# Real-time Upper Limb Tracking via IMU and Flex Sensor

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## Motivation

Real-time upper limb tracking allows the VR user to physically participate in the virtual world. In this project, we present a real-time tracker design using a single inertial measurement units(IMU) plus a flex sensor. An IMU typically contains a tri-axial accelerometer and a tri-axial gyroscope. They measure acceleration and angular velocity independently in real-time without the assist of artificially generated source, thus won't suffer from range limitation and interference. Recent advances in low-cost micro-electro-mechanical systems (MEMS) IMU sensors has made it possible to build wrist-watch-sized tracker. The flex sensor alters its resistance when being bended. Using a kinematically-constrained model, we reconstruct the posture of upper limb from seven-degree sensor measurement.

## Kinematic Model of Upper Limb

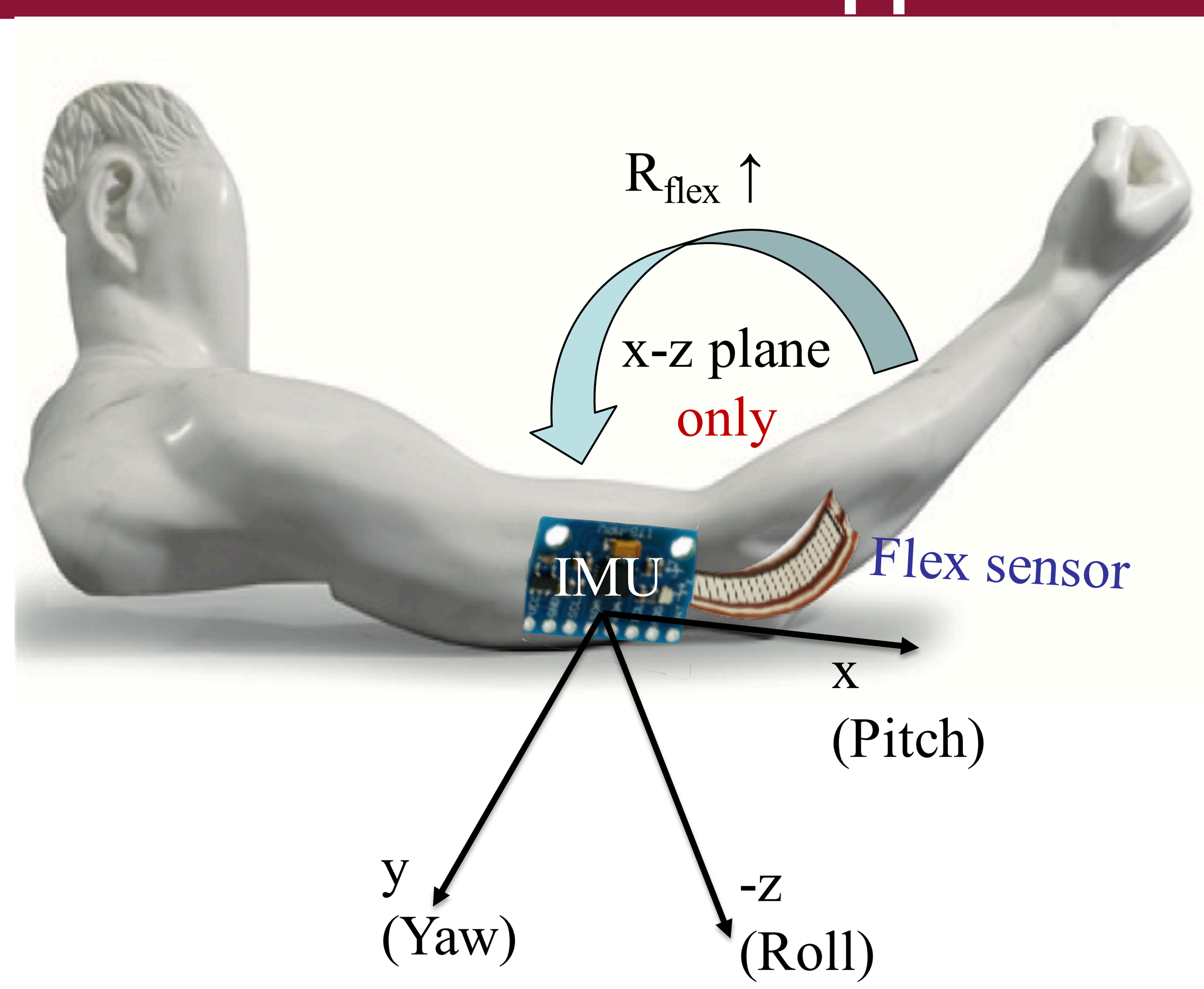


Figure 1: Kinematic model of upper limb

The key observation we made is once the orientation of arm is determined, the forearm can ***only*** rotate along y-axis, namely bend within x-z plane. Thus, by generating one-to-one mapping between the amplified voltage and the extent of bend, we can reconstruct the relative posture between arm and forearm. To track the motion of full upper limb, we follow steps:

1. Obtain the orientation of arm by fusing the 6-degree gyroscope and accelerometer measurement using complementary filter.
2. Rotate the forearm along y-axis based on the flex sensor measurement

