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ADVANCED PERVASIVE COMPUTING

Lecture 4: Intelligent Environments and Activity Classification

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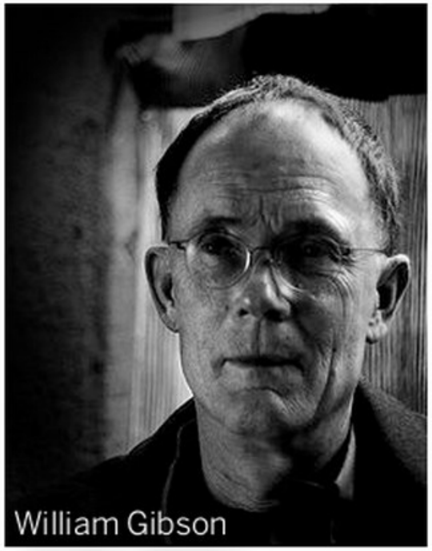
AGENDA

› Intelligent Environments
› Smart Cities
› Smart Homes
› Smart Spaces
› User interfaces
› AAL Smart Homes
› ADL
› IE Challenges
› Focus for Exam



"The future is already here, it's just not evenly distributed."

INTELLIGENT ENVIRONMENTS

Intelligent environments are spaces in which computation is seamlessly used to enhance ordinary activity (Steventon &Wright 2006)

One of the driving forces behind the emerging interest in highly interactive environments is to make computers not only genuine user-friendly but also essentially invisible to the user (Steventon &Wright 2006)

SMART HOMES

A smart home is an application of pervasive computing in a specific environment – a home.

Several synonyms are used for smart home technology:
- smart house, home automation, domotique, intelligent home,
- adaptive home, aware house, aware home

The smart home concept is the integration of different services within a home by using a common communication system. It assures an economic, secure, and comfortable operation of the home and includes a high degree of intelligent functionality and flexibility (Lutolf 1992)

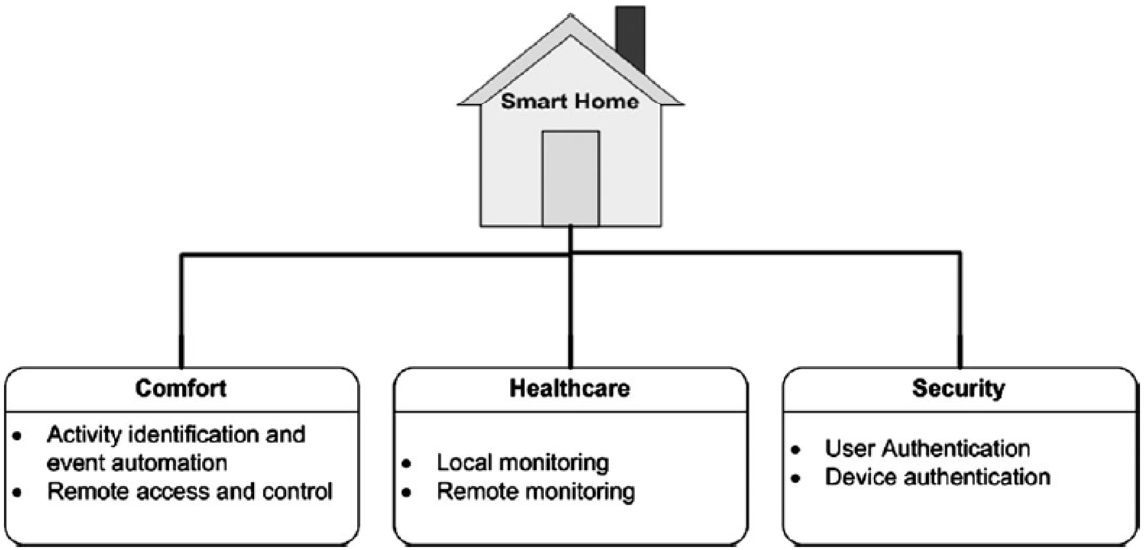
A home or working environment, which includes the technology to allow the devices and systems to be controlled automatically, may be termed a smart home (Berlo et al. 1999)

SMART HOME

"A smart home is a residential setting equipped with a set of advanced electronics, sensors and automated devices specifically designed for care delivery, remote monitoring, early detection of problems or emergency cases and promotion of residential safety and quality of life. Information and Communication Technologies (ICTs) are utilized to allow individuals to live independently in their preferred environment. Thus, systems are patient-centered rather than institution-centered as they are designed to address the needs of individuals, their families and caregivers rather than those of health care facilities." (International Medical Informatics Association, Working Group on Smart Homes and Ambient Assisted Living 2011)

