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Video Semantics and the Sensor Web

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Talk Overview

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- CLARITY, what it is
- Proposition of the sensor web
- Some CLARITY examples of sensor web in different domains … lifelogging, tennis, cycling, environment
- TRECVid … semantics from video
- Some parallels, some relationships, some challenges

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Video, Semantics and the Sensor Web

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CLARITY

CLARITY: Centre for Sensor Web Technologies (2008 – 2013)

National, multi-site research centre funded by Science Foundation Ireland & industry;
5 Year Programme with strong Industry collaboration;
Significant presence in Ireland's research infrastructure, very collaborative

Earlier work proved the 'Sensor Web' Proposition - key developments in crucial Sensor Web technologies

- Wearable technologies
- Environmental monitoring
- Personalized media

Wide range of domains

- Physiotherapy, Sports Science, hardware, networking, engineering, clinicians, neuroscience, new and traditional media
- Significant international collaborations (EU, US)

CLARITY: Multi-disciplines

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Principal Investigators (PIs)

Prof. Barry Smyth	- *Personalization, recommender systems, mobile computing*
Prof. Alan Smeaton	- *Content-based information retrieval*
Prof. Dermot Diamond	- *Materials research, wearable sensors*
Prof. Noel O'Connor	- *Audio-visual analysis, multi-modal information processing*
Prof. Gregory O'Hare	- *Ubiquitous computing, multi-agent systems*

Associate PIs

Prof. Paddy Nixon	- *Pervasive computing, middleware, security, trust, privacy*
Prof. Niall Moyna	- *Sports Science, wearable sensing*
Dr. Simon Dobson	- *Middleware, pervasive computing*
Dr. Cian O'Mathuna	- *Sensor devices, energy-aware hardware*
Dr. Brian Caulfield	- *Physiotherapy, therapeutic gaming, wearable sensors*

Collaborators

Chris Bleakley (UCD), Conor Brennan (DCU), Rem Collier (UCD), Brian Corcoran (DCU), Cathal Gurrin (DCU), Neil Hurley (UCD), Lorraine McGinty (UCD), Kieran Moran (DCU), Kieran Nolan (DCU), Brendan O'Flynn (TNI), Donal O'Gorman (DCU), Brett Paull (DCU), Emanuel Popovici (TNI), Aaron Quigley (UCD), Mark Roantree (DCU)

The Sensor Web

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The 'Old' Web

The Social Web

Dynamic user generated content (UGC) - conventional search tools unable to cope

The Semantic Web

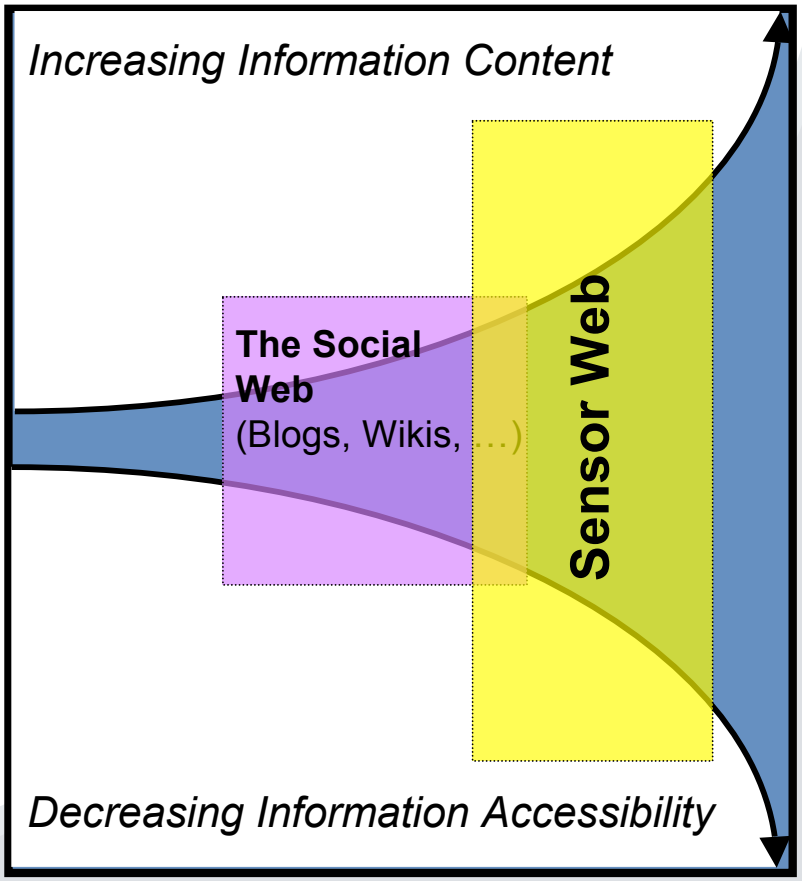
In here somewhere …

The Sensor Web

Increasing availability of cheap, robust, deployable sensors as ubiquitous information sources

Key is that they are networked, mostly wireless, hence global, and integrated - WSNs

Dynamic and reactive but noisy, and unstructured data-streams



CLARITY Applications

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Demonstrator Projects … unifying spaces for research threads

- Multi-model sensing for sports .. Tennis, Hockey, Cycling, GAA, …
- Environmental Sensing Platforms .. water quality, air quality
- Personal Environmental Impact Monitoring .. 'Karbon' footprint
- Ambient Assisted Living

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We will look at some of these as examples of sensors in action

For each, we will ask …
“what do people want”

But first … lifelogging

Sensor App 1: Lifelogging

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Lifelogging is digitally recording daily life

Sometimes for a reason

-- **Work e.g. security personnel, medical staff, etc.**

-- **Personal e.g. diaries, etc.**

Sometimes for posterity

-- **Recording vacations, family gatherings, social occasions**

Sometimes because we can

-- **and we're not yet sure what we'll do with it e.g. MyLifeBits**

Visual Lifelogging Devices

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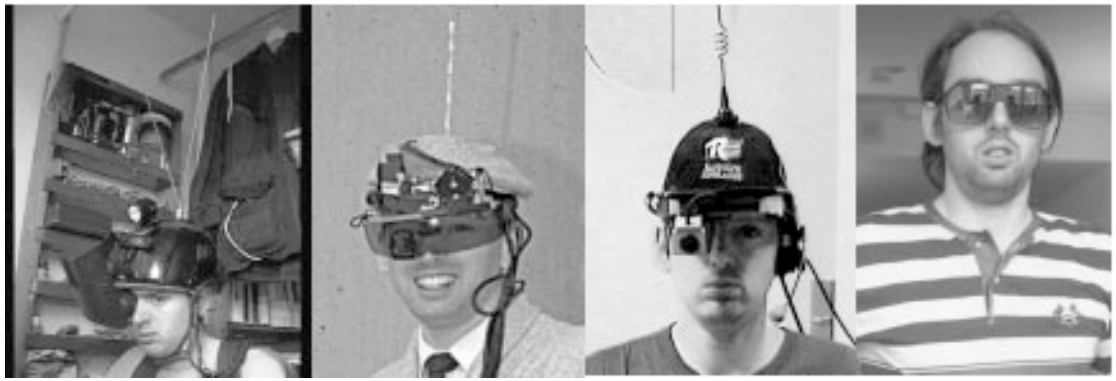
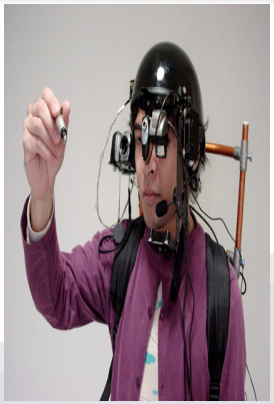
Much past research focus on miniaturising hardware and increasing battery-life + storage e.g. visual lifelogging domain



Steve Mann. Wearable computing: a first step toward personal imaging. Computer, 30:25–32, Feb 1997.

TIMELINE



Tano *et. al.* University of Electro-Communications, Tokyo, Japan

Microsoft Research SenseCam

SC data: c.3.5M SenseCam Images

- **One user wears SC for over 3 years, all day**
  - Each with GPS position

- **Experiences:**
  - Most people don't notice camera
  - Those that do always remember !
  - Most people don't mind the camera
  - Have been spotted/greeted by people who have heard about the 'guy with the camera'

SenseCam Lessons

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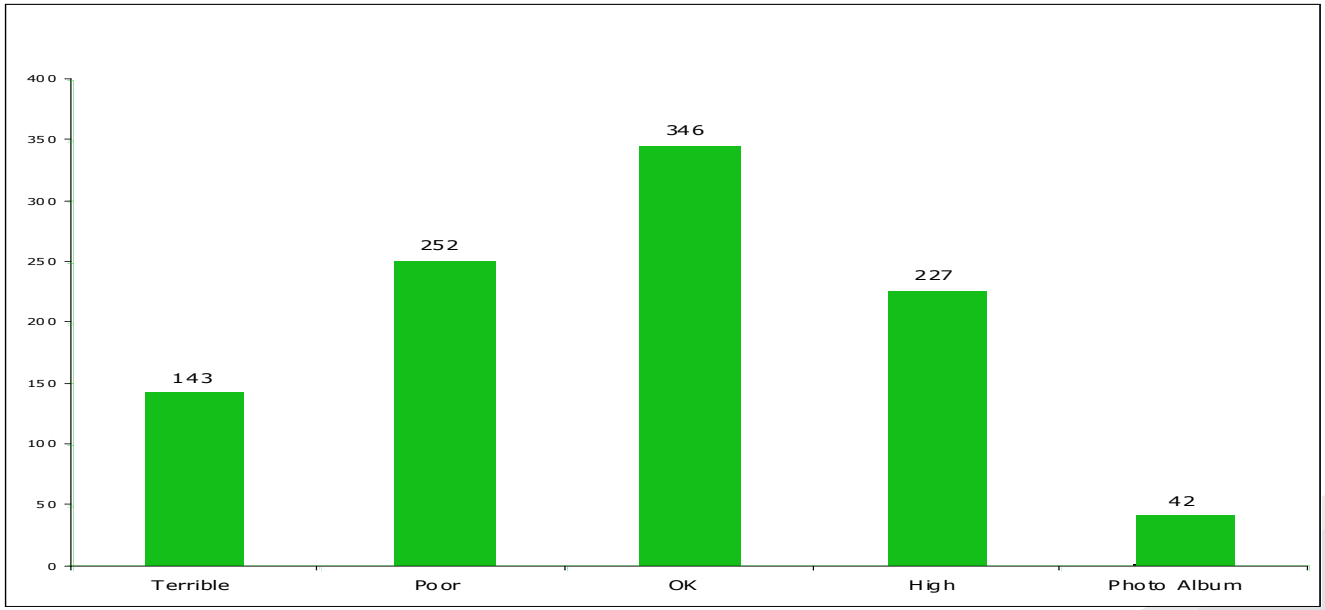
- Event browsing is key
  - Too many photos to browse, need summary of semantic events and then 'drill down' to view event detail if required
- Stop events, (like work desk and driving) should be identified and hidden.
- 'Total Recall', little sign of 'Event Decay'
  - Remembers nearly every (non stop-) event when presented again
  - Experiment underway w/ U.Leeds exploring this
- Lessons from three years research and exposure suggest that lifelogging is of interest to many

SC Image Quality



- 40% of images are of low quality
- Many "boring" images of mundane tasks

Despite this, we can have great (technological) fun …

Advanced Image Matching

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SURF features are extracted

Each feature point casts a weighted vote for multiple database images

Votes are accumulated & the best match is found

Setting Detection – Watching TV

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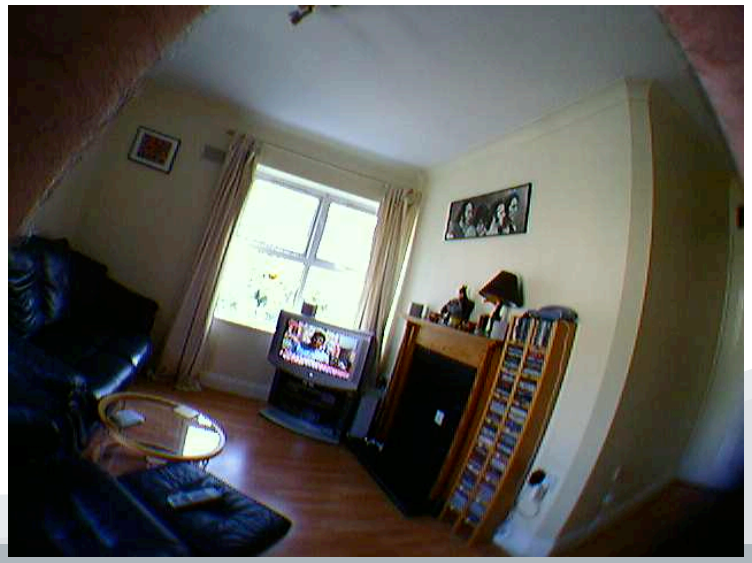

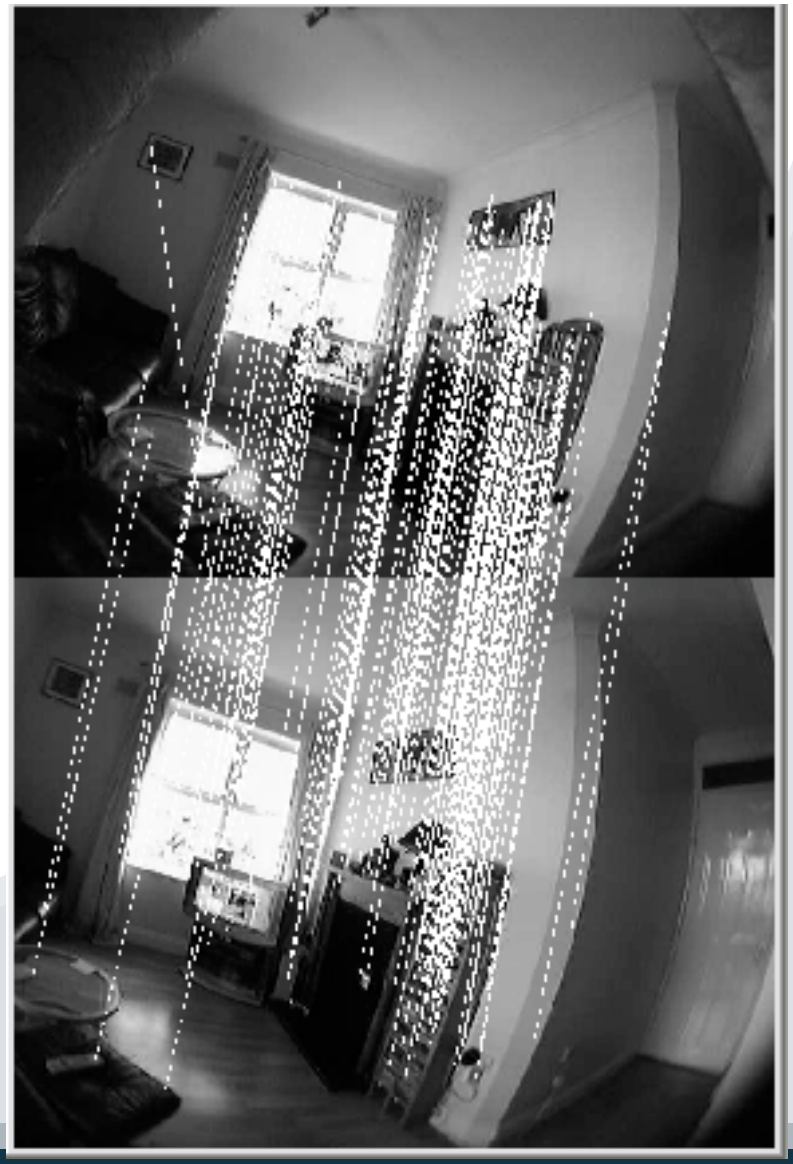

Setting Detection – In the Park

Trajectory Estimation

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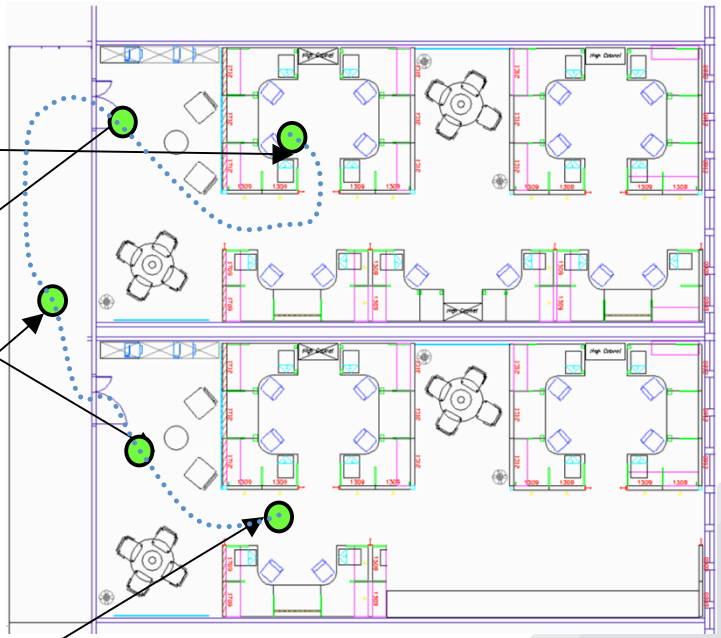
A User's Images



