



## *Privacy in Pervasive Systems*

Nikola B. Šerbedžija

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## Abstract

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- *Seamless and non-explicit man-machine interaction gains significance as technology evolves and mobile applications become smarter. Ultimate goal of novel “empathic” systems is to understand users’ context and needs in order to function supportively, maximizing utilization, comfort and safety whilst minimizing explicit user intervention while preserving privacy . ...*
- *“What you need is what you get” principle is dramatically changing the human-computer interaction landscape. Equipped with numerous sensor devices that observe users in a concrete setting, smart systems are able to derive users’ emotional, cognitive and physical state as well as social context and adapt their functioning accordingly. ...*
- *This tutorial presents a systematic approach to develop control interfaces that can expand present systems with awareness-rich behaviour and it focuses on impacts that such systems may have ...*
- *...The loyalty is here defined as a feature that guarantees the absolute user control over the extent of use of her/his personalized data. The methods and principles of privacy preserving adaptive interaction are explained. ...*
- *... Crossing the discipline barriers, the talk brings different perspectives, tackling issues relevant to life-sciences.*

Keywords: *HCI, pervasive adaptation, ethical issues, privacy*

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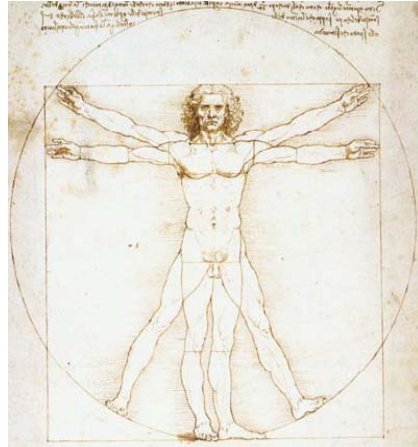


## Outline

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### I. Motivation

- State-of-the-art
- Tendencies
- Consequences



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### II. Technology

- Pervasive adaptation
- Reflective approach
- Privacy matters

### III. Future ...



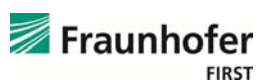
## I. Motivation

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**Engineering Highly Personalized User-centric Systems means also protecting privacy, but**

*How can we protect privacy when we do not know what endangers it?*

- Staus quo
  - IT Trends
  - IT Impacts
- Quo vadis
  - E–society?
  - Homo technicus [1]?
  - Homo simplex?
  - Brave new world?
- Philosophical view
  - Infosphere and Inforgs [2]



- 1. E. Geisler, School of Business, Illinois Institute of Technolgy
- 2. L. Floridi, Oxford University

## Status Quo

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- IT trends:
  - Mobile systems
  - Body nets
  - Smart Technology
  - Case study on most mature: E-Systems
  
- Impact on us
  - Mental
  - Social




## Possible Problem

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- Nowadays, computers have become an integral part of our everyday surroundings.
- Man-machine interface is obsolete
- It is necessary to re-thing and re-design ways in which we cooperate with computers.
- To make a control system a genuine companion in everyday life, it should be enriched with some **adaptation capabilities** to adjust its functioning to the users' needs.
- Otherwise, a modern *homo technicus*, as intrinsically adaptive species may, due to his permanent and enthusiastic exposure to ridged artificial systems, experience unpleasant retrogressive mutation.

## Smart Technology

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- Mobile technology
    - Mobile = traditional
  - FET – European FP7 initiative “Future Emerging Technology” 
    - Pervasive adaptation [REFLECT] 
    - Brain-computer interface
    - Evolutionary computing
    - Smart robotics
    - [BCI Berlin] 
  - Body Networks /Cute Circuit [1]/
    - Mobile Hug
    - Wearable Displays
    - Twirkle T-Shirts
    - Kinetic Dress
- 
-  **Fraunhofer**  
FIRST

## Mobile Hug

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- The Hug Shirt™ is a shirt that makes people send hugs over distance! Embedded in the shirt there are sensors that feel the **strength of the touch**, the **skin warmth** and the **heartbeat rate** of the sender and actuators that recreate the **sensation of touch, warmth and emotion** of the hug to the shirt of the distant loved one.

