

Sensing Technologies for Monitoring Human Behaviour

Prof. Alan F. Smeaton
INSIGHT: Centre for Data Analytics
Dublin City University

alan.smeaton@dcu.ie

Who am I?



- Academic, researcher, computer scientist, entrepreneur
- Information management, content-based web visual material – image and video
- TRECVid coordinator
- Sensors for people, sensor networks
- Lifelogging, personal digital archives
- Firmly believe in collaborations ... across boundaries lies the most interesting work, very varied
- Firmly believe in working with companies ... they have the problems, they have the money
- What gives me the right to present to you ...

I work in Lifelogging



- "Undiscriminating (indiscriminate?) collection of information concerning one's life and behaviour"
 K. O'Hara
- Characteristics are ... digital format ... not selective ... always-on ... first person ... raw and derived data streams ... perhaps real-time ...
- Why? For work, for personal, for posterity, or initially because we could

Overview



- Lifelogging
- Applications heathcare why
- Wearable Sensors
 - SenseCan and visual sensing
 - Concepts -> Behaviour
 - Kinect
 - 1 Accelerometer FitBit, Shine, GPS
- Wearable Sensors for Physiology
 - HR, RR, GSR, Sweat
- Environmental Lifelogging
 - Domestic energy
- Multiple Sensors, Cycling
- Where to find more details

Lifelogging



- Creates a (permanent) digital record human digital archive, a lifelog, personal memory bank
- Presents challenges in terms of
 - Technologies to sense and to capture
 - Technologies to store and transmit
 - Techniques to analyse and understand
 - Techniques to access, retrieve
 - Finding useful applications in which to embed
- This is the wrong way around ... it should be
 - Problem > Solution > Technologies
- Instead its
 - Technologies ... looking for problems to solve ... hence the slow burn startup

Applications



- Very diverse range of lifelog application areas:
- Healthcare self monitoring
 - Many devices for logging energy expenditure Apple and FitBit, Nike Fuelband, Lark – count steps or calories or Nike Fuel "points"
 - Accelerometer / gyro, wristband typically
 - Wrapped into a gamification model CHI workshop 2013 "competition"
 - Not great at logging some exercises ... cycling, swimming

Applications



- Why healthcare self-monitoring ...
 - Because we can
 - Because its been gamified
 - Because its cheap and satisfies a self-curiosity
 - Because its marketed at us

Healthcare self-monitoring has real-life applications

- Diet monitoring difficult to sense what you eat automatically, easy to cheat, so used as a memory trigger for manual log
- Smoking cessation likewise difficult to sense smoking automatically so apps used as a conscience trigger

Healthcare Applications



Memory prosthesis for people with dementia

- Re-living a recent experience from a lifelog can induce a Proustian recall ... trigger can be a smell, sound, image, object, etc. ... or from your own lifelog
- Lots of work using SenseCam especially, to log and then re-play a day ... today ... giving short-term recall, opening cognitive pathways

Lifelog Technology



Divided into ...

- 1. Wearable sensors, on body, sense and log body actions, physiological reactions, either voluntary or involuntary. Exclude GSR, fMRI, EEG because these are reactionary within a *session* rather than logging a whole *life*.
- 2. Environmental sensors to sense and log the human impact or footprint on a place, indirect lifelogging

Wearable technologies



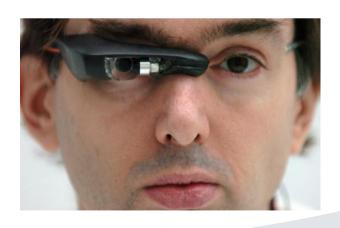














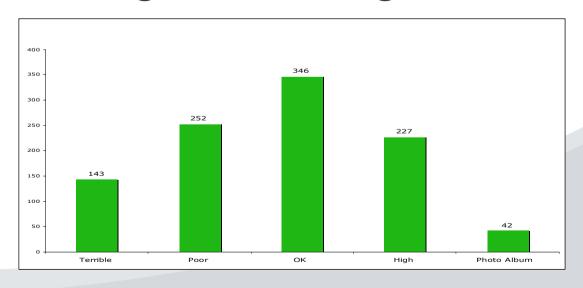




SenseCam



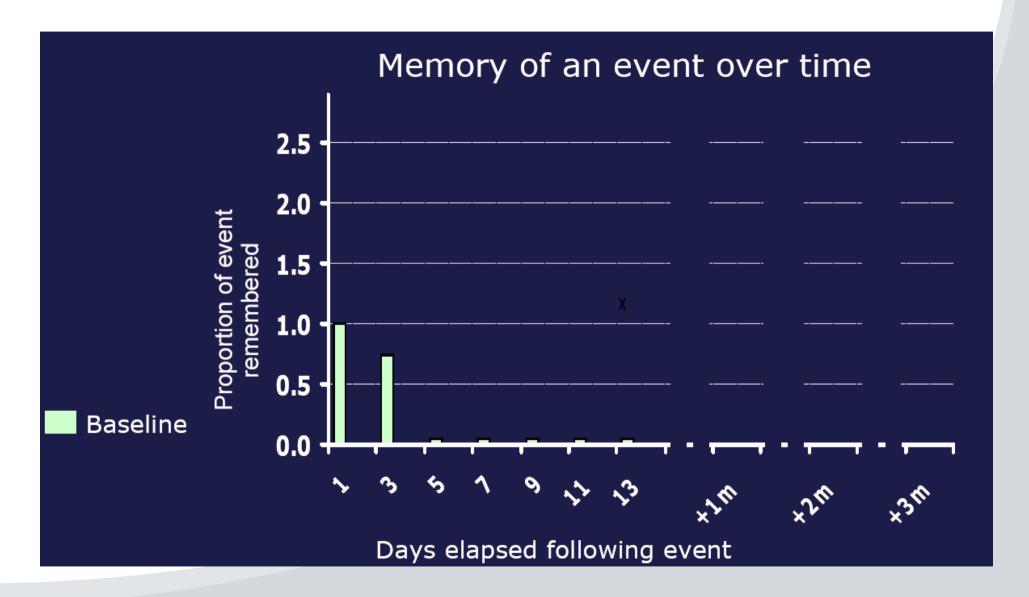
- Much of lifelogging is about recording visuals
- We've use Microsoft SenseCam with various sensors
- Individually poor quality images but can leverage it
- Superseeded by Vicon Revue, Autographer, Memoto
- Over 40 years of cumulative SenseCam data and a background of image and video analysis





Addenbrooke's: SenseCam Wor

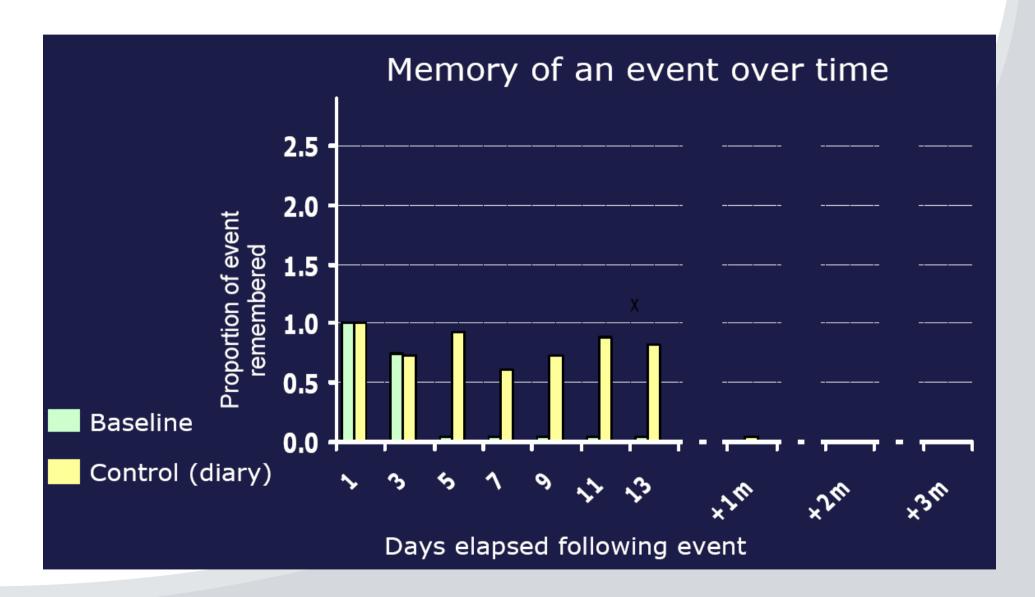




Microsoft Research Cambridge presentation: http://research.microsoft.com/~shodges/presentations/UBICOMP senseCam.pdf

