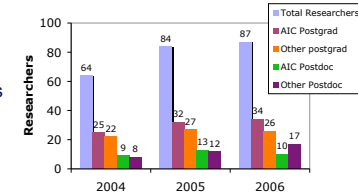


## Contextual Content Analysis for Semantic Knowledge Extraction

Dr. Noel E O'Connor  
Dublin City University  
24/04/2008

## Adaptive Information Cluster

- **Strategic Research Cluster**
  - Funded by Irish government
  - 87 researchers incl. 60 PhDs
- **2003-2007**
  - €5.6m SFI (core) funding
  - €6.5m additional funding from diverse funding sources (EU, EI, SFI, industry)



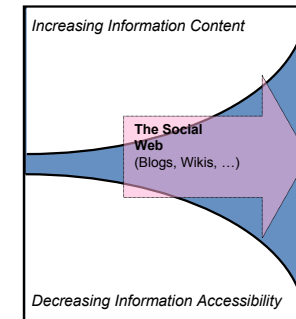
- **Key Performance Indicators**
  - 500+ Publications (incl. 120+ journals)
  - 10 Patents Filings
  - 29 PhD Graduations (+ additional 10 in Q1'08)
  - Tech transfer activities (licensing & spin-out) and significant industry collaborations (ChangingWorlds, Microsoft, Samsung, Vodafone, etc.)
  - Research awards (ECCA, AAAI, AH, CIA Sys.)

## The Information Society

- **Online information continues to grow at near exponential rates**
  - Information content doubling every 3 years ("How Much Information", Berkeley, 2003)
  - Recent developments on the "social web" likely to signal a dramatic increase in online information (blogs, wikis, etc.)
- **Access to online information pervades modern life ...**
  - 67bn searches per month (ComScore 2007)
  - Internet users spending >14hrs/week online (Jupiter 2006)
- **... and the ability to access the right information at the the right time is increasingly important within knowledge economies**
  - 10% of company salary costs lost due to inadequate information access (Butler Group, 2006)

## The Information Access Gap

- **The Web**
  - Information overload is well documented
- **The Social Web**
  - Dynamic user generated content (UGC) on the 'Social Web'
  - Conventional information access tools are failing to cope with new forms of online information and content



## Visual Data

CLARITY

- **490 digital photographs were taken with each digital camera in the EU in 2006**
  - CeWe Color Holding AG, Fact book, March 2007.
- **Estimated that close to half a trillion digital images will be captured in 2009**
- **Camera production reaching 89 million units in 2010 (not including camera phones!)**
  - Lyra Industry Report, Mar 2006

## Benefits of Visual Data

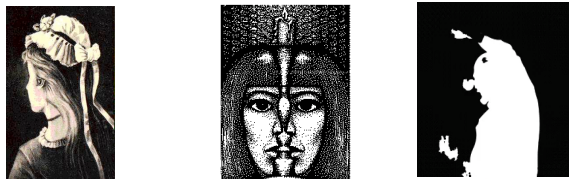
CLARITY

- ***"Un bon croquis vaut mieux qu'un long discours"***
- ***"A good sketch is better than a long speech"***
  - Napoleon Bonaparte (1769 - 1861)
- ***"A picture shows me at a glance what it takes dozens of pages of a book to expound."***
  - Ivan Turgenev (in Fathers and Sons, 1862)
- ***"A picture is worth a 1,000 words"***
  - Fred R. Barnard, 1921, trade journal Printers' Ink, promoting the use of images in adverts on streetcars (not Confucius!)

## The Semantic Gap

CLARITY

- **"The purpose of computing is insight, not numbers."**
  - Richard Hamming (1915-1998)
- **"...the lack of coincidence between the information that one can extract from the visual data and the interpretation that the same data have for a user in a given situation."**
  - Smeulders et al, PAMI 2000



## Approaches

CLARITY

- **Bottom-up**
  - Focus on specific application niches & challenges ... but changing to more generic application scenarios
    - Mature solutions for many complex analysis tasks now available
- **Top-down (Semantic Web)**
  - Tools for ontology creation and management, linking low-level features to concepts
    - Availability of custom-built ontologies defining important concepts
- **Generic**
  - Robust machine learning approaches broadly applied to detect many different concepts
    - Classifier banks, variety of early and late fusion strategies with promising results
- **€€€M of funding, 00's of PhDs, 000's of papers, ...**
- **The Semantic Gap is a Semantic Chasm!**

## Examples: Bottom-up CLARITY

- **Invariant features**
  - [Lowe, IJCV-04]
  - [Van Gool, ECCV-06]
- **Recognising people**
  - [Viola, CVPR-01]
  - [Zisserman, BMVC-06]
- **Recognising settings and objects**
  - [Szeliski, SIGGRAPH06]
  - [Triggs, CVPR-05]
- **Recognising actions**
  - [Laptev, ICCV07]
- **AV Events**
  - [Chang CVPR-07, ICME-06]
- **Audio semantics**
  - [Sikora, 06]
  - [Sandler, IEEE Trans ASLP-07]
  - [Richards, IEEE Trans CSVT-07]

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## Examples CLARITY

- **Top-down**
  - Knowledge assisted analysis using ontologies
    - [Avrithis, IEEE Trans CSVT 07]
    - [Staab, SAMT 06]
  - LSCOM: Large Scale Multimedia Ontology for Multimedia
    - [Hauptmann, ICME-06]
- **Generic**
  - MediaMill 100+ concept detection
    - [Worring, IEEE Trans MM 07]

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## Where Next? CLARITY

- **Is estimating or leveraging context the key to making progress?**
  - What you see or hear depends on who and where you are, when and why you're looking or listening
- **Context**
  - The circumstances that form the setting for an event, statement or idea and in terms of which it can be fully understood and assessed
  - Information pertinent to an item, that is not contained directly in the item
- **Proposed research programme**
  - Extend existing analysis tools and systems with complementary contextual data sources ... location, biometric, social, ...

