NSF REU, "Creating Computer Applications for Medicine"
University of Virginia, Summer 2007

Portable, Inexpensive, and Unobtrusive Accelerometer-based Geriatric Gait Analysis

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What is gait analysis?

Clinical gait analysis is the quantitative and interpretive study of human locomotion.

Gait analysis is particularly effective in aiding in diagnosis of geriatric patients.

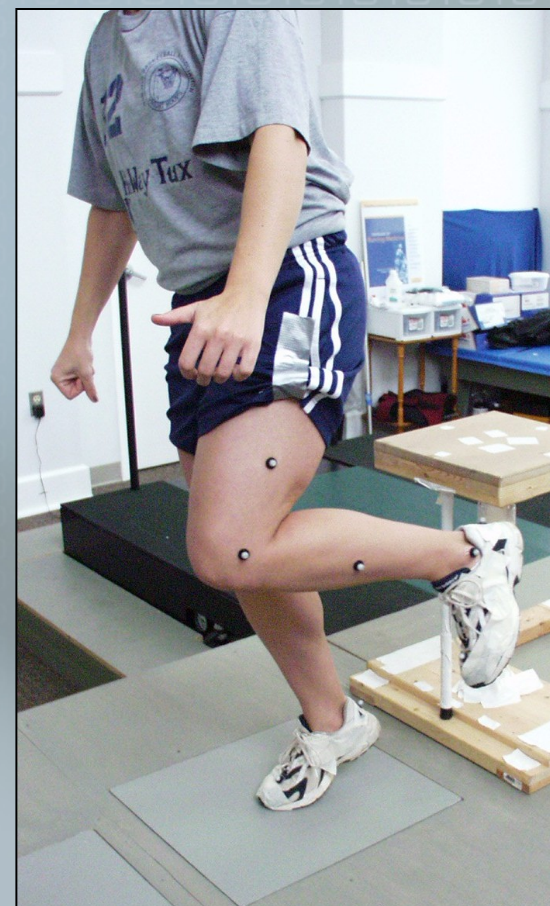
Current state of the art

Two types of clinical gait analysis:

- **Observational Gait Analysis (OGA)** – Extensive observation by highly trained physician, possibly with slow-motion video camera
  - Problems: Qualitative Nature, time consuming
- **Laboratory Based Analysis** – Considerable analysis in expensive motion laboratory
  - Problems: High cost, time consuming, based in specific location

Observational gait analysis

Laboratory based analysis



Motivation

There is a need for a low cost, portable device that produces quantifiable and reliable data.

We would like to analyze the gait of the patient simply by having them walk down a hallway (approximately 15-20 steps), turn around, and walk back.

Benefits: Low cost, unobtrusive, no need to travel to laboratory, constant monitoring is possible

Applications: pre-emptive prediction of geriatric disorders, telemedicine, long-term analysis

The hardware

- Designed by Mark Hansen, UVA ECE
- Initial prototype is wired, using DataFlash® memory card to store data
- Next version (already developed) transmits all information wirelessly through Bluetooth™

Photograph of wired prototype

The sensors

- Four sensors that are attached to:
  - Left and right ankle
  - Right wrist
  - Sacrum

Each sensor contains an accelerometer, which measures locomotion based on remote sensing. The sample rate for each sensor is 90 Hz.

The accelerometers take measurements in the X (dorsal/ventral), Y (caudal/cranial), and Z (medial/lateral) directions.

The 3D vector magnitude

- Much of our analysis was done on what we call the "three-dimensional vector magnitude" (VecMag)
- The VecMag is a way to sum and normalize the data from all directions.
- We calculate the VecMag with the following pseudocode:

