FUNDAMENTALS OF COLLECTIVE ADAPTIVE SYSTEMS
Aware ICT
A Pervasive Computing Perspective

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The Evolution of „Aware ICT“
"A personal computer (PC) is any general-purpose computer whose size, capabilities, and original sales price make it useful for individuals, and is intended to be operated directly by an end-user with no intervening computer operator ..."
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A personal computer may be a desktop computer, a laptop, netbook, a tablet PC, or a handheld PC."
Manipulative Input
The „unaware“ Computer
The Computer for the 21st Century

Specialized elements of hardware and software, connected by wires, radio waves and infrared, will be so ubiquitous that no one will notice their presence

by Mark Weiser

The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it.

Consider writing, perhaps the first information technology. The ability to represent spoken language symbolically for long-term storage freed information is approachable only through complex jargon that has nothing to do with the tasks for which people use computers. The state of the art is perhaps analogous to the period when scribes had to know as much about making ink or baking clay as they did about writing.

The arcane aura that surrounds personal computers is not just a "user interface" issue. To most people, computers are illusory. It's the jobs of computer technology that are real, not the computers or people who use them.

The idea of integrating computers seamlessly into the world at large runs counter to a number of present-day trends. "Ubiquitous computing" in this context does not mean just computers that can be carried to the beach, jungle or airport. Even the most powerful notebook computer, with access to a worldwide information network, still leaves the user feeling detached from the world around them.
The Computer for the 21st Century

Specialized elements of hardware and software, connected by wires, radio waves and infrared, will be reachable only through a system that has nothing to do with which people use computers. The state of the art is perhaps in the period when scribes did as much about making baking clay as they did about writing.

The arcane aura that surrounds personal computers is not just a "user interface," it is a software discipline. A notebook computer, with access to a worldwide information network, still is a machine without a user interface.
I n 1999—almost a decade after Mark Weiser wrote his seminal article—the then-popular search engine Alta Vista found seven hits in response to a “pervasive computing” search query. Today, Google responds with more than 1,900,000 search results (or 2,300,000 for “ubiquitous computing”). The dawning of this research field is over—we’ve reached the break of day! The question now is, what’s next?

Here, I discuss the challenge of identifying new trails of pervasive computing research. In particular, I report on the structured “research roadmap” solicitation process conducted over the past three years, which involved some 240 of the top researchers in the field. The resulting book, Per­vasive Adaptation: The Next Generation Pervasive Computing Research Agenda, coexists in the digital and physical realm and articulates next-generation research directions for the pervasive computing community.

Three Generations of Pervasive Computing

The pervasive computing vision is still about intuitive, unobtrusive, and distraction-free interaction with omnipresent, technology-rich environments. The metaphor of profound technologies weaving “themselves into the fabric of everyday life of societies until they are indistinguishable from it” continues to challenge researchers in the field, accelerated in two diametrically opposed technology trends: the miniaturization of information and communication electronics, and the exponential growth of global communication networks. Over the past two decades, the field has undergone entangled generations of research challenges. At least three such generations are evident.

Connectedness: Late 90s to Early 2000s

Weiser’s vision was groundbreaking and still represents the cornerstone for what might be referred to as the first generation of pervasive computing research. The motivation was a world where you’re surrounded by embedded, hidden, invisible, and autonomic yet networked information and communication technology (ICT) systems—that is, pervasive computing ICT (pervasive ICT).

This first generation gained momentum from technological progress in electronics mini­aturization, gate packaging, and network connectivity with new wireless communication standards and the exponentially growing Internet—that is, the evolution of technologies that can connect literally everything to everything. Net­works of pervasive ICT systems emerged, forming communication clouds of miniaturized, cheap, fast, powerful, wirelessly connected, “always on” systems, enabled by the massive availability of miniaturized computing, memory, communication, and embedded system components. The first pervasive ICT generation is characterized...
Ubiquitous Computing = Computers are Everywhere
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Pervasive Computing = Everything is a Computer
Ubiquitous Computing  = Computers are Everywhere

Pervasive Computing  = Everything is a Computer
Aware ICT - Towards Implicit Interaction
Aware ICT - Towards *Implicit* Interaction
Aware ICT - Towards **Implicit** Interaction