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## Using Context CLARITY

- **Research Question**
  - Does considering non-content data help in understanding or processing the visual content?
- **Example 1**
  - Does knowing the real world location at which a photograph was taken (and who took it) help in figuring out what the photograph represents?
- **Example 2**
  - For very large collections does adding even more diverse sensor sources help determining the importance of images to the user?
- **Example 3**
  - If monitoring human activity visually, does it help to know more about the status of the human body performing the activity?

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## Challenges

CLARITY

- **Need readily available access to new sensor modalities captured in tandem with visual**
- **Sometimes it's easy ☺**
  - E.g. EXIF data & GPS-tagging for image collections
- **Sometimes it's not ☹**
  - For some applications no contextual data available
  - Integrated capture devices (e.g. camera + GPS + motion + ...) don't yet exist
  - Even non-integrated devices don't exist! Sensors in very early stage development (e.g. wearable biometric sensing)

## Challenges

CLARITY

- **Need multi-disciplinary approach**
- **Chemists, physicists & engineers**
  - Design sensors, build platforms for housing the sensor, mechanism to deploy and gather data
- **Domain specialists to inform interpretation of the new data sources**
  - What data is important? What does the data mean in real terms?
  - Need to know this before we can meaningfully associate it with the visual data

## Researchers

CLARITY

### 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
Dr. Noel O'Connor	- Audio-visual analysis, multi-modal information processing
Mr. 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

## Sample Projects

CLARITY

- **Social Media**
  - Managing collaborative photo archives
- **Lifelogging**
  - Recording daily life and activities
- **Sports Applications**
  - Coaching tools for personal health

## Social Media

### Digital Photos + GPS

## Personal Photo Management

- **People take a lot of digital photos**
- **How to manage large photo collections?**
  - Thumbnail display, time-based organisation, manual annotation
  - Inadequate for very large collections
- **User Requirements (Rodden & Wood, 2003)**
  - Thumbnails in chronological order, with many displayed at once
  - Browse by event ... important occurrence (to user)
  - Content-based search not useful (!)
  - People in photos are important

## MediAssist Project

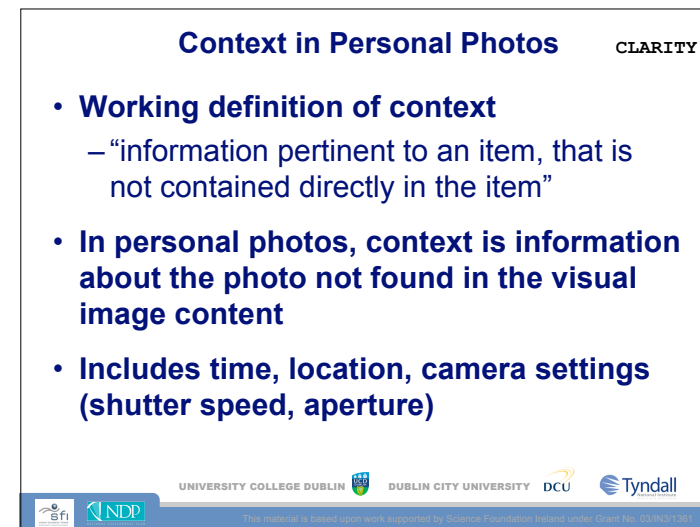
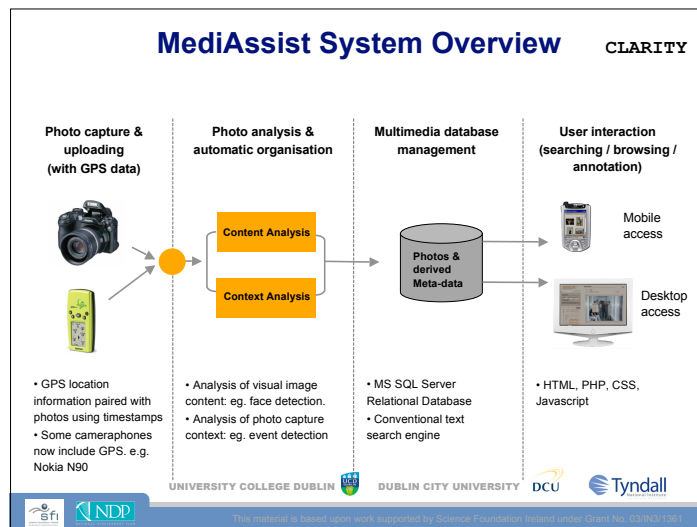
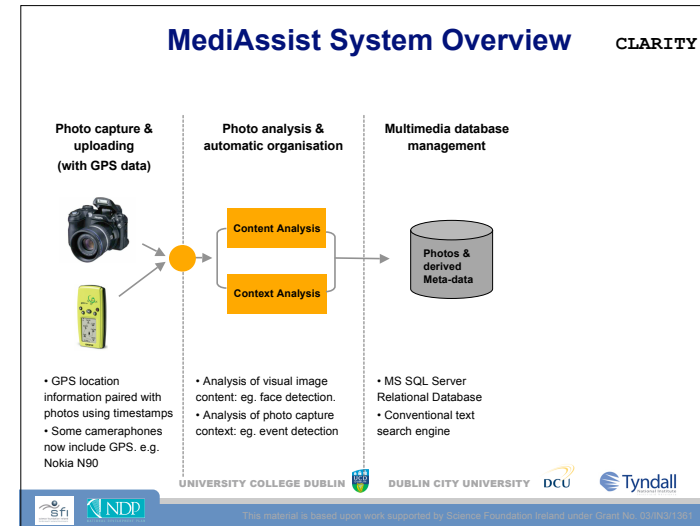
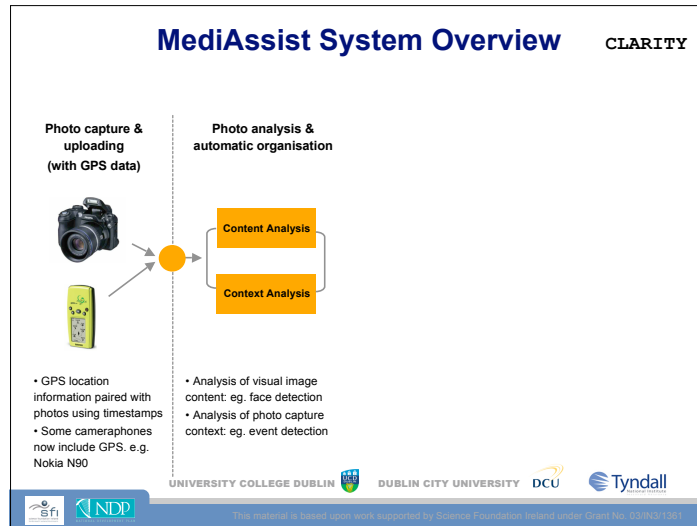
- **Photo management using content and context**
  - Browsing
    - Event-based
  - Searching
    - Context: Time and Location, Light Status, Indoor/Outdoor, Weather
    - Content: Face Detection & Recognition, Body Patch analysis, Building Detection
    - Text search
  - Annotation
    - Semi-Automatic annotation
    - Batch Semi-Automatic annotation

