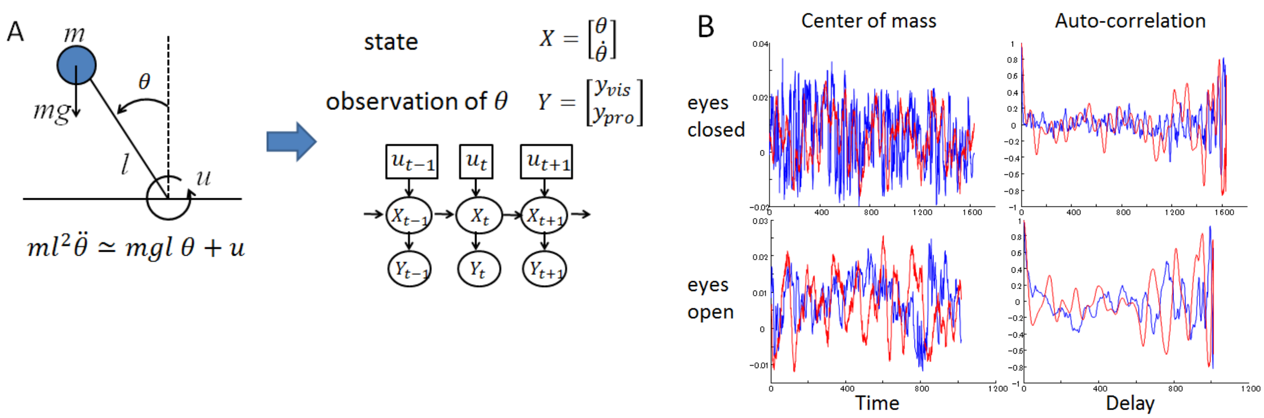

Fig 4: Kalman Filter Model. A. A simple model for effects of noisy visual and proprioceptive observations on balance. **B.** Comparison of experimental (blue lines) and model (red lines) results.