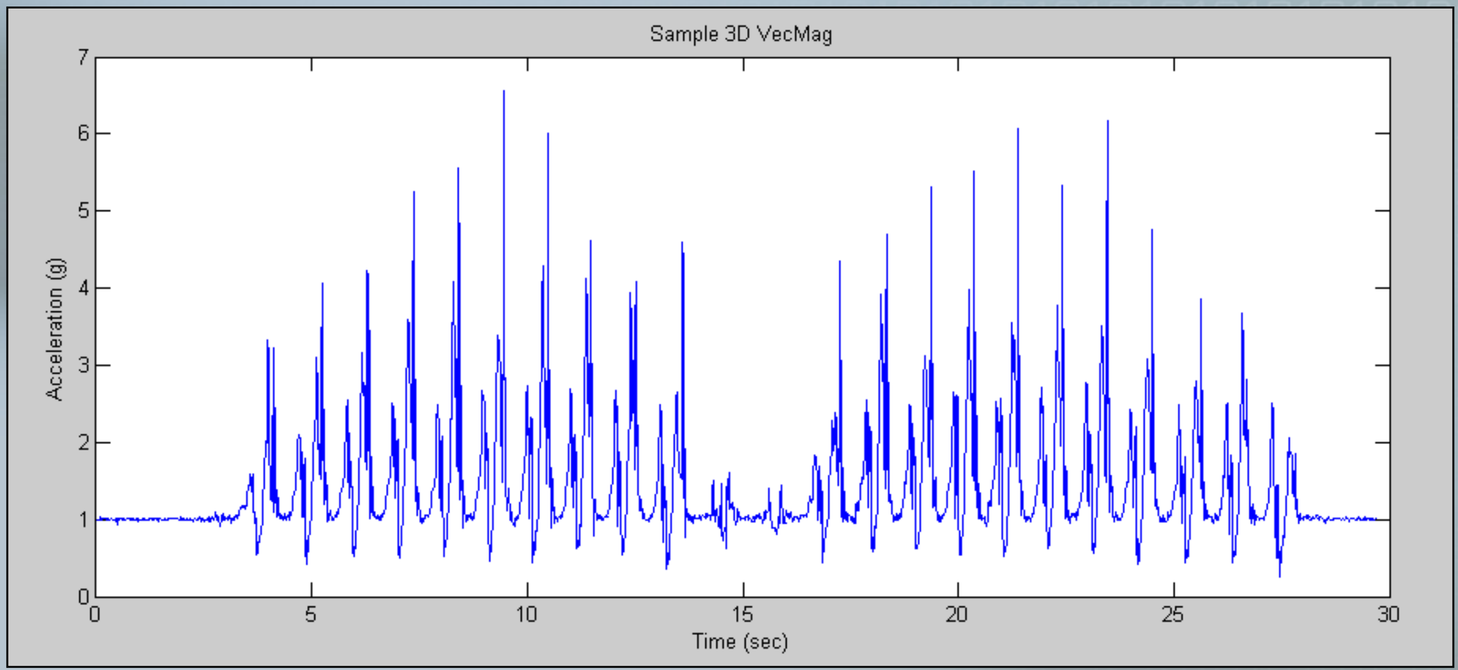
$$for(i = 0; i < size(axialOutput); i++)$$