## MediAssist System Overview

Photo capture & uploading  
(with GPS data)



- GPS location information paired with photos using timestamps
- Some cameraphones now include GPS. e.g. Nokia N90



## Context-Analysis

CLARITY

- **Event Detection**
  - Automatically segment personal photo collections into events, based on time and location of photo capture
- **Temporal Indexing**
  - Linear is not always well-remembered by users
  - But various temporal schemata are remembered by users and can be used to index personal photos
    - Day of week, month of year, time of day
- **Location**
  - Latitude/Longitude co-ordinates converted to placenames using a gazetteer

## Context-Analysis

CLARITY

- **Light Status Classification**
  - Standard astronomical algorithms can calculate sunrise/sunset times, given time and location
  - This makes it easy to classify photos as day/night/dusk/dawn
- **Indoor/Outdoor Classification**
  - The sun provides much more powerful illumination than artificial, indoor lights
  - Camera exposure (reflected in aperture, shutter speed) reflects the strength of environmental light
  - For daytime photos
    - stronger light = outdoor, weaker light = indoor
  - This can be combined with content-based analysis
- **Weather Classification**
  - From web-based logs based on time and location

## Context & Content Analysis

CLARITY

- **Face detection (content-only)**
- **Person recognition (content + context)**
  - Temporal Proximity
    - Who is known to be present shortly before/after the photo
  - Spatial Proximity
    - Who tends to be present in the current location?
  - Co-occurrence
    - If we know some of the people in the current photo/event, who then is also likely to be present?
  - Face and body patch matching using MPEG-7 features
- **Building detection (content + context)**
  - Pre-processing based on context (only consider outdoor photos)
  - Content: edge orientation histogram-based features
  - Context: shutter speed, aperture, flash fired
  - SVM Classifier

