On Context Aware Computing
and Smart Interaction

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Who’s talking

- Petteri Alahuhta, PhD, eMBA
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  Ubiquitous computing, Ambient intelligence, Context aware computing, Mobile technology, Human computer interaction, Technology foresight and management

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VTT Technical Research Centre of Finland

VTT
- The largest research institute in Northern Europe
- Provides high-end technology solutions and innovation services

Figures
- 3187 employees
- Annual turnover 307M€

Funding
- 1/3 industry
- 1/3 government
- 1/3 public sector (EU, Tekes)

Customer sectors
- Biotechnology, pharmaceutical and food industries
- Chemical industry and environment
- Electronics
- Energy
- Forest industry
- ICT
- Machine, vehicle and metal industries
- Real estate and construction
- Services and logistics

Focus areas of research
- Applied materials
- Bio- and chemical processes
- Energy
- Information and communication technologies
- Industrial systems management
- Microtechnologies and electronics
- Services and the built environment
- Business research

VTT operations
- Research and Development
- Strategic Research
- Business Solutions
- Business Development
- Group Services

VTT companies
- VTT Expert Services Ltd (incl. Labtium Ltd, Enas Ltd)
- VTT Ventures Ltd
- VTT International Ltd (incl. VTT Brasil LTDA)
- VTT Memsfab Ltd

Themes of the talk

- Technology trends
- Context aware computing
- Augmented reality
- Way forward

TECHNOLOGIES AND CONCEPTS

- ICT revolution
- Ubiquitous computing and related concepts
ICT-revolution is based on continuous development of basic IT-components

**MOORE’S LAW**

- Computing power => Increases exponentially
  - Moore’s law still holds 2 x every 18 months
- Amount of memory => Increases exponentially
  - txt-docs, pictures, video-clips, movies, everything
- # of connected devices => increases exponentially
  - expecting tens of billions of devices => internet of things
- Amount of information => increases exponentially
  - docs, emails, Facebook, spam, video-surveillance, sensors
- Wireless access increased rapidly (so far)
  - wireless bandwidth GPRS => 4G & WiFi, speed alters within range
- Human Computer Interaction?
Relevant visions

- **Ubiquitous computing** is a vision of an environment where computers are embedded everywhere in our surroundings, and every individual possesses and uses several computers. The environment is equipped with a large number of computers and computing systems of different sizes. These systems and devices are interconnected, and they provide various information processing and environment control-related services for people inside the environment (Weiser 1991).

- **Large Displays**
- **Minority Report**
- **Parc Pad prototype**
- **Parc Tab prototype**
- **iPhone 4**
- **Apple iPad**
- **City displays, Oulu**
- **Pervasive computing**

Relevant concepts 2

- **Pervasive computing** is a vision based on ubiquitous computing. The core of the vision is in the creation of environments saturated with computing and communication capabilities, yet gracefully integrated with human users (Satyanarayanan 2001).

- In the world of **ambient intelligence** embedded electronics and communication capabilities come together to form digital electronic networks of intelligent devices that are integrated into their surroundings and provide information, communication services and entertainment wherever they are. These ambient intelligent environments will be context-aware, personalized, and able to adapt to and even anticipate the wishes, needs and behavior of users (Aarts & Marzano 2003).
Is not only usability and ergonomics of graphical user interface

But

It is about how to get, produce, use and handle information and services that are relevant for us in situation at hand

- How to understand the situation?
- What is the best way to convey the message
- How to make it user friendly?
Our focus has been in:

- Context Aware Computing
- Augmented Reality and 3D Tracking

ON CONTEXT AWARE COMPUTING

- Definitions
- Context components
- Examples
- Personal data
Context aware computing

- **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.

- A system is **context-aware** if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user’s task.