Addenbrooke's: SenseCam Work

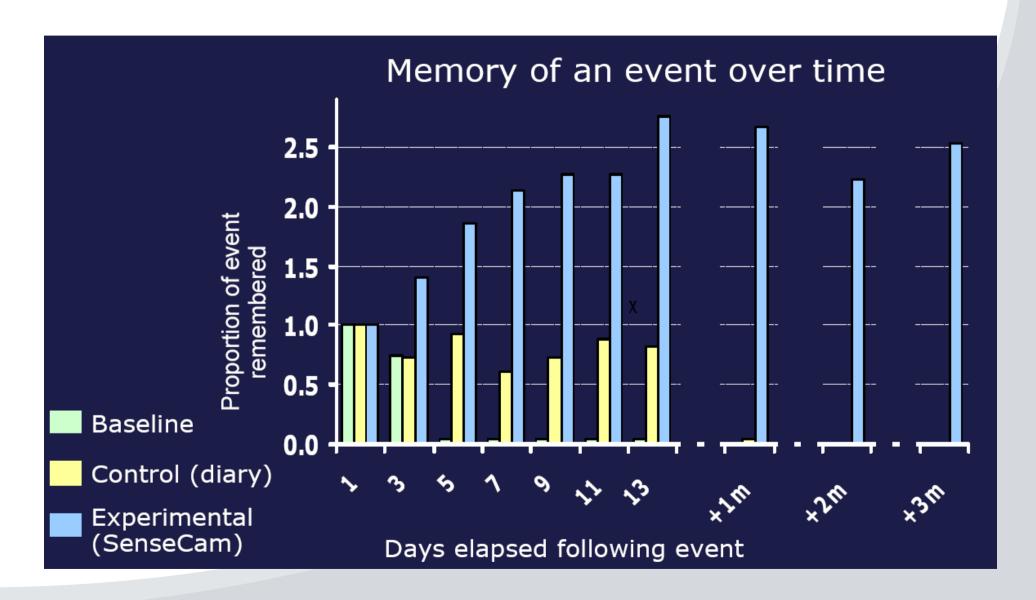




Microsoft Research Cambridge presentation: http://research.microsoft.com/~shodges/presentations/UBICOMP senseCam.pdf

Addenbrooke's: SenseCam Work





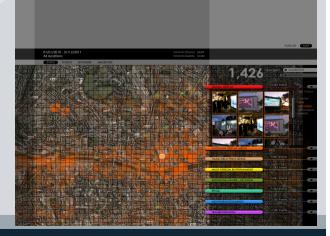
Microsoft Research Cambridge presentation: http://research.microsoft.com/~shodges/presentations/UBICOMP senseCam.pdf

Other Applications



- Corporate Memory Capture procedures
 - Past work on healthcare workers in clinical practice,
 logging their work at the end of shift
- Market research novel qualitative analysis
 - Past work on music festival attendees with visual lifelogging and location-tracking (Android)
 - Information aggregated and images are then searchable.
 Can gain insights into who saw what, where and when





Market Analysis



 Worked with an Irish SME to develop a system to allow upload of lifelog images and data

- Field-tested at 2011 Electric Picnic where 100,000+ images were uploaded from 11 individuals
- Subsequently analysed behaviour patterns; using SIFT/SURF techniques we are able to search for logos/brands
- Now moving to eye-glass based video capture, with eye-tracking









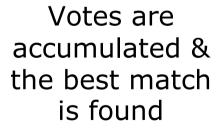
Lifelogging for Market Analysisty



SURF features are extracted



Each feature
point casts a
weighted vote
against multiple
database
images















Analysing visual lifelogs



- Analyse lifelog images to detect concepts
- Same approach as is used to index image or video ... accuracy?
- Built on extracting LLFs as input to SVM classifiers, trained on groundtruth data
- What kind of concepts?
- This becomes the key for behaviour analysis



Food/eating





























Full Motion Body Capture



- Wearables are only an approximation
- Traditional direct approach is Vicon
- Accurate, sampling rate (120-250Hz)
- Disadvantages
- Cumbersome, expensive
- Motion confined to small area
- Markers interfere with









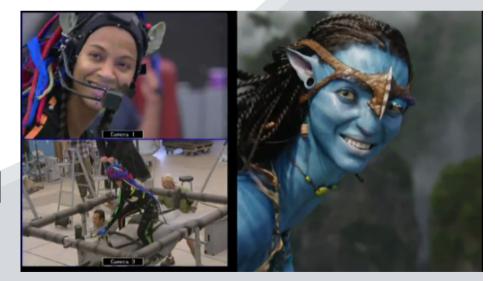












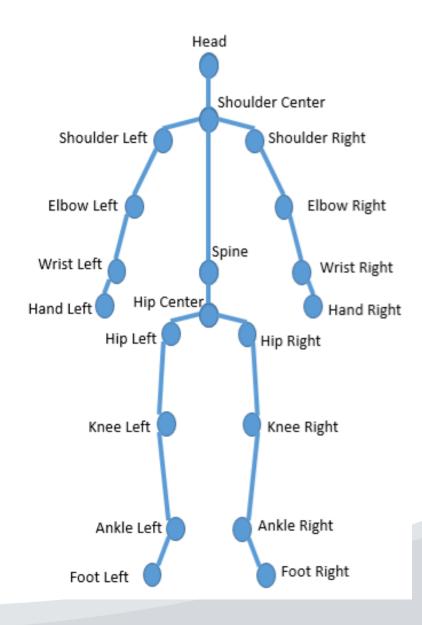
Kinect: Env sensor



- And then came Kinect!
- Integrated mic. array, visible spectrum camera, IR-based depth camera
- Cheap ... €100
- Interface to X-Box gaming console
- Quickly hacked so Microsoft released API
- Simple to tap into depth map video and develop hacks ... Best Kinect hacks http://www.kinecthacks.com/top-10-best-kinect-hacks/

Kinect accuracy





Kinect mounted over screen in noisy office environment, tracking joints

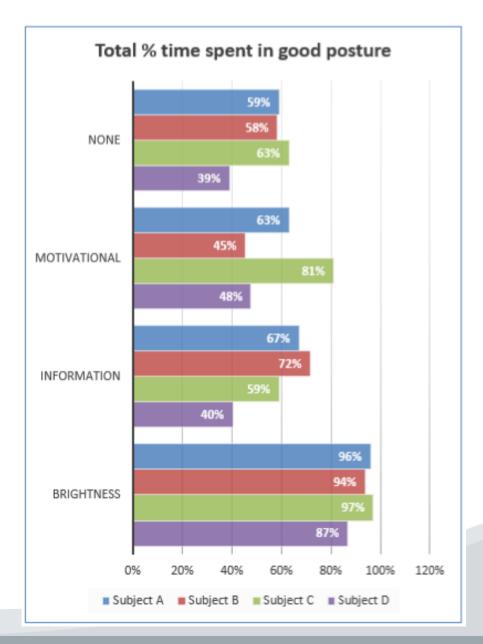
Table 1. % time each joint was successfully tracked over a 4-hour peric

Joint	% Time
Head	99.98%
Right Shoulder	87.83%
Right Elbow	70.56%
Right Wrist	68.42%
Right Hand	68.08%

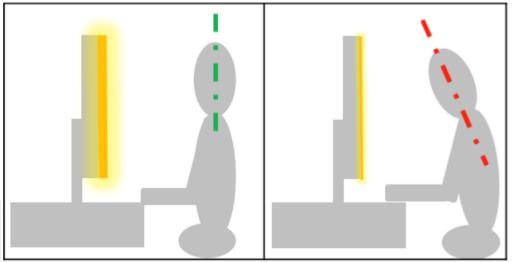
Joint	% Time
Shoulder Centre	99.08%
Left Shoulder	89.65%
Left Elbow	58.52%
Left Wrist	56.62%
Left Hand	55.98%

Posture monitoring





3 kinds of intervention ... popup messages, hourly info, dimming of screens



Kinect



- Best hacks ...
- #10 virtual dressing room captures depth of subject and wraps a 3D non-deforming model of clothes around the subject, ours deforms the clothes = more natural
- #9 (wall) we did this for NMI treasure room (award-winning at MM2011)
- Play the others and be inspired!
- All revolve around sensing what you are doing, now

Activity capture



- Motion capture (Vicon, even Kinect) is high-end, other times we dont need full motion capture, just activity classification
- What can we do using simple accelerometers?
- Wouldn't it be great to be able to identify what a person is doing in real time?
- How can we do it ?