Area Map

Location Database Matching

Trajectory Estimation Results

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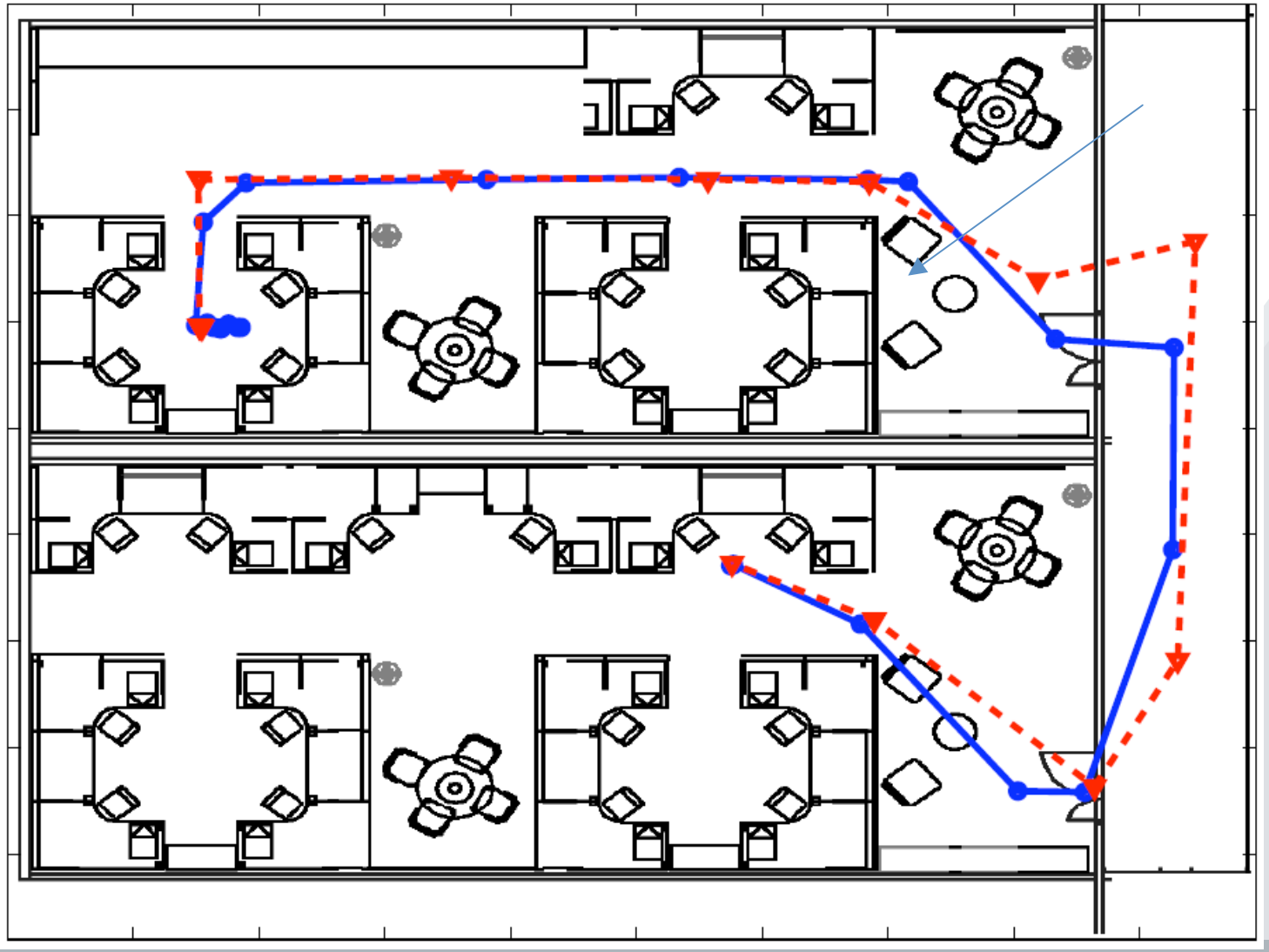
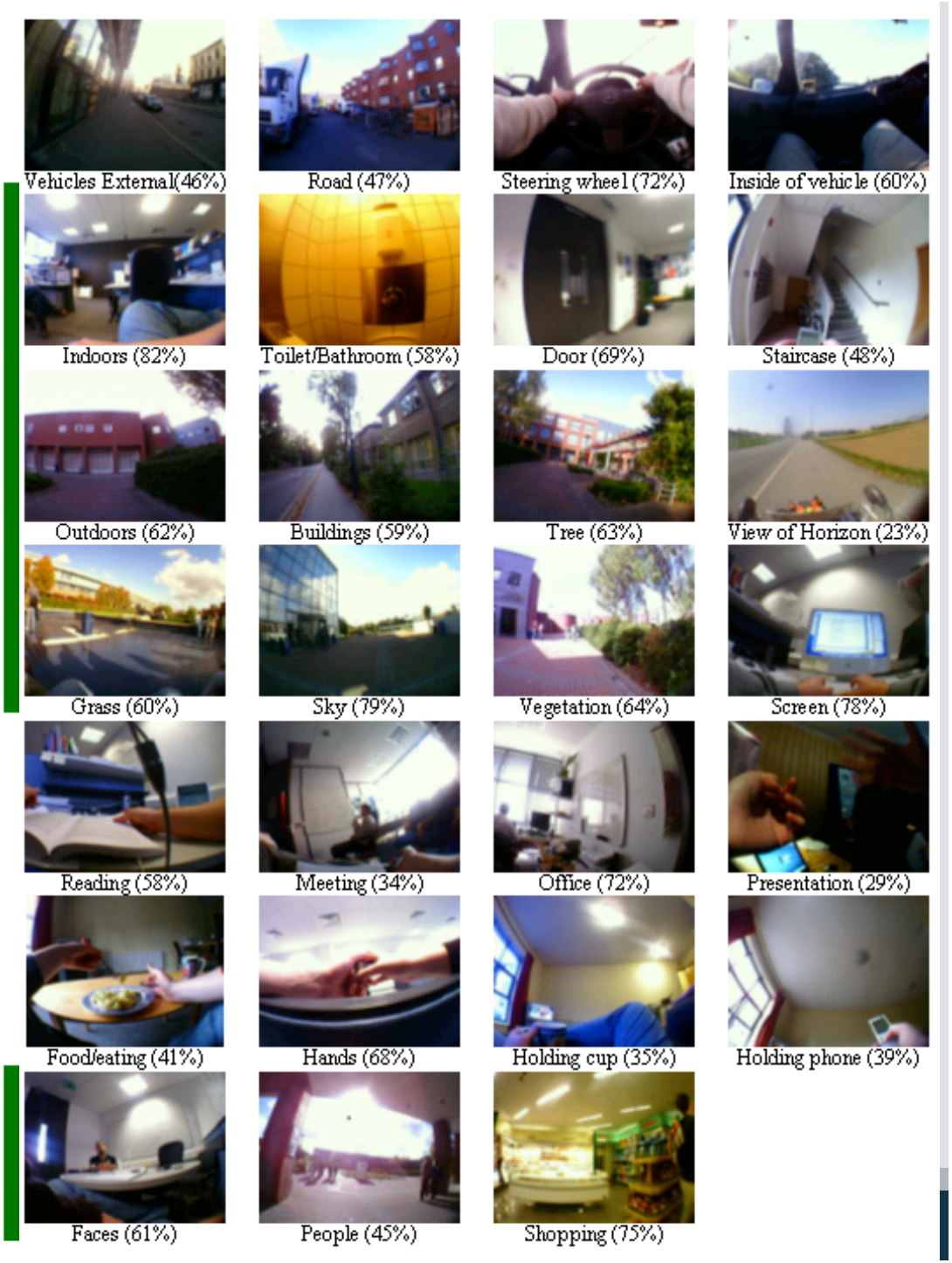


Activity Recognition

27 “concepts”

Outputs manually judged on ~95k images (5 users)



But what do people want ?

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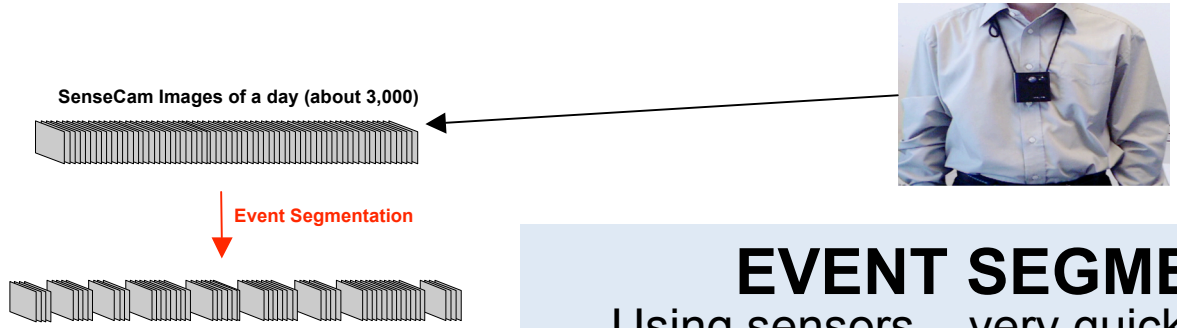
Memory science says … to effectively provide memory retrieval cues using SenseCam images and sensor readings, we need to automatically:

- *Group similar images into distinct semantic "events"*
- *Suggest more interesting/distinctive semantic events*
- *Associate related semantic events*
- *Provide additional retrieval cues from other sources*

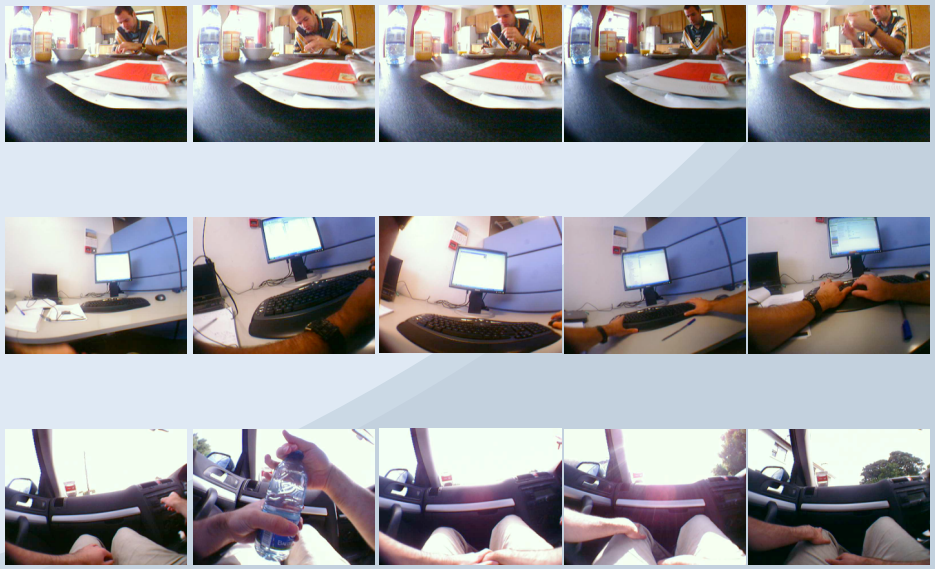
Called *cued recall*, trigger our own memories, not a memory replacement

Daily Overview

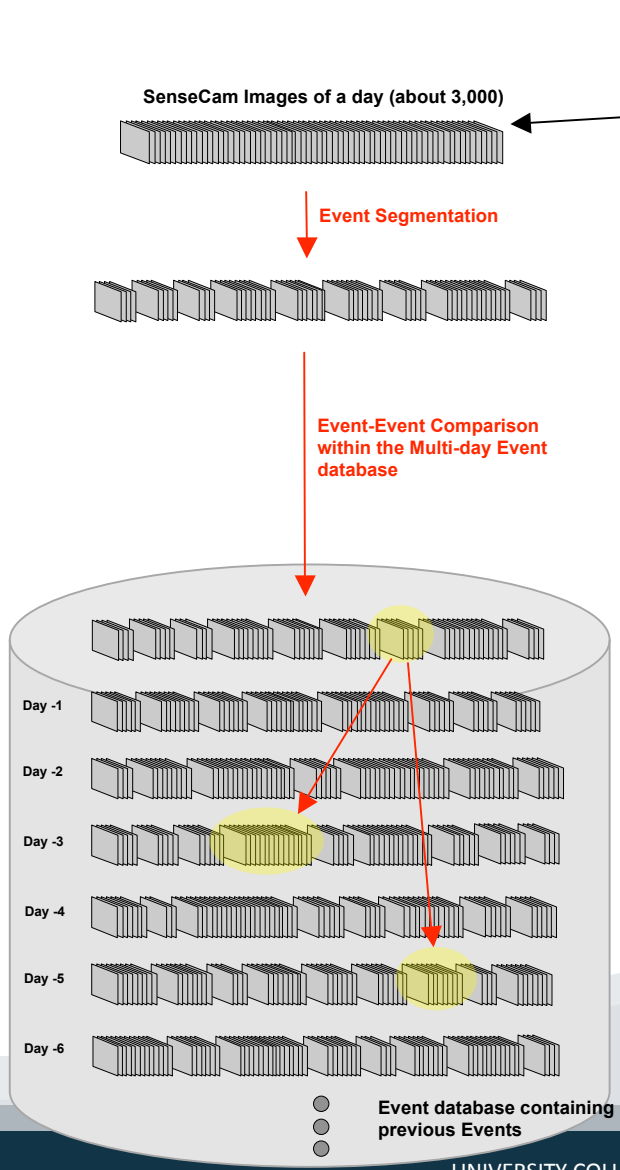


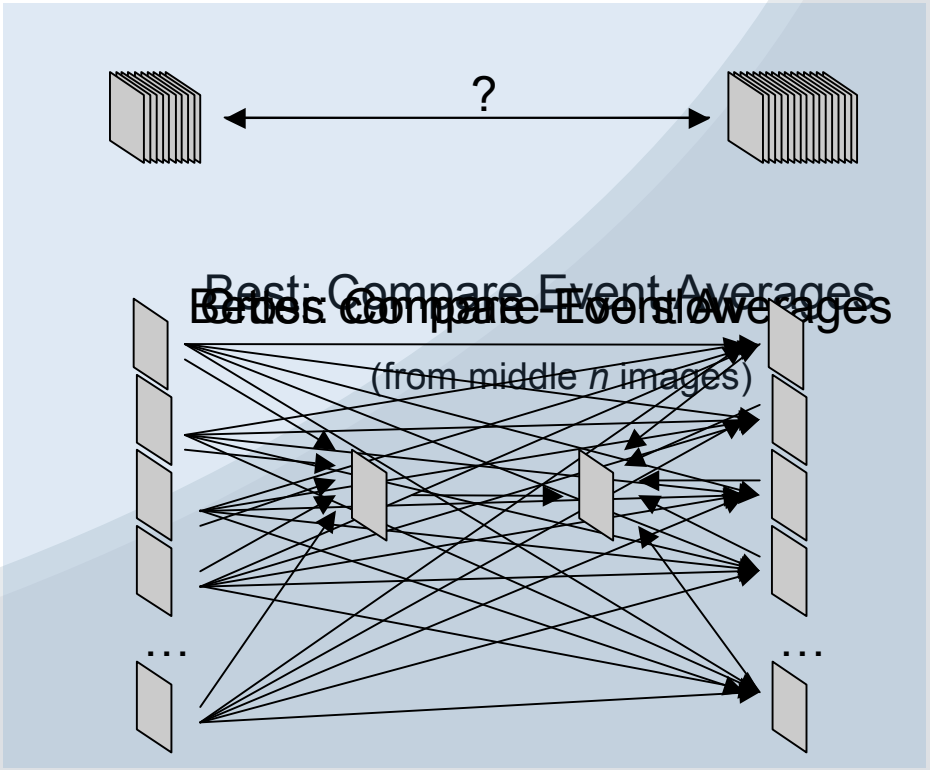
EVENT SEGMENTATION

Using sensors – very quick & accurate



Visual Search Facilities





Selecting Event "Keyframe"