## Sensor Prototype

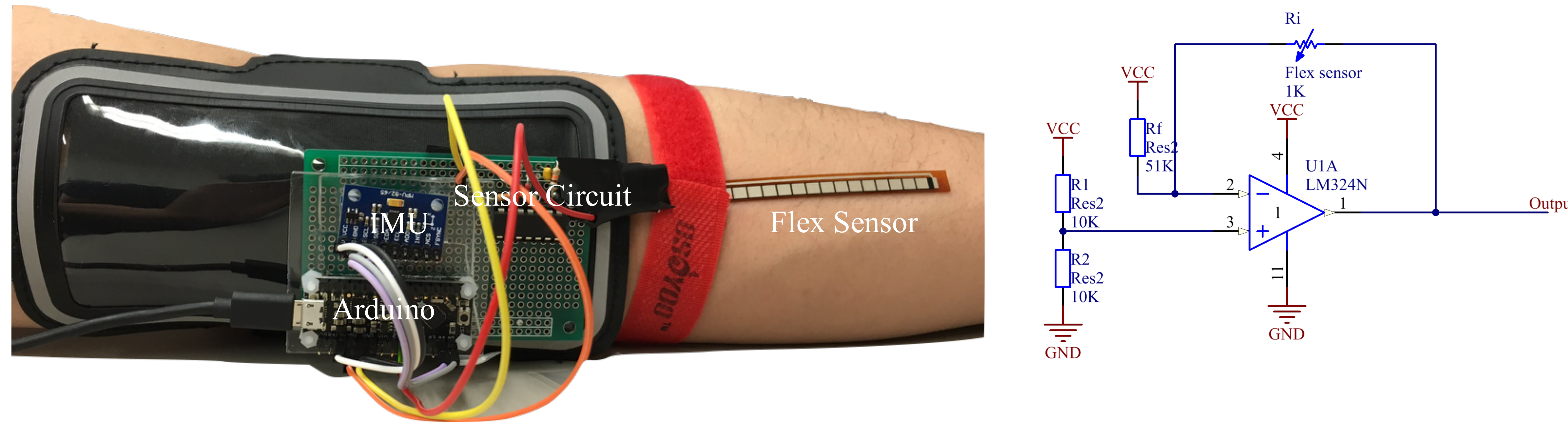


Figure 2: (Left) Equipped sensor prototype (Right) Sensor Circuit

We designed an sensor circuit(Fig. 2(right)) to convert the resistance change to voltage variation. The microcontroller reads and processes the measurement from IMU and flex sensor. It applies the complimentary filter to recover a low-drift and low-noise state vector. It also computes the forearm bending by referencing the voltage-to-angle map. The armband allows the sensor to be sturdily attached. The red band ensures the flex sensor to accurately measure the movement of forearm.

## Game Design & Play Control

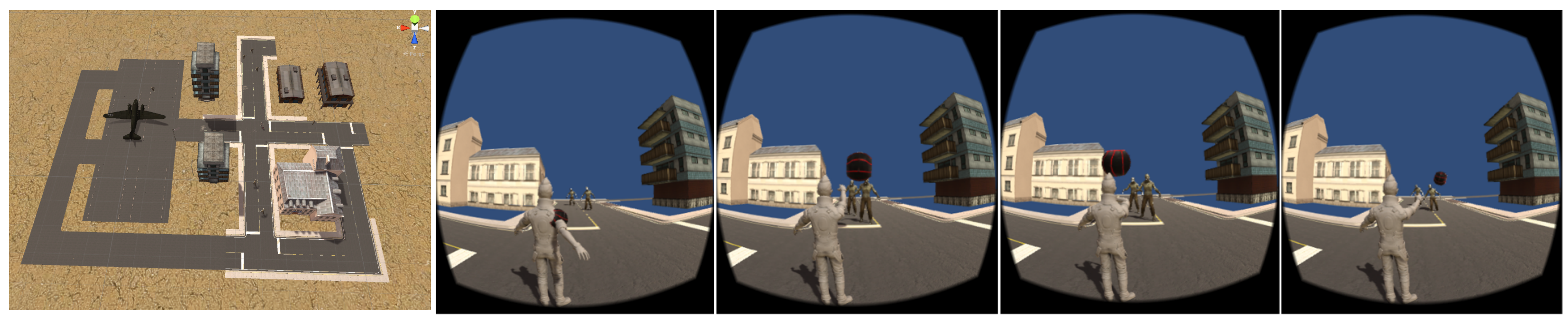

Figure 3: (Left) Full virtual environment (Mid-left) Idle mode (Mid) Loading mode (Mid-right) Spinning mode (Right) Shooting mode

We create a third-person shooting game to demonstrate the effectiveness of our sensor design. An avatar of the player arrives in an abandoned town with zombies surrounded. When the player points his arm straight down, he will stay in the idle mode(Fig.3 Mid-left). As long as he raises and points out his arm, he enters the loading mode where an energy ball rises up from the ground(Fig.3 Mid). Once he bends his forearm, he steps into the spinning mode(Fig.3 Mid-right), where the ball starts to spin fast and ready to be launched. Finally, when he wave the forearm back to straight, the ball is shot out to the direction he targeted(Fig.3 Right). Our sensor accurate measures all the movements and provides an fantastic gaming experience!