Application of inertial measurement units in controlling of a prosthesis hand

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Brief Summary: **Prosthetic limbs provide a vital route to functional rehabilitation of amputees and people with congenital deficit. Importantly, upper-limb referrals are prevalent in highly-skilled technicians, engineering and war veterans. Use of prostheses can improve their quality of life dramatically and contribute to their personal dignity, independence and social inclusion. However, current commercial prosthetic hands offer active control of only a few degrees of freedom (e.g. hand open/close). Therefore the performance of upper-limb prostheses must still improve greatly. The aim of this research is to improve the performance of the hand prostheses by the use of inertial measurement units.**

Background

With the emergence of highly dextrous robotic hands during the past decade and with patients' willingness to pursue a more active lifestyle and the need for sustaining income, the upper-limb prosthetics market has expanded rapidly. However, current commercial prosthetic hands offer active control of only a few degrees of freedom (e.g. hand open/close). For instance, simultaneous control of multiple joints often requires sequential control of individual joints with cumbersome switching techniques that can tire the user after a short while.

One way to improve the control of hand prosthesis is the incorporation of the inertial measurement units (IMUs, e.g. gyroscopes and accelerometers). Recently IMUs have been used extensively in mobile applications. In current commercial prostheses, e.g. the iLimb (Touch Bionics, UK), data from inertial measurement units (e.g. gyroscopes and accelerometers) are used to trigger maximum two 1-dimensional modes of operation.

Research Aim

The aim of this project to design a prosthesis controller that will give the wearer the ability to produce concurrent hand and wrist movements by the use of the IMUs. However, output signals of the off-the-shelf inertial measurement units are noisy. The technical challenge in this is implement a simple, real-time and robust mechanism to enhance the quality of the data measured from two 9-degrees of freedom inertial measurement units.

What is IMU?

Inertial measurement unit (IMU) is an electronic device that measures and reports on :

- velocity and gravitational forces, by accelerometers
- orientation and angular velocity, by gyroscopes
- sometimes include compass data by magnetometers

IMUs are widely used in navigation. As IMUs can provide instant accurate orientation information with additional advantages like small size and cost effective, they meet the need for the real time simulation of hand and wrist movement.

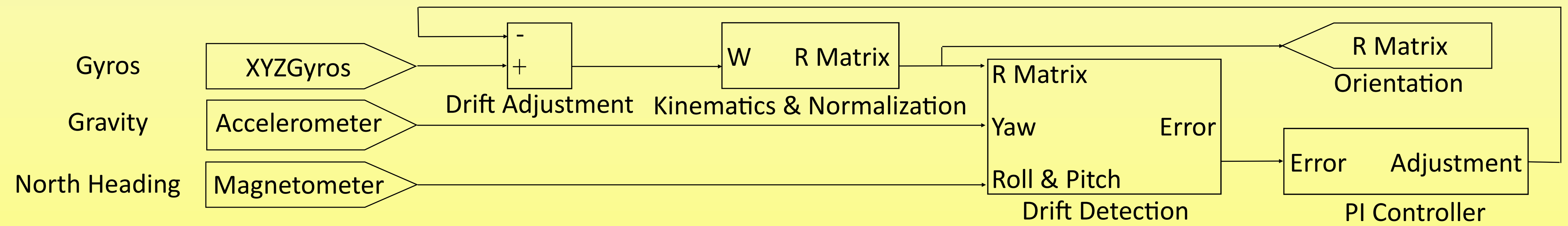
Two 9 Degrees of Freedom Razor IMU boards, which are used in this research, incorporate three sensors :

- ITG-3200 (MEMS triple-axis gyro),
- ADXL345 (triple-axis accelerometer),
- HMC5883L (triple-axis magnetometer),

