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SERG Smart Enviroments Research Group

Working with Sensing Technologies

How to acquire data with contemporary platforms.

Dr Ian Cleland

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Agenda

Technology/ Data Analysis

		Monday, June 26	Tuesday, June 27	Wednesday, June 28	Thursday , June 29
Social	7.00	Jogging, Tuscany Walk, Diving, Water Aerobics	Jogging, Tuscany Walk, Diving, Water Aerobics	Jogging, Tuscany Walk, Diving, Water Aerobics	Jogging, Tuscany Walk, Diving, Water Aerobics
Technology Data Analytics	9.00	Introduction to summer school. Rapid fire introductions by students (1 slide each) .Poster session Introduction Working Group goals. **Chris Nugent, Cristiano Paggetti**	Working with Sensing Technologies: How to acquire data with contemporary platforms. **Ian Cleleand**	Processing Sensor Data: Understanding the development of behavioural and activity models **Oreste Banos**	Advanced Data processing with both sensor and health related data. **Macarena Espinilla**
Coffee	9.45				
Health / Social Sciences	10.00	Research Ethics: Planning your trial and Securing Ethical Approval. **Bryan Scotney**	Understanding the theory behind behaviour change strategies. **Jane Walsh**	How to engage with users when design, developing and evaluating connected health solutions. **Cristian Leorin**	Monitoring and Evaluating the Multidimensional Impact of Social and Health Care Services. **Nick Batey**
Group Work	11.00	Assessing Market potential and impact indicators	Designing the service model and organisational scenarios	Designing and develop technical solutions	Group work presentation
Lunch	12:30				
Service and Policy options	13.30	The role of an innovation manager in healthcare service delivery **RT**	FREE TIME / SOCIAL ACWTIVITIES	Implementation of innovative service in AHA context **Francesco Benvenuti TBC**	Innovative Care Models - A European perspective **Kare Synnes**
Group Work	14.30	Group Work	FREE TIME / SOCIAL ACWTIVITIES	Group Work	Example of Best Reference Service Scenarios at International level
Business Innovation	15.15	Innovation Management and business promotion in AHA (The Business Pitch) **Andrea Piccaluga** TBC ??	FREE TIME / SOCIAL ACWTIVITIES	Open Innovation and contemporary business models **Giuseppe Fico**	How to start a business in a Connected health Domain .....
Wrap Up	16:15 16:30	Wrap–up and introduction to next day's sessions	FREE TIME / SOCIAL ACWTIVITIES	Wrap–up and introduction to next day's sessions	Group Work - Award Ceremony

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Academic Staff

Technology/ Data Analysis

Working with Sensing Technologies: How to acquire data with contemporary platforms.

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shimmer DISCOVERY IN MOTION
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Processing Sensor Data: Understanding the development of behavioural and activity models

Oresti Banos

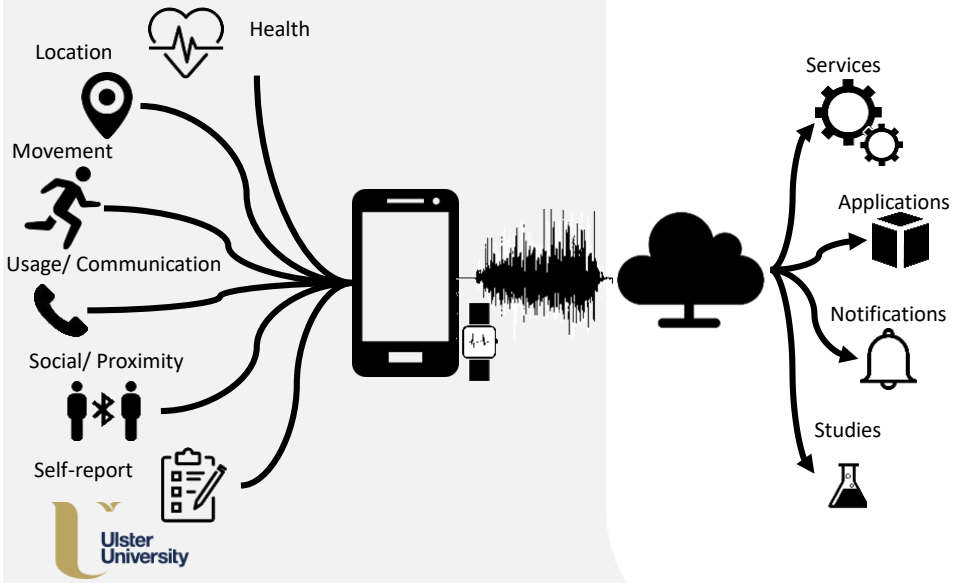
MATLAB

Advanced Data processing with both sensor and health related data.