- Dey and Abowd 2000

Context Aware Computing at VTT

- Research started in 1999

- **Public projects**: Smart-its, Ambience, Nomadic Media, Smart Products, Smarcos, Ramose, Empathic Products, …

- **Approach**: Context recognition algorithms, User interaction, Health care, Mobile implementations of context algorithms

- **Today**: We are now moving to behaviour detection and modelling

New technologies enable context-aware services

- **Sensors** – Location (GPS, Glonass, Galileo), Accelerometer sensors, compass, gyro

- **API’s** – Device resources, active apps, message logs, radio interfaces

- **Wireless access** – WiFi-networks in range, Bluetooth-networks, Bluetooth-devices in range, NFC

- Fusion of context sources provides very accurate and real-time picture of the user of a mobile devices

VTT data analysis/analytics references

Tools experience

![Diagram of data analytics pipeline]

Data analytics pipeline is designed to be able to process very large amount of data. Tools are examples and utilized in VTT data-analysis projects.
VTT data analysis/analytics references
Application areas/examples

- Textual and numerical data mining
- Finding relationships between biological entities from medical publications
- Data fusion in business intelligence
- Anomaly detection in server logs
- Network packet identification
- Recommendation systems and personalization

Context Components

- **Business problem**
  - Several business areas benefit from the rich context information, e.g., Security, military, CRM areas
  - Low power consumption crossplatform solutions urgently needed

- **Solution**
  - Set of easily usable context recognition components for several prominent mobile platforms including Android
  - Light-weight solution with versatile communication capabilities

- **Customer benefits**
  - Customers are easily able to integrate rich context information to their products
  - Long operating times leading to improved user experience

- **IPR**
  - Components based on the two patents owned by VTT
  - SW library to be published as an open source library in 2013

Video: Activity recognition in Blackberry
### Context component library – Tracking smartphone activity

- Group of software components that enable tracking of the mobile phone user behavior in real-time
- Uniform interfaces for several major mobile platforms: Symbian, Maemo/MeeGo, Android, RIM
- Highly optimized detection algorithms, small power consumption
- Based on the VTT’s feather light context recognition platform

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### Detection of walking/running

- Light-weight component for walking and running detection
- Position and placement invariant
- **Input**: acceleration data
- **Output**: timestamp, truth value for running and walking
Potential fall detection

- Component detects potential falling of the mobile user
- Based on the acceleration data and human behaviour model
- Because there exist events in which the accelerations are very high even during the normal use, rare "false alarms" are possible
- Possibility to send an acknowledgment request
- Input: acceleration data
- Output: timestamp, truth value for potential falling

Device status

- Group of components for monitoring of the orientation and stability of the device
- Orientation: Antenna up/down, screen up/down, left/right side up
- Stability of the device: phone stable/unstable
- Foreground application
- Current CellID, location area code
- Current profile
- Input: acceleration data
- Output: timestamp, truth values for orientation and stability, additional device info
Telecom activity

- Call counts for incoming, outgoing and missed calls
- SMS counts (incoming, outgoing)
- Email counts (incoming, outgoing)
- Raw data: send and received bytes
- **Input:** -
- **Output:** telecom activity data

Detection of important places

- Components for the recognition of geographical places
- Each component recognizes one place
- No limitations for the number of places
- No data communications requirements, the component is based only on the cellular network identifiers
- **Input:** CellID-data
- **Output:** timestamp, truth value for a place
A versatile tool for mobile phones’ energy consumption tracking and management

Challenge:
- For a mobile-phone user, the energy consumption of modern smartphones leads to several questions:
  - How long will the battery last with the user’s normal usage habits?
  - How much energy does a new downloaded application use?
  - What is the condition of the battery pack?
  - How can the user control the energy use of the phone?

Solution:
- VTT has developed, in collaboration with Nokia, a versatile tool for a mobile phone’s energy consumption tracking and management.
- The tool is able to detect the normal application usage patterns and the energy consumption of the applications running on the phone.
- It also models the characteristics of the battery pack.
- The tool allows the user to control when to switch the phone over to power-save mode.

Benefits:
- Ability to estimate the energy consumption of mobile phone applications
- Accurate and adaptive battery models
- Ability to estimate the actual remaining usage time of the phone.

Automatic CO2 footprint calculation

Challenge:
- Consumer decisions will be heavily dependent on green values in the near future.
- Green values will become a major component of company information, leading to an overflow of green information.
- A need exists for automatic means to simplify and synthesize the information.