CLARITY



**CLARITY**

- **Features:**
  - Face Detection




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**CLARITY**

- **Features:**
  - Face Detection
  - Body Patch



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**CLARITY**

- **Features:**
  - Face Detection
  - Body Patch
  - Face Features




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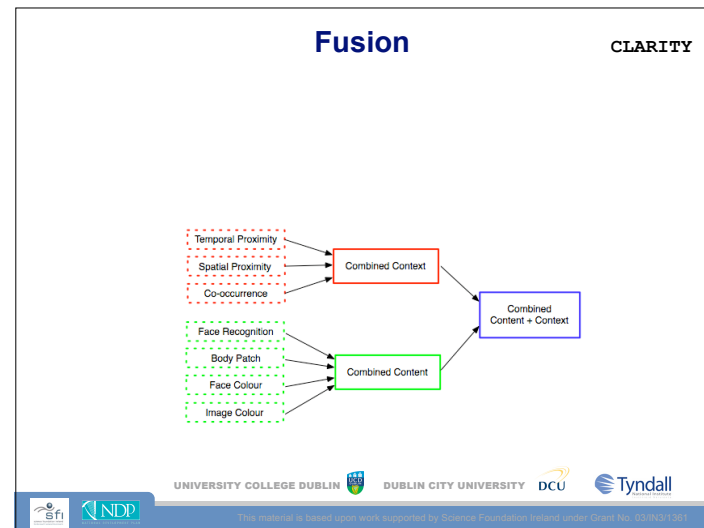
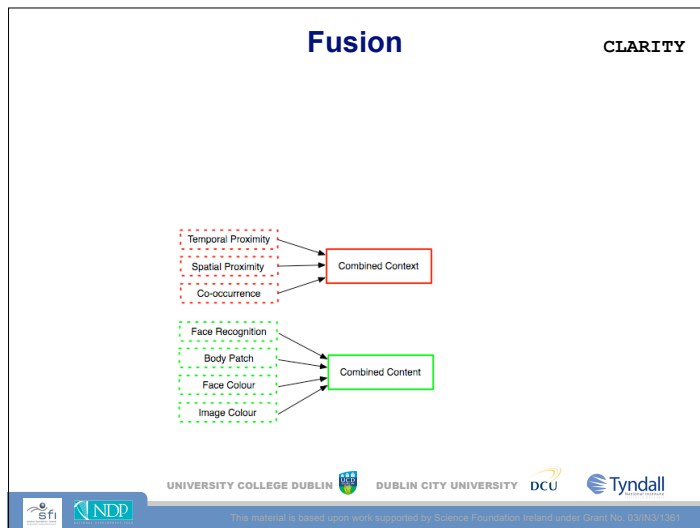
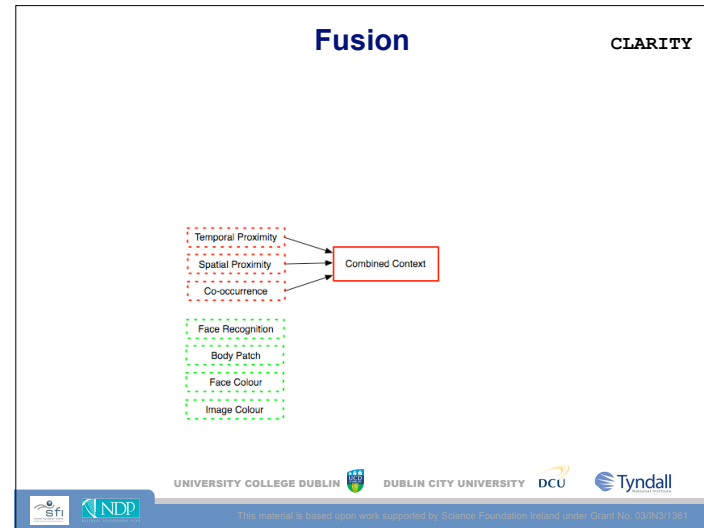
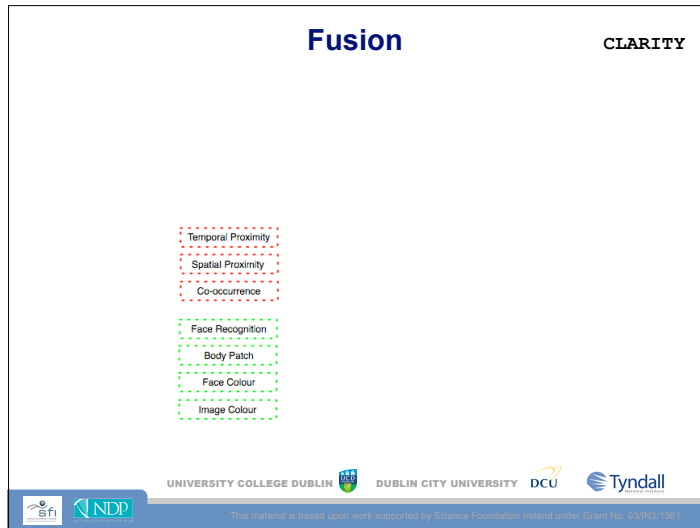
**CLARITY**

- **Features:**
  - Face Detection
  - Body Patch
  - Face Features
- **Body Patch, Face Colour: MPEG-7 Scalable Colour**
- **Nearest Neighbour classification using Manhattan distance**



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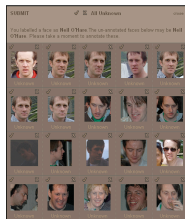
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## Semi-Automatic Person Annotation CLARITY

- **Classification**

- Names suggested for all un-annotated faces



- **Retrieval**

- Faces suggested for a given name
- Enables batch annotation



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CLARITY

## Demo



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## Papers CLARITY

- "Using Text Search for Personal Photo Collections with the MediAssist System", O'Hare N, Gurrin C, Jones G, Lee H, O'Connor N and Smeaton A.F. SAC2007 - 22nd Annual ACM Symposium on Applied Computing, Seoul, Korea, 11-15 March 2007.
- "Automatic Text Searching for Personal Photos", O'Hare N, Lee H, Cooray S, Gurrin C, Jones G, Malobabic J, O'Connor N, Smeaton A.F and Usclowski B. SAMT 2006 - Poster and Demo Proceedings of The First International Conference on Semantics And Digital Media Technology, Athens, Greece, 6-8 December 2006. (pp43-44)
- "Identifying Person Re-occurrences for Personal Photo Management Applications", Cooray S, O'Connor N, Gurrin C, Jones G, O'Hare N and Smeaton A.F. VIE 2006 - IEE International Conference on Visual Information Engineering, Innovation and Creativity in Visual Media Processing and Graphics, Bangalore, India, 26-28 September 2006. (pp144-149)
- "MediAssist: Using Content-Based Analysis and Context to Manage Personal Photo Collections", O'Hare N, Lee H, Cooray S, Gurrin C, Jones G, Malobabic J, O'Connor N, Smeaton A.F and Usclowski B. CIVR2006 - 5th International Conference on Image and Video Retrieval. Springer Lecture Notes in Computer Science Vol. 4071, Vol. 4071 / 2006, No. , Tempe, AZ, 13-15 July 2006. (pp529-532)
- "Combination of Content Analysis and Context Features for Digital Photograph Retrieval", O'Hare N, Gurrin C, Jones G and Smeaton A.F. 2nd IEE European Workshop on the Integration of Knowledge, Semantic and Digital Media Technologies, London, U.K., 30 November-1 December 2005. (pp323-328)
- My Digital Photos: Where and When?. O'Hare N, Gurrin C, Lee H, Murphy N, Smeaton A.F and Jones G. ACM Multimedia 2005 - 13th ACM International Conference on Multimedia 2005, Singapore, 6-12 November 2005. (pp261-262)



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CLARITY

## Lifelogging

Images + GPS + Motion



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## Lifelogging

CLARITY

- **Lifelogging is about recording daily life, digitally**
- **Sometimes its for a reason**
  - Work related e.g. security personnel, medical staff
- **Sometimes its for personal posterity**
  - Vacations, family gatherings, social occasions;
- **Sometimes its because we can!**
  - Even if not yet sure why e.g. MyLifeBits;