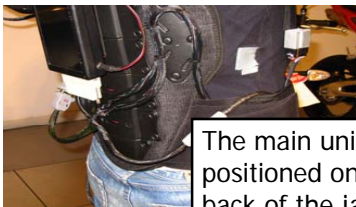
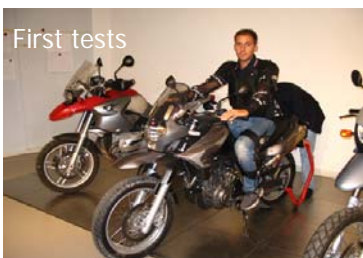


## Twinkle T-Shirts

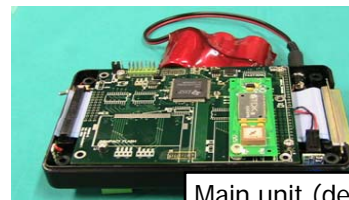
- The Twinkle T-Shirt is a t-shirt that adds sparkle to your style day and night. During the day the colorful crystals sparkle in the sunlight and at night an array of tiny white or full color LEDs twinkle and glow following the **movement of the wearer's body**. The Twinkle t-shirt is washable and works with two small watch batteries.



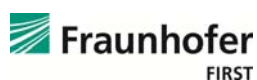
## Bodynet to study human posture on motorbikes



The main unit is positioned on the back of the jacket



Main unit (detail)



## Case study on Impact: Web 2.0

We live in interesting web times by witnessing the major web transformation taking place all over the Internet:

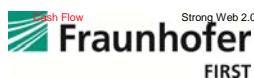
- social software,
- artificial intelligence experiments,
- multi-user collaborative AJAX-based tools,
- semantic applications,
- next-net contextual approaches, sharing knowledge gigantic sites, bookmarking facilities and photo,
- video and music tagging, sharing and transferring mixtures to modern server-, client-, and web-based platforms, s
- unrealistic concepts and TV/Multimedia/Web mashups,



[<http://web2innovations.com/money/>]

## Ranking "Criteria" for Web 2.0 Sites

Innovativeness	Profits	Semantic Technologies	International Operations
Trendsetter	Products	Web 3.0 Skeleton Lied Out	
Leadership	Services	Large-Scale / Huge Web Properties	Spam Level
Disruptor	Solutions	Search Engine Optimized	Scam Level
Effectiveness	Brand Awareness	Multilingual	Crap Content
Uniqueness	Overall Public Image	Well Funded	Site Corruption Level
Competitiveness	Buzz Level	High-Profile Investors Involved	Fishy Level
Trustworthiness	Popularity	Location, Location, Location	Debts Level
Simplicity	Traffic / Visitors	The Management	Bad Expenditures Habits
Respectfulness	Alexa Ranking Overall Situation	Directors, Advisors, Partners	Scandals Level
Overall Performance	Google(r) Indexation Level	Customer Service	Malpractice
Influential	Google(r) PageRank(tm)	Equal Opportunity Employer	Bad Web Practice
Authority	Link Popularity Level	Social Responsibility	Complaints Level
Maturity	Web Mention Level	Philanthropy	Lawsuits
R&D Activity	Press Coverage Level	Transparency and Openness	Legal Issues
Concept	Blogs Mention Level	§Distinctive / Defendable Technology	Adware
The Idea	Logo	§Growth Potential	Evil Company
Business Model	Overall Design / Layout	Potential of Becoming \$1B Opportunity	Overall Negative Image
Revenue Generating	Site Architecture / Technology	The Industry, Market, Sector, Niche Overall Situation	
Cash Flow	Strong Web 2.0 Concept and Technologies	Market Acceptance	



## Quo Vadis: E-Society

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- Technology vs. Business
- Principles vs. Practice
- Distribution vs. Centralisation  
(democracy vs. autocracy)