HOW?



- You only need one accelerometer-enabled phone and some clever software... to get 98% accuracy in classifying activities!
- Walking, standing, running, driving, and so on...

How to identify human activity from accelerometers?

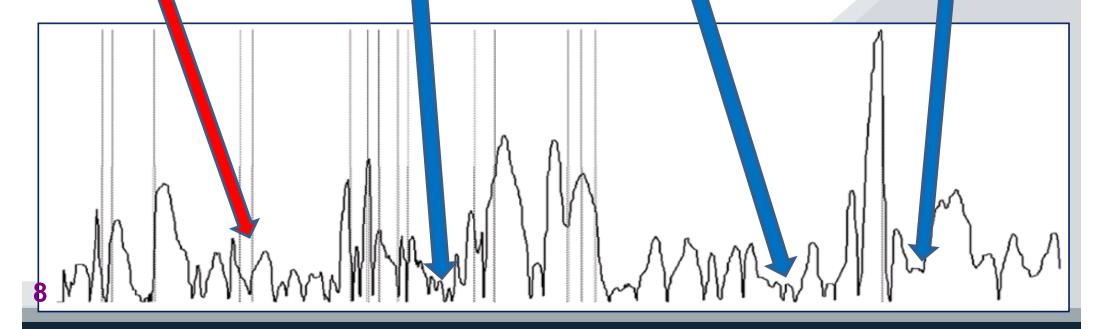
- 1 week groundtruth (132,247 acc readings)
- SVM 39 features (mean/range/stdev of previous 1/5/20/120/300 on X/Y/Z axes)
- Precision score of 0.82 recorded after re-occurrence smoothing











Identifying Activities Sitting/Standing = 93% accurate

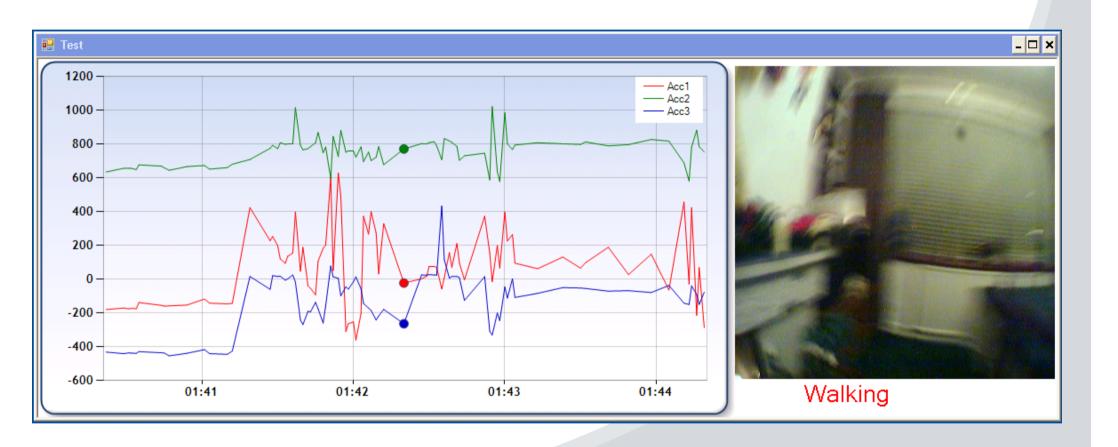


Using a range of classifiers: Logistic Regression, Naïve Bayes, J48, SVM, etc.



Identifying Activities Walking = 97% Accurate





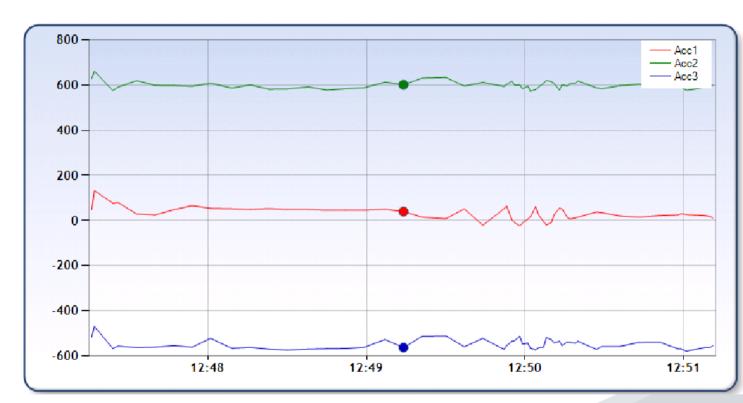
Identifying Activities Driving = 98% Accurate