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SenseCam Images of a day (about 3,000)

Event Segmentation

Event-Event Comparison within the Multi-day Event database

Day -1

Day -2

Day -3

Day -4

Day -5

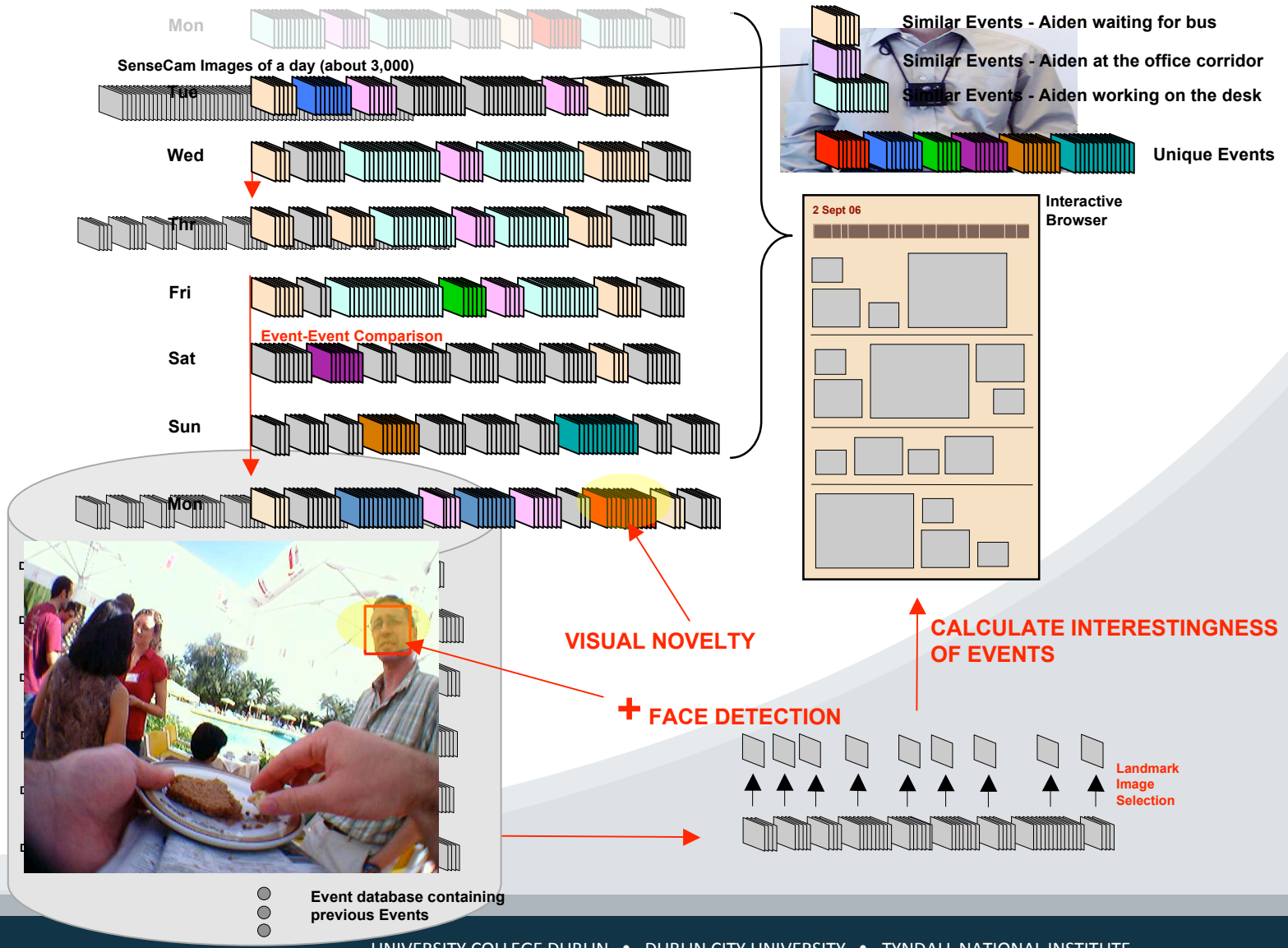
Day -6

Event database containing previous Events

Best QUALITY image around MIDDLE of event

Landmark Image Selection

Suggest Interesting Events



Event augmentation

SenseCam picture at a pier in Santa Barbara

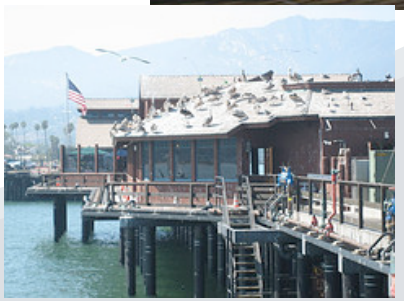
WITH GPS we can search for other pictures in the same location…

Event augmentation – more cues

- We receive the following geotagged images…
- Then after some processing on text associated with these images we get many more images, and even YouTube videos
- Then do visual filtering to choose those for SC event augmentation





Event augmentation

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Operational from 6 web sources, tested and evaluated with users.

Bringing the threads together … segmentation into semantic events, KF selection, event importance, event searching, and event augmentation …

… a system to manage a lifelog

My Visual Diary with SenseCam

hlee: 76,430 photos (25 days)

MY ACCOUNT | SIGN OUT | ABOUT

CALENDAR

◀ MAY ▶ 2006

S	M	T	W	T	F	S
30	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31	1	2	3
4	5	6	7	8	9	10

DURATION ▶

CAPTION SEARCH

WEEKLY SUMMARY

Selected day is shown below in the context of whole week. Move mouse curosr over to see other similar Events in the week

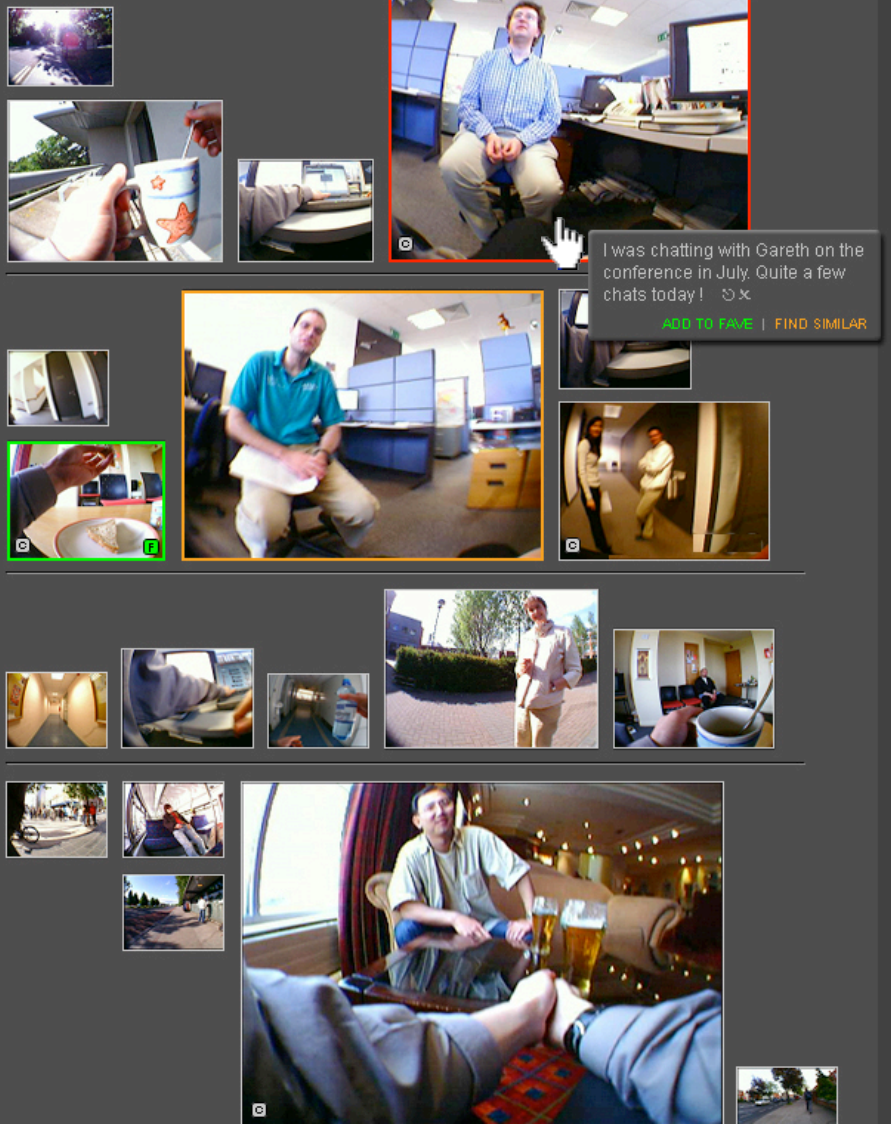
S
M
T
W
T
F
S

29 May 2006

19 EVENTS

Drag the slider bar to adjust the number of Important Events

0 am | 6 am | 12pm | 6pm | 0am



I was chatting with Gareth on the conference in July. Quite a few chats today !

ADD TO FAVE | FIND SIMILAR

MY FAVOURITE EVENTS

25 Favourite Events are shown below. Click on the photo to replay all photos within the Event.

| 1 | 2 | 3 |

Sort by: TIME | SIMILARITY | #PEOPLE

16:20 (Duration: 08m 43s)
14 APR 2006 ▶

13:45 (Duration: 14m 05s)
14 APR 2006 ▶

10:02 (Duration: 23m 56s)
13 APR 2006 ▶

14:39 (Duration: 15m 30s)
12 APR 2006 ▶

11:25 (Duration: 08m 21s)
12 APR 2006 ▶

09:52 (Duration: 01m 03s)
12 APR 2006 ▶

Lifelogging Roadmap …

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Device miniaturisation

***Stories* from memories**

Ambient replay

Autocueing for recall

Other sources

Sensor App 2: Tennis

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Initial focus on tennis, indoor

Pairs or doubles, well-structured game, intense physical activity, non-contact sport

Then move to team sport

Probably still non-contact, team tactics, outdoor, field hockey and GAA

Wide definition of sensors

A/V, movement and location, physiology

Body Sensors

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Use off the shelf technology

Polar Heart Rate Monitor

BodyMedia SenseWear Armband

Galvanic Skin Response (GSR), heat flux, skin temperature, accelerometer

Foster Miller vests

Respiration, body temperature, heart rate, GPS
Robust, comfortable, re-usable

Infrastructure

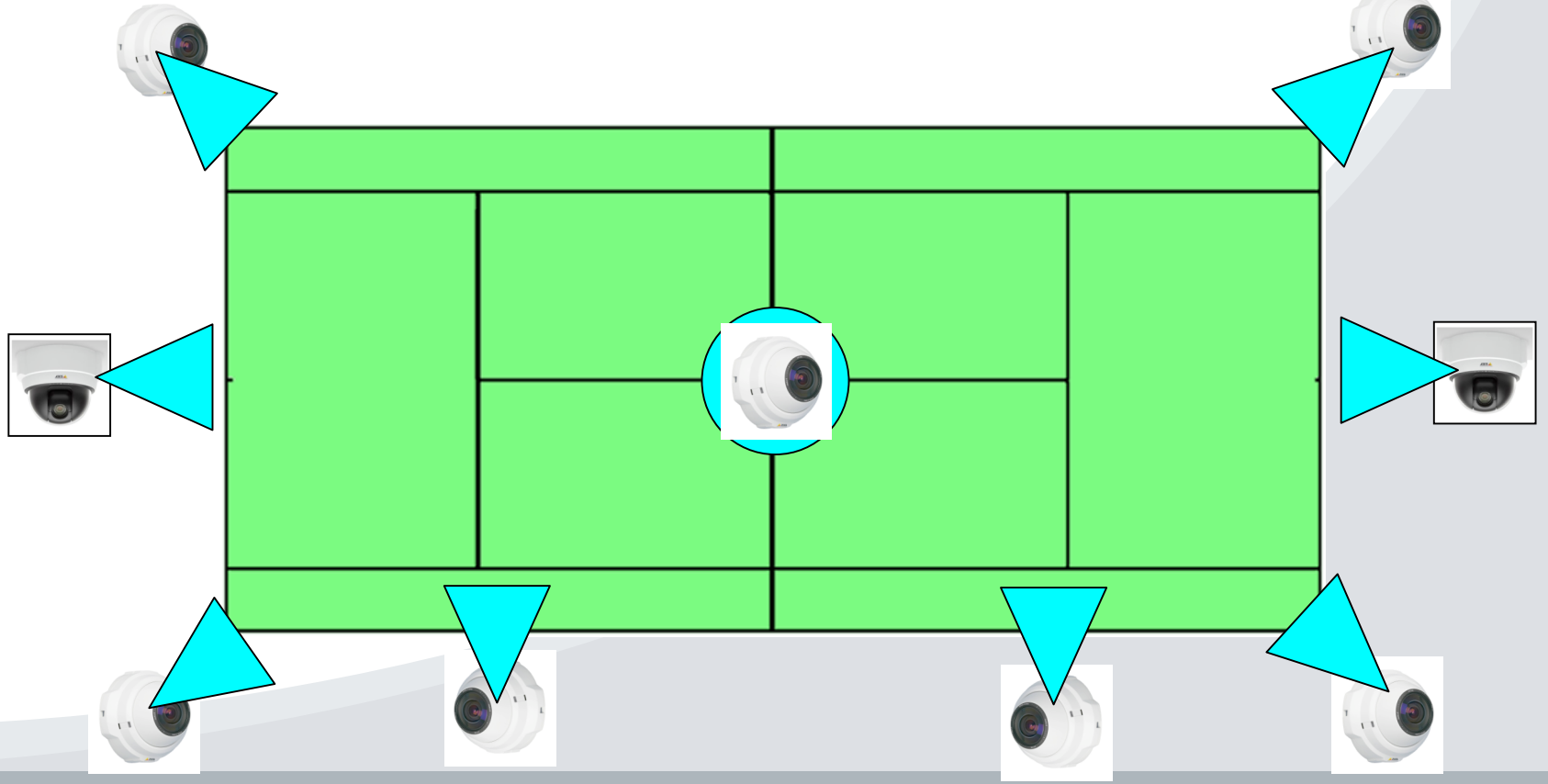
Tennis Ireland, National Tennis Federation

