# Predicting Short-Range Displacements From Sensor Data

Maurice Shih, Jun-Ting (Tim) Hsieh, Pranav Samir Rajpurkar, Daniel Sanchez, Dan Boneh

Stanford University and SRI International

## Smart Device Data

With the advent of Internet of Things (IoT) and mobile devices, a key question is, "how much can we learn about a user by the data from smart devices?"
Our project helps to answer this question by to develop a method to predict short-range displacements of hand gestures using smart devices.
Using acceleration data, we seek to build a better algorithm that current existing methods, such as double integration.

## Statement of Purpose

The current method of using double integrations of acceleration data to apply simple Newtonian models is very inaccurate.

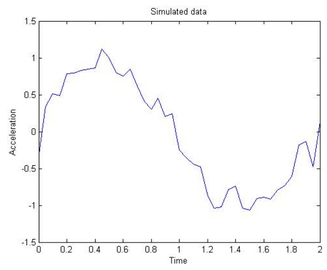
Figure: Example of simulated accleration

| Angle Error (degrees) | Acceleration Error (m/s/s) | Velocity Error (m/s) at 1/3 second | Position Error (m) at 1/3 second | Position Error (m) at 1 minute | Position Error (m) at 10 minutes | Position Error (m) at 1 hour |
|---|---|---|---|---|---|---|
| 0.1 | 0.017 | 0.17 | 1.7 | 61.2 | 6120 | 220 e 3 |
| 0.5 | 0.086 | 0.86 | 8.6 | 309.6 | 30960 | 1.1 e 6 |
| 1.0 | 0.17 | 1.7 | 17 | 612 | 61200 | 2.2 e 6 |
| 1.5 | 0.256 | 2.56 | 25.6 | 921.6 | 92160 | 3.3 e 6 |
| 2.0 | 0.342 | 3.42 | 34.2 | 1231.2 | 123120 | 4.4 e 6 |
| 3.0 | 0.513 | 5.13 | 51.3 | 1846.8 | 184680 | 6.6 e 6 |
| 5.0 | 0.854 | 8.54 | 85.4 | 3074.4 | 307440 | 11 e 6 |

## Preliminary Tests

We first attempt to measure the accuracy of current existing methods against artificial data with noise.
The acceleration in the y direction can be roughly estimated as a sine curve, so we created sine curves (with noise) and measured how double integration and linear regression determined the total distance travelled.
Double integral: average error: 6.5%
Linear regression: average error: 2.5%

Figure: Example of simulated accleration




## Setup

An app for the pebble watch and android phone was created to measure and store the acceleration caused by the short displacements.
We created an ipad app to measure the distance travelled by the middle finger during short displacements. This model assumes that the distance travelled by a finger is very similar to the distance travelled by the wrist. In order to increase the accuracy of this, a split was used to limit the motion of the wrist.

## Pebble Smartwatch

Work has been done on identifying motion gestures based with accelerometers, but little done with identitfiy/classifying gestures that take a short amount of time (e.g. a few seconds).

The goal is to used the acclerometer data to identify the distance travelled. This is especially hard since the orientation is not possible to determine, since there is no gyroscope.

Potential applications are virtual keyboards, authentication as well as maliciously possibilities, like picking up a users keystrokes.

## Processing Data Pipeline

### 1. Collect raw Data

The initial raw data is similar to the figure below.

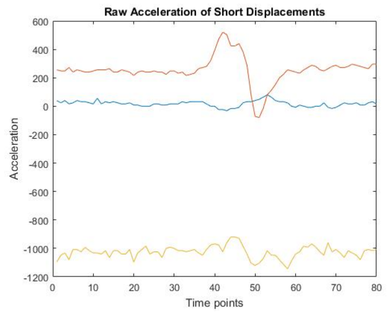
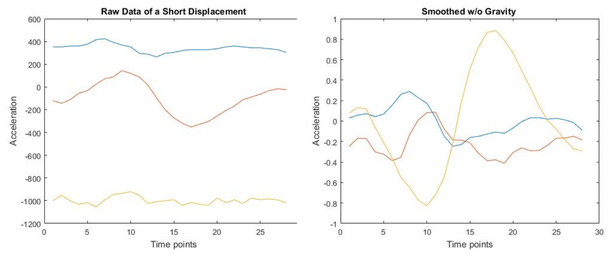



Figure: Data from ten taps, where values of 1000 is equal to 9.8 m/s

## Processing Data

### Data Segmentation




## Neutral Networks

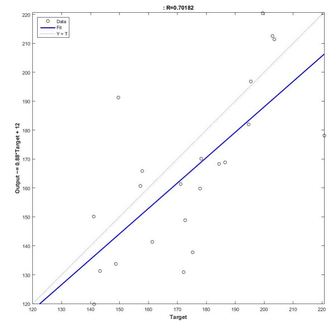



Figure: The output of the network has an R values of .70182 in relation to the actual distance

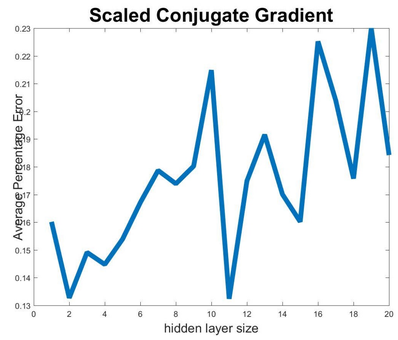



Figure: After training, the average percentage error for test cases

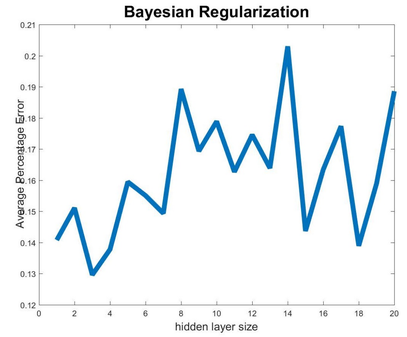



Figure: After training, the average percentage error for test cases

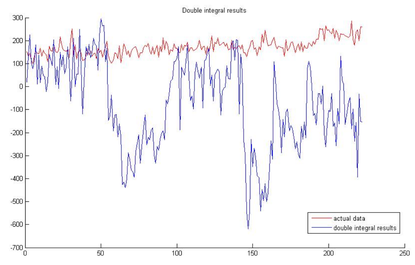



Figure: Double integration vs Actual

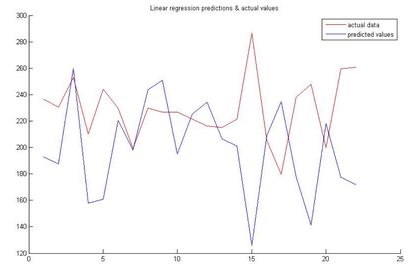



Figure: Linear Regression vs Actual

## Future Work

Fine tuning of the model with more data. We also hope to generalize out work will smart devices that offer more data, such as gyroscope. We are currently looking at using apple watch.