Identifying Activities Lying = 98% Accurate



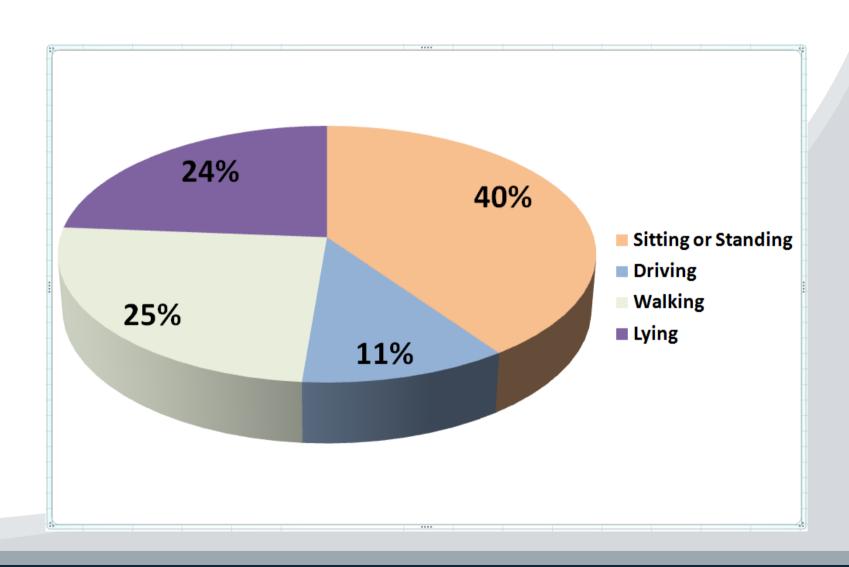




Lying

1 week's activities





OTS Energy Expenditure

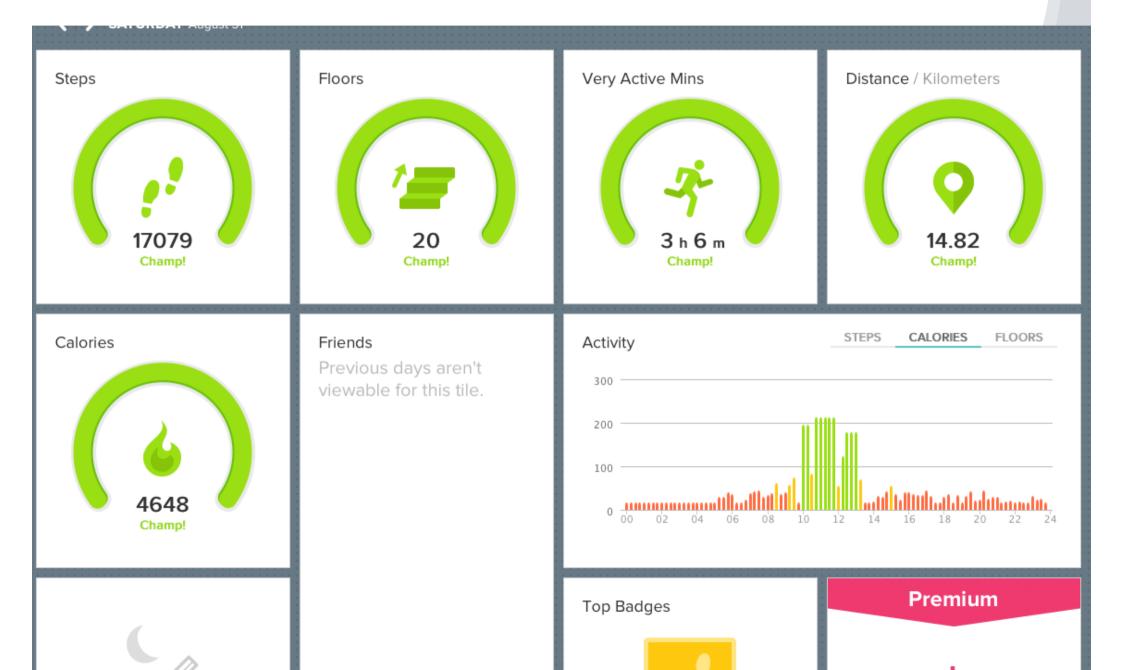


- Nowadays there are many OTS, "trendy" energy monitors ... FitBit, Nike Pulse, Jawbone, Shine, ...
- Worn on wrist or pinned to clothes
- All very similar, but different
- All use gyro, accel and magnetometers
- Vary on amount/sophistication of on-board processing for activity classification, and algorithms for calculating energy expenditure, APIs
- Some use calories, others something proprietary (i.e. don't reveal inaccuracy, depend on user satisfaction with relative comparisons)

M NIKE #fitbit **IAWBONE** MISFIT Fuelband Shine One Flex Up Simplicity & versatility Integrated into daily life Aspirational, athletic Whole life management Elegance, wear anywhere Product Positioning Aircraft-grade alumnum Plastic, rubber Material Plastic, rubber Plastic, rubber Plastic, rubber Waterproof 50 meters None None None Shower Display LED OLED LED LED None 8 Watch Function Progress Bar Tracks Steps Non-step activity Swimming Sleep (tracks sleep) Wearing Positions Hip/Pants Chest/Shirt/Bra Wrist Shoes Neck Wearing Occasions Formal/Business Casual/Fitness Sleep wear Swim wear Proprietary cable USB cable Proprietary cable Charging None Proprietary cable Battery life 120-180 days 5-7 days 5 days 4 days 10 days

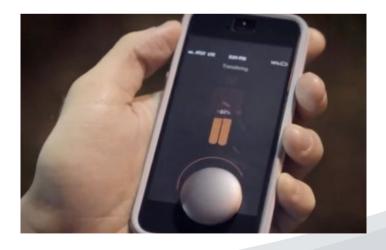
FitBit web dashboard





Shine iPhone(5)







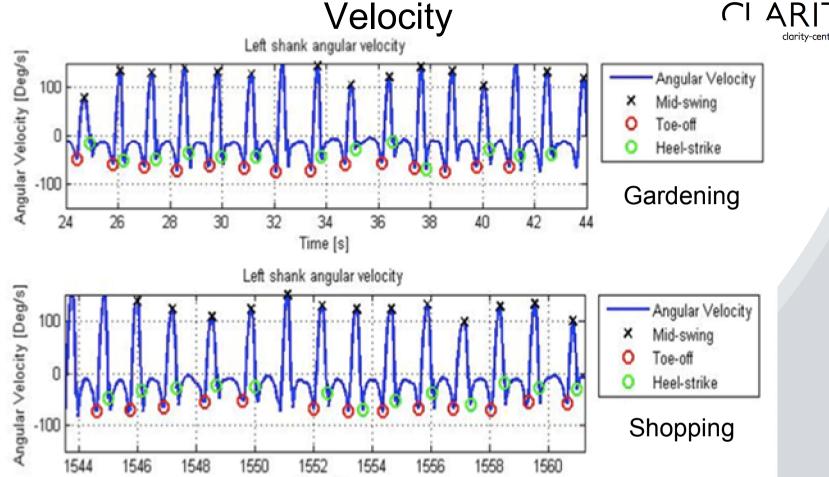
Sensing for Falls Prevention



- We can monitor the gait of a wearer using the SHIMMER platform.
- The SHIMMER can incorporate many sensors including tilt and vibration.



 Working with the wearer afterwards, a health professional can analyse data and diagnose, but a difficulty is re-creating context Comparison of Right Shank Sagittal Angular



patterns or differences may be due to differences in floor surface or cognitive challenge posed by surrounding stimuli.

Time [s]

How to determine this? Dialogue with wearer but sometimes this is difficult.

James Smith

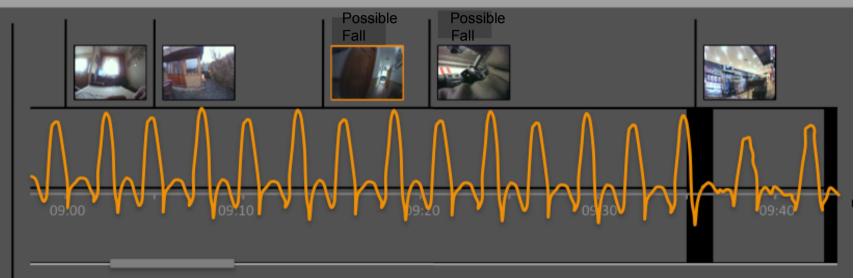
Age: 67

April 2011 07:26 – 21:40



Duration 16 hrs
Events 38
Possible falls 3
Images 1,435
Notes 7











NOTES

Changes in gait could be due to reduced lighting in the area of the kitchen

GPS



- GPS in an obvious one ... so much we can leverage using public resources from simple long-lat-altitude data ... placenames, weather, events, photos, etc.
- GPS on Smartphones ... works for you and me, but people with some human conditions?
- Oct 2012, GTX Corp announced the following, aimed at people with dementia, included in the "100 Most Important Inventions of Mankind" Exhibit in the National Museum of Science and Technology in Sweden ...

GPS



... with the usual support ... website, geofencing, SMS alerts, API, etc.

: Aetrex Navistar GPS Shoes



/istar Men's - Lace X801M

are ptions



Aetrex Navistar Men's GPS Shoe - Lace X821M

€227.60

Not Rated

Compare

Choose Options



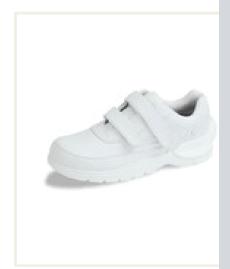
Aetrex Navistar Men's GPS Shoe - Strap X920M

€227.60

Not Rated

Compare

Choose Options



Aetrex Navistar Men's GPS Shoe - Strap X926V

€227.60

Not Rated

Compare

Choose Options

Sleep



Devices for logging your sleep – duration and quality

Parameters are sleep onset, % deep sleep, %

shallow sleep,

 Wristband (worn, LARK), or device/smartphone under the pillow using accelerometers/ gyros

