Biometrics using an Inertial Measurement Unit and Laser Range Finder

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Introduction

This spring, students in BIOENG 1150 (Methods) participating in the Biometrics Module were introduced to a family of inexpensive data logging modules from SparkFun Electronics, gathering measurements from a 6 degree of freedom (DoF) inertial measurement unit (IMU) (3D accelerometer and 3D gyroscope) and a laser time-of-flight range finder (LRF). The resulting device was built into a cap (Fig. A) to be worn by a subject, permitting the pose and motion of the body and head to be analyzed in a variety of ways. The IMU provided measurements of linear acceleration and angular rotation, while the LRF measured distance to a wall using time-of-flight technology.

Data Collection

Out of the box, the SparkFun Internet of Things (IoT) Data Logger family of products are designed to collect raw data, which can be observed and interacted with using a terminal application on a computer. To efficiently input the data for analysis, a custom executable program was developed to read and parse the data at a customizable rate and save it as a .csv file for analysis. The program provided a convenient platform to run the various experiments in the Biometrics Module of the Methods Course. The actual format and units of the data collected is shown in Fig. B.

Experiments

Establishing the noise floor:
Students began by collecting data while the cap was stationary on a fixed surface. The RMS noise and bias was calculated and the actual precision of each type of data determined.

Studying balance under different conditions:
Subjects attempted various postures with varying degrees of visual and proprioceptive feedback: standing on 2 feet with eyes open and closed, standing on 1 foot with and without touching a wall for balance, as well as other postures proposed by individual groups. Mathematical analysis included using standard deviation and various filters to separate the effects of sway from gravity, and to characterize the influence of the above factors on balance.

Correlating acceleration with distance:
The subject faced a wall, swaying intentionally towards and away from the wall, with both acceleration in that direction (from the IMU) and distance to the wall (from the laser rangefinder) collected. These two data sources were then "fused" using derivatives, integration, and various filters.

Differentiating head nods:
A classifier was designed to differentiate between the subject nodding "yes" vs. "no" vs no nod, using the 3D gyroscope data. The accuracy of the classifier was then analyzed using a confusion matrix.

***Figure A**: SparkFun Data Logger affixed to cap for experimentation.*

4901358,	717,	0,	-251.930,	-100.284,	984.906,	122.500,	385.000,	437.500
t	d	s	A_x	A_y	A_z	G_x	G_y	G_z

"Time" t in milliseconds since program start.

"Distance" d in mm.

"Range Status" $s = \{0, 1, 2, 3, 4\}$ with 0 indicating the distance reading is reliable.

"Acceleration" $\boldsymbol{A} = (A_x, A_y, A_z)$ in milli-g (where g = 9.806 N kg-1, the acceleration due to gravity at the earth's surface).

"Gyroscope" $\boldsymbol{G} = (G_x, G_y, G_z)$ angular velocity in milli-degrees per second around the corresponding axis.

***Figure B**: DataCollector Output Format*

This work was conducted in the Visualization and Image Analysis (VIA) Laboratory in the Department of Bioengineering at the University of Pittsburgh.