Digital – Physical Substrate

- Sensors to Actuators
- Actuators to Sensors
- Reasoning - Recognition

Aware ICT // PECCS 2015 // Angres // February 12, 2015 // 18
Context Aware ICT
Context Aware ICT :: SPECTACLES
Context Aware ICT :: SPECTACLES
Context Aware ICT :: SPECTACLES
Situations
The Evolution of „Aware ICT“

Context

“... is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and application themselves.”[1]

Seminal work on context modeling, context recognition, context awareness by A. Dey
Activity Aware ICT
The Evolution of „Aware ICT“

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Activity
“… Humans construct their plans as they engage in specific activities, creating and altering their next move on the basis of what has happened … , looking at how humans achieve their goals by acting through the execution of activities engagement.” “… Activity-aware computing is supported by the automatic recognition of users’ activities” [2]

Seminal work on activity recognition by K.P. Fishkin
Activity Aware ICT :: Sensor Shoe

\[
\begin{align*}
\text{Acc}_y &\quad 0 \text{ m/s}^2 \\
\text{Acc}_z &\quad 0 \text{ m/s}^2 \\
\text{Pitch} &\quad 0^\circ \\
\end{align*}
\]

\[
\begin{align*}
\text{Acc}_y &\quad > \text{ m/s}^2 \\
\text{Acc}_z &\quad << \text{ m/s}^2 \\
\text{Pitch} &\quad 25^\circ \\
\end{align*}
\]

\[
\begin{align*}
\text{Acc}_y &\quad >> \text{ m/s}^2 \\
\text{Acc}_z &\quad > \text{ m/s}^2 \\
\text{Pitch} &\quad 55^\circ \\
\end{align*}
\]

\[
\begin{align*}
\text{Acc}_y &\quad 0 \text{ m/s}^2 \\
\text{Acc}_z &\quad 0 \text{ m/s}^2 \\
\text{Pitch} &\quad -25^\circ \\
\end{align*}
\]
Activity Aware ICT :: Sensor Shoe

Straight walk

Pitch

Accz

Staircase Up

Pitch

Accz

…

walking

sitting

standing

lying

reading

cooking

sleeping

…
Activity Aware ICT :: PowerIT
## PowerIT :: Activity Data Collection

<table>
<thead>
<tr>
<th>read</th>
<th>eat</th>
<th>meet</th>
<th>smoke</th>
</tr>
</thead>
<tbody>
<tr>
<td>break_smoke</td>
<td>education</td>
<td>don't</td>
<td>socialize</td>
</tr>
<tr>
<td>car_driving</td>
<td>entertainment</td>
<td>phonecall</td>
<td>sports</td>
</tr>
<tr>
<td>coffee</td>
<td>family_care</td>
<td>pray</td>
<td>travel</td>
</tr>
<tr>
<td>computer</td>
<td>household</td>
<td>relax_think</td>
<td>tv</td>
</tr>
<tr>
<td>cook</td>
<td>hygiene</td>
<td>shop</td>
<td>work</td>
</tr>
<tr>
<td>drink</td>
<td>locomotion</td>
<td>sleep</td>
<td>write</td>
</tr>
</tbody>
</table>

Identification of activities of daily living and iconographic representation

(Semi-)automatic time of use survey

Automatic activity extraction for implicit appliance control pending

## PowerIT :: Energy Meter and Control

- **Switch Circuit**
- **Control Logic**
- **Measurement Circuit**
- **Custom Prototype**

A. Ferscha

Aware ICT // PECCS 2015 // Angres // February 12, 2015 // 33
Activity Aware ICT :: Pattern Recognition Chain
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(i) Sensor Signal Acquisition
- Sensors of different modalities measure environmental quantities
  - e.g., acceleration, noise, humidity, temperature, light, ...