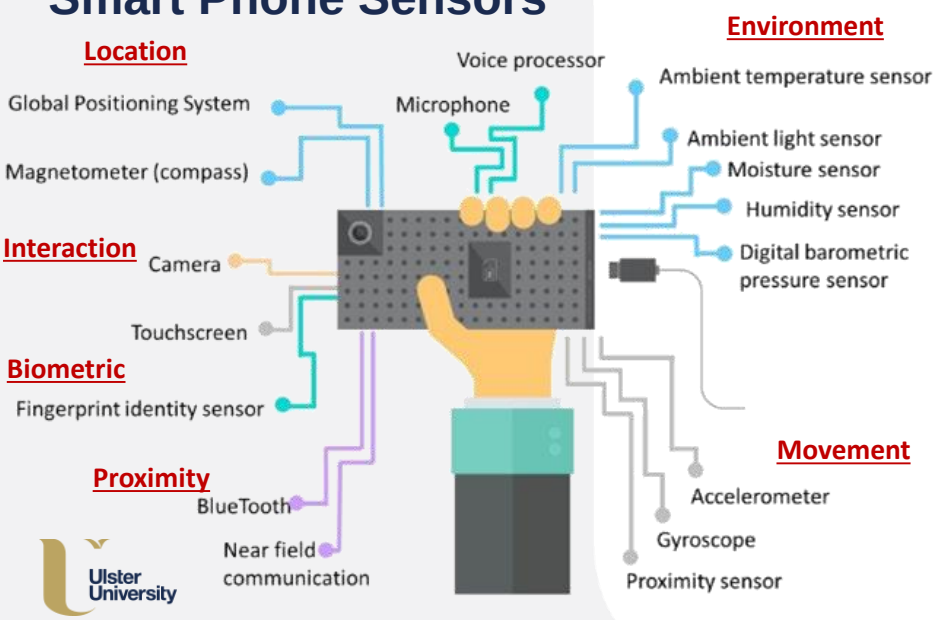
Macarena Espinilla

WEKA The University of Waikato

Collected Through a Smartphone



Smart Phone Sensors



Smartphone Data

Functions, Features, and the Behaviours they Capture

			Behaviors Captured from Smartphone Data		
Type of Smartphone Data	**Function in the Device**	**Features of the Data**	**Social Interactions**	**Daily Activities**	**Mobility Patterns**
Mobile sensor data					
Accelerometer sensor	Orients the phone display horizontally or vertically	XYZ coordinates; duration and degree of movement vs. stationary		✓	✓
Bluetooth radio (BT)	Allows the phone to exchange data with other BT-enabled devices	Number of unique scans; Number of repeated scans	✓		
Global-positioning system scans (GPS)	Obtains the phone location from satellites	Latitude and longitude coordinates; coarse (100-500 meters) or fine-grained (100 meters or less)		✓	✓
Light sensor	Monitors the brightness of the environment to adjust phone display	Information about ambient light in the environment		✓	✓
Microphone sensor	Permits audio for calls	Audio recordings in the acoustic environment	✓	✓	
Proximity sensor	Indexes when the phone is near the user's face to put display to sleep	Measurement of the proximity of an object to the screen (e.g., in centimeters)		✓	
WiFi scans	Permits the phone to connect to a wireless network	Number of unique WiFi scans; locations of WiFi networks			✓
Other phone data					
Call log	Records calls made and received	Incoming and outgoing calls; no. of unique contacts	✓		
Short Message Service (SMS) log	Records text messages made and received	Incoming and outgoing text messages	✓		
Application (app) use log	Records phone applications used and installed	Number of apps; frequency and duration of app use	✓	✓	
Battery status log	Records battery status	Battery charge times; low/med/high battery status		✓	

Crowd Sensing

Opportunistic and Participatory Sensing

- It allows widespread, automated collection by privately-owned smartphones and tablets, as well as cars or even public-service bicycles.
- Exploits the trend devices to be increasingly equipped with GPS, cameras and different types of sensors.
- Involvement of users in sensing can be categorized into participatory and opportunistic sensing
  - **Participatory** sensing is active participation
  - **Opportunistic** sensing is passive participation

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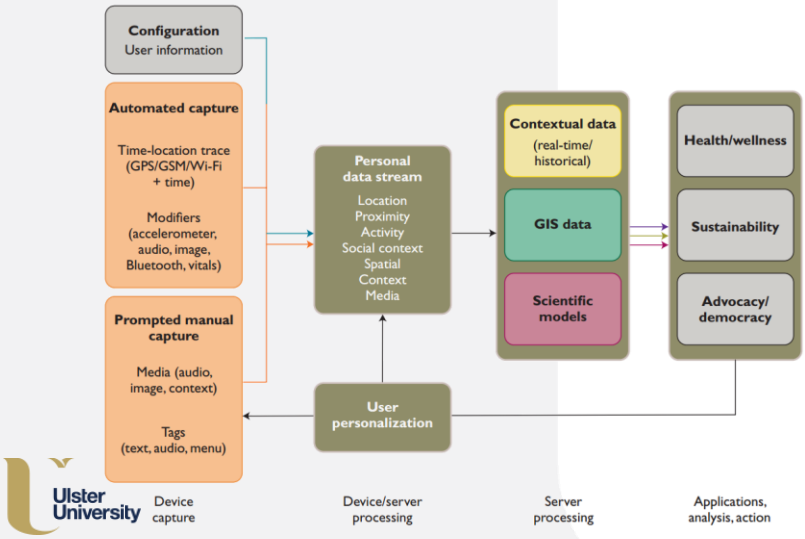
Crowd Sensing