Solution:
- Jointly with Nokia Research Centre, VTT has developed a mobile-phone application that can recognize trips made by a mobile-phone user automatically.
- The application also detects several modes of travel automatically and is able to estimate the CO2 emissions of the user.

Benefits:
- Rich and accurate information on the CO2 emissions caused by travelling.
- No need to remember the timing and length of the trips
- Enabling of novel services, such as company-level CO2 emission tracking.
Remote detection of the situation/context of persons or vehicles

Challenge:
- It is difficult to know the context of a person or object remotely.
- Usually no real-time information is available on the safety of a person working alone in a dangerous environment or the proper handling of expensive equipment.
- Current device or mobile phone solutions provide only raw data such as acceleration metrics, but do not provide context recognition.

Solution:
- VTT offers an Intelligent Context Recognition Solution that includes both a hardware platform and software.
- Activity recognition algorithms detect whether a person is running, falling, still or doing other activities.

Benefits:
- Small embedded device that has both context recognition and communication capabilities.
- It can be carried by a person or embedded in a vehicle.
- Small-scale production possible. VTT manufactures the device and tailors the software to customer needs.

Use case example: A security guard catches a thief by running and has to use physical force to hold down the suspect. VTT hardware in the guard’s belt informs the operation centre about this drastic change in context. More units are sent to the site.

User verification with mobile phone-motion sensors

Challenge:
- A mobile phone is a personal device that often contains sensitive or even confidential information.
- The phone and the information contained therein may be lost or stolen.
- The phone cannot verify whether it is being used by its real user.

Solution:
- VTT’s walking pattern detection system GAIT can be used as a biometric identifier.
- Motion sensors embedded in the mobile phone can be used to obtain the gait pattern of the user and thus to verify the user.

Benefits to customers:
- The confidential material stored in the phone can be protected against theft.
- User identification can be extended to embedded devices.

Use case example: The mobile phone PIN code is not used when the mobile phone detects that it is being carried by its rightful owner. When the mobile phone is stolen, it locks itself with PIN.
User identification with a car key

**Challenge:**
- The car should be usable only by authorized persons.
- The same key can be used by several family members, who may well have different personal preferences for the car.
- The car does not know the context linked to a driver.

**Solution:**
- An algorithm that identifies a driver by his or her walking style.
- The algorithm uses the data from accelerometers in a car key, and comparison is made between the walking style of the current key-holder and the database of authorized users.
- The car can personalize the seat and mirror positions in advance to match driver preferences.

**Benefits:**
- Improved safety
- No need for additional hardware
- Lightweight implementation

Application: Life pattern recognition

- Detection of daily routines of people
  - How much and when do you typically sleep?
  - When do you typically work on Thursdays?
  - When do you do your hobbies?
- Two major components
  - Mobile clients for Symbian, Maemo/MeeGo, Android – daily average distribution of the activities
  - Server collecting anonymous information from the clients – Typical daily routines in different geographical areas
- Introduced in Mobile World Congress 2011
- Augmented Reality
- ALVAR Augmented reality sw
- AR examples

AUGMENTED REALITY AND 3D TRACKING

Introduction

Augmented Reality (AR)
- Mixes virtual objects with view of real world
- C.f. Virtual Reality (completely virtual worlds)
- Properties: real-time, interactive, 3D registration
- Challenges: tracking, accuracy, speed, mobile

Related technologies
- Augmented Virtuality
- Mediated Reality
- Diminished Reality, ...
- Mixed Reality (MR)

Reality / Video image  →  Augmented Reality  ←  Virtual Reality / Computer graphics
Augmented reality software

**Challenge:**
- Augmented reality (AR) applications require real-time video-tracking algorithms that identify features on the picture.
- There is little support for augmented reality application developers.
- End-users have a large variety of devices and platforms that require different AR solutions.

**Solution:**
- VTT has developed ALVAR (A Library for Virtual and Augmented Reality) software.
- Platforms: Windows, Linux, Flash, Silverlight, iPhone/iPad, Android, Symbian and Maemo.
- References: Vuzix (data glasses), VividWorks (furniture interior design), Futurecode (children’s storybook), Columbia University and MIT.