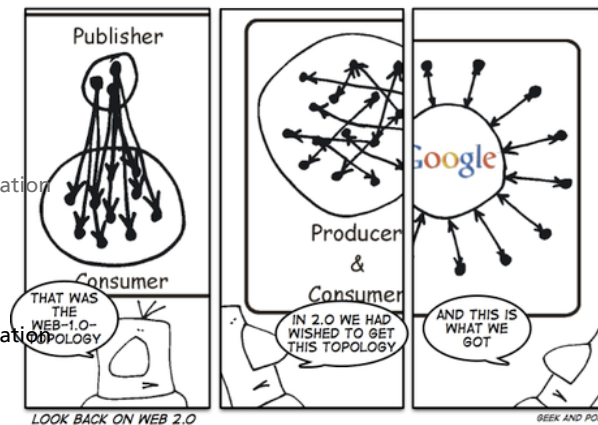


- E-Mutation
- E-Privacy

## Principles vs. Practice

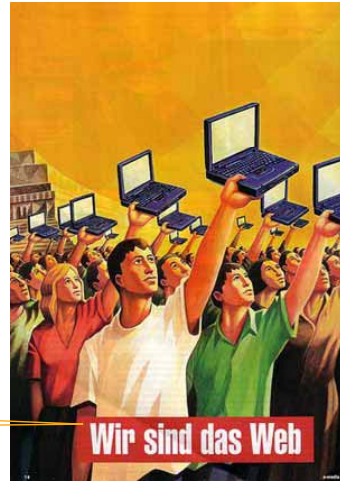
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- Web 1.0
  - Technology vs. Business
  - Principles vs. Practice
  - Distribution vs. Centralization
- Web 2.0
  - Technology vs. Business
  - Principles vs. Practice
  - Distribution vs. Centralization
- Web 3.0
  - !?!

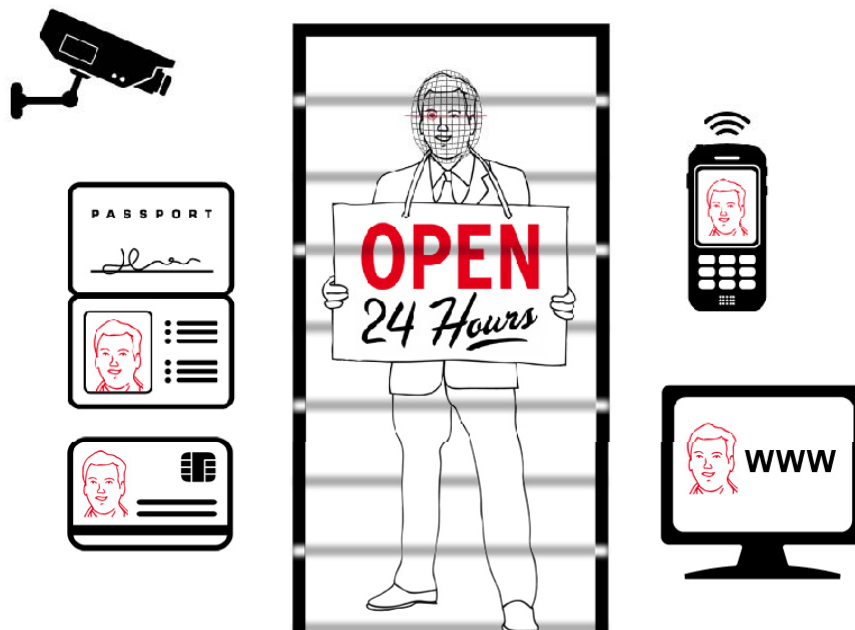


## Not on the Agenda

- E-Mutation?



Ger.: We are the web



## Quo Vadis Homo Simplex

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- Adaptation (technology vs. us)
  - Who is more adaptive?
- Evolution (technology vs. us)
  - who is in control?
  
- Privacy protection
  - Who needs that?
  
- Simplification (technicus vs. simplex)
  - Who is simpler?
- Individualization (technicus vs. simplex)
  - Who is more original?

## Infosphere (info vs. bio)

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Within the information society, it seems that we are modifying our ontological perspective, from a materialist one, in which physical objects and processes still play a key role, to an informational one, in which

- a) objects and processes are **dephysicalised**, **typified** and perfectly **clonable**;
- b) the **right of usage** is perceived to be at least as important as the right to **ownership**; and
- c) the criterion for **existence** is no longer being **immutable** (Greek metaphysics) or being potentially subject to **perception** (modern metaphysics) but being **interactable**.

## Inforg

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- We become **mass-produced**, anonymous entities among other anonymous entities, exposed to billions of other similar inforgs online.
- So we self-brand and re-appropriate ourselves in cyberspace by blogs and facebook entries, homepages, youtube videos, and flickr albums.
- We use and expose information about ourselves to become less informationally indiscernible.
- We wish to maintain a high level of informational privacy almost as if that were the only way of saving a precious capital that can then be publicly invested by us in order to construct ourselves as individuals discernible by others.