Opportunistic and Participatory Sensing



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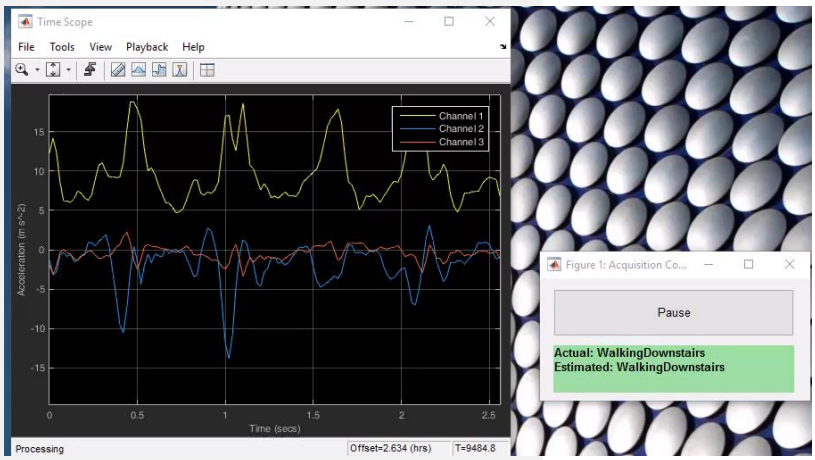
Activity Recognition



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Motivation

Why learn these techniques?

- Signals are ubiquitous across many research and development domains.
- Engineers and scientists need to process, analyse, and extract information from time-domain data as part of their day-to-day responsibilities.
- In a range of **data analytics** applications, signals are the raw data that machine learning systems must be able to leverage for the purpose of creating understanding and for informing decision-making.

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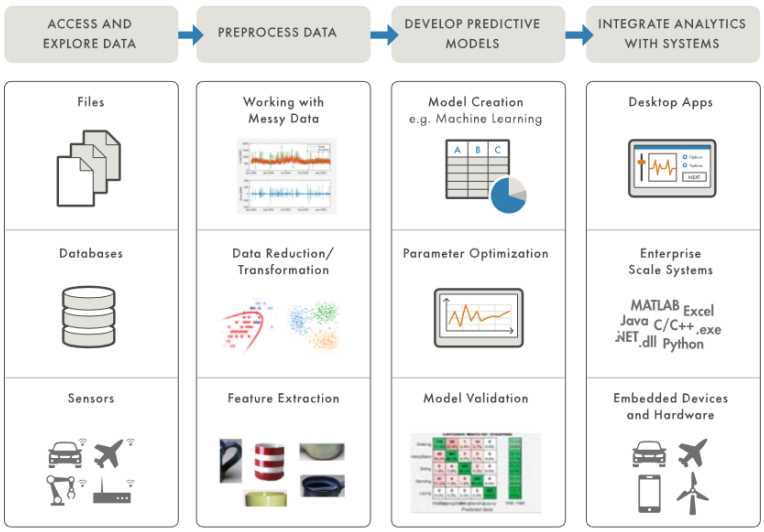
Data Analytics Work Flow



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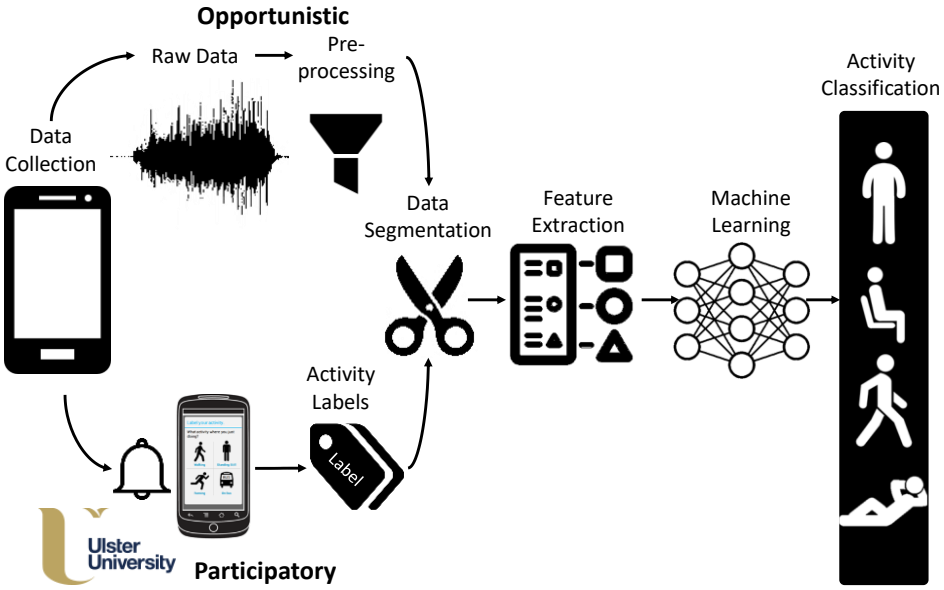
Activity Recognition Work Flow