**Benefits to customers:**
- World-class video feature tracking technology made available for customers.
- Licence IPR from VTT; in addition, desktop version 2.0 is released as Open Source (LGPL).

Use case example: When a family eats breakfast, the children use a mobile phone to see an augmented cartoon character on the cereal package. They also participate in a daily story game, with new content presented every morning.

Enhancement of reader experience through augmented reality

**Challenge:**
- How can one enable digital content to be efficiently linked with print media?

**Solution:**
- An augmented-reality application distributed with the Dibidogs children’s book and with two magazines makes the main characters of the television series seem to pop out of the pages and have engaging interaction with the reader.
- Besides PC and browser platforms, VTT’s technology is available for major mobile platforms – namely, Android, iPhone, and Nokia systems.

**Benefits:**
- Ready-to-be-applied technology and easy solution development
- Novel and interesting combination of print media and digital content
- Creation of engaging interaction with users and efficient capture of their attention
- An enhanced reading experience, which provides better insight into the message the text is conveying.
Augmented-reality interior design

**Challenge:**
- To seamlessly integrate virtual furniture into real living environments

**Solution:**
- VividWorks developed their new product line VividAR on the basis of VTT’s augmented-reality tracking technology (from the ALVAR SDK).
- The solution is tightly integrated with the existing VividWorks’ product line

**Benefits:**
- A new, unique product line for VividWorks
- A spearhead for the company’s international marketing and growth
- A new marketing and sales tool for furniture manufacturers and resellers
- Improved ways for consumers to evaluate furniture and make purchase decisions.

Building Applications – Case Digitalo

- ARScaleModel
- ARFloorPlan
- ARWebCam
- CAVE / Multitouch
Mobile AR – Case Skanska

New Skanska offices in Helsinki
- Devices: laptop PC, UMPC, data glasses (Sep 2009)
- Photorealistic visualization of architectural model (May 2010)
- Augmenting 4D plans during construction work (Oct 2010)
- Comparison with partially ready building (May 2011)
- Client/server solution -> mobile phones (Aug 2011)

Mobile AR – Case Kämp Tower

City development project in Helsinki Jätkäsaari
- Incl. KämpTower, tallest building in Helsinki (33 floors)
- Mobile AR visualization presented to Helsinki city council members, March 2012
- Windows tablets, operated by architects & other users
Augmented-reality solutions for data glasses

**Challenge:**
- Vuzix wanted to provide tools for creating and testing 3D content for the AR applications.
- It is not possible to test the 3D models easily with an AR application at design time.

**Solution:**
- Vuzix developed maxReality, an add-on tool for 3ds Max.
- It takes the newly created 3D model, adapts it to max-Reality Viewer, and allows the designer to test the AR experience within 3ds Max and by using the Vuzix data glasses.
- The maxReality Viewer system is based on VTT’s ALVAR technology.

**Benefits:**
- A faster, more efficient, and dramatically easier 3D content design process for AR applications
- A larger user base for data glasses from among professional content designers and their customers
- A new business area and revenue stream for the company.

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**3D-PROCESSING AND ANALYSIS**

- 3D-sensing
- Our approach
- Examples
Camera analysis toolbox for surveillance solutions

- Platform for various image analysis and human-computer interaction (e.g. gesture interfaces) systems
- Face/hand/human/object detection and tracking
- Motion and event analysis
- New features and processing modules can be added quickly
- Portable to embedded environments (e.g. Linux, based)
- Depth sensor based motion detection and tracking

Alvar-tracker

- Client-Server mobile tracking solution
- Mobile client 6-DOF egomotion tracking
- Using offline-optimized feature point cloud provided by the server based on the client location
- Accurate: Can be used for augmented reality
- Fast: Works on mobile phones (e.g. N900)
- Scalable: Pointclouds can be downloaded as needed for the mobile client

**3D Sensing in scene interpretation**

- **Opportunity:** Low cost depth sensors are quickly revolutionizing the computer vision field, but much of the industry is still treating them as novelties, or are having trouble making the leap into 3D sensing from traditional 2D image analysis.