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- e.g., High- / Low-Pass Filter

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- Segmentation into sections
  - e.g., Sliding Windows

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  - e.g., Sliding Windows

(iv) Feature Extraction
- reducing dimensionality
- calculation on segments

Activity Aware ICT :: Pattern Recognition Chain

(v) Classification
- mapping the features into a set of classes (activities)
Activity Aware ICT :: Pattern Recognition Chain

(v) Classification
- mapping the features into a set of classes (→ context)

(vi) Decision Fusion
- fuse classification results of multiple classifiers to gain higher accuracy

Activity Aware ICT :: Pattern Recognition Chain

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- Reject not class-assignable features
Activity Aware ICT :: Pattern Recognition Chain

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(viii) Symbolic Processing
- Reasoning using domain knowledge

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Context Activity
Activity Aware ICT :: Pattern Recognition Chain

vast *heterogeneity* of sensors and *modalities*

- Acceleration, Gyroscope, Pressure, Temperature, Light, GPS, Earth-magnetic-field (Compass),….
- “subtypes”
  - Visible light, infrared light, X-rays,…

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- Acceleration, Gyroscope, Pressure, Temperature, Light, GPS, Earth-magnetic-field (Compass), …
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  - Visible light, infrared light, X-rays, …
Activity Recognition / Classification

Feature Space: modes of Locomotion

(selected features: mean crossing rate of x, y and z axes, std of magnitude)

Stand; Walk; Sit; Lie

Feature spaces for the eight sensor nodes and the selected features, projected into 3-D space through a Principal Components Analysis.

Calatoni et al, Transferring Activity Recognition Capabilities between Body-Worn Motion Sensors: How to Train Newcomers to Recognize Modes of Locomotion, INSS, 2011
Activity Recognition / Classification

Feature Space: modes of Locomotion

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Feature Space: modes of Locomotion

(selected features: ratio of x and y axes, ratio of y and z axes, std of magnitude)

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Sensor setup
Activity Recognition / Classification

Activity Recognition / Classification

The Training Dilemma

MotionJacket
Five Xsens MTx sensors on left/right upper-/lower arm and one on the back
Trained for \textit{WALK, SIT, STAND, LIE}

Supervised Expert Training
(Time Consuming and Expensive)

The Training Dilemma

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Untrained Sensors
One BlueTooth accelerometer on the right knee.
SunSPOTs attached on the left/right shoe.

Transfer Learning

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One BlueTooth accelerometer on the right knee.
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If MotionJacket fails or is put away, recognition fails.
Train new sensors on the fly with knowledge from old ones…

- Unsupervised adaptation
- Dynamic re-organization

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Transfer Learning

Transfer of Modes of Locomotion
  • WALK, SIT, STAND, LIE

Four triaxial acceleration sensors
  • Two Xsens MTx sensors on right upper-/lower arm
  • One BlueTooth accelerometer on the right knee
  • One SunSPOT attached on the right shoe

Trained Ensemble (Teacher)
  • RUA, SHOE, RKN
  • NCC classifier with majority voting fusion (DoF: 0.792)

Learner Sensor
  • RLA (same Classifier)

Result Summary
  Duration 15 min
  Classes 4
  DoF_T 0.792
  Comparison ~350.000
  $\vartheta$ (cum. mov. avg) 0.65
  DoF_L 0.792*0.65 = 0.51
The OPPORTUNITY Framework

**Infrastructure/Dataflow Visualization**
- Active Sensing Missions (incl. stated Goal)
- Sensor Infrastructure (active/inactive)
- Dataflows from Sensors to Sensing Missions
- Configured Ensembles

**Video Playback**
- Groundtruth Video
- Simulation Scenario
- Synchronized to Sensor Data

**Sensor Data**
- Active Sensor Data Visualization
- Real-Time Streaming & processing

**Result Visualizer**
- Groundtruth and actual Time
- Active Sensing Missions (incl. QoS metric)
- Recognition Result

**Console Window**
- Debug Outputs
- System internal Information

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D. Roggen, G. Tröster, P. Lukowicz, A. Ferscha, J. del R. Millán, R. Chavarriaga
*Opportunistic Human Activity and Context Recognition*
Socially Aware ICT
The Evolution of „Aware ICT“

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**Sociality**
“… is the additional non-verbal information (e.g. signals from the body language, facial expression, and tone of voice, etc.) transmitted among communicating people, and which is the main determinant of a successful social interaction and engagement.” [3,4]

Seminal work on cognitive and social analysis of human communication by A. Pentland
Vibro-Tactile Communication

Duisburg, July 24, 2010
(18 civilians died)

London, July 7, 2005
(52 civilians died)