Dublin City University

Audio-Visual Network

X 2 Pan+Zoom

X 7 Wide-Angle



AV Coverage

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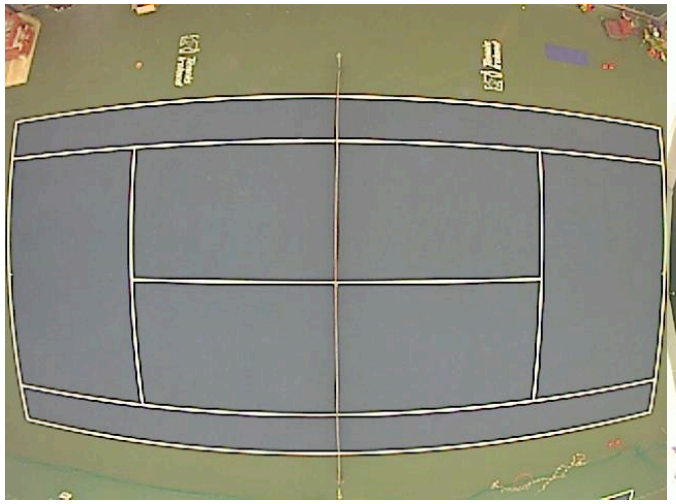
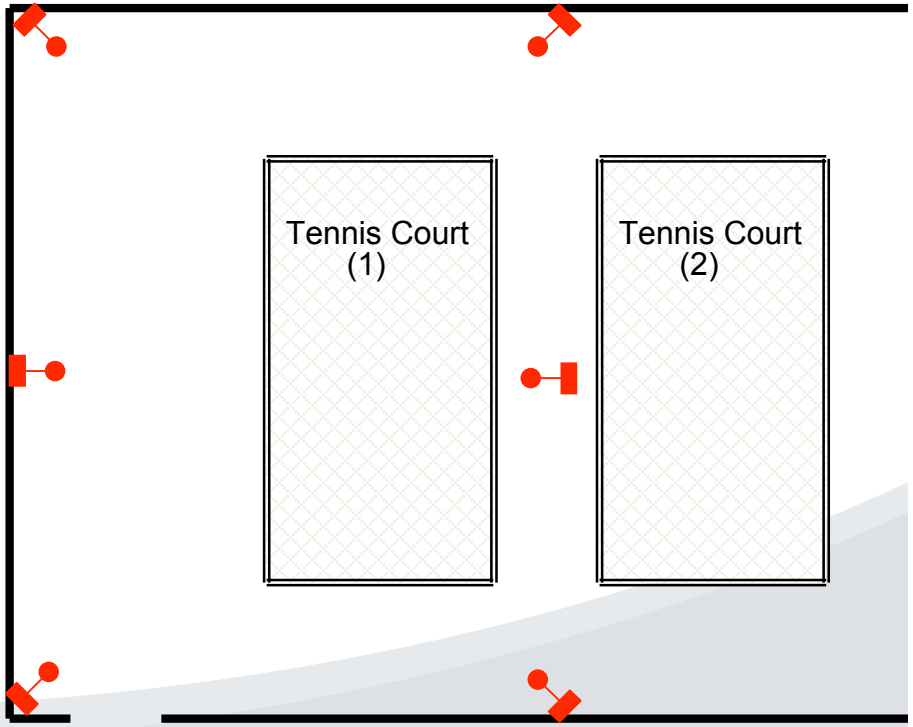




Localisation

Ubisense: Real-time location system, high positional accuracy

UWB RF technology



Sensor Pipeline

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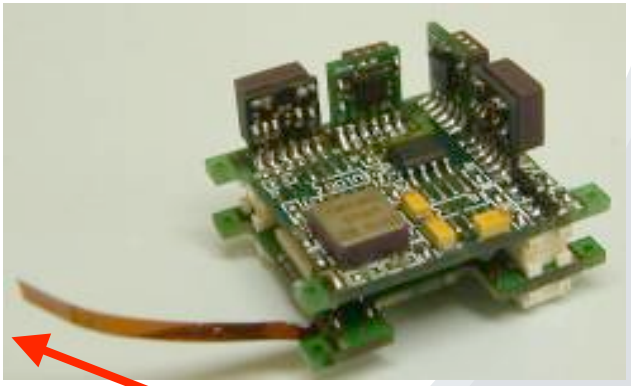
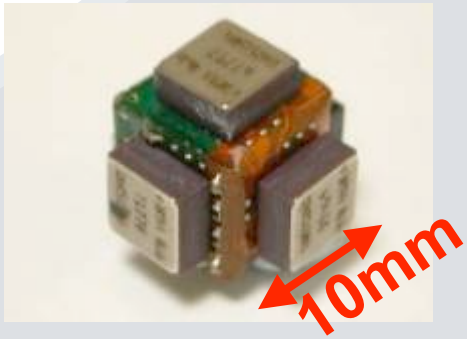
6 DOF Wearable inertial sensing platform (WISP)

Developed for Tyndall 25mm Mote



Features:

- 3 Accelerometers
- 3 Gyroscopes
- 3 magnetometers
- ADC: analog-digital converter
- Microprocessor
- Serial Wireless Link



Sensor Pipeline

Conducting polymers or "synthetic metals"
Polymers are macromolecules, and usually they are insulators but some, such as polypyrrole, conduct electricity (c.1970)

Coat onto substrates
Foam or lycra or anything that moves, twists, bends

Easily produced, rapid response times, comfortable to wear

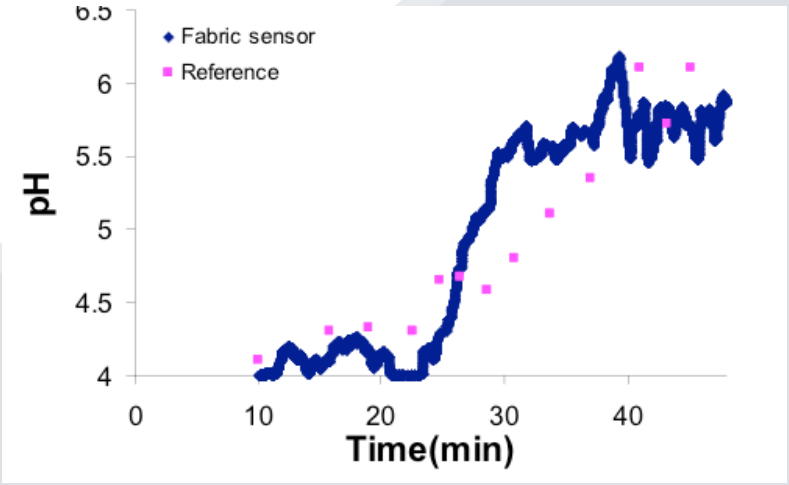
Sensor Pipeline

Fluid-handling platform based on polyamide lycra®
Super absorbent material (SAB) provides a passive pumping mechanism

Used to draw sweat into its fluidic channel

Optical detection of pH induced colour changes in the dye
Paired emitter-detector LED system

Controlled by a wireless mote



What do people want ?

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Tennis coaches, sports scientists …

- Physiological wellness indicators in real time … recovery between points, overall fatigue, fluid intake .. matches and training
- Strategic analysis of play for game and point winning
- Stroke analysis in training, 3D model from limb movement and WIMUs

Roadmap ?

More integration of sensors, real time response

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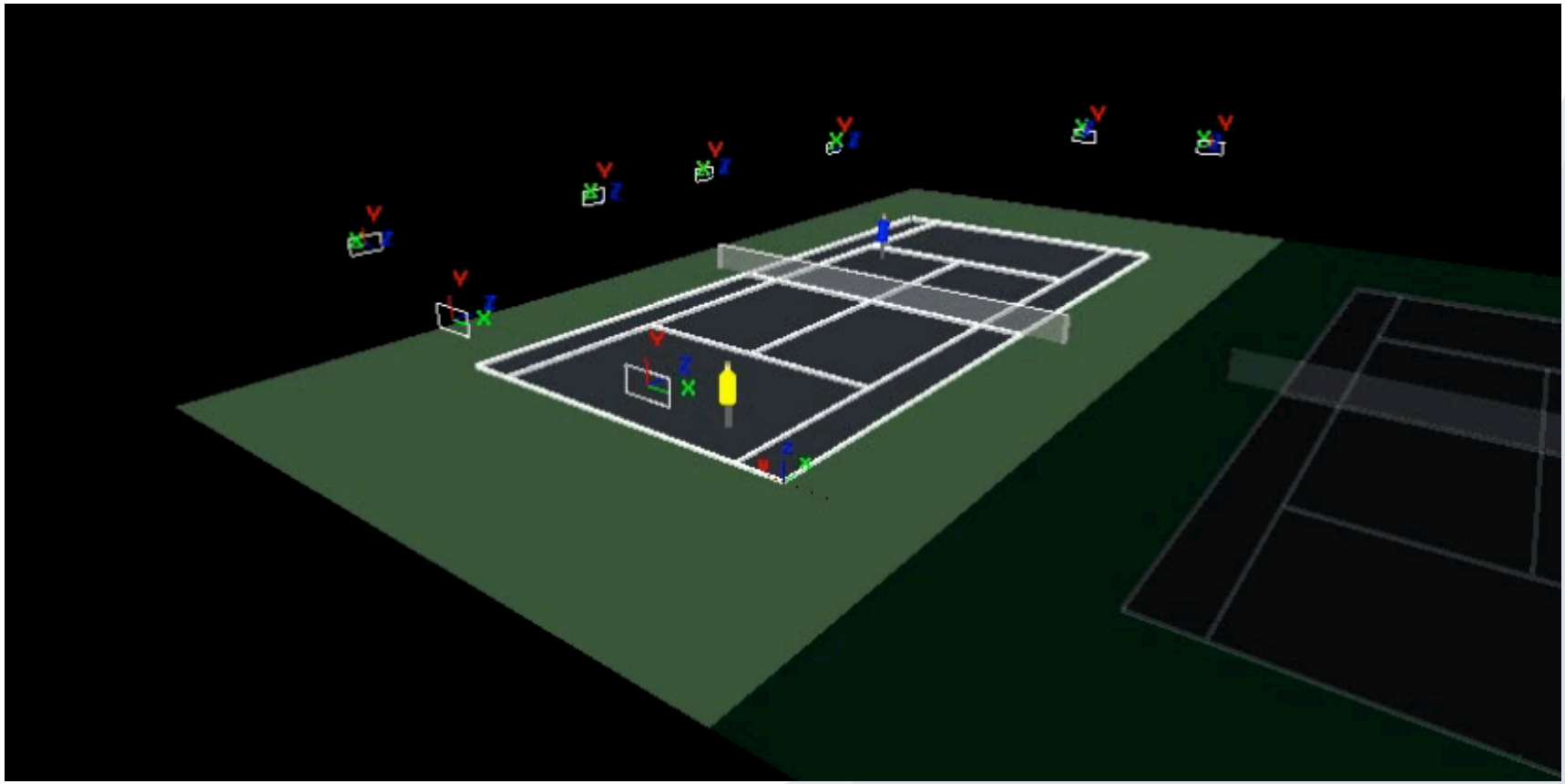

Sensor App 3: Cycling

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Round 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, recovery

Human performance scientists interests

How the human body recovers, how to maximise performance over 5-day endurance what recovery techniques work best

Cycle Sensors

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On Body …

Heart rate, GSR, respiration, fluid intake, food intake, sweat analysis, blood analysis, rest and recovery techniques, massage,

On Bike …

WIMU gives yaw and roll, in/out saddle
Power gauge gives power output
Speedo gives speed & cadence
Some direct feedback

Environment …

Weather, wind, temperature, RH, road surface, wet/dry, video tracking using geo-spatial measurement jeep, based on MIT

Sensors for Cycling

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What do people want ?

Study of performance (degradation) over time, impact of different recovery techniques

Roadmap ?

Insights into endurance performance

Sensor App 4: Env. Monitoring

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River Lee, Cork, Ireland, a city centre tidal river

We can sense …

Water turbidity (NTU), water temperature (degrees Celsius), pH, water conductivity (milli-Siemens), water depth (feet), dissolved oxygen, nitrates and sulphates, air temperature, relative humidity and light (lux @ 520nm)

Phosphates are nutrients and are bad because encourage plant growth, consume O2

Sensor platform is microfluidic-based, 1-year field lifetime, shoebox size, solar powered

Initial test site

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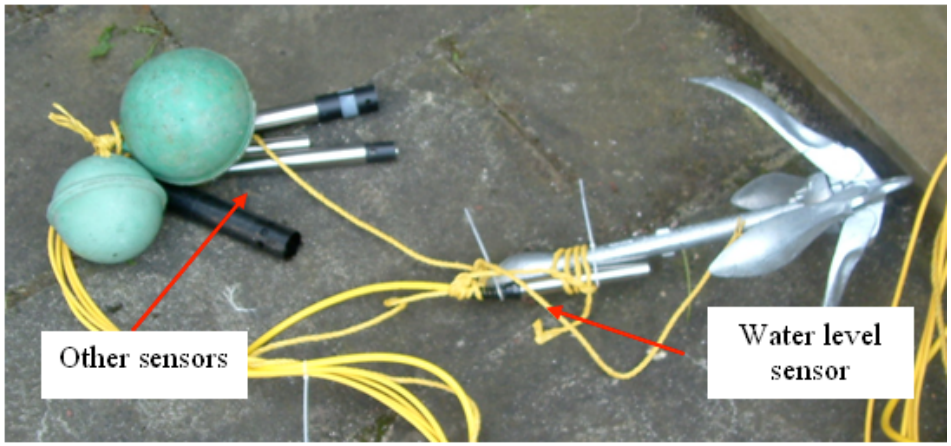