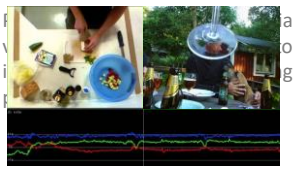
Data collection methods

Collection and Labelling

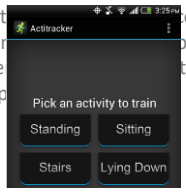
Semi Structured

12.00 Start Walking
12.05 Go down stairs
12.10 walk to Bus
12.20 Ride bus to office

Free living- Video

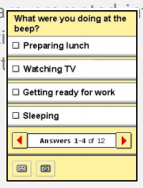


Self annotation/ Training



Experience sampling

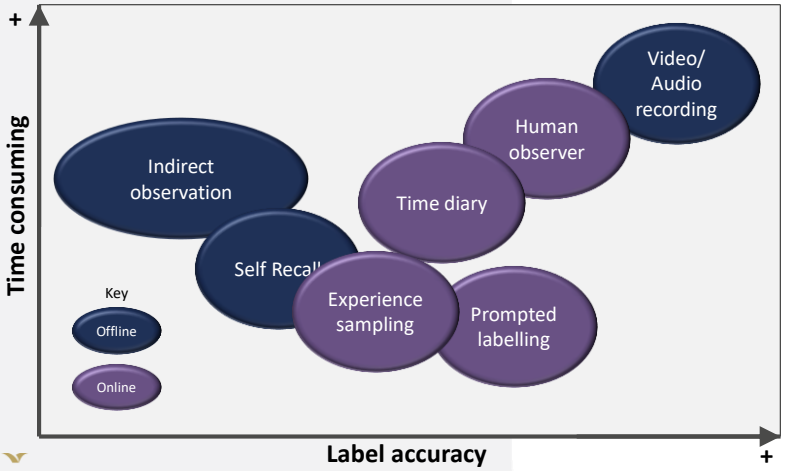
Users a... ...ntermittently at set ti... information on the t... just doing.



(Intille 2003)

Data collection methods

Collection and Labelling



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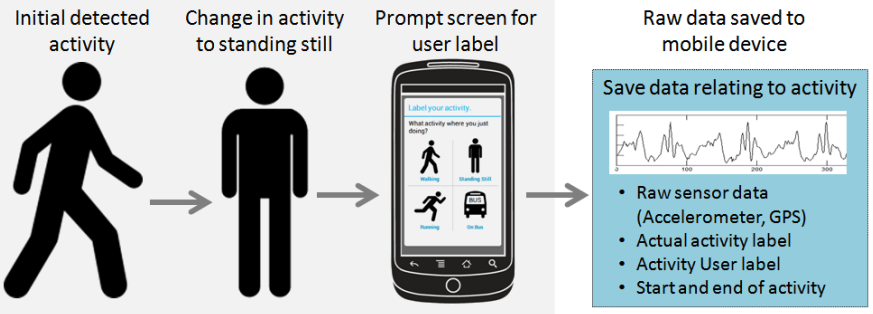
Participatory Sensing

Activity Recognition



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Collecting Movement Data

Things to consider in opportunistic sensing of movement data

Review of previous works

Reference	Activities (number studied)	n	Accelerometer Placements	Features	Accuracy
Bao and Intille [7]	Walking, sitting, running, cycling, vacuuming, folding laundry (20)	20	Upper arm, lower arm, hip, thigh, foot	Mean, entropy, energy	Decision tree (84%), kNN (83%), Naive Bayes (52%)
Karantonis [11]	Sitting, Standing, walking, lying in various positions and falls (12)	6	Waist	Signal magnitude area, tilt angle, signal magnitude vector	Decision tree (91%)
Olguin and Pentland [9]	Sitting, Running, walking, standing, lying and crawling (7)	3	Chest, hip, wrist	Mean and variance	HMM (65-92%)
Ravi [15]	Standing, walking, running, stairs up, stairs down, vacuuming,(8)	2	Waist	Mean, Standard deviation, energy, correlation	Naive bayes (64%) SVM (63%) Decision tree (57%) kNN (50%)
Bonomi [16]	Lying, sitting, standing, working on a computer, walking, running, cycling (7)	20	Lower back	Mean, Standard deviation, peak-to-peak distance, cross-correlation, spectral power, dominant frequency	Decision tree (93%)
Yeoh [17]	Sitting, lying, standing and walking speed (4)	5	Waist and thigh	Accelerometer inclination	Heuristic model (100%)
Atallah [2]	Lying, walking, running, cycling, sitting, transitional (15)	11	Chest, upper arm, wrist, hip thigh, ankle, ear	Variance, RMS, mean, energy, entropy, skewness, kurtosis, covariance	kNN (na), Bayesian (na)

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Methodology concerns

What to consider for data collection

Methodology	Sub items	Options
Data collection	Collection method Data labelling	Fully natural structured semi structured Video, self-annotation, experience sampling
Data type	Subjects Population Demographic Activities Duration	N= 1, 2, 20….100? Student, Older, Condition Age, gender etc. Run, walk, jog, stairs 5 mins, 1 hour, 1 week
Sensors	Type Sampling rate Sensitivity Number Location Orientation	Accel, GPS, Gyro 20Hz, 50Hz… +/- 2g, 6g 1, 2, 3… N Pocket, belt, wrist… Vertical, fixed/ free
Signal & Features	Raw Transform Window	m/s^2 or G Statistical or Frequency 2, 5, 10 … seconds
Results and validation	Performance validation	Accuracy, precision recall, F score N-Fold, LOSOM, Test and train, % split

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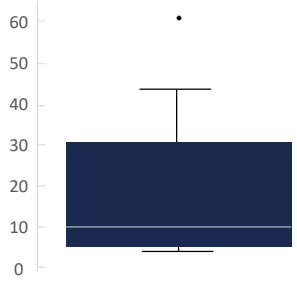
Number of Participants