## Lifelogging

CLARITY

- **Vannevar Bush, “As We May Think”, 1945**
  - Concept of the “Memex”
    - ‘a device in which an individual stores all his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility’.
- **Requires:**
  - Logging intentional user activities like media consumption (TV, radio, music, books) and cyberspace activities (Web)
  - Logging what’s seen and heard via passive (wearable) capture devices
- **Inspired a variety of passive capture devices to capture what we see**

## SenseCam

CLARITY

- **SenseCam is a Microsoft Research Prototype**
- **Multi-sensor device**
  - Colour camera
  - 3 accelerometers
  - Light meter
  - Passive infrared sensor
- **1GB flash memory storage of a few days**
- **Smart image capture ~3 images/min**
- **We’ve had 2 since April 2006 (recently received 4 more)**



## SenseCam

CLARITY

- **Captured images**
  - Fisheye lens
  - No variable aperture
  - Low resolution



CLARITY

## Video

### A Day in the Life

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## 1,000,000 SenseCam Images


CLARITY




- **One user wearing SC for 15 months**
  - Over 1 million SenseCam images
  - Each with GPS position !
- **Experiences:**
  - Most people don't notice the 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'
  - About 40% of photos captured are low quality, even more are stop-photos (banal photos of typical scenes like driving or working at desk).
  - Need an extremely understanding girlfriend!



Millionth Image



Most Important Image



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## Types of People Encountered




CLARITY



- **Not Bothered/Not Notice:** just don't care, this accounts for most people.
- **Cautious:** ask if they are being captured, then ask if it captures audio too, always remember the sensecam and comment 'still wearing it' when meet you again. Usually these people become 'Not Bothered' types.
- **Sensitive:** don't like it on at all, will try to get you to take it off, often are people with cameras themselves!
- **Avoider:** avoid contact because of camera, or at least avoid sitting in front of you.
- **Argumentative:** point out they don't give permission to take their photo, argue a lot, don't accept.

Most



Least




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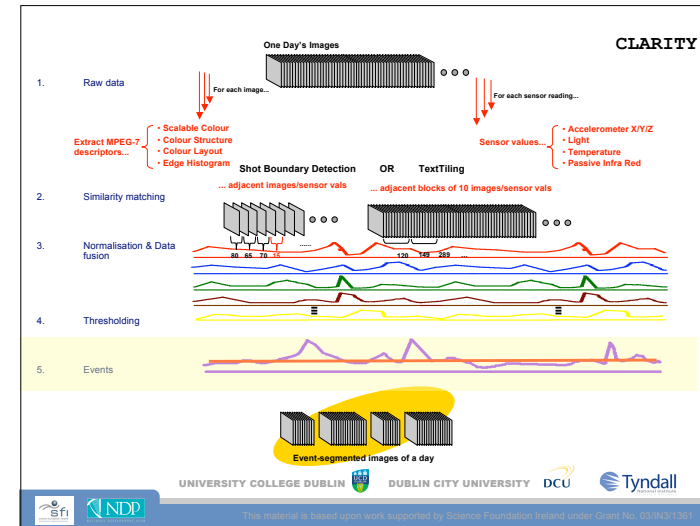
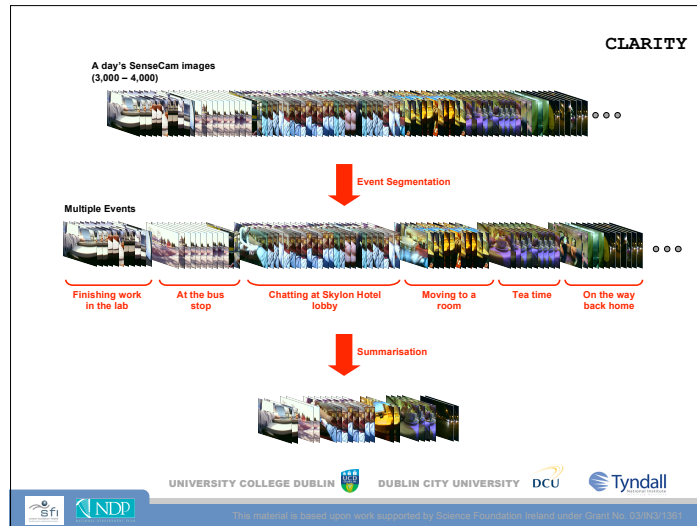
## User's thoughts after 15 months

CLARITY

- **Events are the key**
  - Too many photos to browse, need event summary and then 'drill down' to view event in detail
  - Stop events, (like work desk and driving) can be hidden.
- **'Total Recall'**
  - "I remember nearly every (non stop-) event when I see it..."
- **Important axes for event search:**
  - Location of the event
  - People in the event
- **Time based organisation less important**
  - "I will probably not remember time/day/date, but I will remember location and people there."

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**CLARITY**

## Experiments

- **5 different users wearing SenseCam for 1 month each**
  - Total = 270k images
  - Each user groundtruthed their own data into events
- **From groundtruth:**
  - Average of 1,785 images per user per day
  - Average of 20 events per day
- **Performance:**
  - Sensor only (f score = 0.55)
  - Image + Sensor (f score = 0.60)
- **2 Approaches Recommended:**
  - Most accurate (include MPEG-7 features)
  - Quick segmentation (sensor values only)