This definition limits smart home technologies to one user group

SMART HOME TAXONOMY



(Alam et al. 2012)

SMART HOME OBJECTIVES

› Improving the user experience

› efficiency
› comfort
› healthcare
› safety
› security
› energy conservation

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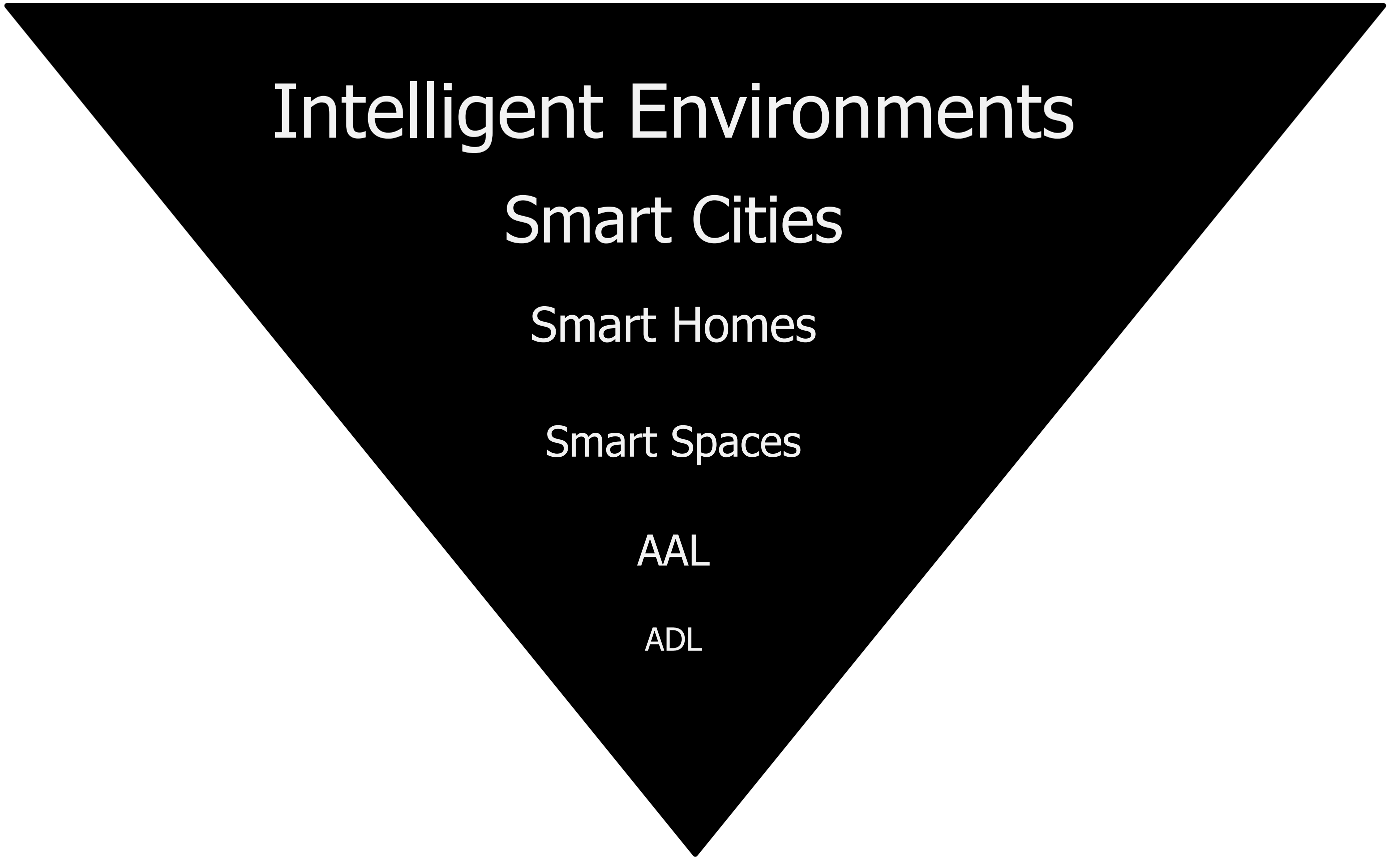
FOCUSING COURSE EFFORTS