Kaprun, November 11, 2000
(11 out of 161 survived)
Vibro-Tactile Communication :: LifeBelt

tactor elements
variation of (i) frequency, (ii) attenuation, (iii) mode

micro controller

belt system

body worn belt system
Vibro-Tactile Communication :: LifeBelt

Notifying Distance:
location + attenuation

Notifying Orientation:
location + frequency
Vibro-Tactile Communication :: LifeBelt
Multiagent Evacuation Simulation (Linz main railway station geometry):
2500 agents; 4% “Life-Belt” agents evacuated after iteration 300: 88%

Multiagent Evacuation Simulation (Linz main railway station geometry):
2500 agents; 100% “Life-Belt” agents evacuated after iteration 300: 96%
Socio-Inspired Information Eco-System :: Evacuating the City of Linz

Simplifying Agents Formalism: From Real to Virtual

High Level Agent Formalism
- One-to-one correspondence between real world actors and virtual agents
- Interplay between space and regular agents
- Dynamic Space
- Agents heterogeneity (types)
- Interaction extent and periodicity
- Variety in interaction modes
- Parallelizable agents and space
- Information sharing and spread; local, networked, global

Raster map of city of Linz
Bitmap of raster: 200 sectors (10 columns x 20 rows)
What is the estimated amount of information that can be perceived via stimuli coming from wrist worn tactors, given the recipient is not expecting or attentive to the potential occurrence of an alert?
Channels of Perception

Visual: 10.000.000 bit/s ca. 70-80%
Auditory: 1.000.000 bit/s ca. 10-15%
Haptic: 400.000 bits/s ca. 8-9%
Olfactory: 5000 bit/s ca. 0.5%
Gustatory: 1000 bit/s ca. 0.5%

“Cognitive Overload”: 12.000.000 bit/s <> 16 bit/s

Perception Memory max16 bit/s
Short Term Memory max 0,5-0,7 bit/s
Long Term Memory max 0,05 bit/s
Tactile Perception

4 Types of Mechanoreceptors

- **Pacinian Corpuscles (PCs)**
  - high spatial resolution
  - high sensitivity
  - availability all over the body
  - fast adaptation speed

- **Meissner's Corpuscles**
- **Merkel's Discs**
- **Ruffini Corpuscles**

**Two Point Pressure Discrimination Threshold**
- Hands, feet, thighs, head appear less convenient/appropriate
  (highly in motion, wearing comfort)
- Two-point discrimination threshold
  38 mm (left), 40 mm (right) forearm

System Design

Vibro-tactile Feedback via tactile transducer stimulating Pacinian corpuscles with "Vibration Patterns"

“Tactograms” variations of vibro-tactile control parameters: Intensity, Frequency, Duration, Modulation, Sequences
System Design :: Technology

Tactor Placement Options:

- around the wrist, along the band (WRIST)
- on top of the wrist, in the clock face (FACE)

Maximum number of tactors is 4

- otherwise violation of two-point touch threshold
- Preliminary testing confirms that 4 tactors can be distinguished when fully focused
Experiments

A. Ferscha
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Experiments

**PRIMARY TASK**
- **S** (visual)  →  **R** (motor) permanent attentive
  - low
  - moderate
  - high

**SECONDARY TASK**
- **S** (tactile)  →  **R** (vocal) sudden non-attentive
Experiments

PRIMARY TASK

S visual → R motor
permanent attentive

low moderate high

SECONDARY TASK

S tactile → R vocal
sudden non-attentive

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Experiments

**PRIMARY TASK**
- S visual
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**SECONDARY TASK**
- S tactile
- R vocal
- Sudden non-attentive

**Single task, response after trial, unlimited time**
- **Primary task**
  - "4.2" push button
  - countdown
  - Reaction time

- **Secondary task**
  - tactile pattern
  - Unlimited response time

- Vocal response

A. Ferscha / PECCS 2015 / Angres / February 12, 2015 / 77
Validation :: Evidence

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\[ \hat{T} = \sum_{j=1}^{k} \sum_{i=1}^{k} \frac{n_{ij}}{n} \log_2 \frac{n_{ij} \times n}{n_i \times n_j} \]

- \( i \) : stimuli
- \( j \) : response
- \( n \) : number of trials
- \( k \) : number of stimuli
- \( n_i \) : number of trials with stimulus \( i \)
- \( n_j \) : number of trials with response \( j \)
- \( n_{ij} \) : number of trials where \( i \) was responded with \( j \)