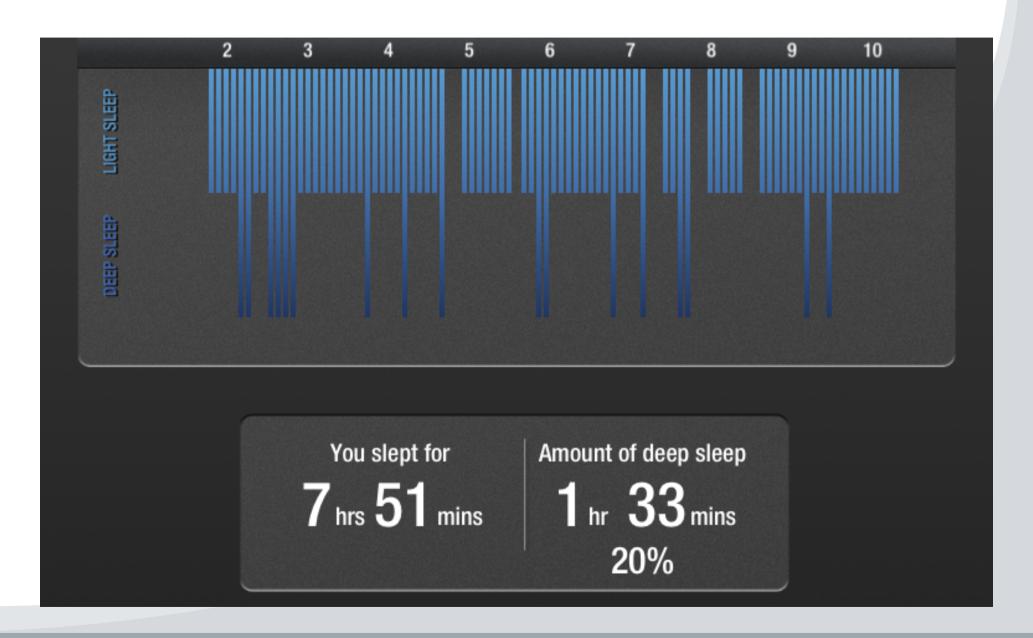
- Logging of breathing patterns Gear4
 Renew Sleepclock uses ultra-sensitive sonar and measures refraction as we breathe/move, so it is contactless
- Should really be used in IC units in hospitals but it's a product!





Gear4 Data Visualisation





Gear4 Data Visualisation





LARK dashboard



<<

Week May 5 - May 11















Thu, May 9, 2013



Good evening
alan.smeaton@dcu.ie
54 M, 185 lbs, 5' 11", Switcher

You slept OK.

Sleep Stats

Time Asleep

9.0 out of 10

Sleep Quality

Fell Asleep In

5 min Woke Up

15 times

Sleep Pattern

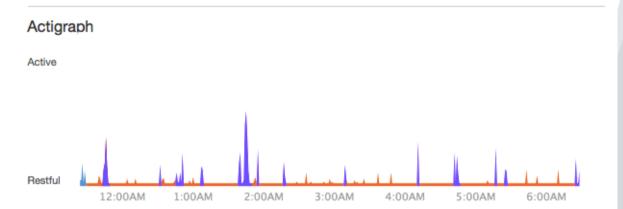
Total time 7h 5m

Bedtime 11:24 PM

Wake up 6:29







Historical stats	Since March 01, 2012		
Data for	Avg Time Asleep	Avg Total Time in Bed	Avg Sleep Quality
324 nights	6h	7h	8.6
Rate of use 74%	31m	36m	0.0
, .		Avg Bedtime 11:55 PM Avg Wake Up 7:31 AM	Avg Time to Fall Asleep 25 min Avg Times Awaken 17 times

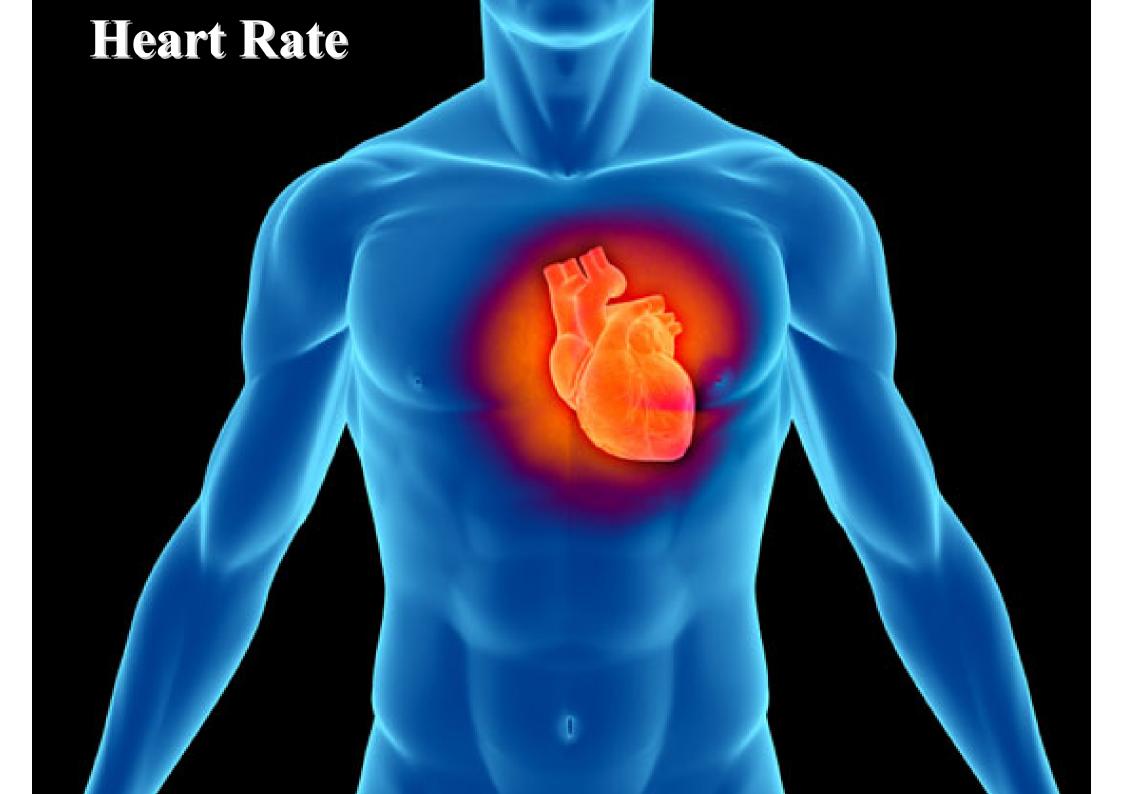
Sensing Physiology



- We can sense human physiology and how it is an indicator of stress or tension or relaxation or whatever
- We can measure HR, breathing (RR), GSR
- We could also do EEG, fMRI but these are sessional rather than lifelog
- Why do our physiology readings change, what induces stress, annoyance, discomfort, fear, relaxation, etc.
- We have reactions to the following ...