No. of and Diversity in Subjects

- Many studies use very limited datasets, often with fewer than 10 subjects.
- More testing data – some systems need particularly to be robustly evidenced across subjects and scenarios.
- More training data (quantity and subjects) increases recognition performance.
- Need more diverse representative data:
  - Activities, Social situations, Environments



No. Of subjects in AR datasets within the literature

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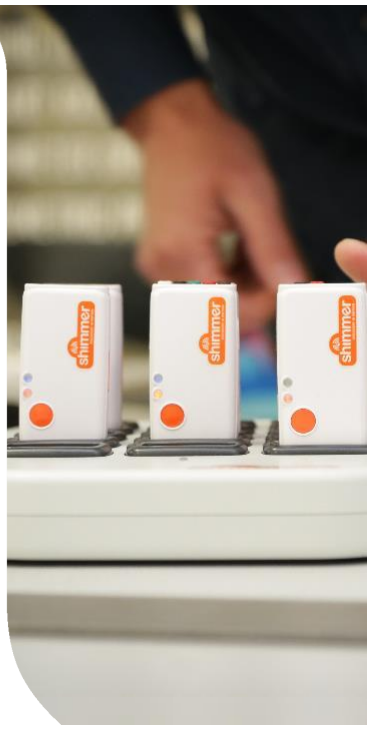
What is Shimmer?

- Shimmer is a small medical grade **wireless sensor** platform
- It can record and transmit **physiological, kinematic, environmental** data in real-time.
- Applications include, **health, environmental and sport monitoring.**



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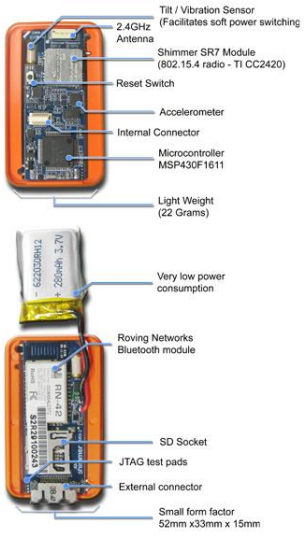
Platform features

- **Very low power consumption**
- **Small form factor: 50mm x 25mm x 12.5mm**
- **Light weight: 15 grams**
- **8Channel 12 bit A/D Converter**
- **Connects via Bluetooth or 802.15.4**
- **Offline Data Capture – Micro SD**
- **Integrated 3-axis MEMS accelerometer.**
- **Integrated tilt / vibration sensor**
- **Internal and external connectors for expansion**
- **Rechargeable Li-ion battery.**
- **Open platform, driven by TinyOS**



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What is an accelerometer

How does it work?

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Acceleration in Human Terms

What are some "g" reference points?

Description	"g" level
Earth's gravity	1g
Passenger car in corner	2g
Bumps in road	2g
Indy car driver in corner	3g
Bobsled rider in corner	5g
Human unconsciousness	7g
Space shuttle	10g

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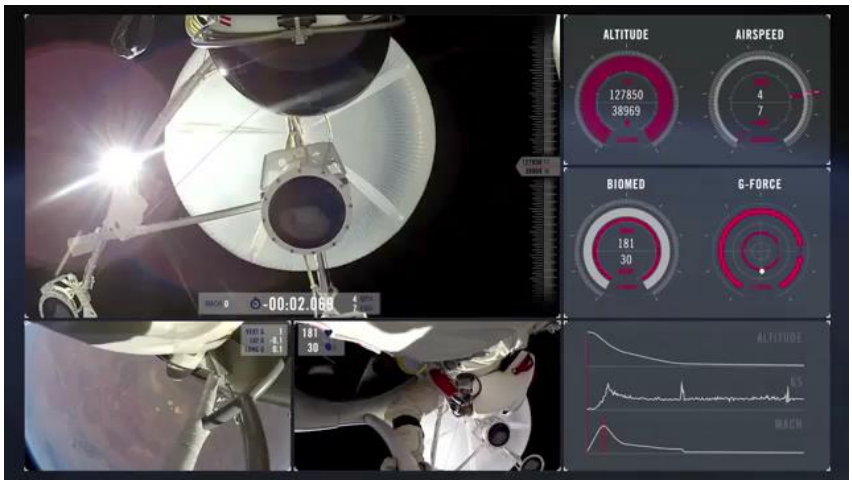
Acceleration Super-Human Terms



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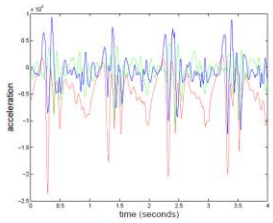
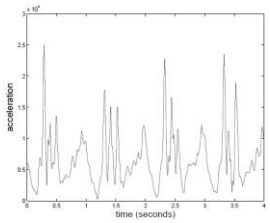
Accelerometer signal

Dynamic component- Movement

- All movement patterns result in time varying segmental accelerations.
- Before these patterns are analysed, the signal is first high pass filtered (typically 0.2–0.5 Hz) to remove any baseline offset (Gravity).
- The magnitude of all three vectors is considered so that it is not sensitive to the orientation of the sensors. $\|X\| = \sqrt{x^2 + y^2 + z^2}$