## II. Technology

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*Motto: "What You need is what you get"*

- **(Collective) Pervasive adaptation[1]**
  - Cognitive experience
  - Emotional experience
  - Physical experience
  - Case studies
- **Reflective approach[2]**
  - Theoretical background
  - Reflective Middleware
  - Case studies
- Ethical issues: {privacy, social, integrity} protection

## Motivation: What you need is what you get

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- The ideal man-machine confluence is the one that minimises explicit interaction and maximises the functionality of the system.
- The goal is to avoid giving commands to a control system, but rather enabling the system to understand what is needed in given circumstances.
- In a similar way that text editing has been revolutionized by the „what you see is what you get“ principle, the motto “what you need is what you get” is radically changing the landscape of man-machine interface.

## Pervasive Adaptation

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- Definitions
- Physiological/affective computing
- Biocybernetic loop
  - Cognitive experience
  - Emotional experience
  - Physical experience
- Case studies

## PA - Pervasive Adaptation

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- Adaptation is a system capability to dynamically adjust its functioning according to the run-time situation. Adaptation requires:
  - awareness
  - self-(re)organization
  - evolve-ability
- Pervasive adaptation is adaptation that happens seamlessly and further affects the humans and their surroundings!

online dictionary, <http://www.thefreedictionary.com/>

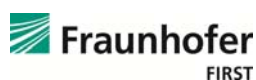
Awareness == A knowledge gained through one's own perceptions or by means of information  
Adjustment == An act of change, "so as to become suitable to a new or special situation"  
Adaptation == An alteration or adjustment in structure or habits, often hereditary, by which a species or individual improves its condition in relationship to its environment.  
Evolution == A gradual process in which something changes into a different and improved form



## Awareness

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- Awareness is achieved by processing any information that can be used to characterize the user, user's situation, and ambient. Information may be collected/determined by:
  - Sensors
    - temporal and spatial location
    - environmental attributes
    - resources nearby
    - **psycho-physiological measurements**
  - User preferences and profiles
    - schedules, agendas
    - wish lists (e.g. itineraries)
    - characteristics
    - social context
    - chronology (habits)



## System Requirements

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A control system should continuously monitor users, diagnose their state and influence it, according to the application needs.

- Multimodal monitoring technology used to capture the user status, is divided into three distinct categories, featuring:
  1. overt actions (e.g. location tracking, observing, and pointing),
  2. overt expression (e.g. changes in behavior associated with psychological expression), and
  3. covert expression (e.g. changes in physiology associated with psychological expression).
- Numerous actuator devices are used to control and influence the users and their environment

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\* Overt actions and performance represent a source of data that is open to visual inspection

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## The Biocybernetic Loop

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- In a repetitive and self-correcting manner, the loop captures the status of the user, according to the psychophysiological data collected, analyses it and decides on the actions in order to affect it (accordingly).
- The function of the loop is to monitor changes in user state in order to initiate an appropriate adaptive response.
- The biocybernetic loop is designed according to a specific rationale, which serves a number of specific meta-goals; e.g. the biocybernetic loop may be designed to:
  - promote and sustain a state of positive engagement with the some task
  - minimize health or safety risks in everyday situations



## PA Summary

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### **Problem**

(Collective) pervasive adaptive systems are complex because they must cope with dynamic properties of adaptability and self- and group-organization as well as with algorithms, structural design and concurrency ...

### **Challenges**

- To understand the very essence of the phenomenon
- To formulate (select) a class of underlying attributes/features
- To mimic the nature (whether understood or not)
- To find the technical solution
- To envisage novel scenarios – use cases

### **Principle**

Solutions should not be more complex than the problem itself!

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## Essentials

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### **Problem**

**Collective adaptive systems should support:**



**Individualism:** habits, customs, character, daily routine, both consciousness and unconsciousness, personality, emotions, cognitions, physical state, both intrinsic and extrinsic behaviors, ...



**Collectivism:** social grouping, long and short term social behaviors, social practice, both prejudices and tolerance, fashion, tradition, ...

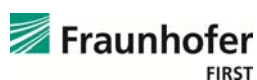
### **Observation**



- Most stated principles have been seriously neglected in present systems
- The **ethics** need to be built-in any solution, providing ethical sensitivity to each of the above aspects.

