Juggling the Effects of Latency:

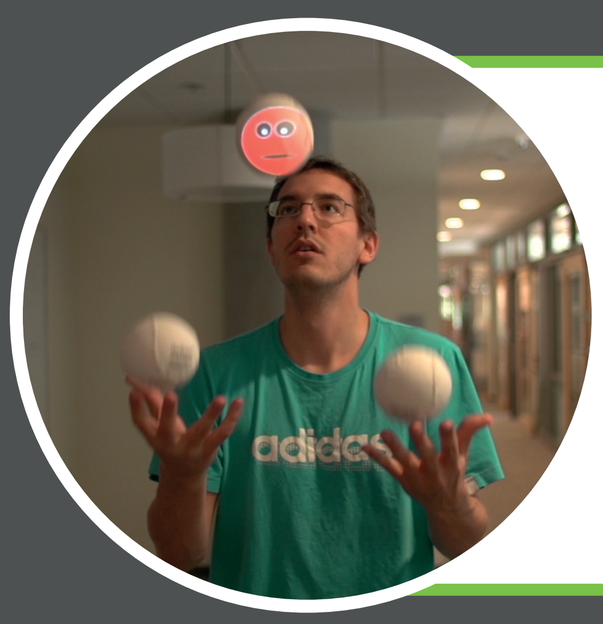
Software Approaches to Minimizing Latency in Dynamic Projector-Camera Systems

Latency in projector-camera systems (pro-cams) causes the projection to slip from its target.

As a result of this, the use of pro-cams in truly active scenarios has been avoided.

Previous work has addressed latency with custom hardware or multi-camera setups. This is at odds with the commodity hardware favored by researchers in this space.

We explore software only approaches to latency reduction; increasing projection accuracy on any hardware configuration.



Predictable Motion - Objects in free flight

We developed a juggling display. Given latency of ~100ms and juggling speeds >4m/s, this can result in 40cm of projection slip.

The balls' location at any point in time can be calculated based on a set of physical laws. We fit a Kalman Filter with a projectile motion model to track and predict the balls' future location.

Semi-Predictable Motion - On Body Projection

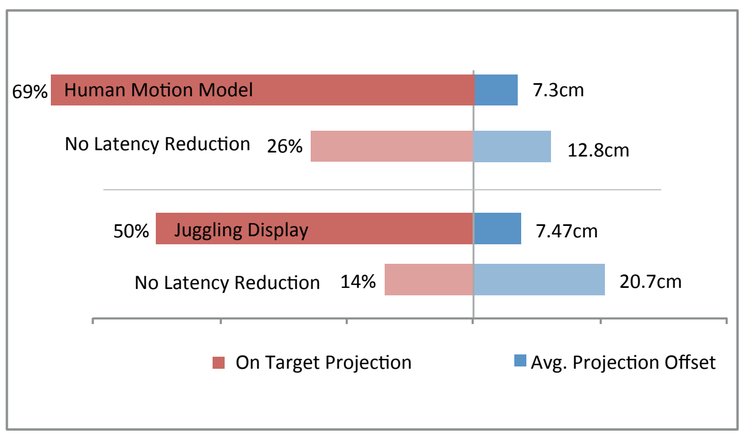
Human motion includes patterns and repetition, e.g. in walking, dancing and athletic performance (such as the basic performance of different tennis shots).

To predict bodily motion, we train a lookup model based on a person's previous movements. After a brief training window (20secs), the model can predict taking into account the intricacies of personal performance. The performer's ongoing movement continues to train the model.

Preliminary Results and Conclusions

We tested our prediction with 3 participants. The jugglers' juggled with 3 balls for 2 minutes at 2.5m from the pro-cam. The bodily motion involved up-down and cyclical motion at 1.5m/s.

We achieve **34% increase** in projection alignment under predictable motion and **40% increase** under semi-predictable motion.



Our results are challenged by the initialisation of the kalman filter and the camera's rolling shutter.

Although our initial results fall short of the accuracy achieved with custom hardware, we believe they motivate further work on software-only approaches to latency reduction.

Jarrod Knibbe, Hrvoje Benko, Andy Wilson

Microsoft® Research

BIG
Bristol Interaction and Graphics