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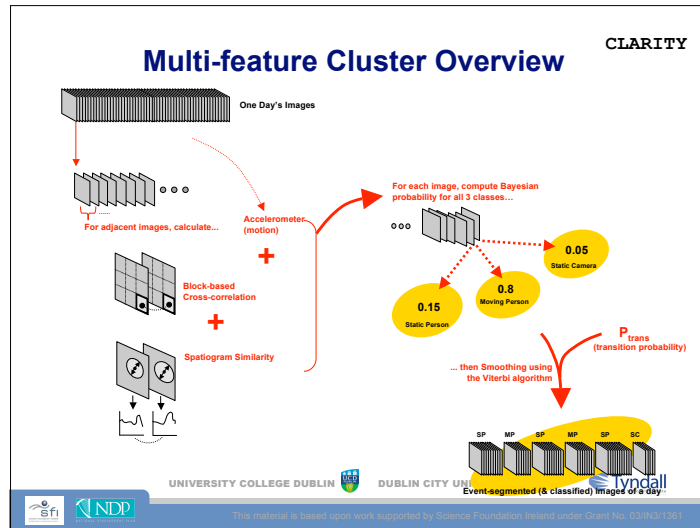
**CLARITY**

## Event Segmentation (V2)

- **(1) Colour Features**
  - Image spatiogram
- **(2) Edge features**
  - Block-based cross-correlation
- **(3) Motion features**
  - Accelerometer readings
- **Complimentary and independent**

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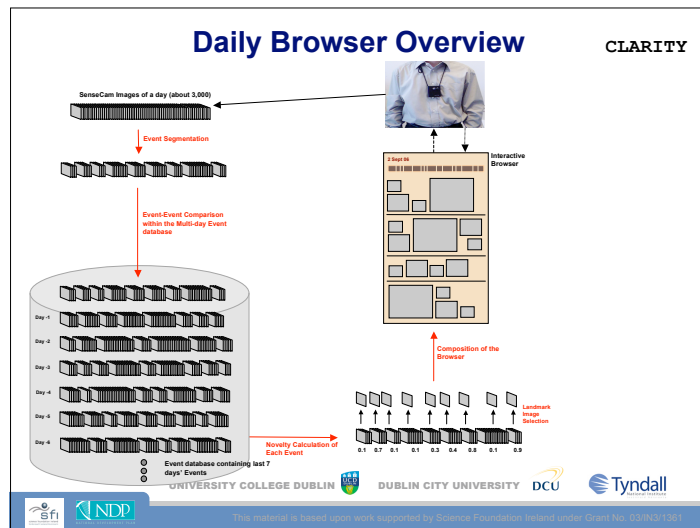
### Multi-feature Cluster Overview

CLARITY

- Classify Images into 3 classes
- Static Camera (SC)
- Static Person (SP)
- Moving Person (MP)

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### My Visual Diary WITH SENSECAM

CLARITY

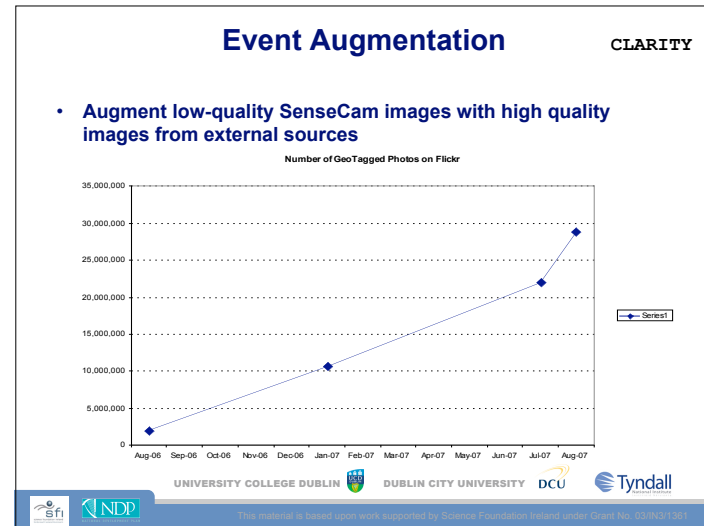
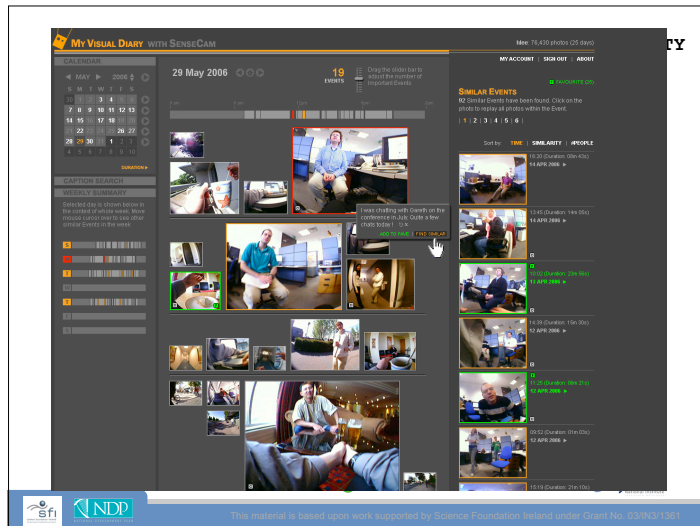
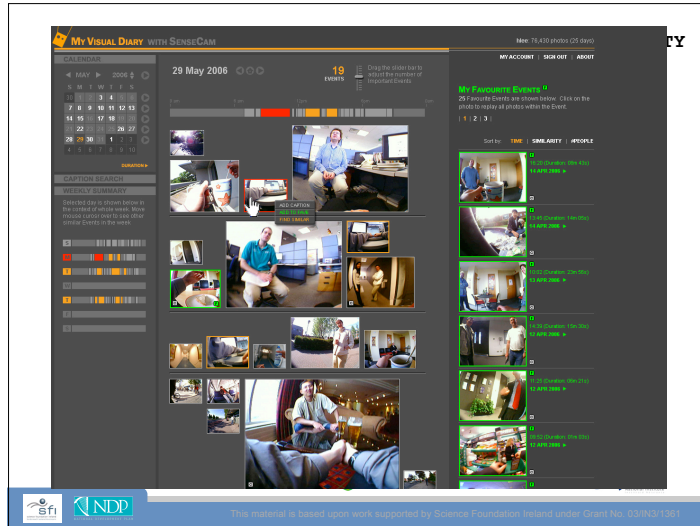
My Visual Diary WITH SENSECAM