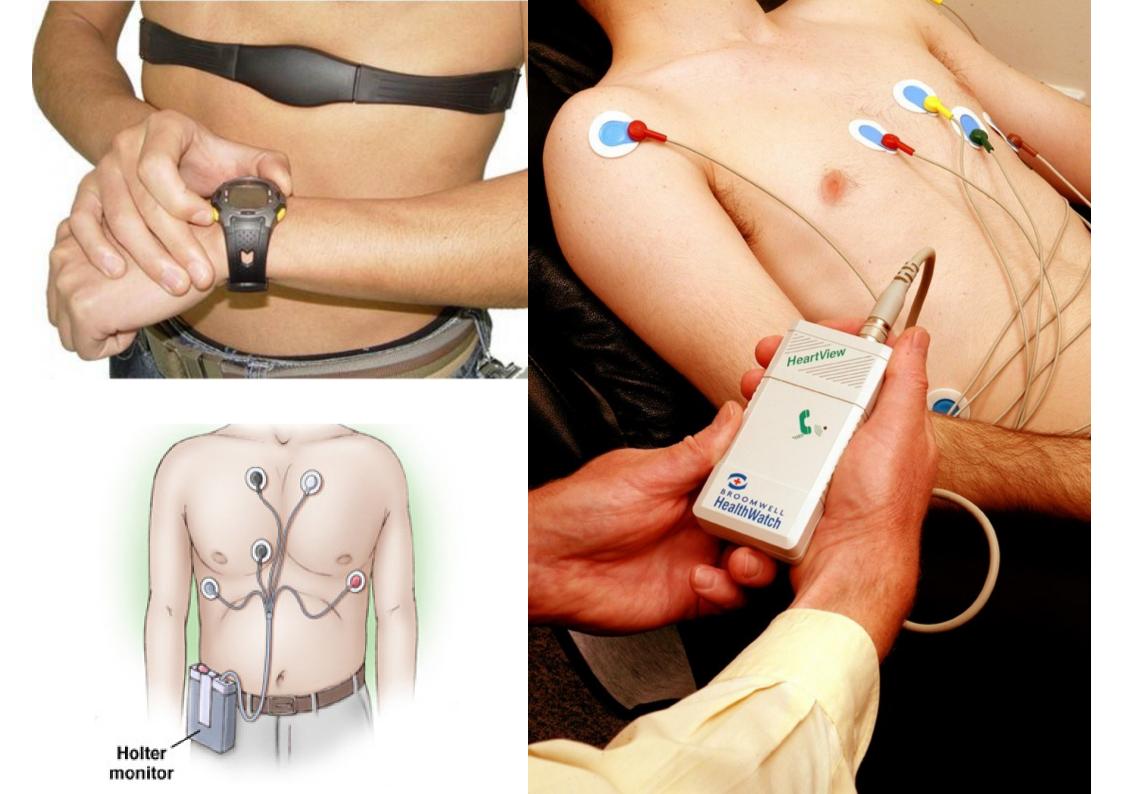


Heart Rate

- no. of heart beats per minute (bpm)
- regulated by autonomic nervous system
- sympathetic activity \trianglet HR
 e.g. exercise
- e.g. trained athletes

Heart rate Variability

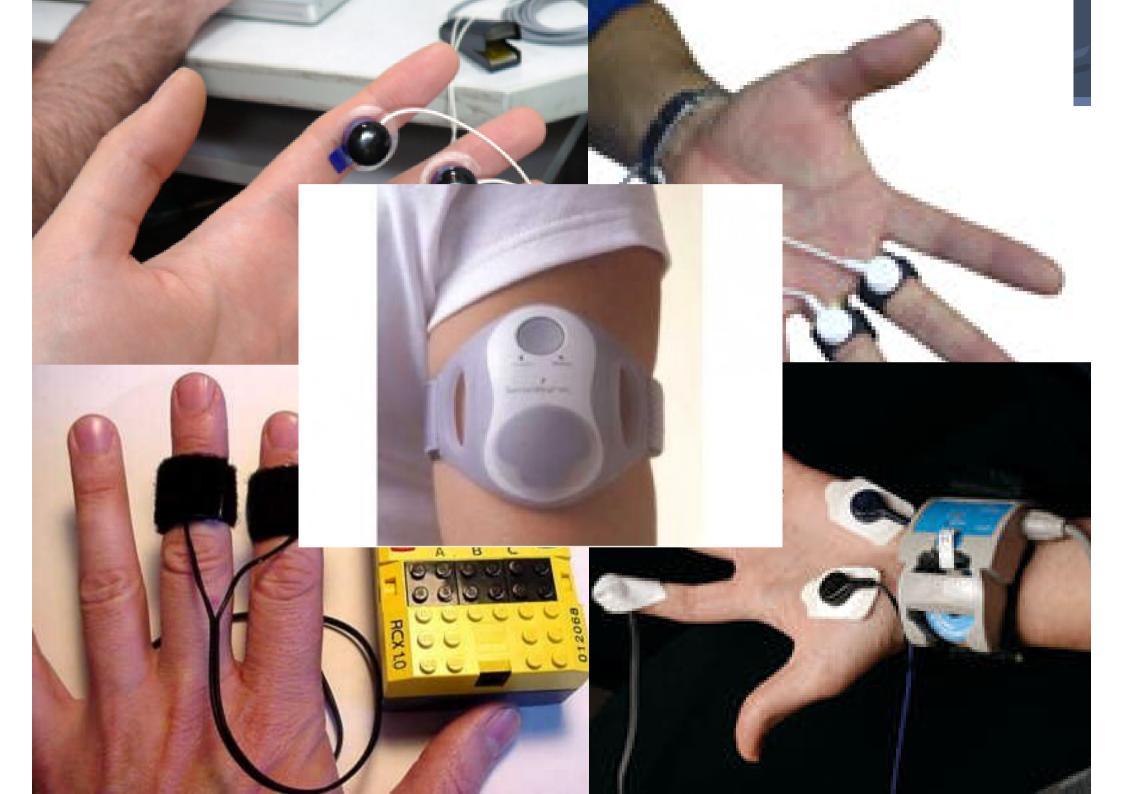
- beat to beat variation
- interaction symp & para activity



GSR

- Measure changes in electrical properties of skin caused by change in interaction between environment and psychological state
- Valid indicator for measuring arousal, responds to smallest variations
- Measured simultaneously with exposure to stimulii









What does all that tell us ...

 ... we can record human responses to stimuli, in real time, using portable but cumbersone technology;

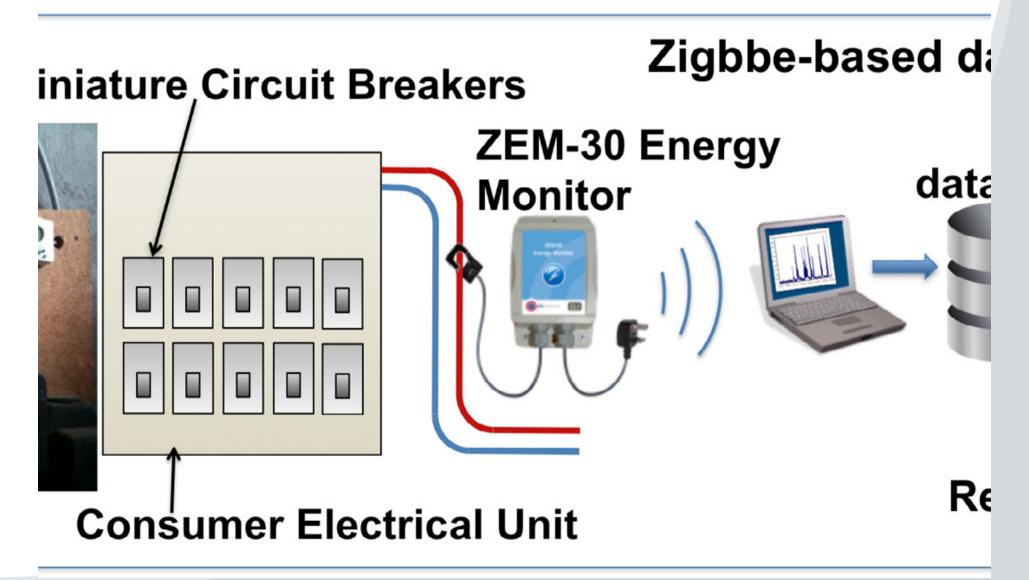
Environmental Lifelogging



- Much of our environment is monitored
- We're interested in logging the impact that we each have, on our environment
- This isn't surveillance, its sousveillance
- Not applicable to public spaces, or shared environments, like here, but to our personal spaces
- What sensing in our homes?
 - Our homes may have PIR and contact sensors for burglar alarms and companies do log these and monitor patterns and deviations
 - Our homes have, or will have, sensing of energy consumption for smart metering



Experimental set-up

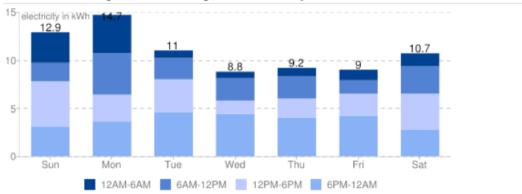


Weekly Email



Weekly email ... Google Powermeter did this ...

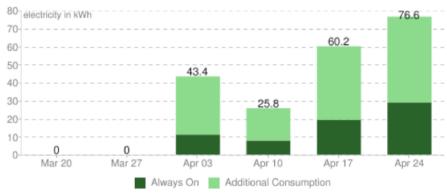
Breakdown by Time of Day, Week of Apr 24



Always On is the amount of electricity you are using all the time during the day. All other bars are electricity above the Always On.

Total Consumption by Week

This week: 77 kWh + 16 kWh (+27%)



NOTE: During your first week, we have incomplete data so consumption may be misestimated. Last reading at 11:32PM on Mon May 09 2011.