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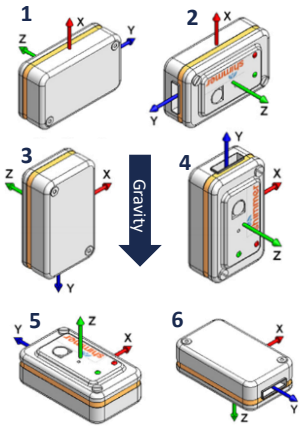
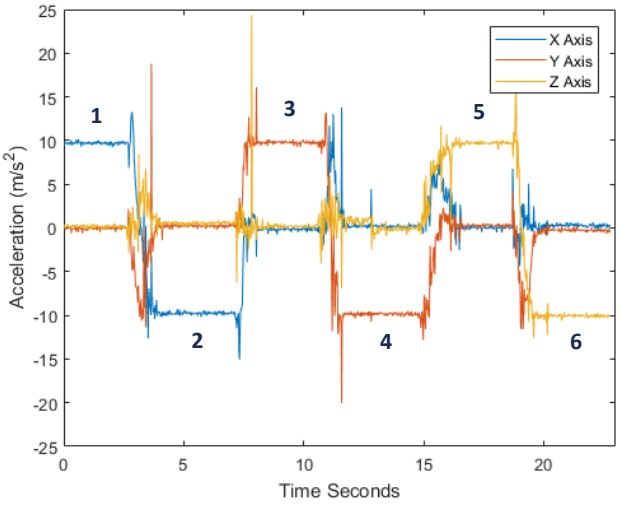
Static Component

Effects of Gravity





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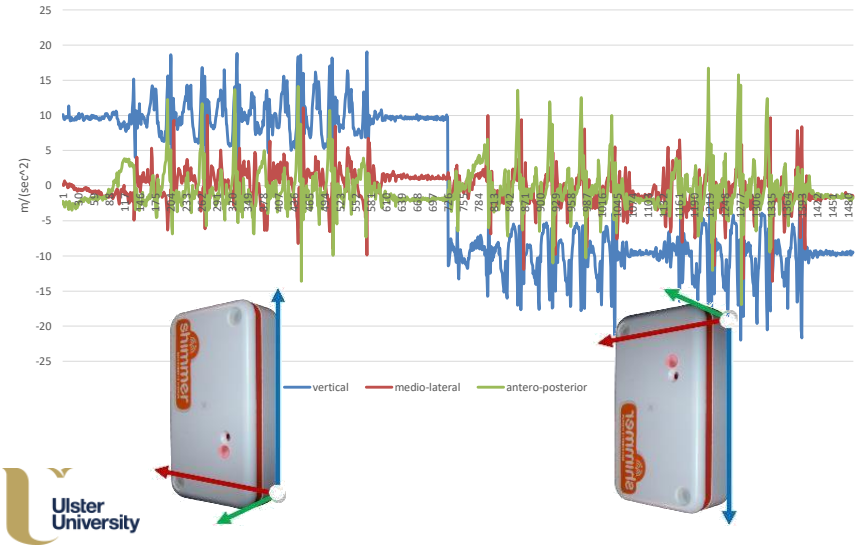
Static Component

Orientation of the sensor on the body



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What impacts the Signal?

- The acceleration signal recorded from the body depends upon the location of the sensing device and the activity being performed.
  - Location
  - Orientation
  - Activity performed
- Other influences include:
  - How its attached
  - Sensitivity
  - Calibration
  - Sampling rate

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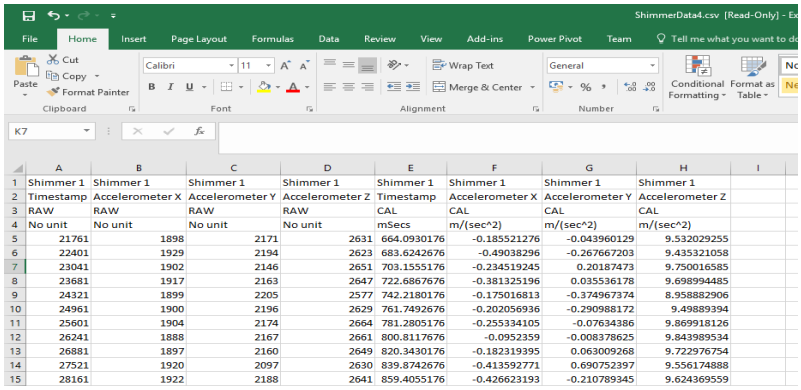
Accelerometer Data