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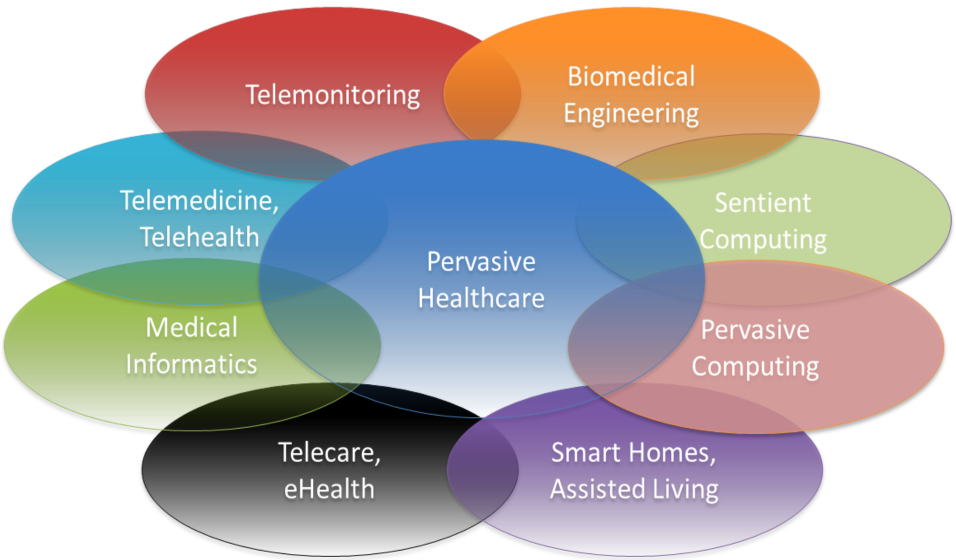
AMBIENT ASSISTED LIVING

- Several uses for smart home technology
- Example: Ambient assisted living
- - Safety (fall detection/prevention), self-care (dressing, bathing, cooking, medication), telehealth



ACTIVITIES OF DAILY LIVING

Activities of Daily Living (ADL), as
defined by the medical community, are:
“the things we normally do in daily living including any daily activity we perform for self-care (such as feeding ourselves, bathing, dressing, grooming), work, homemaking, and leisure” (Fleury et al. 2010)

- The ability to self care can be modeled using an ADL scale as a standardized measure of a persons ability to self care as compared to the “normal” range
- The ability to correctly self-measure, self-medicate, and self-exercise can be modeled using AMML, which is related to self care
- Other relevant modeling could include safety hazards, energy consumption, artifact tracking and discovery, and more

ADL SCALE (KATZ & AKPOM 1976)

- Bathing (sponge bath, tub bath, or shower),
- receives either no assistance or assistance in bathing only one part of the body
- Dressing,
- finds clothes and dresses without any assistance except for tying shoes.
- Toilet use,
- goes to the toilet, uses toilet, dresses, and returns without any assistance (may use cane or walker for support and may use bedpan/urinal at night)
- Transferring
- moves in and out of bed and chair without assistance (may use cane or walker).
- Continence,
- full control of bowel and bladder.
- Feeding,
- feeds without assistance (except for help with cutting meat or buttering bread).

Depending on the answer yes or no to each of these questions, geriatricians compute the ADL score of the elderly person. This scale is internationally recognized as one of the references.

ADL MONITORING

Can be achieved by using distributed context sensor technology

- Sensors
  - Infrastructure-based, wearable, stand-alone, collaborating
- Network infrastructure
  - Cabled, wireless (WiFi, Zwave, ZigBee), web services, CORBA, DDS, ICE
- Context model
  - Context toolkit, JCAF, own implementation, other
- Context reasoning engine
  - First order logic, Bayesian networks, HMM, SVM, Decision tree
- Actuators
  - User interfaces, external communication, service robots, automatic ventilation