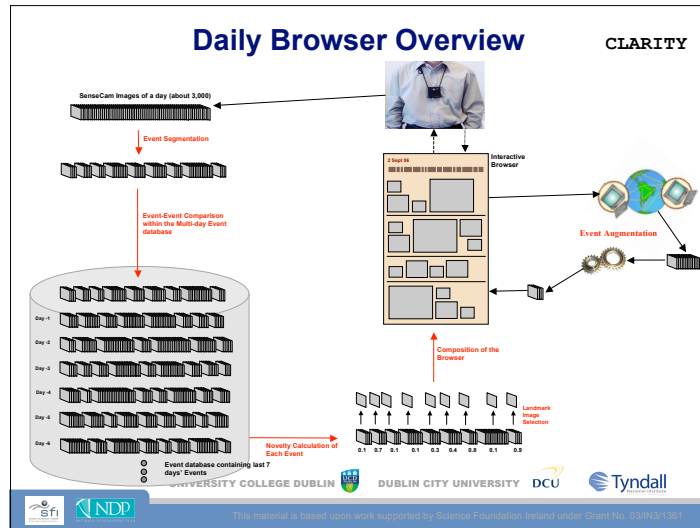
29 May 2006

My Favourite Events

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### Event Augmentation – Croke Park CLARITY

Here's an image from a SenseCam after a big match in Croke Park. We'd really like to see other people's pictures of this match.

Let's search by location...

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### Event Augmentation – Croke Park CLARITY

- Receive the following pictures...
- Then filter out to just those results from the same day

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### Event Augmentation – Croke Park CLARITY

- Receive the following pictures...
- Then filter out to just those results from the same day

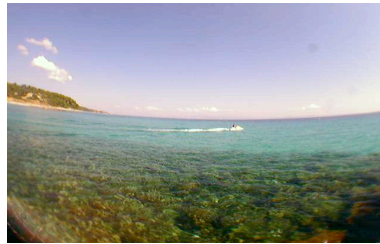
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## Event Augmentation - Chalkidiki CLARITY

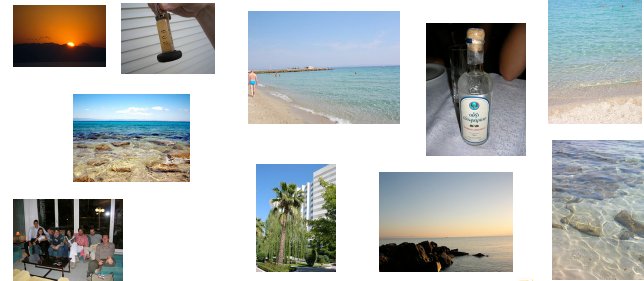
Here's an image from my SenseCam at a beach in Chalkidiki in Greece. I'd really like to see other people's pictures of this beach

Therefore I search by location firstly...



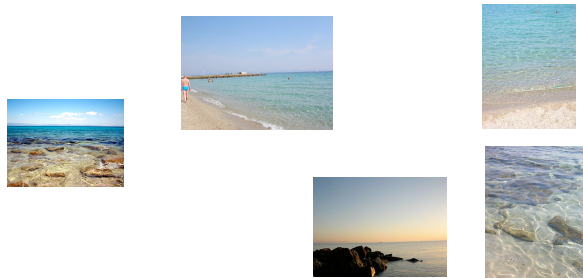
## Event Augmentation - Chalkidiki CLARITY

- I receive the following pictures...
- Then I filter out to just those visually similar results



## Event Augmentation - Chalkidiki CLARITY

- I receive the following pictures...
- Then I filter out to just those visually similar results



## Papers CLARITY

- "MyPlaces: Detecting Important Settings in a Visual Diary", Blighe M and O'Connor N. CIVR 2008 – ACM International Conference on Image and Video Retrieval, Niagara Falls, Canada, 7-9 July 2008.
- "Mo Músaem Fíorúil: A Web-based Search and Information Service for Museum Visitors", Blighe M, Sav S, Lee H, and O'Connor N. ICIAR 2008 –International Conference on Image Analysis and REcognition, Povoa de Varzim, Portugal, 25-27 June 2008.
- "Automatically Segmenting Lifelog Data into Events", Doherty A.R. and Smeaton A.F. WIAMIS 2008 - 9th International Workshop on Image Analysis for Multimedia Interactive Services, Klagenfurt, Austria, 7-9 May 2008.
- "Applying Contextual Memory Cues for Retrieval from Personal Information Archives", Fuller M, Kelly L and Jones G. PIM 2008 - Proceedings of Personal Information Management, Workshop at CHI 2008, Florence, Italy, 5-6 April 2008.
- "Multimodal Segmentation of Lifelog Data", Doherty A, Smeaton A.F, Lee K, and Ellis D. 8th RIAO Conference - Large-Scale Semantic Access to Content (Text, Image, Video and Sound), Pittsburgh, PA, 30 May - 1 June, 2007.
- "Organising a daily Visual Diary Using Multi-Feature Clustering", O'Conaire C, O'Connor N, Smeaton A.F. and Jones G. SPIE Electronic Imaging - Multimedia Content Access: Algorithms and Systems (EI121), San Jose, CA, 28 January - 1 February 2007.
- "Adaptive Visual Summary of LifeLog Photos for Personal Information Management", Hyowon Lee, Alan F. Smeaton, Noel E. O'Connor and Gareth J.F. Jones. AIR 2006 - First International Workshop on Adaptive Information Retrieval, Glasgow, U.K., 14 October 2006.
- "Exploiting Context Information to aid Landmark Detection in SenseCam Images", Blighe M, Le Borgne H, O'Connor N, Smeaton A.F and Jones G. ECHISE 2006 - 2nd International Workshop on Exploiting Context Histories in Smart Environments - Infrastructures and Design, 8th International Conference of Ubiquitous Computing (UbiComp 2006), Orange County, CA, 17-21 September 2006.