Captured by shimmer



	A	B	C	D	E	F	G	H
1	Shimmer 1	Shimmer 1	Shimmer 1	Shimmer 1	Shimmer 1	Shimmer 1	Shimmer 1	Shimmer 1
2	Timestamp	Accelerometer X	Accelerometer Y	Accelerometer Z	Timestamp	Accelerometer X	Accelerometer Y	Accelerometer Z
3	RAW	RAW	RAW	RAW	CAL	CAL	CAL	CAL
4	No unit	No unit	No unit	No unit	mSecs	m/(sec^2)	m/(sec^2)	m/(sec^2)
5	21761	1898	2171	2631	664.0930176	-0.185521276	-0.043960129	9.532029255
6	22401	1929	2194	2623	683.6242676	-0.49038296	-0.267667203	9.435321058
7	23041	1902	2146	2651	703.1555176	-0.234519245	0.20187473	9.750016585
8	23681	1917	2163	2647	722.6867676	-0.381325196	0.035536178	9.698994485
9	24321	1899	2205	2577	742.2180176	-0.175016813	-0.374967374	8.958882906
10	24961	1900	2196	2629	761.7492676	-0.202056936	-0.290988172	9.49889394
11	25601	1904	2174	2664	781.2805176	-0.255334105	-0.07634386	9.869918126
12	26241	1888	2167	2661	800.8117676	-0.0952359	-0.008378625	9.843989534
13	26881	1897	2160	2649	820.3430176	-0.182319395	0.063009268	9.722976754
14	27521	1920	2097	2630	839.8742676	-0.413592771	0.690752397	9.556174888
15	28161	1922	2188	2641	859.4055176	-0.426623193	-0.210789345	9.624369559

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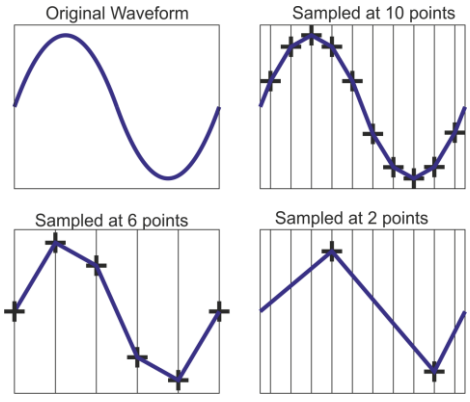
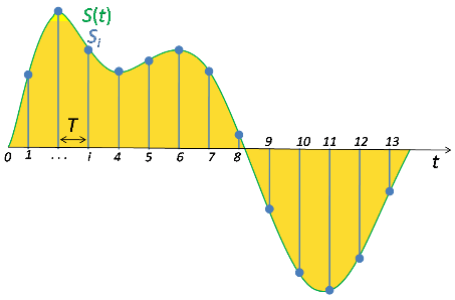
Sampling Rate

What is sampling rate?



Sample rate indicates the number of digital snapshots (Samples) taken of a signal each second.



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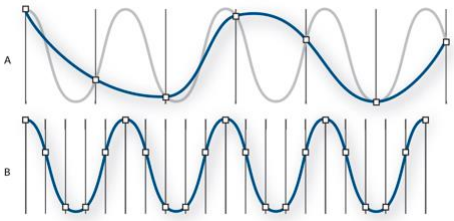
Sampling Rate

What is sampling rate?

- Hight sample rates generally equate to better representation of the signal.
- However they can include some high frequency noise that is not representative of the signal



A. Low sample rate that distorts the original sound wave.

B. High sample rate that perfectly reproduces the original sound wave.

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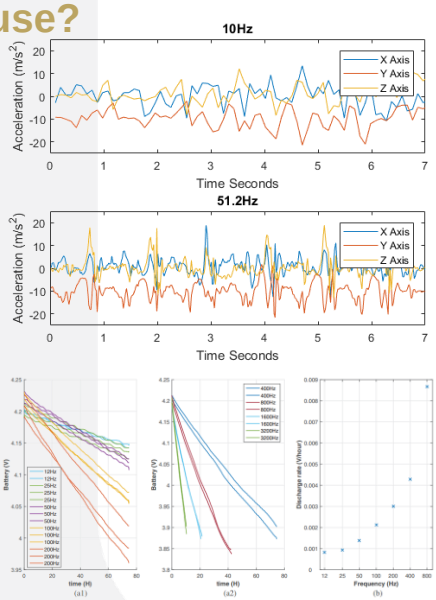
Sampling Rate

What Sampling rate to use?

- 99% of bodily acceleration is concentrated below 15Hz
- Previous work suggests that sampling rates of approximately 20Hz are reasonable for “standard” human activities.
- For example, datasets like Opportunity were recorded at 30Hz.
- Health and sports assessment scenarios 100 Hz
- Other domains sampling rates as high as 250 Hz have been used.



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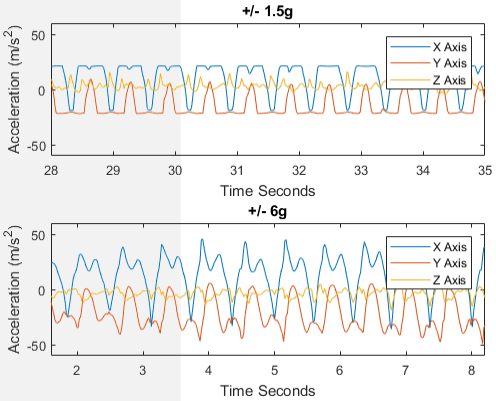
Accelerometer range

What range to use?