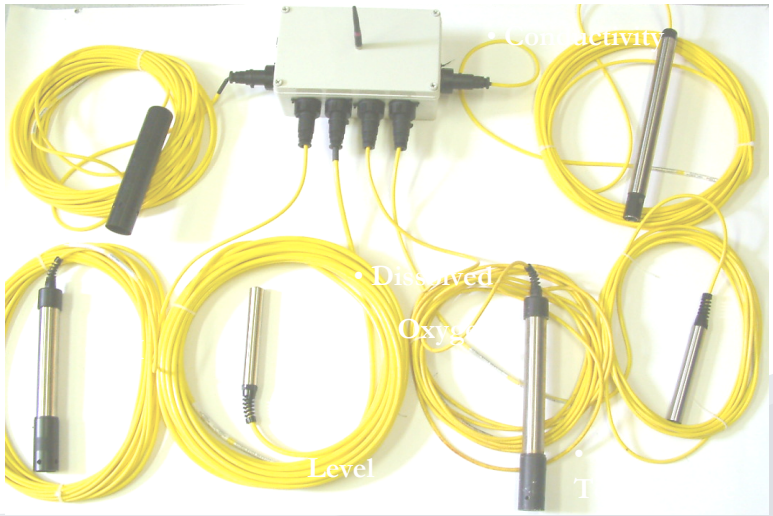

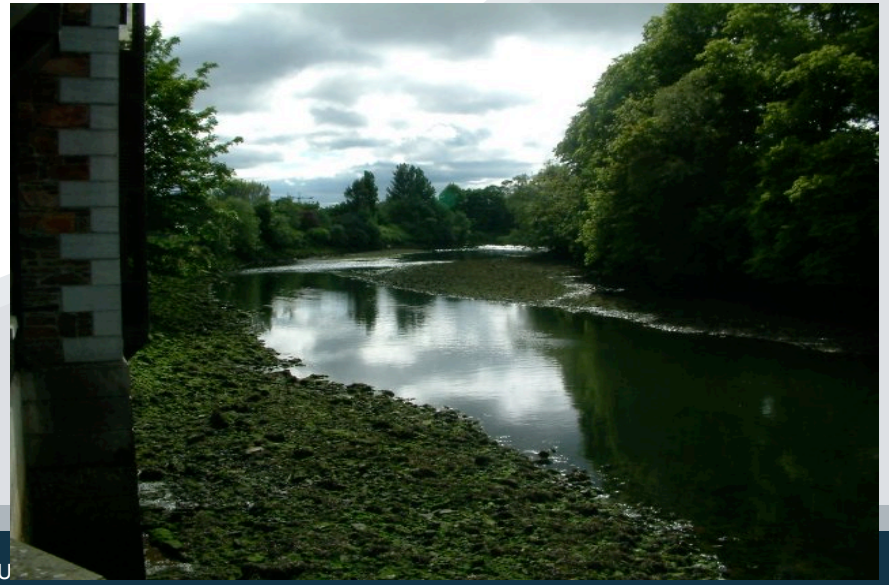

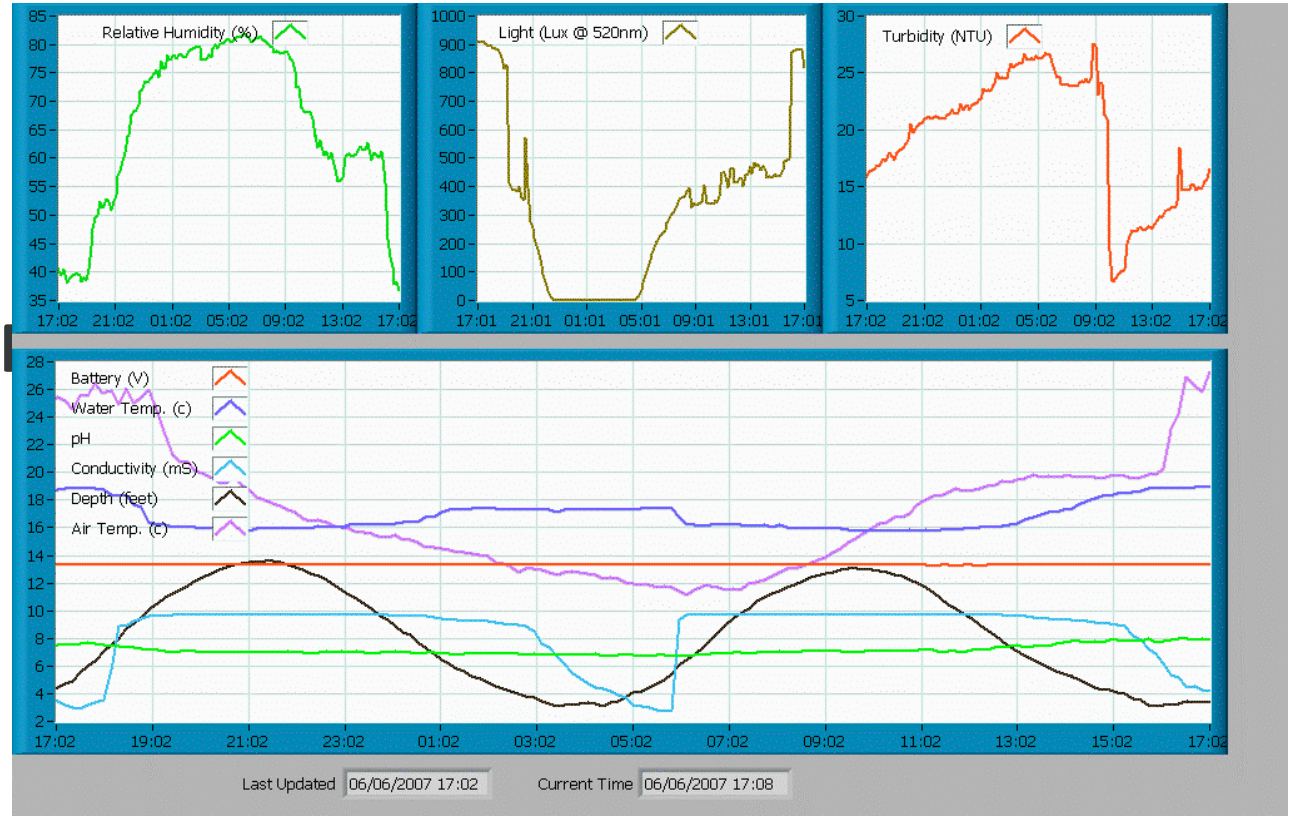

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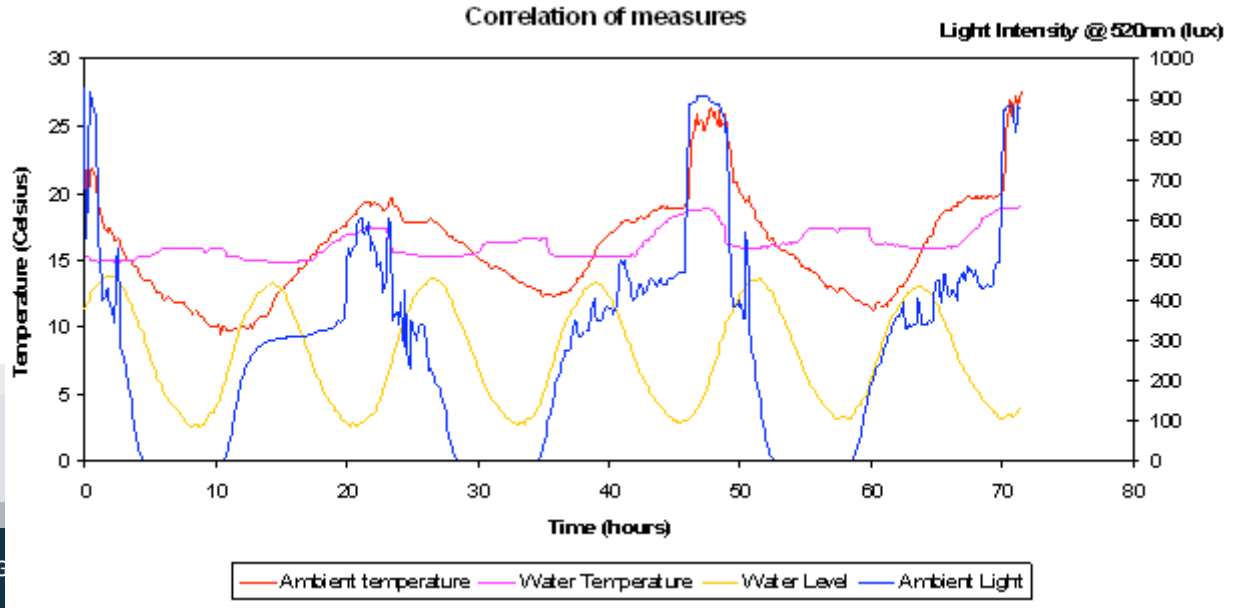

Data Analysis, what do we do with it all?

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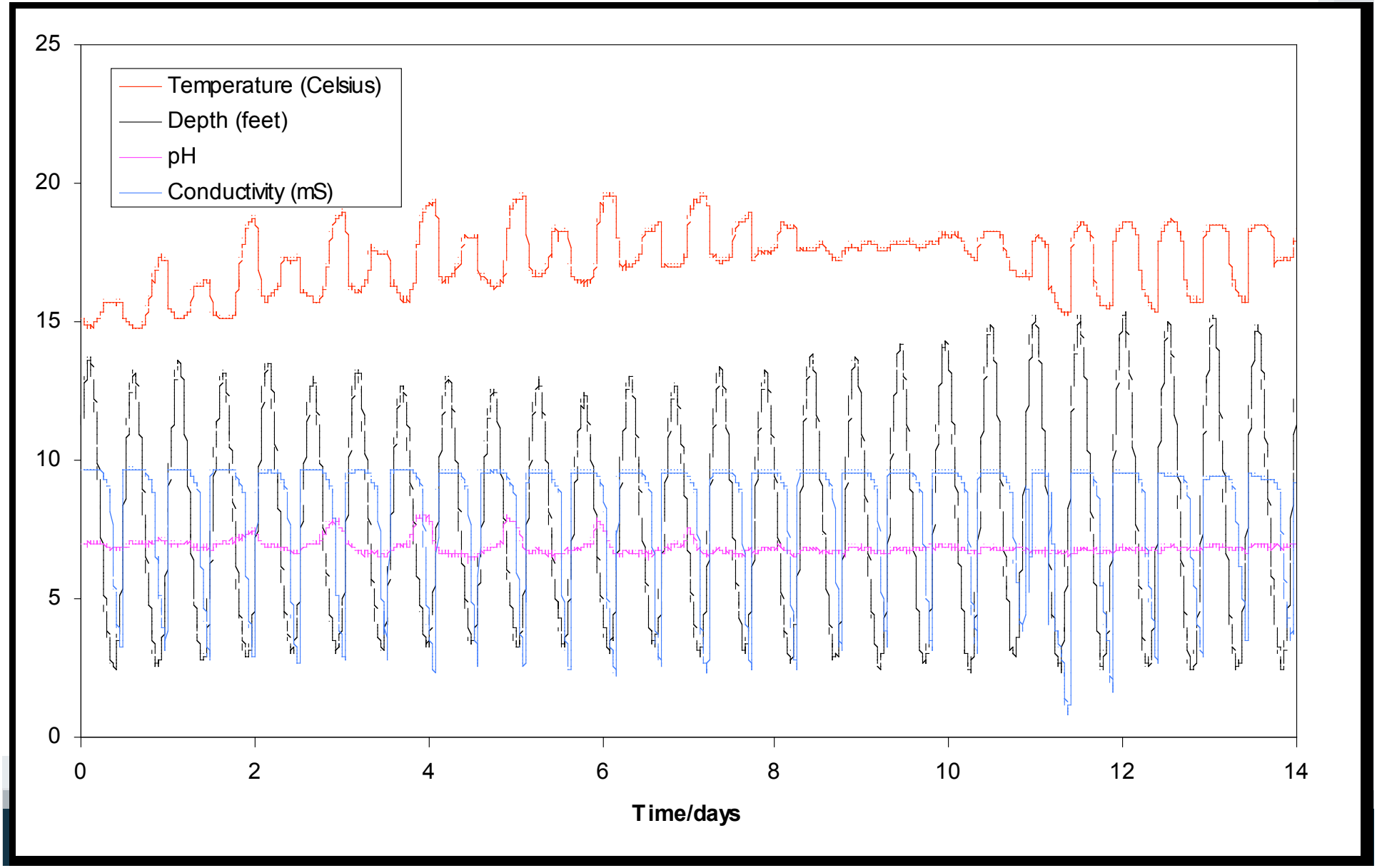


Other deployments …

River Liffey (near Dublin)

River Tolka (near Botanic Gardens, Dublin)

Oberstown waste water treatment plant, Co Kildare

Black river, Newport, Co Mayo

… all measuring phosphates, nitrates, DO, as well as "off-the-shelf" sensors, WSN-based, ;

Problem … longevity

Problem with these sensors is longevity … reagents need to be replaced

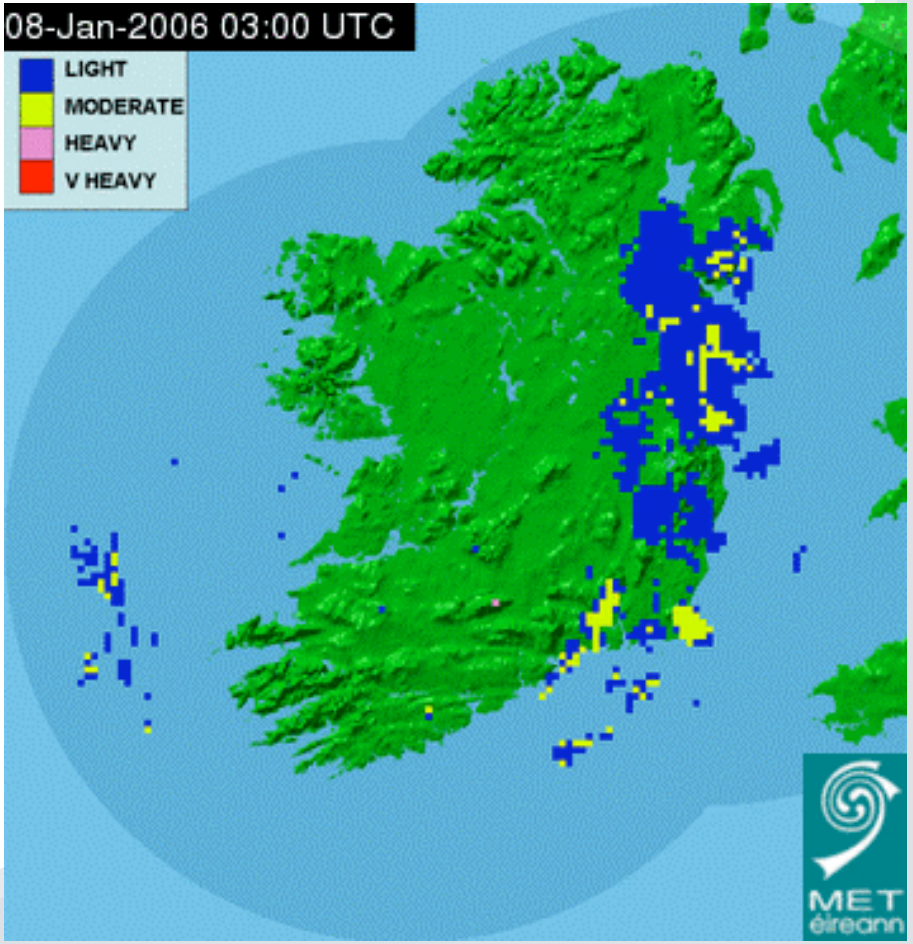
Environmental scientists want readings at times of change, not times of stability … changing times are predictable based on rainfall

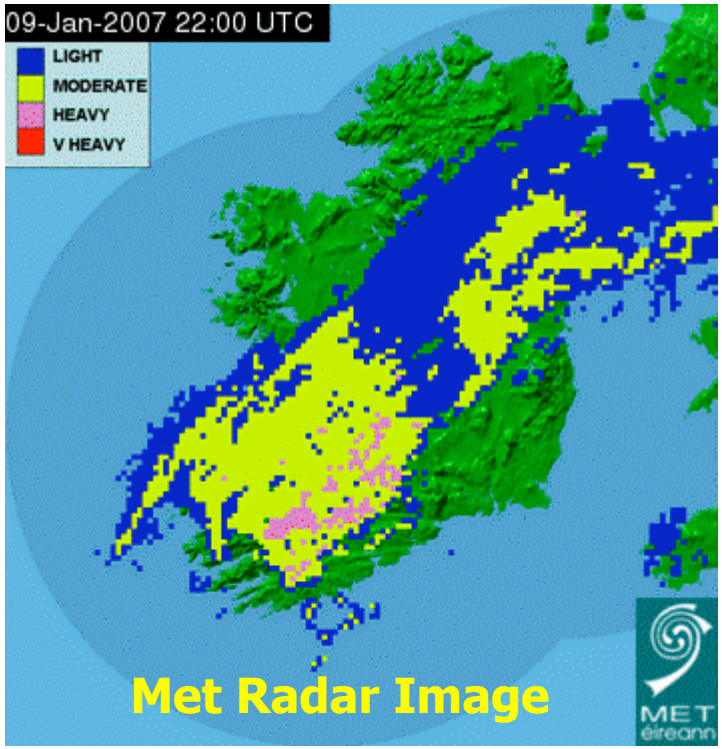
So we use another sensor … rainfall radar