Graph:
- [bits] 3.0
- WRIST
- FACE
- Low: 1.90
- Moderate: 2.49, 2.41
- High: 1.68, 2.41

A. Ferscha

Aware ICT // PECCS 2015 // Angres // February 12, 2015 // 78
Regaining Attention

Typical Presentation

- Introduction
- Various Themes
- Conclusion

Audience Attention vs. Time
Attention :: Sensechair
Attention :: Sensechair

„attentive“  „relaxed“
Attention :: Sensechair

Sit Upright  Lean Forward  Slump Back  Side Lean
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“… is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought … It implies withdrawal from some things in order to deal effectively with others ..” [5]

Attention

“Every one knows what attention is. It is the **taking possession of the mind**, in clear and vivid form, **of one** out of what seem several simultaneously possible **objects** or **trains of thought** …

W. James (1842-1910)

The Principles of Psychology, Harvard, 1890.
Attention

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… It implies withdrawal from some things in order to deal effectively with others …”

The Principles of Psychology, Harvard, 1890.
Attention Economics

“... in an information-rich world, the wealth of information means a dearth of something else: a scarcity of whatever it is that information consumes, (which is) the attention of its recipients ...”

H. Simon (1916 - 2001)
Attention Span :: Focused vs Sustained

**Degrading Attention Span**

Attention spans have shrunk dramatically over the past decade

- **Focused Attention Spans**
  - 1998: 12 sec, 2008: 8 sec

- **Sustained Attention Spans**
  - 1998: 12 min, 2008: 5 min

**Causes of lost attention span**

- Stress: 18%
- Decision Overload: 17%

Attention Span :: Focused vs Sustained

Degrading Attention Span
Attention spans have shrunk by 50% over the past decade
Focused Attention Spans 1998: 12 sec, 2008: 8 sec
Sustained Attention Spans 1998: 12 min, 2008: 5 min

Impact of lost attention span
- Percentage of teens who forget major details 25%
- Percentage of people who forget their own birthday 7%
- Average No office worker checks email 30 per hour
- Average length watched for a single internet video 2.7 minutes
- Average span viewing ads on facebook 15 sec

Attention Aware ICT
Attention Aware ICT
Attention Aware ICT
Theories of Attention :: The SEEV Model

SEEV explains **probability of attending** to an area in visual space: (linear weight of four components)

\[ P(A) = s \cdot S - e \cdot F + (e \cdot E + v \cdot V) \]

Allocation of attention in dynamic environments is

1. driven by bottom-up attention capture of **Salient** (S) events,

2. inhibited by the **Effort** (EF) required to move attention (as well as the effort imposed by concurrent cognitive activity)

3. is also driven by the **Expectancy** (EX), of

4. of seeing **Valuable** (V) events at certain locations in

Directed Effort Recognition

Physical Effort as indicator for attention shifts

Undirected effort: mobility described as
(i) speed of movement
(ii) direction of movement
(iii) orientation

Directed effort: effort change in
(i) acceleration / deceleration
(ii) direction change from/towards PD
(iii) orientation of upper body

Attention Rating: from effort directed to object
Directed Effort Recognition

Multi-User Tracking
- identification and tracking of users via depth image streams:
  - behavior analysis
  - orientation estimation
  - body pose analysis
- Head Pose Estimation via RGB image stream analysis
  - quantified angles for ‘Yaw’ and ‘Tilt’

Classification
- Support Vector Machines used for training and evaluation of computed feature vectors
- Real-time classification of overall and current attention values

Processing Pipeline

1. Head Orientation
2. Movement features
3. Classification
4. Trained behavior model

\[
\begin{align*}
\mathbf{v} &= |\mathbf{v}| = |\mathbf{p}(O,t) - \mathbf{p}(O,t-1)| \\
\Theta &= \arccos \left( \frac{\mathbf{v} \cdot \mathbf{\dot{p}}(O,t)}{|\mathbf{v}| |\mathbf{\dot{p}}(O,t)|} \right) \Theta \in [0, \pm 180] \\
\alpha &= \Delta v = v(t) - v(t-1) \\
d &= |\mathbf{\dot{p}}(O,t)| \\
d_r &= \frac{|\mathbf{\dot{p}}(O,t) - \mathbf{\dot{p}}(O,t_e)|}{D} \\
D &= \sum e |\mathbf{p}(O,t+1) - \mathbf{\dot{p}}(O,t)|
\end{align*}
\]