and on-board Arduino microcontroller - ATmega328

Methods Used and Results Achieved

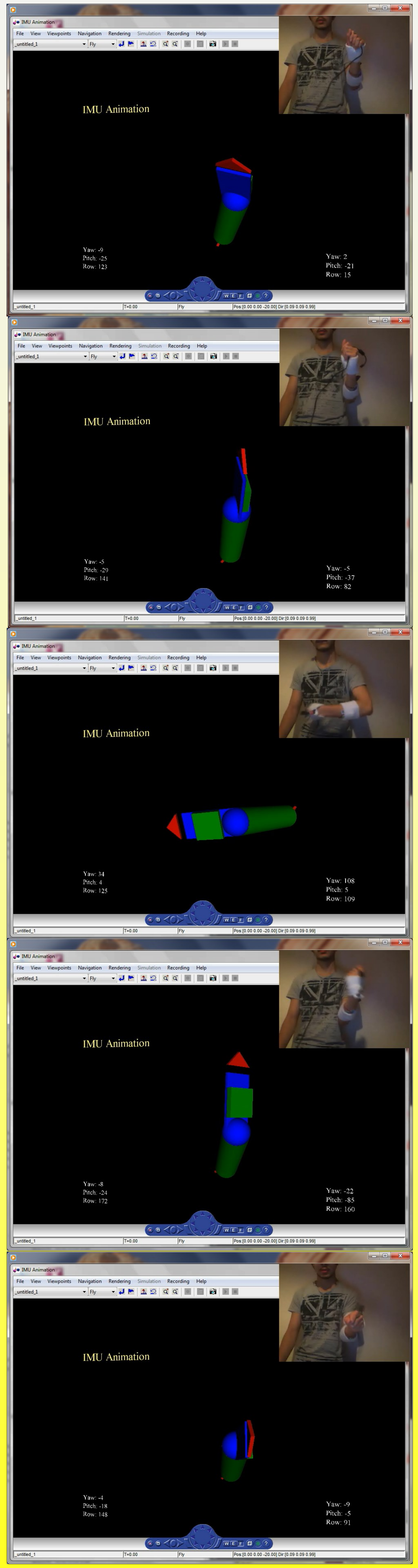
This work is based on the IMU code and work which are commonly seen in navigation has been used. Those works has been modified so that it is applicable to the simulation of the subject's hand movement. In our works, all simulations rely on orientation information only without calculating position information, due to double integration is involved in the calculation of position measurement - a small inertial error with cause a huge different which make the data obtained unusable. On the other hand, the measurement of orientation gives a high accuracy without drift which mean no further calibration is needed after initial setting. In order to lower the demand of computation processing, feedback controller (second order complementary filter) mechanism and Direction Cosine Matrix (DCM) are used. As a result, calculation can be run on the microcontroller of the IMU which give out the orientation data at 50Hz rate. As we know the relative orientation of each IMU sensor to the ground with such a high rate, real time simulation of the orientation of the forearm and palm is achievable by just feed the data back in Matlab, and hence wrist movement can tracked at real time, no position data is needed.



Block Diagram of Feedback controller & Direction Cosine Matrix

As shown in the block diagram above, the gyros are used as the primary source of orientation information. As the numerical errors in the integration will gradually violate the orthogonality constraints that DCM must satisfy, regular, small adjustments to the elements of the matrix need to be made. In addition, the numerical errors, together with gyro drift and gyro offset, will gradually accumulate errors in the DCM elements, reference vectors will be used to detect errors and a proportional plus integral (PI) negative feedback controller between the detected errors and the gyro inputs, to dissipate the errors faster than they can build up. Magnetometer (Compass) is used to detect yaw error while accelerometers (Gravity force direction) are used to detect pitch and roll error.

In our work's result, real time simulation of wrist movement on Matlab by the use of IMUs is done successfully. Each IMU is placed on both the subject's hand and palm. The microcontroller on board gather all the sensors data, calculate through the preprogramed feedback controller mechanism and output the updated orientation data by angle - yaw, pitch and roll. Then Matlab will use those angle data to demonstrate the simulation of hand movement through the 3D animation world in Simulink. The successful of this work has been demonstrated by the video and computer screen recording to the subject's hand movement and 3D hand simulation simultaneously. The screenshots of the video are shown on the right.



Future Application

This research is the first step in development of prosthesis limb. As it can give accurate orientation information of each limb, that will make it easier for the future researcher to find the relationship between neuron signals and each hand movement. Finding this relationship can help to develop the prosthesis hand controlled by mind as if real hands.

Apart from that, as this work can be used to capture the real time body motion, it can be used in the internet to create a virtual world which showing each user's body movement. This will give further interaction when people meeting each other online as gesture play a significant role in human communication. It can be used as an interface with the machine, e.g. hand movement as the command of the mouse cursor's movement.

Reference and Credit Building an AHRS using the SparkFun "9DOF Razor IMU" or "9DOF Sensor Stick" Tutorial, by Peter Bartz : (https://github.com/ptrbrtz/razor-9dof-ahrs/wiki/Tutorial), "Direction Cosine Matrix IMU: Theory" by William Premerlani and Paul Bizard, IMU Photo Credit: SparkFun electronics

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