- Bodily acceleration amplitude ranges up to ±12G.
- Promising results can be obtained using ±2 G
- Although acceleration at body extremities can exhibit a 12 G range
- Majority of points near the torso and hip experience only a 6 G



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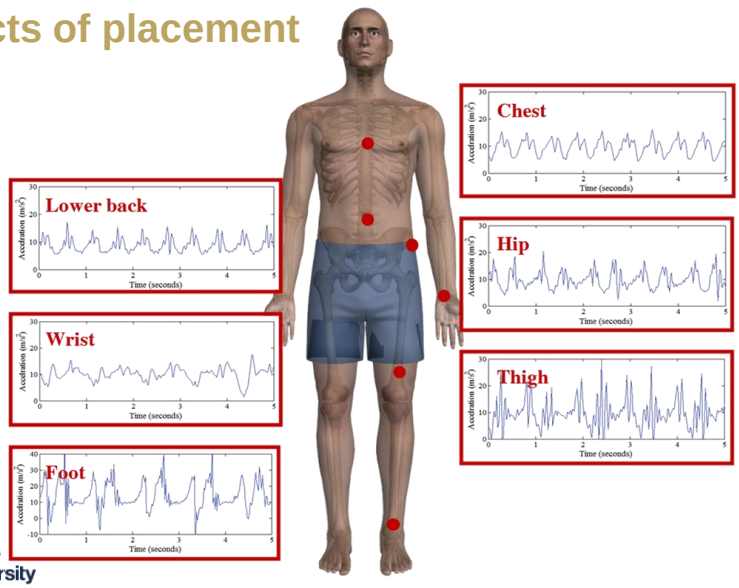
Placement of Accelerometer

Effects of placement



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Placement of Accelerometer

What location is best?

- The **hip** and **wrist** are the most common locations for placement, Whole body movement, practical.
- The **thigh** easily differentiate sitting/lying vs. standing and other activities.
- The **ankle** is used commonly in gait studies. Useful for sub-gait phases.
- The **upper arm** is a location that has been used by some commercial fitness monitors and exercise monitoring phone apps.

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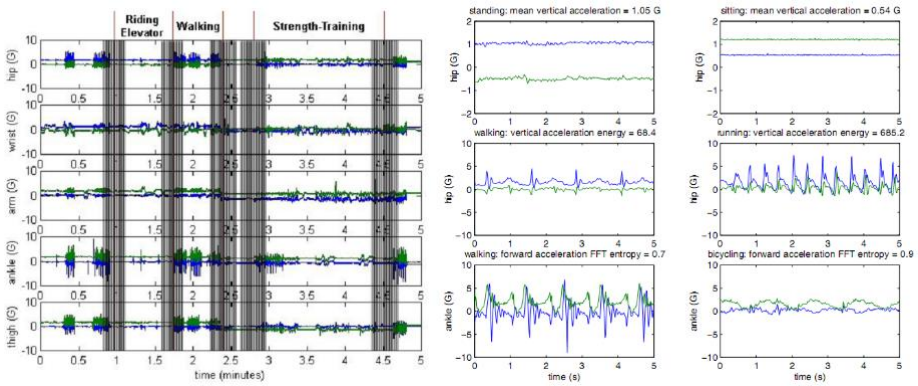
Activity Being performed

Type and intensity of movement

- The type of activity being performed.
- The intensity of the movement.
- The transitions between activities.



Bao and Intille

Working with Sensing Technologies

Collecting Movement Data

- Learn about the Shimmer wireless sensing platform and how to communicate with it from your PC using Bluetooth.
- Be briefly introduced to tri-axial accelerometers.
- See, in real time, how each axis of the accelerometer reacts to sensor movement in different directions.
- Collect data for activity recognition.

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Working with Sensing Technologies

Collecting Movement Data

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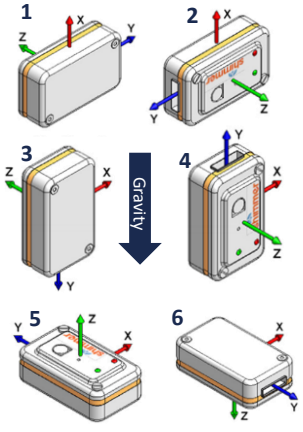
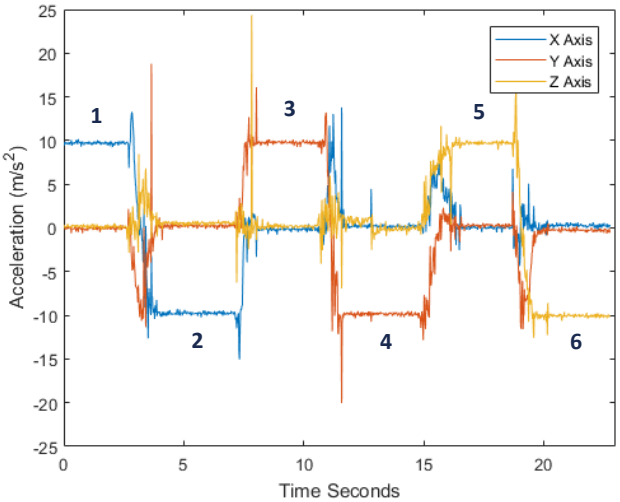
Static Component

Effects of Gravity





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Further reading

Activity recognition

Avci, Akin, et al. "Activity recognition using inertial sensing for healthcare, wellbeing and sports applications: A survey." *Architecture of computing systems (ARCS), 2010 23rd international conference on*. VDE, 2010.

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Data Gathering Practical

https://goo.gl/2oXTyG

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Questions?

Full body motion Capture

Xsens-IMU Demo