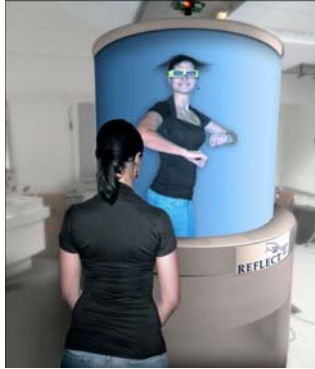
**Multidisciplinary approach: Practitioners, Philosophers, Sociologists, ...**

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## REFLECTIVE Approach: Emathic Applications

Reflective display



Reflective vehicle

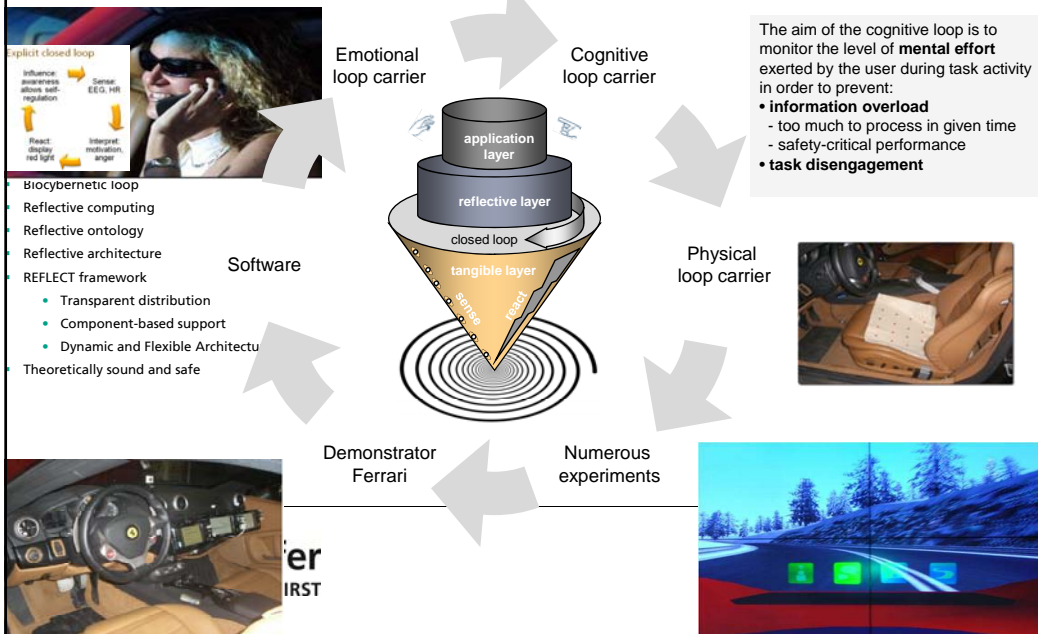
standard



reflective



## Reflective Approach



## REFLECTIVE Software

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### Major goal

To develop a framework that supports pervasive adaptive applications with non explicit man-machine interaction and seamless ambient improvements

### Major system's features

- Awareness
  - Context awareness
  - Personal awareness
- Adaptation
  - Immediate response/improvisation
  - Dynamic adjustments
  - Co-evolution
- Pervasive adaptation through close loop control on multiple time scales  
= **biocybernetic loop**

## REFLECTIVE Computing

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### Major computing characteristics

- Reflective computing
    - Emotional
    - Cognitive
    - Physical
  - Event driven
  - Real-time
  - Parallel and distributed
    - Middleware
    - Service orientation
    - Component orientation
- Adaptation
- Pervasiveness

## Reflective Ontology

### Ontology:

- a structure of entities within a domain, organized by relationships

### UML

- a language for describing the REFLECT ontology

### The primary role

- a notation for formal modeling of reflective systems and definition of rules and roles among structural elements

### The secondary effect

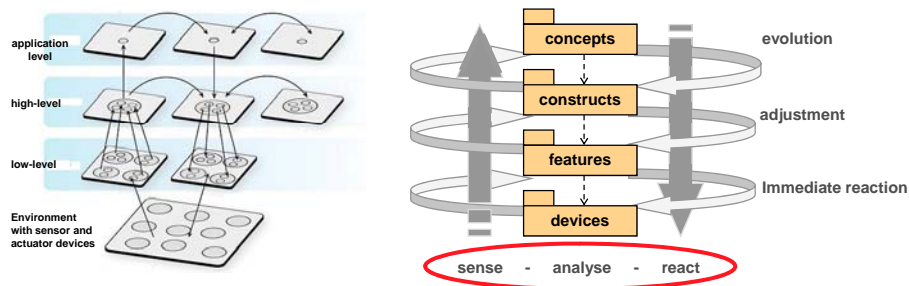
- syntactical aspects of the ontology provide straightforward taxonomies that can be expressed in XML descriptions