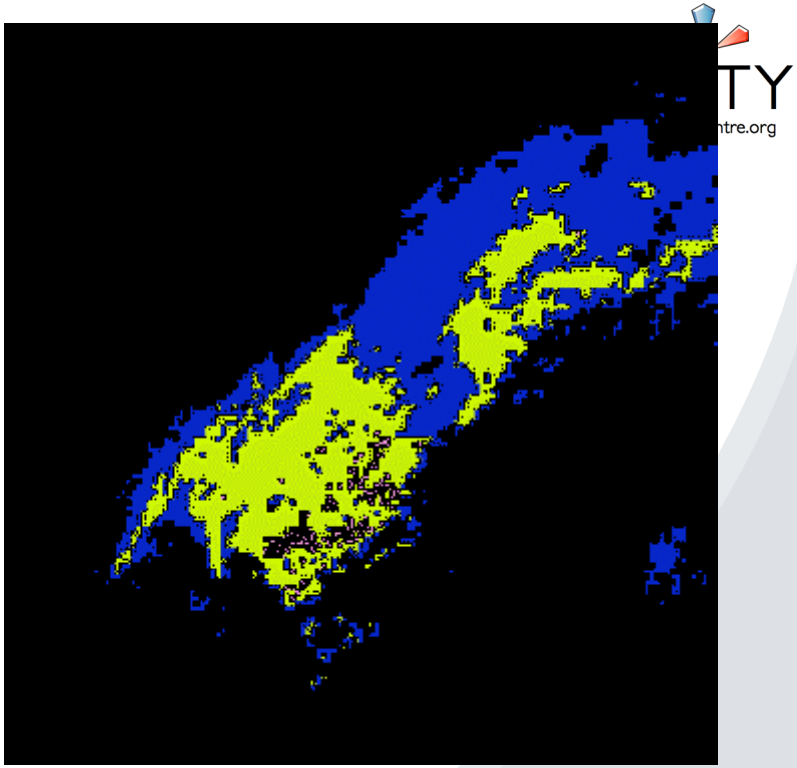
Met Éireann Met.ie

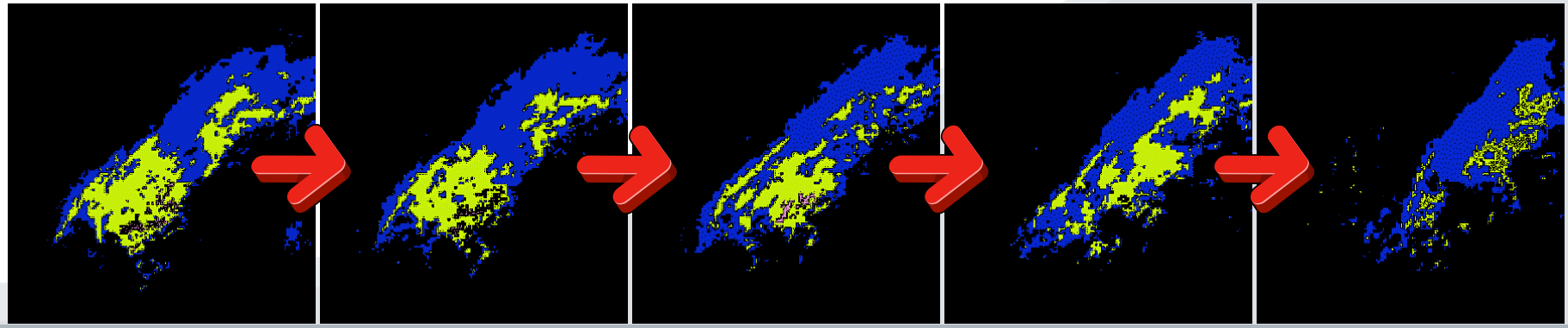
Public website - down-sampled radar images;

We harvest and process to track (and predict with 70% F-measure) rainfall in near-term for specific locations, the rainfall catchment areas for our river sensors;




09-Jan-2007 22:00 UTC
LIGHT
MODERATE
HEAVY
V HEAVY
Met Radar Image
MET éireann





Environmental Monitoring

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What do people want ?

Long lived sensors

No biofouling !

Real time readings and prediction

Integration across sensors and sensor sources

Events !

Roadmap ?

Smaller, cheaper sensing platforms

CLARITY Sensor Webs

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What is common across lifelogging, tennis, cycling, and environmental monitoring … people want semantic events

Events are determined by aggregating across sensors, should be done automatically

Where else are events automatically detected … video

TRECVid goals and strategy

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Promote progress in content-based analysis, detection, retrieval on large amounts of digital video

Focus on relatively high-level functionality - automatic components:

Automatic search,
High-level feature detection,
Shot bound detection,
Content-based copy detection,
Event detection

Do all this in a hugely collaborative and supportive framework, over 9 years

Evolution: data, tasks, participants, ...

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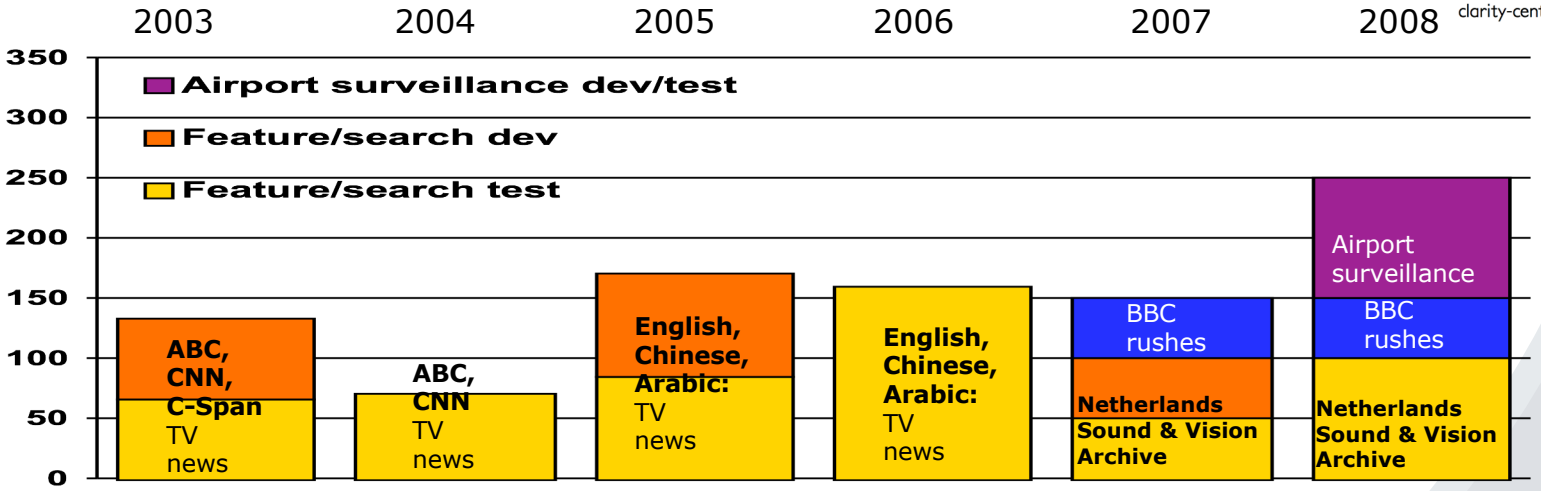
Data:

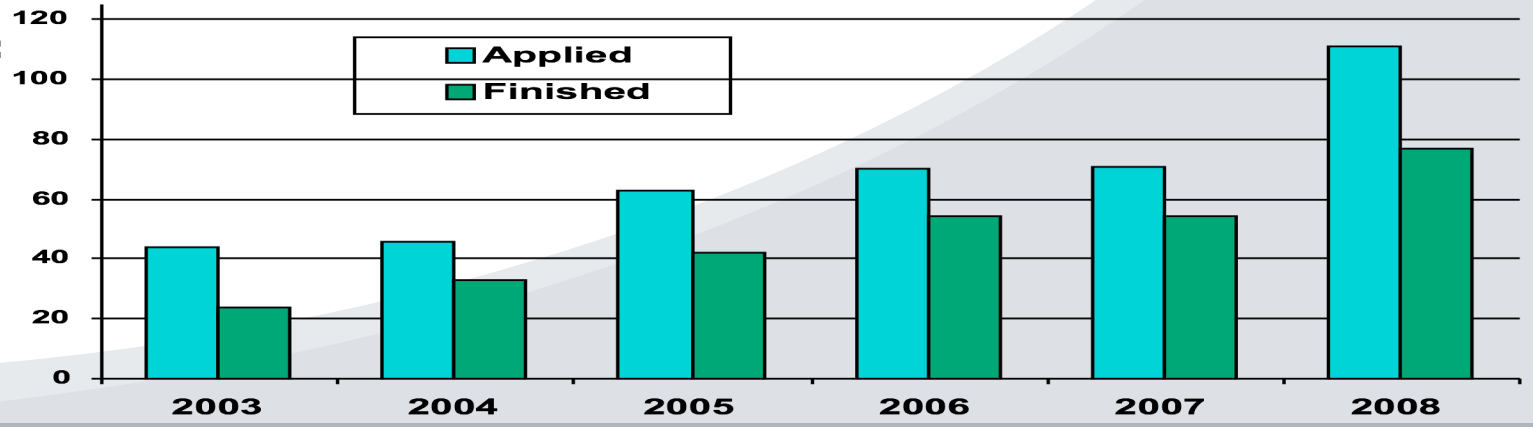


Tasks:

Shot boundaries ----------|
Search ---------- **Search**
Features ---------- **Features**
Stories ----------| **BBC rushes** ---------- **Summaries** ------ **Summaries**
Camera motion
Surveillance events
Copy detection

New pilot tasks

Participants:



TRECVid 2008: Details

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Data:

- 200 hrs - Netherlands Institute for Sound and Vision (S&V)
- 40 hrs - BBC rushes
- 100 hrs of airport surveillance data - UK Home Office

5 evaluated tasks

- Content-based copy detection – 2010 video queries,…
- **Semantic feature extraction - 20 features**
- Search (automatic, manually-assisted, interactive) - 48 topics
- Video summarization
- Event detection on airport surveillance video
  (5 cameras * 2 hours * 10 days)

TV2008 Finishers

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Athens Information Technology
Asahikasei Co.
AT&T Labs - Research
Beckman Institute
Bilkent University
University of Bradford
Beijing Jiaotong University
Brno University of Technology
Beijing University of Posts and Telecommunications
Carnegie Mellon University
Columbia University
Computer Research Institute of Montreal
COST292 Team (Delft Univ.)
cs24_kobe (Kobe Univ.)
Dublin City University
ETIS Laboratory
EURECOM
Florida International Univ.
Fudan University
FX Palo Alto Laboratory
IBM T. J. Watson Research Center
INRIA-LEAR
INRIA-IMIA
IntuVision, Inc.
Ipan_uoi (University of Ioannina)
IRIM
ISM (The Institute of Statistical Mathematics)
Istanbul Technical University
IUPR-DFKI
JOANNEUM RESEARCH Forschungsgesellschaft mbH
KB Video Retrieval
K-Space
LIG (Laboratoire d'Informatique de Grenoble)
Laboratoire LIRIS (LYON)
University of Twente and CWI
LSIS_GLOT(CNRS LSIS)
Marburg
Chinese Academy of Sciences (MCG-ICT-CAS)
Mediamill (Univ. of Amsterdam)
MESH
MMIS (Open Univ.)
Microsoft Research Asia
NHKSTRL
National Institute of Informatics
National University of Singapore
National Taiwan University

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NTT Cyber Solutions Laboratories
Orange Labs - France Telecom Group
Osaka University
Oxford Univ.
PKU-ICST (Peking Univ.)
PicSom (Helsinki University of Technology)
Queen Mary University of London
Queensland University of Technology
REGIM
Shanghai Jiao Tong University (SJTU)
SP-UC3M (Universidad Carlos III de Madrid)
The Hong Kong Polytechnic University
Tsinghua University - Intel China Research Center
Tsinghua University
TNO-ICT
Toshiba Corporation
Tokyo Institute of Technology
University of Alabama
University of Electro-Communications
University of Glasgow
University of Karlsruhe (TH)
University of Ottawa - SITE
University of Sheffield
University of Southern California
Universidad Rey Juan Carlos
Universidad Autonoma de Madrid
Universite Pierre et Marie Curie - LIP6
VIREO (City University of Hong Kong)
vision@ucf (University of Central Florida)
VITALAS (CERTH-ITI (GR), CWI(NL), U.Sunderland (UK))
XJTU (Xi'an Jiaotong University)

Semantic Feature Detection

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20 LSCOM features evaluated

1 Classroom
2 Bridge
3 Emergency_Vehicle
4 Dog
5 Kitchen
6 Airplane_flying
7 Two people
8 Bus
9 Driver
10 Cityscape
11 Harbor
12 Telephone
13 Street
14 Demonstration_Or_Protest
15 Hand
16 Mountain
17 Nighttime
18 Boat_ship
19 Flower
20 Singing

Task Context

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Common shot bounds, multiple ‘run’ submissions allowed

Manually annotated training data available - double or triple annotation (collaborative)

Much supplemental material shared among participants

Time-bound process, c.5 weeks to complete task

Assessment based on pooling submissions and manual assessment of feature presence

Significance testing validates results

General observations

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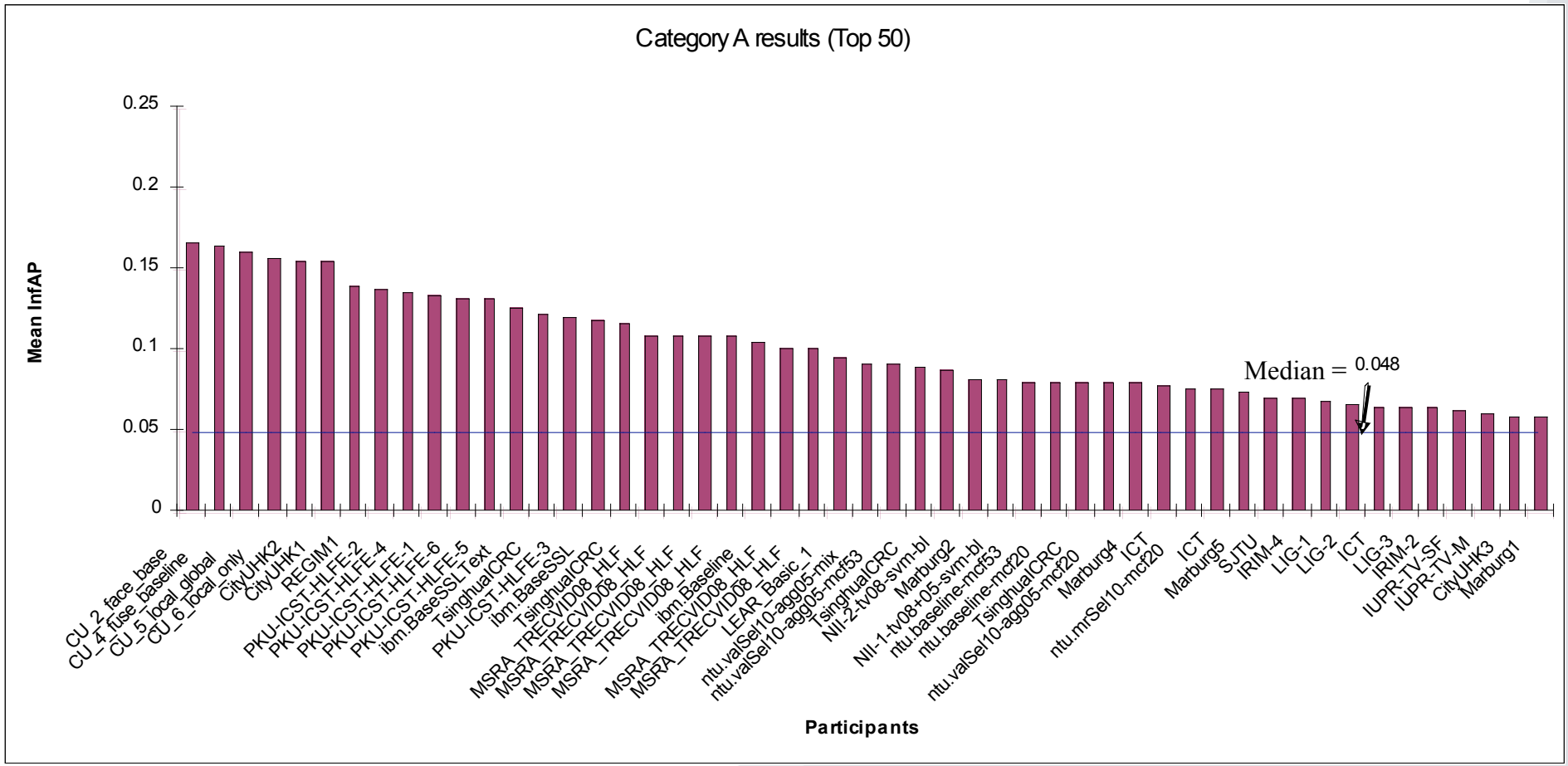
- Very popular task;
- Hardly any feature-specific approaches;
- Large variety in classifier architectures and choices of feature representations;
- Usually a single, cpu, but some medium and larger clusters;
- No. classifiers used for fusion ranges 1 .. >1160
- Times vary between 10m and 150h per feature;
- 30% of runs do some form of temporal analysis;
- 50% of runs use salient/SIFT points;
- These are features PER SHOT, or per KF - not per scene !