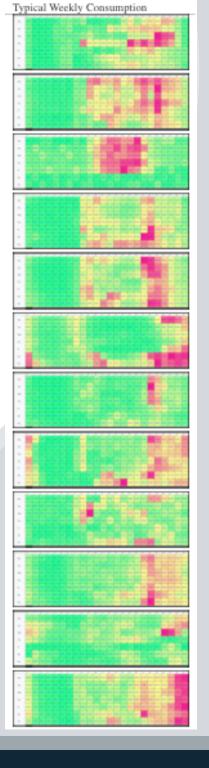
Anecdotes

Guess what? We found the same as everyone else ... initial enthusiasm gives way to bad habits - need to continuously inform

- Touch-screen application well received and good performance in savings
- E-mail competition generated lots of discussion, but no noticeable effect on electricity consumption, so we didn't get the social/peer groupings correct
- Web portal not accessed very much, thanks Leon

Strange outcome #1

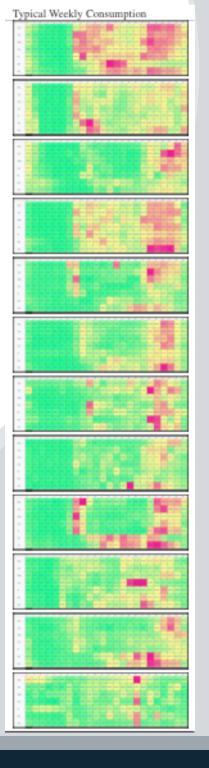
- A strange outcome was the interest in the heatmaps as a tool to summarise lifestyles;
- One ambient, cheap sensor telling a lot about living patterns;
- Work with ethnographers and geriatricians on monitoring the lifestyles of people;
- Don't need high resolution energy sensing, cheap €100 option does



Strange Outcome #1

This will be even cheaper with rollout of smart meters, where this can be done for free;

Could allow easy inter-user comparisons, better identification of peer groups, for comparison, long-term deviation detection ... all for reducing energy ... but what else?



Sensing The Home



Since each electrical appliance has a signature (duration, load, etc.) we learned signatures for devices, automatically

Applied signature recognition to sensed data allowing appliance recognition and usage Currently off-line and archival, but moving to RT

What use is this?

Use Case: My Shower Usage, 6 months CLARITY

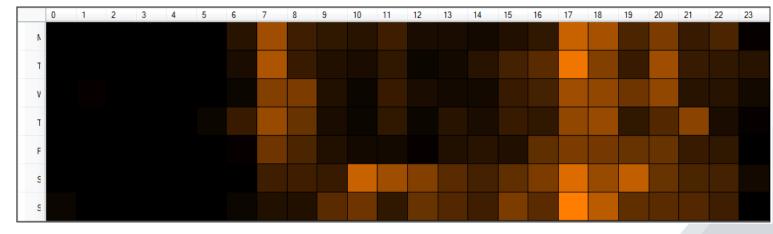
- 520 showers
- Average duration = 8 minutes (min = 3 min, max = 27 min)
- 8am Tuesday morning is peak time

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	U	1	2	3	4	5	0	/	0	3	10	11	12	13	14	10	10	17	10	13	20	21	22	23
Mon	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	9.15%	26.14%	53.59%	49.02%	75.16%	66.67%	54.90%	33.99%	25.49%	0.00%	10.46%	1.96%	4.58%	7.19%	11.76%	0.00%	0.00%	2.61%
Tue	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	7.19%	50.33%	100.0	64.71%	37.91%	57.52%	0.00%	37.25%	5.88%	6.54%	6.54%	1.96%	5.88%	0.00%	0.00%	3.27%	11.11%	0.00%
Wed	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	9.15%	61.44%	79.08%	52.29%	49.67%	38.56%	31.37%	18.30%	6.54%	11.76%	2.61%	9.15%	11.11%	7.19%	0.00%	0.00%	3.92%	0.00%
Thu	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.27%	77.12%	60.78%	96.73%	56.21%	58.17%	19.61%	33.33%	22.22%	9.15%	14.38%	0.00%	0.00%	13.07%	7.19%	8.50%	3.27%	0.00%
Fri	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	11.76%	46.41%	64.05%	64.05%	13.07%	30.72%	16.34%	31.37%	19.61%	3.27%	33.99%	25.49%	0.00%	0.00%	8.50%	1.96%	0.00%	0.00%
Sat	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	13.73%	29.41%	33.33%	13.07%	33.99%	85.62%	79.08%	50.33%	29.41%	33.33%	14.38%	5.88%	5.88%	4.58%	0.00%	7.19%	3.27%
Sun	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	18.30%	18.95%	13.73%	43.14%	32.03%	50.33%	25.49%	30.07%	18.30%	28.76%	24.18%	4.58%	0.00%	7.84%	7.84%	4.58%	0.00%

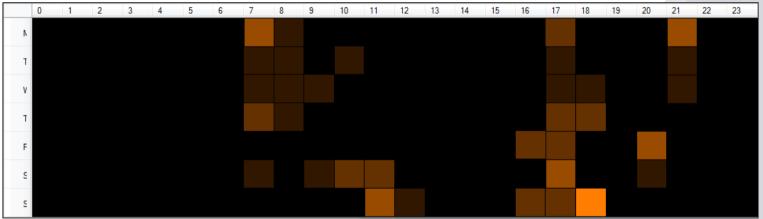
Kettle usage, chez-moi!







June



This is useful for energy analysis but also environmental lifelogging, what is happening in the home from 1 cheap ambient sensor

Overinstrumenting:Cycling



- Race Around Ireland cycle race
 - Non-stop, 1,350 miles, solo or team of 4, some hills, mostly flat;
- Strategy and pacing are key to completion
 - When to rest, how to pace, who to race, recovery;
- Human performance scientists interests
 - How the human body recovers, how to maximise performance over 4/5-day endurance, what recovery techniques work best.

Over-

CLARITY

instrumenting:Cycling

So we instrumented a team with sensors

- On Body ...
 - Heart rate, GSR, respiration, fluid intake, food intake, sweat analysis, blood analysis, massage,
 - Ankle-mounted WIMU gives cadence, cycle/rest times

On Bike ...

- WIMU gives yaw and roll, in/out saddle
- Power gauge gives power output

• Environment ...

Weather, wind, temperature,
 road surface, wet/dry, day/night
 video tracking using geospatial measurement jeep





Over-

CLARITY

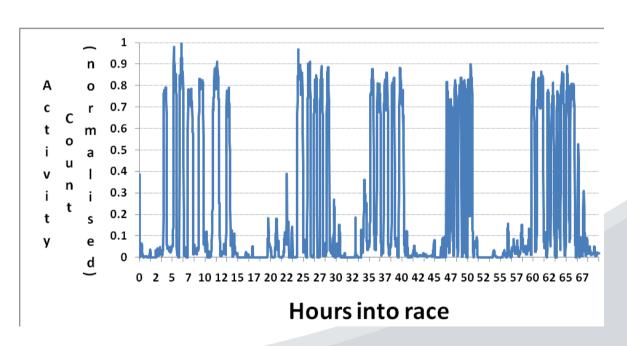
instrumenting:Cycling

What do sports scientists want?

Study of performance (degradation) over time, impact of

different recovery techniques

Insights into endurance performance





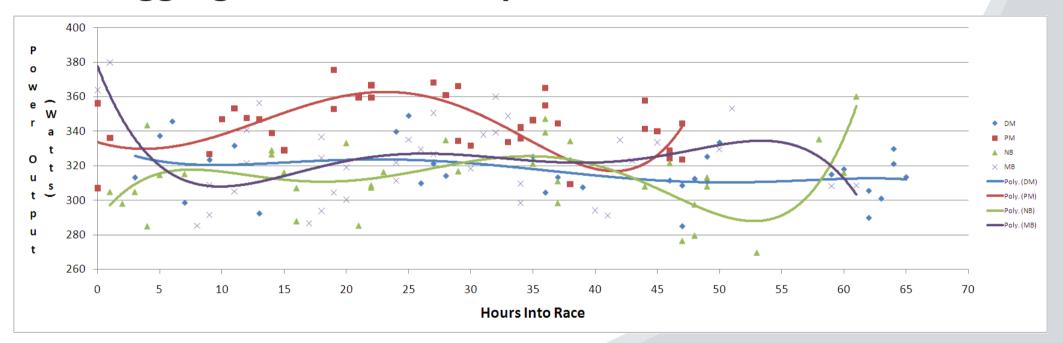


Over-



instrumenting:Cycling

• For sports scientists, the following is gold ... aggregated from multiple sensors;



Applications



- So lots of lifelogging application areas, mostly driven by throwing technology at problems ... what about availability of tools?
- personalinformatics.org is a good starting point



Know thyself.