### Specification requirements

- are supported by the REFLECT ontology



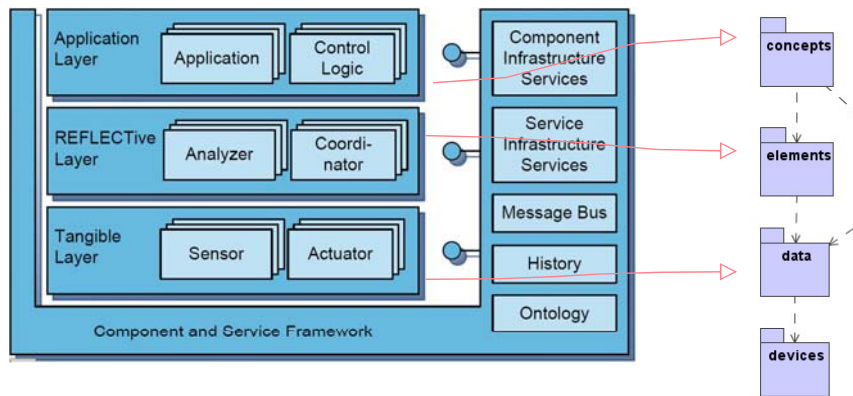
## Reflective Ontology: Basic Idea



to hierarchically organize the **sense–analyse–react** cycle



## Relating REFLECT Architecture and Ontology



## Tangible Interface

- Automated capture of experiences
- Context-aware and context sensitive interactions
- Natural and implicit interfaces
- Omnipresent and generic services

### Multi-Ontology approach

senses  
constructs  
situation



## Case Studies

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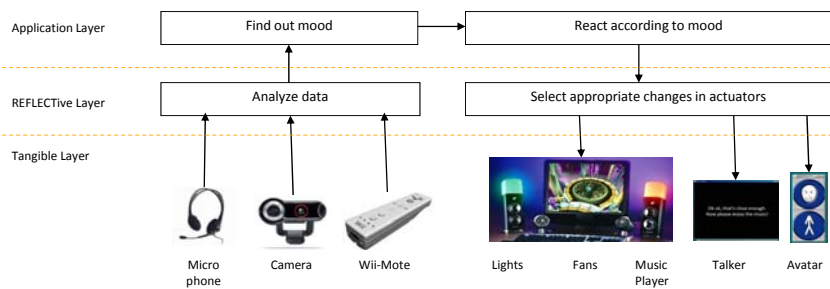
1. Active Music player ([FET09])
2. CAN Bus - simulation and real
3. Seat adaptation
4. Head up display
5. Reflective home for elderly

} Reflective vehicle



## Active Music Player Architecture

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## Active Music Player (cont.)

Detects the current mood of the people in its range, and reacts accordingly (with music, lighting and aircondition)

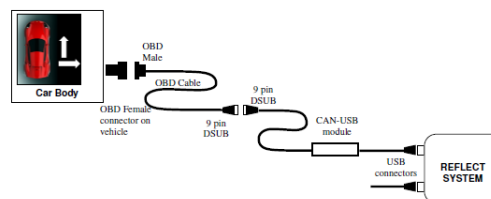


## Case study 2: Can Bus Interface

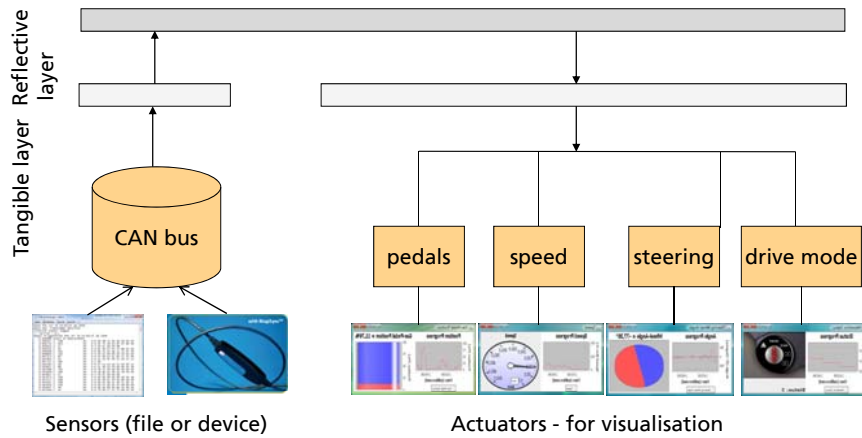
The REFLECT demonstrator requires a number of in-car sensors to detect the driver's emotional, cognitive and physical state. Additional data about the driving behavior (needed to complement psycho-physiological data) is retrieved via the vehicular CAN bus.