Category A results (Top 50)
Mean InfAP
0.25
0.2
0.15
0.1
0.05
0
Median = 0.048
CU_2_face_base
CU_4_fuse_baseline
CU_5_local_global
CU_6_local_only
CityUHK2
CityUHK1
REGIM1
PKU-ICST-HLFE-2
PKU-ICST-HLFE-4
PKU-ICST-HLFE-1
PKU-ICST-HLFE-6
PKU-ICST-HLFE-5
ibm.BaseSSLText
TsinghuaICRC
PKU-ICST-HLFE-3
ibm.BaseSSL
TsinghuaICRC
MSRA_TRECVID08_HLF
MSRA_TRECVID08_HLF
MSRA_TRECVID08_HLF
ibm.Baseline
MSRA_TRECVID08_HLF
MSRA_TRECVID08_HLF
LEAR_Basic_1
ntu.valSel10-agg05-mix
ntu.valSel10-agg05-mcf53
TsinghuaICRC
NII-2-tv08-svm-bl
Marburg2
NII-1-tv08+05-svm-bl
ntu.baseline-mcf53
ntu.baseline-mcf20
TsinghuaICRC
ntu.valSel10-agg05-mcf20
Marburg4
ICT
ntu.mrSel10-mcf20
ICT
Marburg5
SJTU
IRIM-4
LIG-1
LIG-2
ICT
LIG-3
IRIM-2
IUPR-TV-SF
IUPR-TV-M
CityUHK3
Marburg1
Participants

1 Classroom 2 Bridge 3 Emergency_Vehicle 4 Dog 5 Kitchen 6 Airplane_flying 7 Two people 8 Bus
9 Driver 10 Cityscape 11 Harbor 12 Telephone 13 Street 14 Demonstration_Or_Protest 15 Hand
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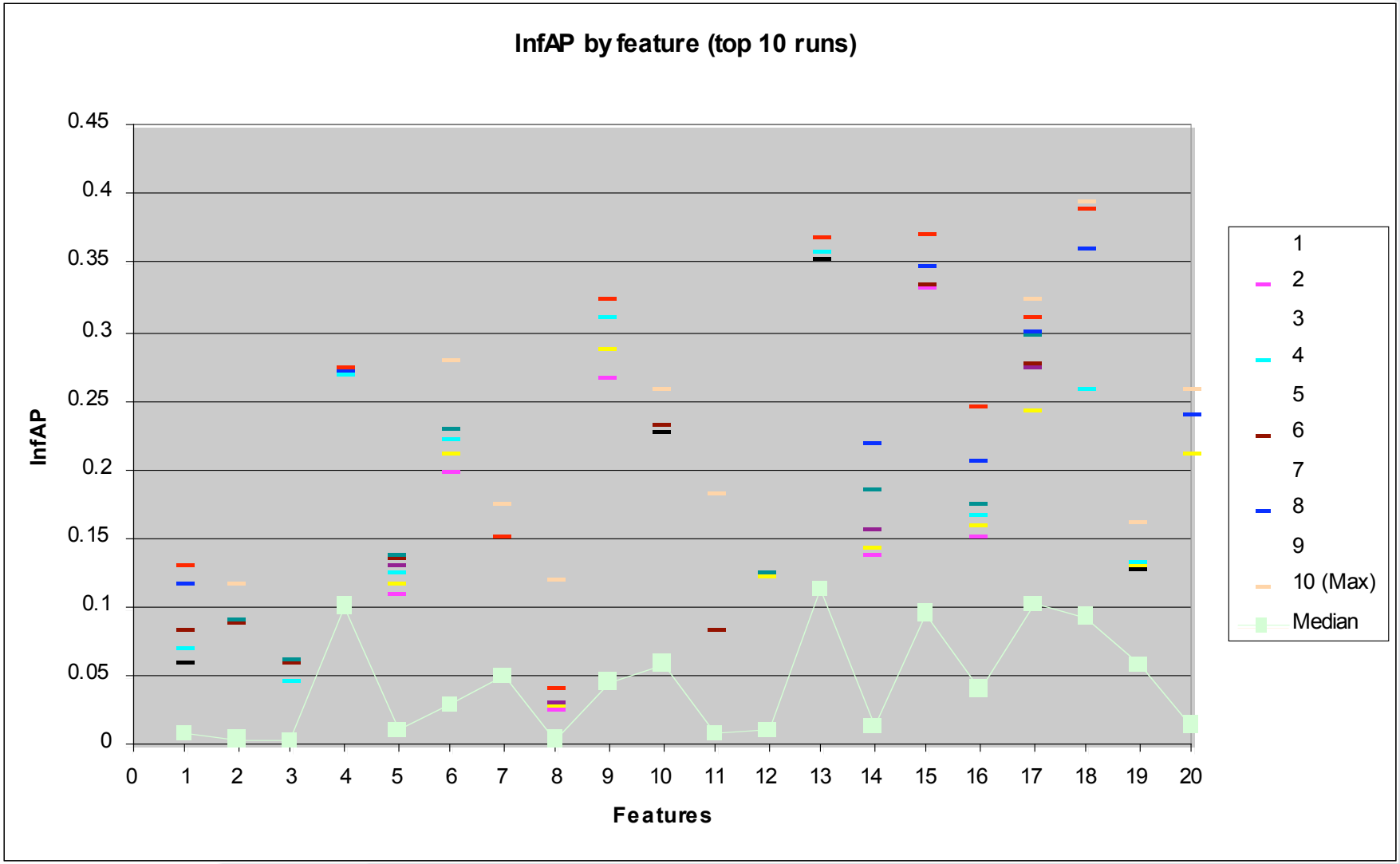
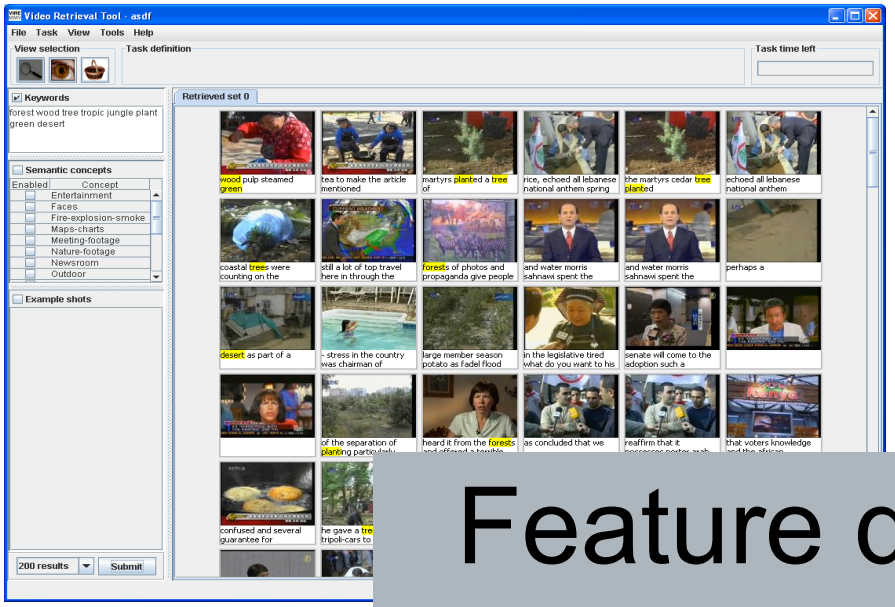
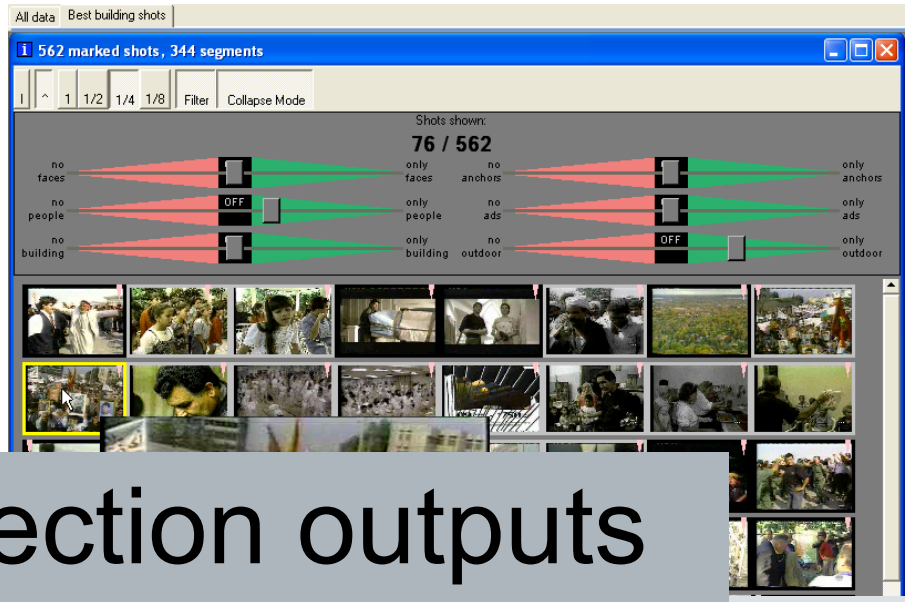
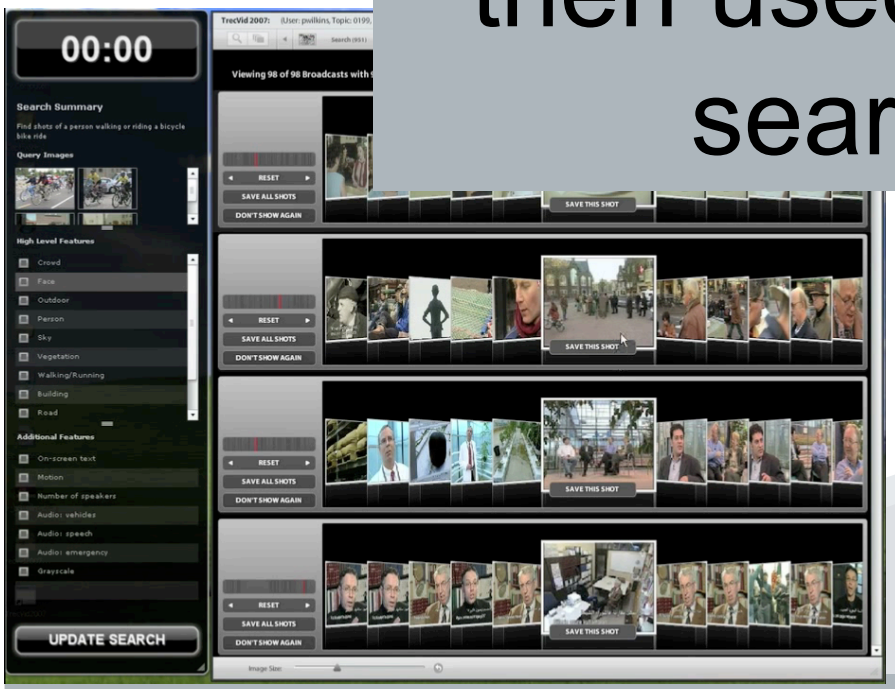
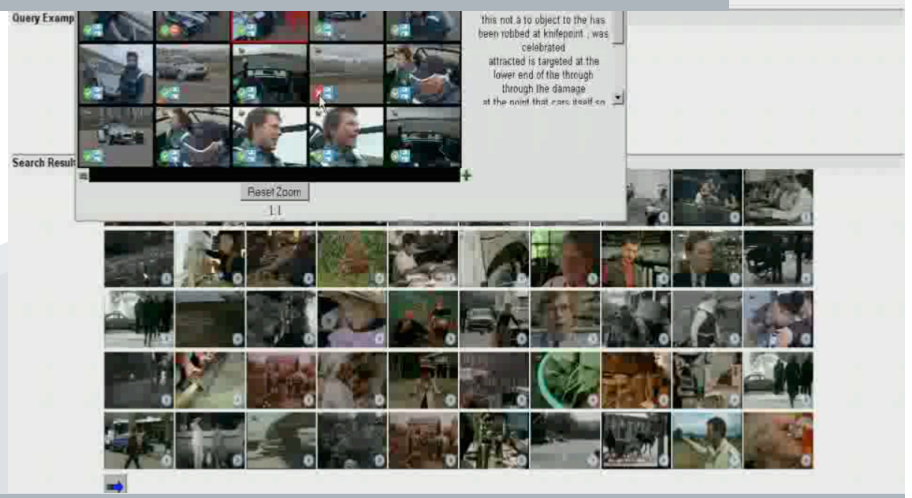






Feature detection outputs then used in participants' search systems





TRECVid Summary

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On small, closed video libraries, content based video search works well; with metadata and UGC it would be even better …

We're still only doing keyframe/image and tasking shot retrieval and we're purposely not using metadata or tags or UGC;

Feature detection accuracy, scale-up to more features, relationships between features, move away from independence to ontology-based … need to progress this;

Combining concepts, keyframe match, text and objects for searching in a natural and usable way;

What do people want ?

Better accuracy, more concepts, concept dependencies, diversity in video sources

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Feature detection accuracy, scale-up to more features, relationships between features, move away from independence to ontology-based … need to progress this;

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What do people want ?

Sound Familiar ?

Better accuracy, …encies, diversity in video sources

Earlier I introduced …

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The 'Old' Web

The Social Web

Dynamic user generated content (UGC) - conventional search tools unable to cope

The Semantic Web

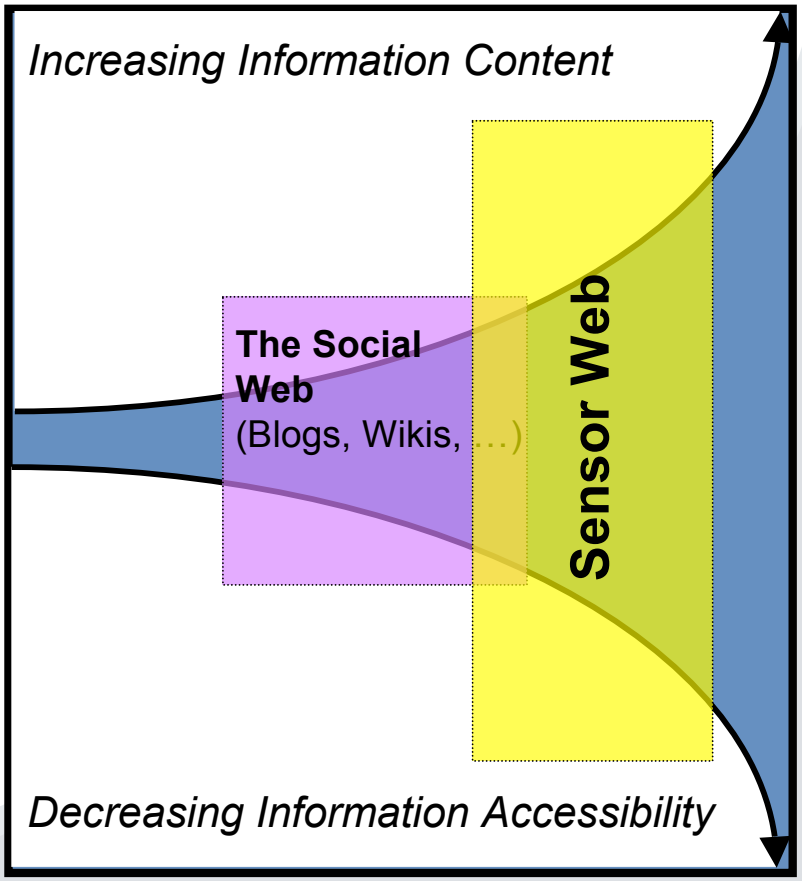
In here somewhere …

The Sensor Web

Increasing availability of cheap, robust, deployable sensors as ubiquitous information sources

Key is that they are networked, mostly wireless, hence global, and integrated - WSNs

Dynamic and reactive but noisy, and unstructured data-streams



The Sensor Web

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Mooted because sensors for local control surpassed by networked sensors, giving networked, online hotspots;

Vision of a global, wholly integrated, WSN web … not here anytime soon;

We saw examples of local sensor networks with SN characteristics … noise, errors, calibration, etc.