$$\{$$

$$VecMag[i] = \sqrt{axialX[i]^2 + axialY[i]^2 + axialZ[i]^2}$$

$$\}$$

A sample waveform

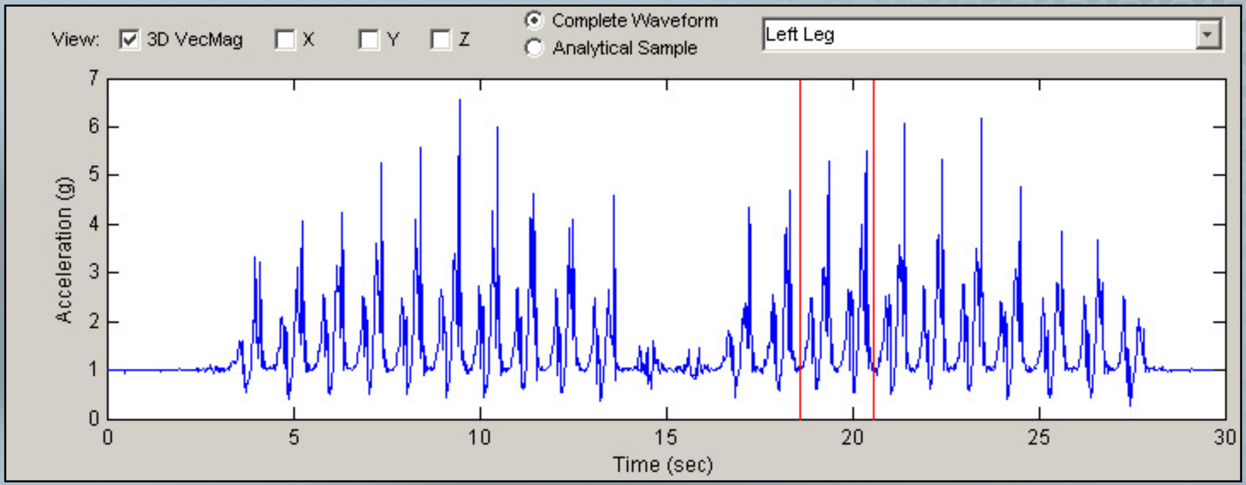


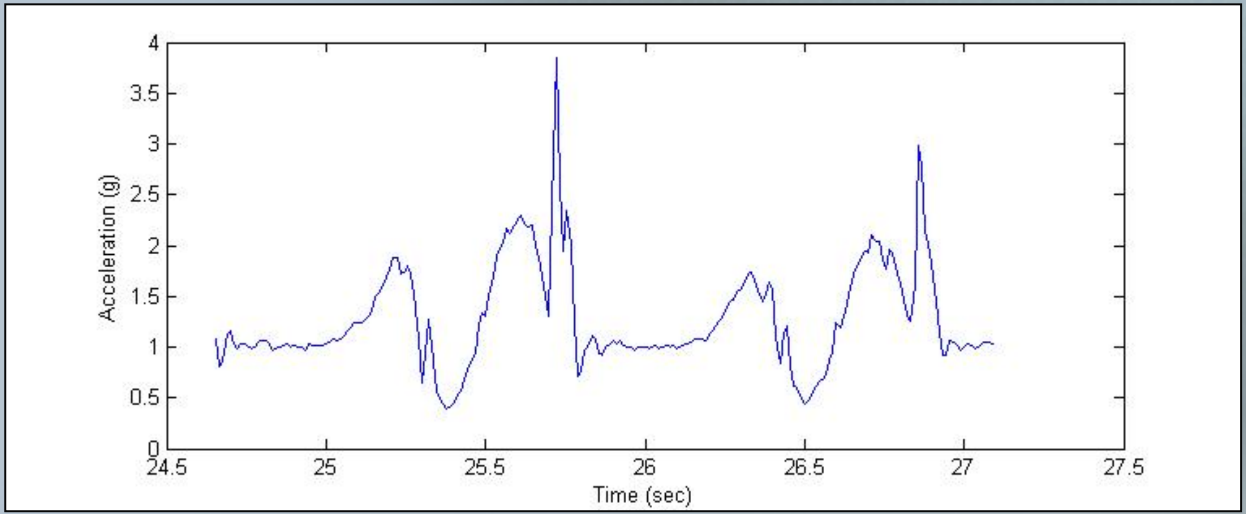
A sample plot of the 3D VecMag

The analytical sample

- We have found that the best data to analyze is a few steps into the waveform after the patient has turned around.
- We call this section the **analytical sample**, and its length is two periods of the waveform.