Directed Effort - a generic measurand for higher level behavior analysis
Hypothesis

Laparoscopic surgical suboptimal outcomes (in patient safety measures) are correlated with

• cognitive load / level of attention of the operating surgeon

• frequency and degree of disruptions to surgical workflow

• misalignment of visual and motor axes in laparoscopic equipment / setting
Visual Attention Recognition :: Salience Maps

Modeling Visual Attention via Saliency Maps

Model for prediction of stimuli-driven gaze patterns
- Computational image/video analysis
- Extraction of local information density ("Shannon Entropy") / attractiveness of image areas
- Most important characteristics:
  - Movement
  - Color
  - Contrast

Prediction of visually attractive, environmental stimuli that are likely to capture attention

Main applications
- Object identification
- Video summarization
- Prediction eye-gaze / distribution of visual attention
Visual Attention Recognition :: Salience Maps

Overlay:
light blue circle = captured visual focus
blue/yellow circle = predicted focus
green dots = potential foci points

Calculated saliency map of surgeon's view
Managing Attention :: Visual Attention Quality

Visual Focus **Orientation and Intensity**

**Fixations / Saccades**

- Saccades and fixations provide somatic indicators suitable for the detection of attention shifts, to distinguish focused vs. selective attention, as well as to distinguish extern vs. inner-controlled activities (overt vs. covert attention)

  [Hiko00] Hikosaka, O. et al. (2000) Role of the basal ganglia in the control of purposive saccadic eye movements. Physiol. Rev. 80, 953–978

- Fixation **duration as indicator for intensity of engagement**

  Fixation heatmap of surgeon’s view
Visual Attention Recognition :: Fixations / Saccades

**Fixations**
- Gaze is resting in position
- View processing during fixation
- Longer fixations indicate complex scene / strong focus

**Saccades**
- Gaze is jumping to new position
- Fixations and Saccades form a Scan Path
- Microsaccades (very small, occur involuntarily during fixations)
Visual Attention Recognition :: Fixations / Saccades

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**Metrics**

- **Minimum Saccade**
  - Length/Distance in pixels of shortest saccade in last 1/3 second.

- **Maximum Saccade**
  - Length/Distance in pixels of longest saccade in last 1/3 second.

- **Number of Saccades**
  - Duration of last saccade in multiples of 1/30 seconds.

- **Blinks**
  - Duration of last blink in multiples of 1/30 seconds.

- **Average Saccade Length**
  - Average Length/Distance in pixels of all saccades in last 1/3 second.

- **Fixation Duration**
  - Duration of last fixation in multiples of 1/30 seconds.
Overview Number of Fixations / Saccades Duration for Patient 0B181114
Somatic Indicators of Attention

Pupil dilation / Pupil response: Indicator for cognitive activity

- Pupil dilation shows correlations to the **locus coeruleus-norepinephrine system (LC-NE)**, a part of the middle brain which is responsible for controlling attention. The correlation with attention control expresses in impact on the **inhibition of return (IOR)**.


Spontaneous dilation independent fr. illumination

- Pupil response associated with illumination shows **either fast retraction or slow dilation**


Visual Attention Recognition :: Pupil Dilation

Pupil dilation over time as indicator for cognitive activity, data extracted from test recordings 11/14
Visual Attention Recognition :: Pupil Dilation

pupil response without activity / illumination influence
=> Cognitive Effects, increased load
Managing Attention in Laparoscopic Surgery
James further derived that attention—“always withdrawn from some things in order to deal effectively with others and is a condition which has a real opposite in the confused, dazed state called distraction”—is a scarce commodity. According to Dugald Stewart, this idea of “a single pulse of consciousness” exemplifies how the mind perceives points in a picture. In Elements of the Philosophy of the Human Mind, Stewart wrote the following (Quoted from The Principles of Psychology):

It is impossible for the mind to attend to more than one point at once; and as the perception of the figure depends on the simultaneous perception of many points, the different means whereby we effect this all we can conclude that the perception of the figure is the result of a combination of different acts of attention. Those acts of attention, however, as performed with equal rapidity, do the effect, and respect to each, as much as the perception of the figure.