We also saw examples of what users want, which drives sensor development

Sensor Web/Net Characteristics

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Common characteristics …

-- Niche domains

-- Known, pre-defined events to be detected

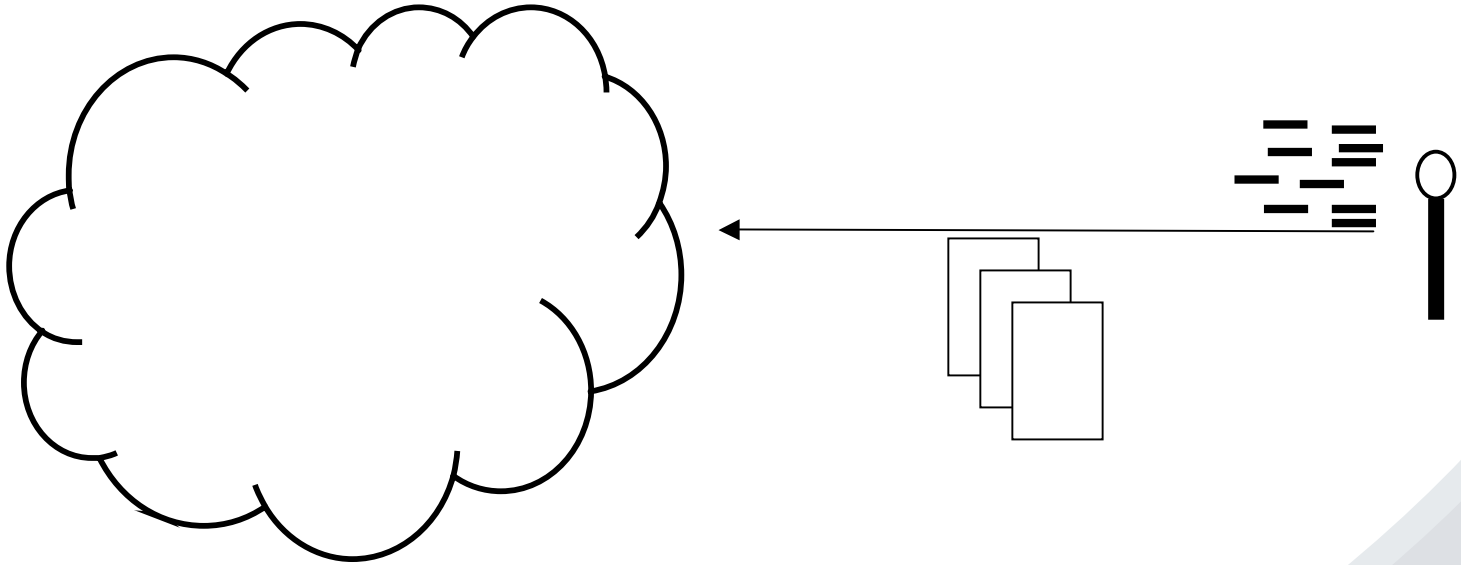
-- No single best detection solution, no rules

-- Detection accuracy not always great, but workable

-- Limited uses of concept ontology

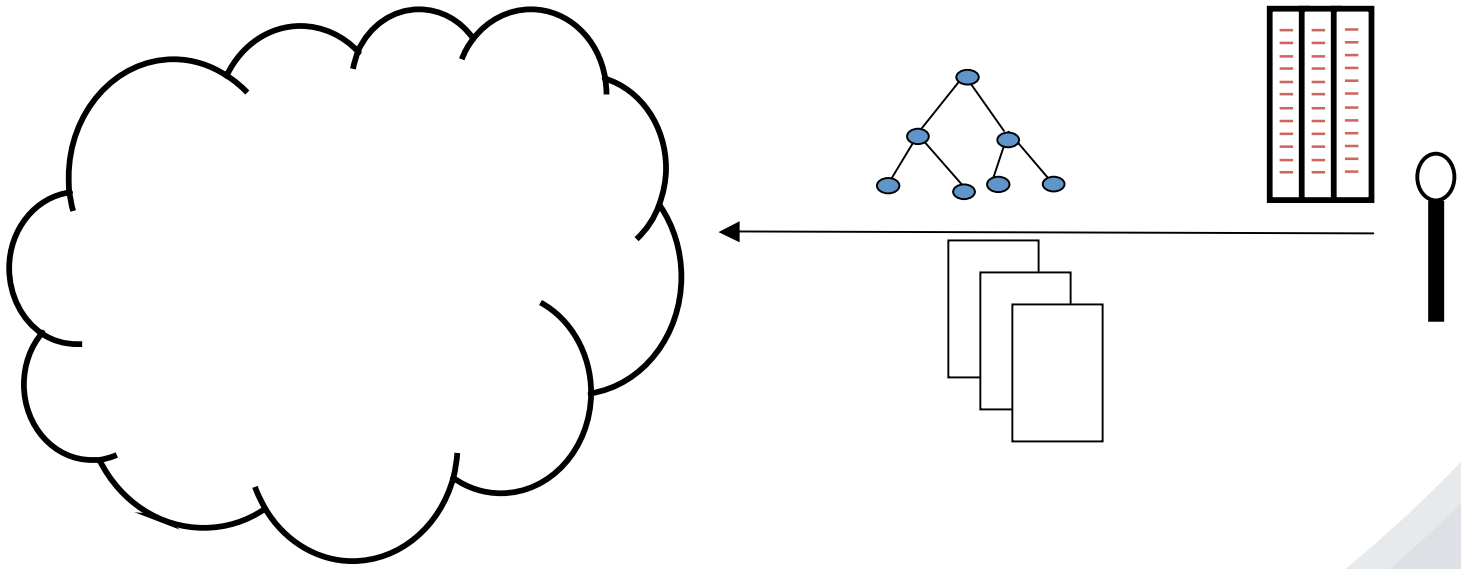
These are precisely the same characteristics as concept detection in video - a surprising parallel

And where does the sensor web fit in ?



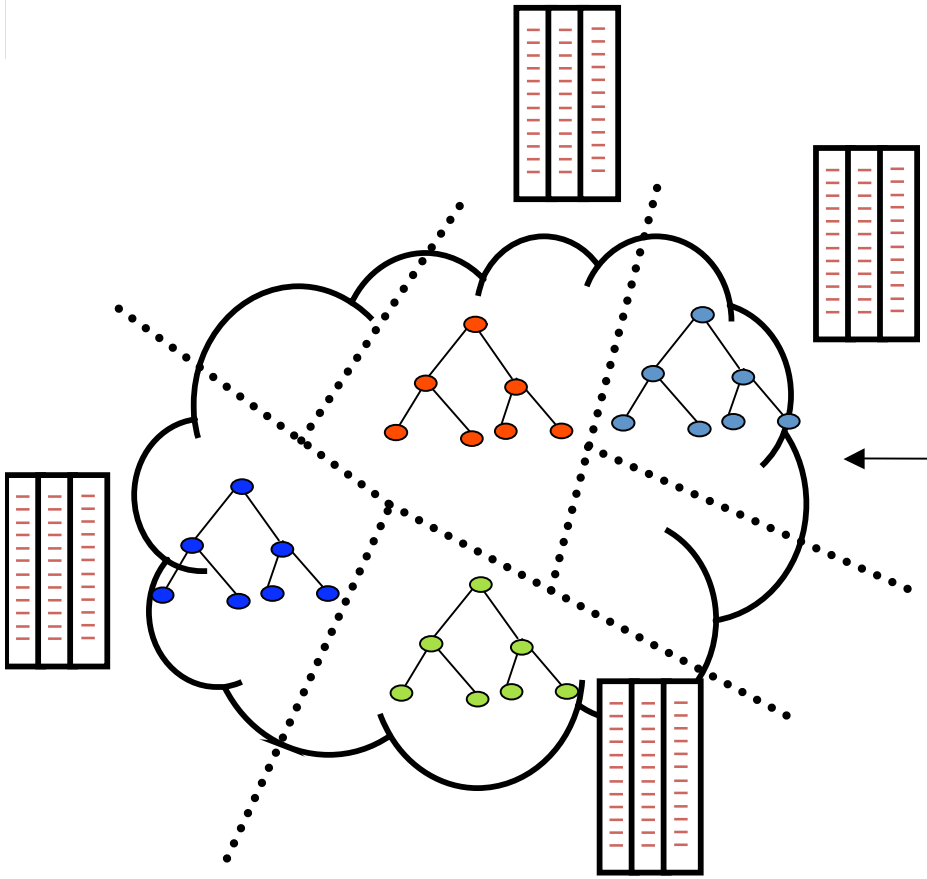
The ‘old’ web !

Challenges: scale, polysemy, NLP



The semantic web

Initially … one SW to bind them all … now …



The semantic web

Challenges are as before
… + …
ontology creation, etc.
content parsing
scale and processing
inference and reasoning

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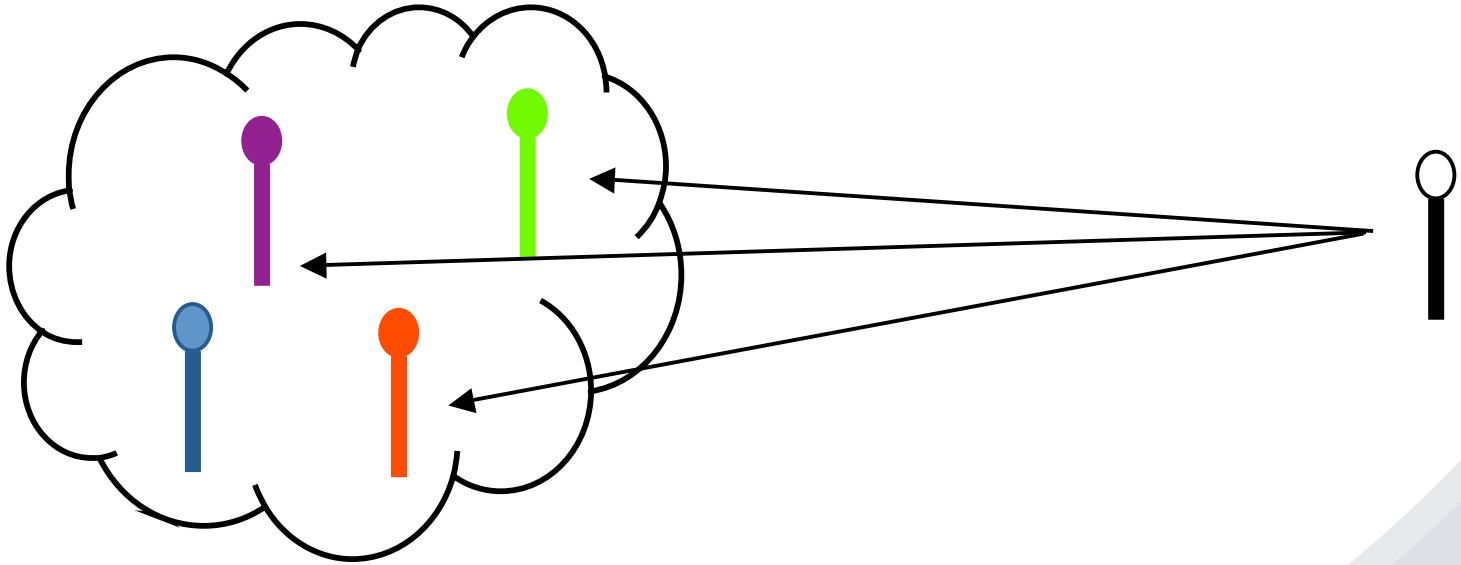
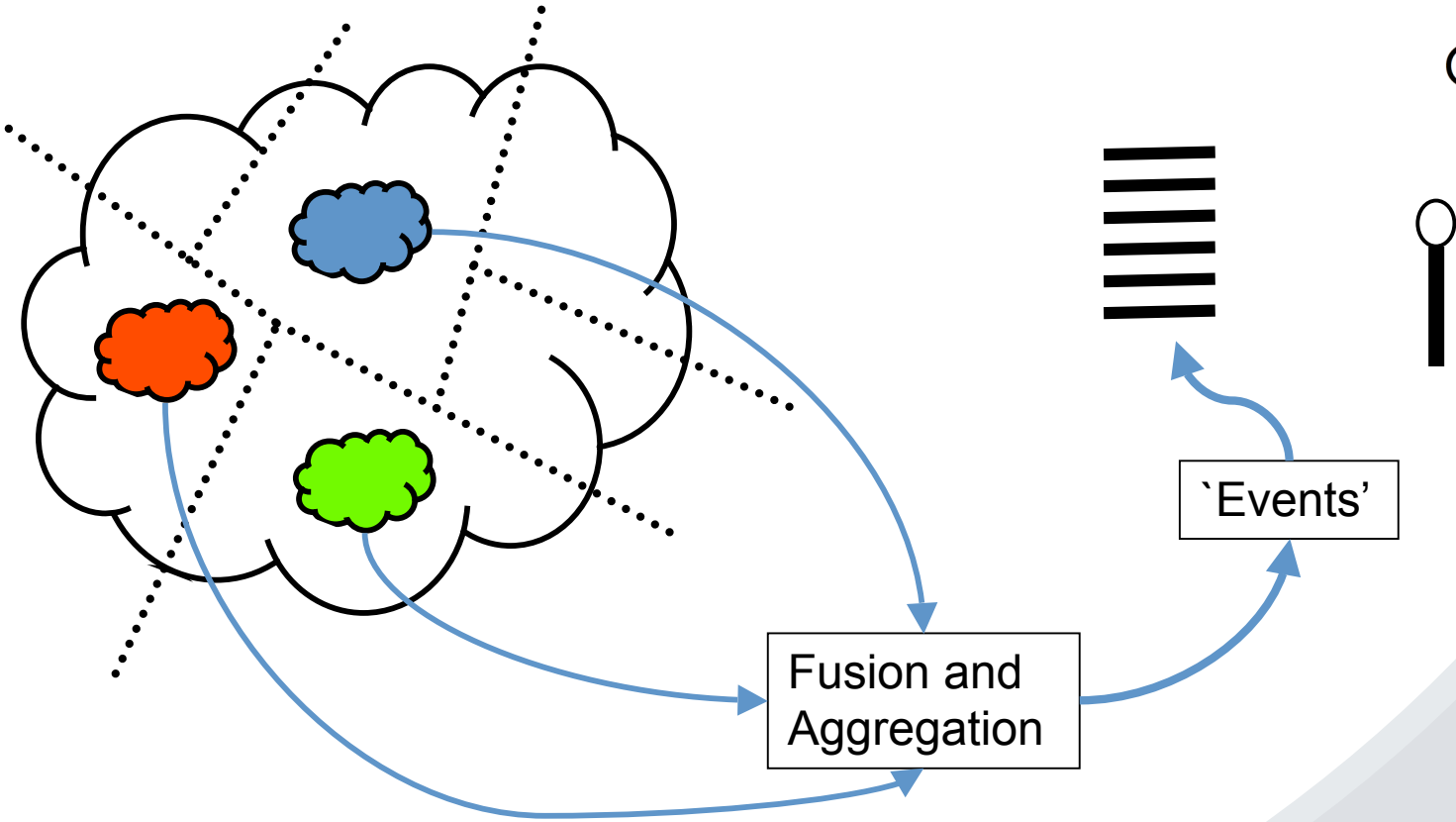


The social web

Challenges are …
- people-centric
- information diversity
 (source, media, sentiment)
- archive to realtime info.



The sensor web(s)

Challenges are …
- errorsome data
- fusion and aggregation
- event detection, not always deterministic and rule-based

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Thanks to …

Very many people in Dublin … colleagues, students, collaborators

Science Foundation Ireland

… the organisers for inviting me