Personal informatics is a class of tools that help people collect personally relevant information for the purpose of self-reflection and self-monitoring. These tools help people gain self-knowledge about one's behaviors, habits, and thoughts. It goes by other names such as living by numbers, personal analytics, quantified self, and self-tracking.

This site is a resource for all things related to personal informatics.

Tools See all »











Connect

Follow @allpi on Twitter.

Join the Personal Informatics Group on Facebook.

Contact

Send links to questions, articles, research, and applications to lan Li: ianli@personalinformatics.org





Tools RSS feed M clarity-centre.org

Tools

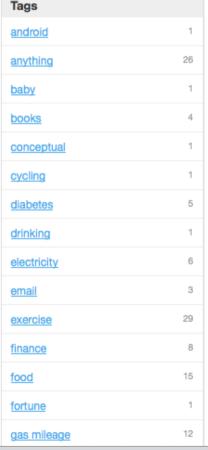
Displaying tools 1 - 20 of 207 in total

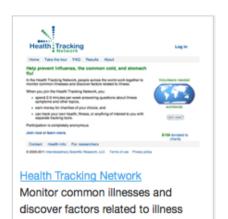








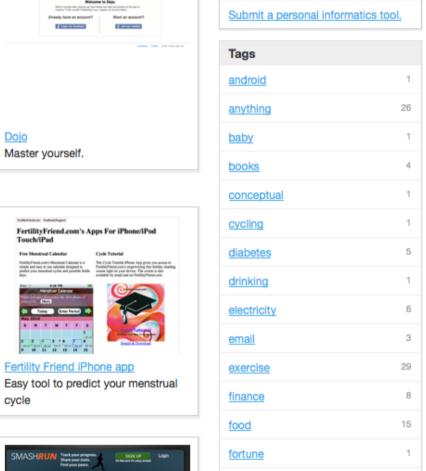












Contribute



Tools

5 diabetes
6 electricity

29 exercise

8 finance

15 food

23andMe

Genetics just got personal

https://www.23andme.com/

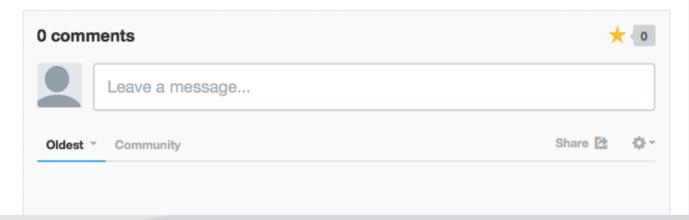
23andMe is a genetic testing service that provides information and tools to understand your DNA. Its mission is to be the world's trusted source of personal genetic information.

TAGS genetics

Posted on December 29, 2009



Contribute	15 1000
Submit a personal infe	12 gas mileage
Tags	10 goals
android	13 health
anything	47 iphone
baby	12 mood
books	10 productivity
conceptual	¹ 7 sleep
cycling	4 social web
diabetes	⁵ 9 time
drinking	management
electricity	8 timeline
<u>email</u>	3
<u>exercise</u>	₂₉ 4 <u>travel</u>
finance	₃10 <u>twitter</u>
food	5 web activity







Drinking Diary

Monitor how much alcohol you drink - and reduce it!









Know yourself better than your doctor



gottaFeeling

gottaFeeling? Share it





textWeight

A simple way to track your weight and see your progress



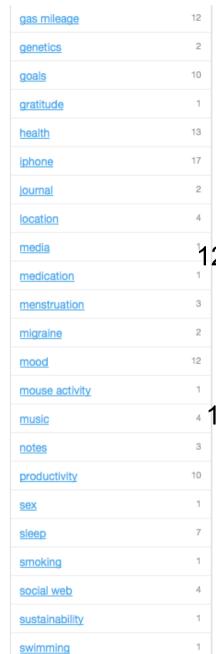
MyMigraineJournal

Statistical analysis of your migraine triggers



Daileez

The first icon online diary & journal



time management



5 diabetes 6 electricity 29 exercise 8 finance 15 food 12 gas mileage 10 goals 13 health 17 iphone 12 mood **10 productivity** 7 sleep 4 social web 9 time management 8 timeline 4 travel 10 twitter 5 web activity



York House, chapters - their - three

textWeight

A simple way to track your weight and see your progress



A free on-line service to make losing weight a bit more fun!





Statistical analysis of your migraine triggers



Achieve your goals - one choice at a

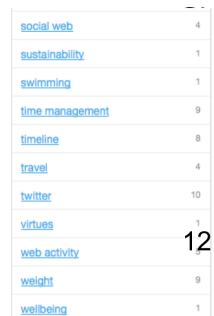


GoalsOnTrack

Keep your goals on track and get







Created by Ian Li. HCII, Carnegie Mellon University.



5 diabetes 6 electricity 29 exercise 8 finance 15 food 12 gas mileage 10 goals 13 health

> 17 iphone 12 mood

10 productivity

7 sleep

4 social web

9 time

management

8 timeline

4 travel

10 twitter

5 web activity

9 weight



things done.

« Previous 1 2 3 4 5 6 7 8 9 10 11 Next »

Home Tools Lab

Blog Feedback

Media

This work is licensed under a Creative Commons Attribution-Share Alike license.

Home Tools Lab Blog CHI 2013 Workshop



Tools





Contribute

Submit a personal informatics tool.

23andMe

Genetics just got personal

https://www.23andme.com/

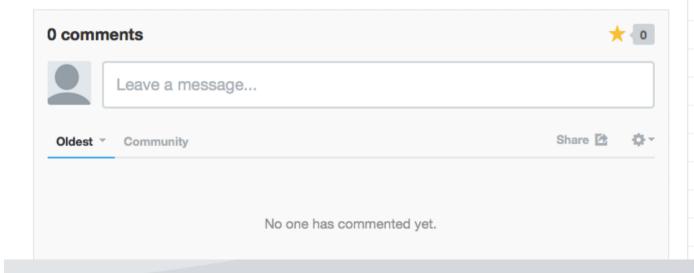
23andMe is a genetic testing service that provides information and tools to understand your DNA. Its mission is to be the world's trusted source of personal genetic information.

genetics

Posted on December 29, 2009







Tags	
android	1
anything	26
baby	1
books	4
conceptual	1
cycling	1
diabetes	5
drinking	1
electricity	6
email	3
exercise	29
finance	8
food	15
fortune	1
	40

Lifelogging - multiples



- Lifelogging is about sensing
- Sensing any natural phenomenon benefits from a multiplicity of viewpoints
- It is the combination and correlation across sensors that gives us insights to get holistic viewpoints

Healthcare Applications



- Using lifelogs for detection of longer-term cognitive decline or gradual behaviour change, for example, is far more difficult because of daily variations ... there is no *normal* day in our lives
- Many AAL projects instrumenting homes, storing data and seeking patterns, e.g. Great Northern Haven in Dundalk with 100+ sensors per home ... PIRs, contacts, power use, switches, audio, water, mattress, etc.

Lifelog Platforms



- There is no single best lifelog sensor, not even video
- Lifelogging is best when it combines, so are there platforms for combining?
- There is no universal platform for "mashing" personal sensor data
- Most OTS products have open APIs
- It is both good, and bad, that there is no universal storage approach for personal data
 - Good there is no single company dominating, c.f. search
 - Bad there is a lack of progress