## Sporting Applications

Video + GPS + Motion + Respiration +  
Perspiration

## Motivation

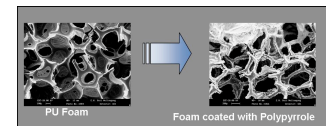
- **Use content and context analysis to bring innovation to personal health and well being.**
- **Next generation ICT coaching tools**
  - Provide biometric and technical (sporting technique) feedback to both elite and amateur athletes.
- **Coaches already do this ... but**
  - Currently key biometric monitoring only possible in laboratory environments
  - Training sessions video taped to review tactics and technique, but this usually means a laborious process of fast forwarding and rewinding

## Recording Biometrics

- **Off the shelf**
  - 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
- **Smart Textiles**
  - Move from discrete sensors with electronic components attached to fabric to functionalised fabrics which sense stretching, bending, pressure, movements

## Some Basic Chemistry

- **Polymers are macromolecules, and usually they are insulators but some, such as polypyrrole, conduct electricity (c.1970)**
  - Known as conducting polymers or “synthetic metals”
  - We can now coat onto substrates ... including textiles like foam or lycra or anything that moves, twists, bends
- **These conducting textiles can be used as wearable sensors**
  - Respond to stress or strains by changing their electrical conductivity
- **They are:**
  - Easily produced
  - Show rapid response times
  - Can be comfortable to wear



## Some Basic Chemistry

CLARITY



- **Prof. Dermot Diamond**
  - National Centre for Sensor Research



Video



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## Input from Domain Experts

CLARITY

- **Prof. Niall Moyna's team**
  - School of Sports Science and Human Performance
- **What do coaches need to know?**
  - Optimal athlete performance depends on balancing the contribution of aerobic and anaerobic metabolism.
  - A change in sweat pH may signal an increased reliance on anaerobic metabolism.
  - Knowing this would greatly assist in developing training programs and monitoring the physiological demands of competition.
- **Lack of reliable methods for assessing pH during exercise**



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## Cue More Basic Chemistry

CLARITY

- **A new fluid-handling platform**
- **Based on polyamide lycra®**
- **A super absorbent material (SAB) that provides a passive pumping mechanism, controlling fluid flow.**
  - Used to draw sweat into its fluidic channel
- **The optical detection of pH induced colour changes in the dye**
  - Paired emitter-detector LED system
- **Controlled by a Mica2dot mote**
  - Transmits sensor readings from the optical detection, remotely to a base station and PC.

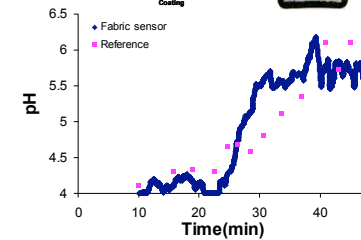
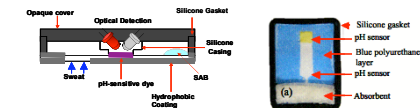


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## Sweat Patch in Action

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## Initial Attempt

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- Phil Kelly as test subject
- Lunch-time informal soccer matches
- AV Content
  - 2 x video cams
  - Close-in and whole field
- Context
  - GPS, FM vest, BodyMedia, Polar heart monitor
- Aggregated into complete CBIR system



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## Video

### SoccerSense Content Management System



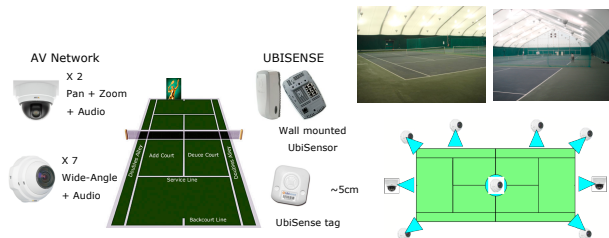
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## Second Attempt

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- **TenniSense**
  - Advanced sensing modalities
    - Sensorised fabrics for real-time monitoring of limb movement & sweat pH
  - High precision localisation via UbiSense
  - AV capture for entire court



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## Video

### UbiSense in Operation



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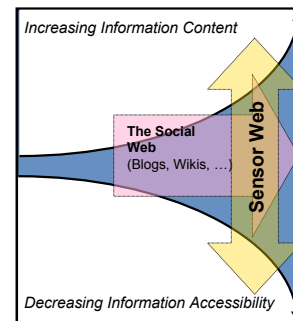
## Conclusion

## Back to Context

- **Have we bridged the Semantic Gap by incorporating context?**
  - No ☹️ Analysis problems are just different but that opens up many new research questions
- **Does allow us to side-step some of the traditionally “hard” image analysis and content management problems**
  - Finding semantically related images
  - Recognising people in images
  - Organising large volumes of content based on real world concepts that are important to the user
  - More robust activity classification and recognition (?)
  - New paradigms in interface design and content access
- **Event detection is a key enabling technology!**

## The Information Access Gap

- **The Web**
  - Information overload is well documented
- **The Social Web**
  - Dynamic user generated content (UGC) on the ‘Social Web’
  - Conventional information access tools are failing to cope with new forms of online information and content
- **The “Sensor Web”**
  - The increasing availability of cheap, robust, and deployable sensor technologies will usher in a new wave of ubiquitous information sources
  - Dynamic, noisy, reactive, unstructured data-streams
- **The gap is getting bigger!**



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CLARITY

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