### • CAN = Controller–Area Network

- A bus system in vehicles
- Allows microcontrollers and in-car devices to communicate
- CAN bus access:
  - Read driving data (car speed, acceleration, ...)
  - Find out the driver's driving style (driving aggressive, ...)
  - First step – read from a recorded file
  - Second step – read directly from bus (via USB)



## CAN bus in REFLECT



## Case study 3: Seat Adaptation System

Aim: the improvement of driver's comfort during a driving experience

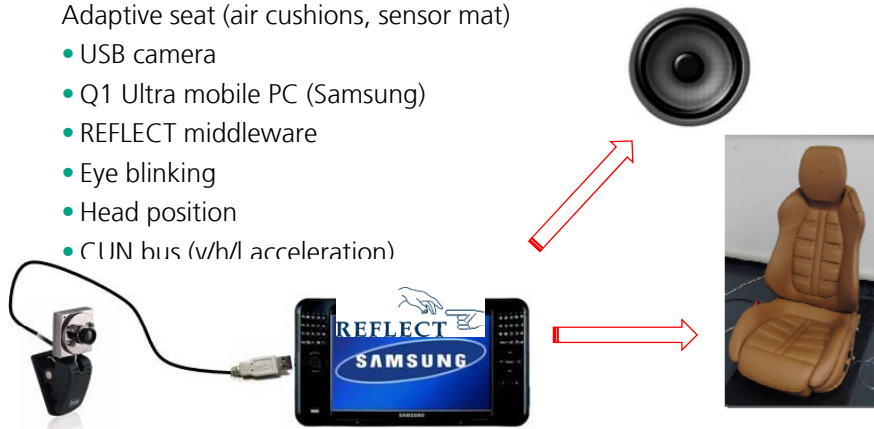
- monitoring the postural behaviour of a driver
- detecting uncomfortable positions on the seat
- acting on the car seat in order to help the driver find a more comfortable position.

## Proposed solution

### Components:

Adaptive seat (air cushions, sensor mat)

- USB camera
- Q1 Ultra mobile PC (Samsung)
- REFLECT middleware
- Eye blinking
- Head position
- CIJN bus (v/h/l acceleration)



## Case Study 4: Adaptive Head-Up Display

- Implicit feedback on driving conditions and driver attention



- Facial expression source
  - Fraunhofer SHORE
- Telemetry data source
  - Open-source racing simulation TORCS (<http://torcs.sf.net>)
  - Ferrari California using CAN-Bus connector



## Case study 5: Reflective Home

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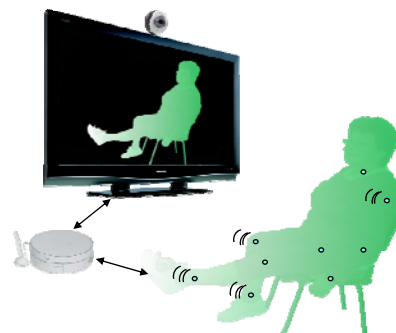
Aim: the improvement of driver's comfort during a driving experience

- monitoring the postural behaviour of a driver
- detecting uncomfortable positions on the seat
- acting on the car seat in order to help the driver find a more comfortable position.