- **Aim:** exploiting low cost depth sensors (~100EUR commodity hardware) for environment sensing and understanding together with other sensor modalities. Practical applications and smart/novel use of depth data.

1. Software: methods and tools
2. Algorithms for analyzing the environment
3. Prototypes and demonstrations
4. from commodity hardware to industrial applications

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**Motivation and Applications**

- New business opportunities by adoption of depth sensing technologies
- Robust and low cost 3D sensors that can be used to overcome the traditional difficulties in computer vision: occlusions, segment objects with similar textures, measure distances, calibration, etc.
- Upgrading existing computer vision (CV) systems with depth information
- Bring (3D)CV to fruition in domains that have earlier been technologically and commercially too challenging
- Lower the threshold for SME companies to go and make an impact with their ideas
- Increase awareness of the possibilities of 3D sensing technologies in areas where serious consideration of them hasn’t up until now occurred

**POSSIBLE APPLICATIONS**

- Assembly
- Automation
- Autonomous vehicles
- Entertainment
- HCI
- Healthcare
- Logistics
- Marketing
- Robotics
- Surveillance
- Traffic

*Wherever there is a requirement to observe the environment*
Multitouch user interface

- Detects hand and fingers
  - 3d movement
- Surface touching mimics mouse click
- UI element for projected interfaces and finger/hand gesture detection
- Depth camera point cloud processing

A depth camera enabling new kinds of interaction with gestures

Challenge:
- Our environment does not support fluent and intuitive interaction with devices and objects with gesture based interaction.
- For gesture based interaction, video content analysis development using traditional 2D cameras faces very difficult problems (e.g. scene illumination changes, object recognition, object connectivity and pose estimation).

Solution:
- Most of these issues can be conveniently solved by using 3D sensors.
- Price of depth sensors has dropped dramatically in the past years.
- VTT offers a software platform for rapid development of natural/gesture-based user interfaces and video surveillance systems.

Benefits to customers:
- Broad knowledge base of state-of-the-art technologies at VTT allows for fast prototyping.
- Customer owns the resulting IPR, and can also licence technology already developed by VTT.

Use case example: A person sees an interesting digital signage display in a shop. The customer interacts with the display by means of hand gestures and sees advertisements based on his/her gender and age.
CHALLENGES FOR THE FUTURE

Data analytics & personalization

User behaviour analytics
- Predicting user behaviour
- e.g. Advertisement, media-consumption

Ref. Lifeliner (Youtube)
http://youtu.be/XT4Cq8Y48Pg

Personal data economy
- Semantic, portable profiles
- Privacy preserving personalization solutions & technologies

Ref. www.profile.vtt.fi, wolf-personal data report
Augmented and mixed reality

**Mirror World Interactions**
- Combine AR, VR, presence, context-awareness, HUD
  - Telepresence with augmented reality & Mirror world settings (Youtube)
    http://www.youtube.com/watch?v=GBD1ob9aETE&feature=share&list=UU4Msoi7FsOIWsVCJCOrODRw

**Mixed reality for designers and citizens**
- AR tools enabling citizens’ participation to urban planning with 3D city models visualized mobile on site

New UI Enablers

**Interaction with 3D Holographs**
- ref. IronMan-movie (Youtube)
  http://youtu.be/mbs3Xk0oDweH

**Surface interfaces**
- User interfaces integrated into surfaces (walls, furniture, floors, etc.)
- Ref. everyday Object interaction by Touché (Disney Labs) (Youtube)
  http://youtu.be/E4YqXiV7sA
Multidevice interaction & Head mounted displays

Depth camera in user interface enabler
- 3D sensing in user interfaces
- Low cost UI devices & new possibilities

Ref. Leap Motion
http://youtu.be/9c6W4CCU9M4

Interaction for HUDs
- HUD – Heads-up displays
- Input technologies for consumer HUDs

Ref. Google Glass project
http://youtu.be/_d6KuiuteIA

More information

- VTT Technical Research Centre of Finland – www.vtt.fi
- Context aware computing at VTT – http://ca.vtt.fi
- Augmented reality & Tracking tech at VTT – www.vtt.fi/multimedia
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