An example analytical sample





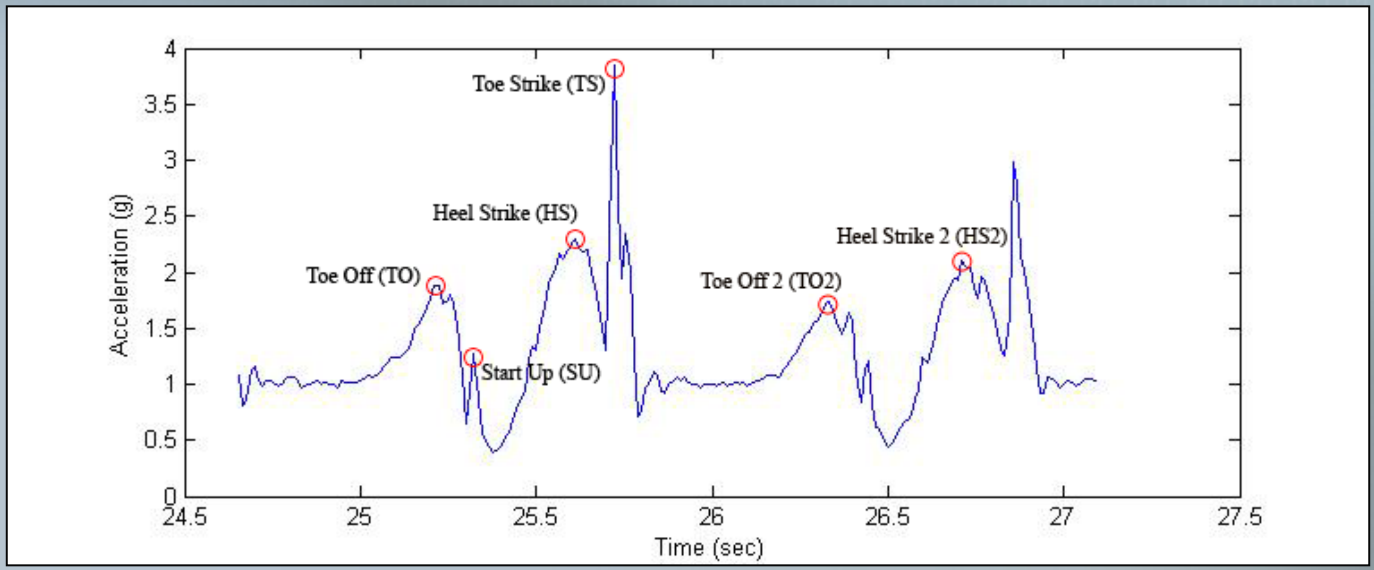
Finding the essential points

- Once an analytical sample has been found, six essential points are calculated for each leg.

- The essential points are found by using signal processing techniques on the analytical sample.

The six essential points

- Toe Off (x2)
- Start-Up
- Heel Strike (x2)
- Toe Strike



Critical values

Once the six essential points for each leg are found, we can find 53 “critical values” in the waveform with minimal calculations. For example:

- Heel Strike Interval (difference in time between two consecutive heel strikes)
- Toe-Off Amplitude (Acceleration in g’s of the toe off)
- Steps per minute

Goals

- Find analytical sample
- Find essential points
- Develop a fully-functioning, reliable, user-friendly, and accurate analysis tool for gait waveforms
- Fine tune our method to produce accurate results 95% of the time
- Produce a demonstration video

What we started with…

- 56 sets of raw accelerometer data
- Prototype wired sensor system

Developing the GaitMate tool

- All coding for GaitMate was done in MATLAB 7.4.0 (R2007a)
- No MATLAB plug-ins required
- GUI and console-based versions

The graphical user interface

Subject pool

GaitMate was evaluated on a pool of 56 geriatric patients, ranging from 67 to 94 years of age.

The subjects suffered from afflictions such as Parkinson's disease, memory impairment, spastic hemiparesis and paraparesis, arthritis, and stroke.

Healthy patients were included, as well as subjects with a history of falling.

Testing results

- Our algorithm correctly identifies 97 percent of the essential points
- The Start-Up point gave the most errors; usually due to a low amplitude which can't be distinguished by the naked eye

Demonstration Videos

Artifacts

- Over 4,750 lines of code
- Documentation
- Demonstration Video
- Fully-functional GUI to assist physicians with waveform analysis
- Script that produces real-time .avi video files from raw accelerometer data

Future Work

- Use of GaitMate tool by physician to aid in diagnosis
- Create a large database of “registered” gaits
- Comparison of sample waveform to database to determine the probability with which a patient has a particular affliction
- Determine probability that a patient will need assisted living

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- University of Virginia Computer Science
- University of Virginia Health System

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