## Reha Lab

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- Sensor based multi media system for exercising and rehabilitation
- Movement therapy with entertainment
- Customized to individual needs
- Analyses of movement
- Monitoring of vital parameters
- Both clinical and home use
- Prevention and rehabilitation



### III. Future

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*Mimicking the nature:  
do we understand/ respect/ follow the rules?*

- Technical issues
  
- Social issues
  
  
- Ethical issues



1. [www.perada.eu](http://www.perada.eu)
2. [www.first.fraunhofer.de/reflect](http://www.first.fraunhofer.de/reflect)

### Technical Issues

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- |                 |  |                    |  |
|-----------------|--|--------------------|--|
|                 | <ul style="list-style-type: none"><li>• Reflective software<ul style="list-style-type: none"><li>• more tools for application developers</li><li>• enrich the reflective interface with more devices</li><li>• improve pervasive character of the system</li></ul></li></ul> |                    |  |
| Research Themes | <ul style="list-style-type: none"><li>• Reflective computing<ul style="list-style-type: none"><li>• Emotional</li><li>• Cognitive</li><li>• Physical</li></ul></li><li>• Reflective application</li></ul>  | Further challenges | <ul style="list-style-type: none"><li>• Improve psychophysiological analyses</li><li>• extend the spectrum of diagnosed users' states</li><li>• overcome conflicting biocybernetic loops</li><li>• synchronize the combination of different biocybernetic loops</li></ul>  |
|                 | <ul style="list-style-type: none"><li>• Ethical issues</li></ul>   |                    | <ul style="list-style-type: none"><li>• Extend the exploitation strategies</li><li>• Expand the application domain:<ul style="list-style-type: none"><li>- mobile applications, AAL, smart displays, etc</li></ul></li><li>• Develop models for:<ul style="list-style-type: none"><li>- system loyalty</li><li>- multi-level, user-controlled privacy protection</li><li>- social behavior</li></ul></li></ul> |



## Framework Extension: Loyalty, Friendliness, Familiarity

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- Critical point: interaction with other systems
  
- Other systems:
  - Loyal systems (owned by the same user)
  - Friendly systems (owned by close friends)
  - Familiar systems (owned by familiar people, institution)
  - Other systems

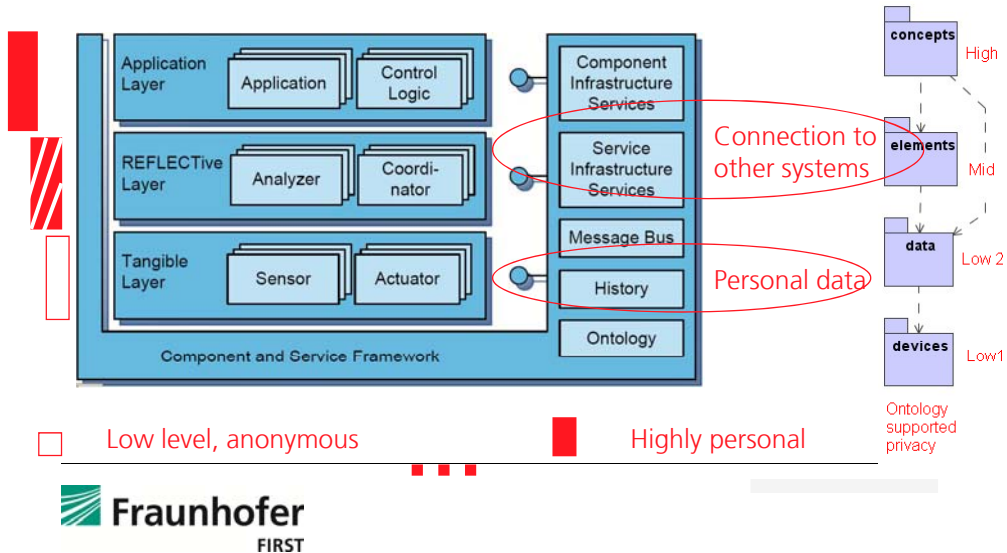
Loyal: e.g. belonging to the same owner  
Friendly: e.g. sharing the same preferences  
Familiar: e.g. having the same system goals

## Framework Extension: Personal Data

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- No personal-administrative data in system whatsoever!  
(*user recognition through personal characteristics*)
- Low level personal data (*ppv*)
  - system internal – non exchangeable
- Mid level personal data (*ppv versus user state*)
  - system internal – exchangeable only within “friendly systems”
- High level personal data (*goals, habits, preferences*)
  - Application and user specific – exchangeable only with explicit permission
    - Friendly systems
    - Familiar systems

## Framework Extension: Privacy



## Future Steps ?

### Multidisciplinary Endeavour?

- **Technology**
  - data protection
  - E-privacy
  - E-cloning
- **Arts (literature, art)?**
- **Humanities ?**
- **Society ?**
- **Politics !**
- **Business !**