Today, this idea is more commonly known as the single channel theory (SCT).

Single Channel Theory

Kenneth Craik and especially Donald Broadbent investigated the competitive selection process that the mind seemingly undergoes when confronted with a multitude of stimuli. A. Ferscha

Managing Attention

Attention, Please!

Angres // February 12, 2015 // 112

1955, William James, a philosopher and professor at Harvard University, wrote the following in The Principles of Psychology:

Everyone sooner or later attention at: It is the taking possession of the mind, in so short and sudden a form, of one out of what seem several simultaneously possible objects or trains of thought. Possession [and concentration] of consciousness are of the essence.

The concept of information economics emerged from Thomas Davenport and John Beck’s economic theory about attention scarcity in The Attention Economy: Understanding the New Currency of Business. Davenport and Beck explain the devotion of attention as part of an (economic) act: “Attention is focused mental engagement on a particular item of information. Information enters into our awareness, we attend to a particular item, and then we consider the consequence of the action.”

Exploring attention scarcity and the relationship between attention and action is critical to designing today’s systems. We need to build an attention research and the theories and models it has produced to address issues of information and sensory overload. Ultimately, we must create a bridge between the fundamental results on selective attentional processes, created by research work in psychology and neuroscience, and the endeavor to apply these results in HCI in general and pervasive computing in particular.

ATTENTION THEORIES

The core of many theories of attention is a question James asked: “To how many things can we attend at once?” He himself answered it—“In any moment of thinking, the mind is…given to a single object.”

In 1955, Broadbent introduced the single channel theory (SCT). His own answer turned out to be the number 2—“independently depending on the powers of the individual channels, on the form of the apprehension, and on what the things are,” yet he further argues that we must measure the “thing” they can only be known as a single pulse of consciousness.”

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Single Channel Theory

Kenneth Craik and especially Donald Broadbent investigated the competitive selection process that the mind seemingly undergoes when confronted with a multitude of stimuli.
Tsunami ICT = A Design Mistake?
Tsunami ICT = A Design Mistake?

Subliminal ICT = A Design Opportunity?
The Evolution of „Aware ICT“

**Context**

"... is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and application themselves.“ [1]

Seminal work on context modeling, context recognition, context awareness by A. Dey

**Activity**

"... Humans construct their plans as they engage in specific activities, creating and altering their next move on the basis of what has happened ..., looking at how humans achieve their goals by acting through the execution of activities engagement." "... Activity-aware computing is supported by the automatic recognition of users’ activities“ [2]

Seminal work on activity recognition by K.P. Fishkin

**Sociality**

"... is the additional non-verbal information (e.g. signals from the body language, facial expression, and tone of voice, etc.) transmitted among communicating people, and which is the main determinant of a successful social interaction and engagement." [3,4]

Seminal work on cognitive and social analysis of human communication by A. Pentland

**Attention**

"... is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought ... It implies withdrawal from some things in order to deal effectively with others .." [5]
The Evolution of „Aware ICT“

- **Context Aware ICT**
  - Context
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  - Attention
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  - Social Systems principles as design/operational reference for future ICT
    - “… instead of considering each device for itself, look at them as a socially collaborating collective ...”

- **Activity Aware ICT**
  - Socially Aware ICT
  - Attention Aware ICT
  - Socio-Inspired ICT
Understanding the hidden laws and processes of society

- Ethics, Moral Norm
- Social Awareness, Behaviour
- Self-Organization
- Cooperation, Competition
- Conflict Resolution
- Negotiation, Decision Making
- Reputation
- Trust

Inspire the development of a new wave of robust, trustworthy and adaptive ICT based on the principles of social interactions

- Dignity
- Respect
- Sovereignty
- Privacy
- Autonomy
- Collective Behaviour
Position Paper

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**Socio-inspired ICT**


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FUNDAMENTALS OF COLLECTIVE ADAPTIVE SYSTEMS
Aware ICT
A Pervasive Computing Perspective

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5th International Conference on
Pervasive and Embedded Computing and Communication Systems

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