Software frameworks for rapid prototyping important for domain comprehension

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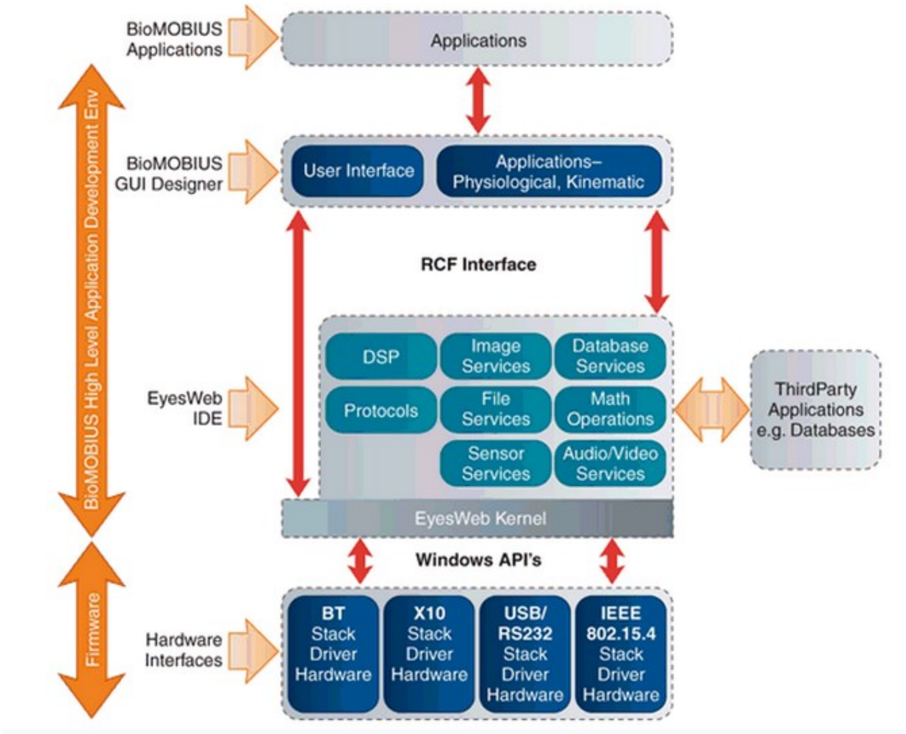
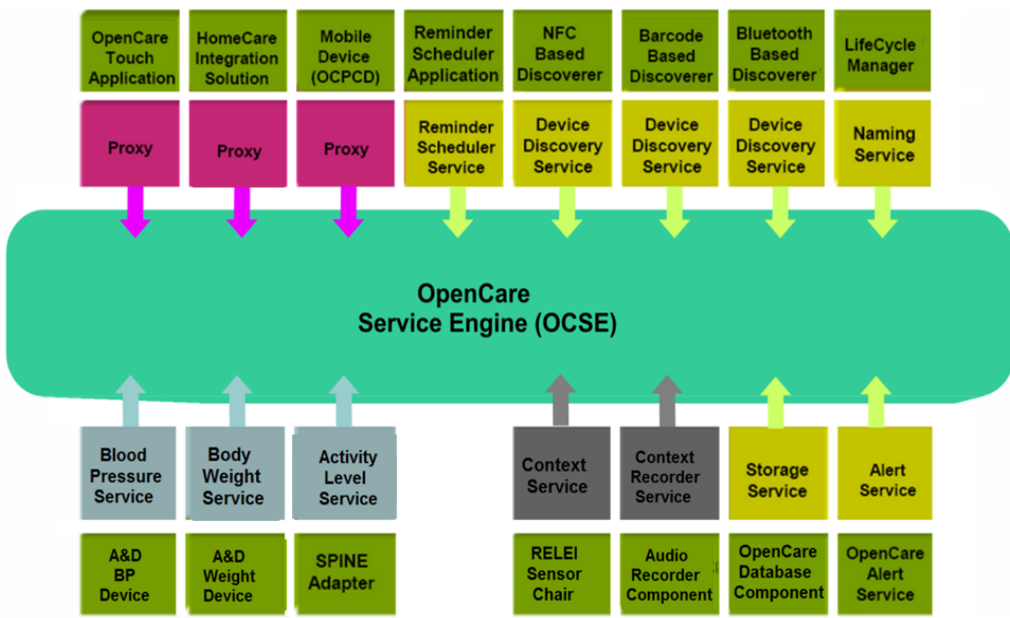
FRAMEWORKS

- Activity Classification Rapid Prototyping Toolkits
- OpenCare RELEI
- SPINE
- BioMOBIUS
- Shimmer3 Prototyping Tools

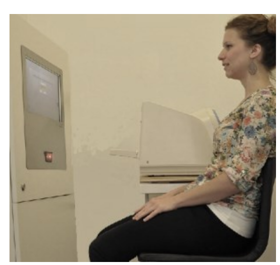


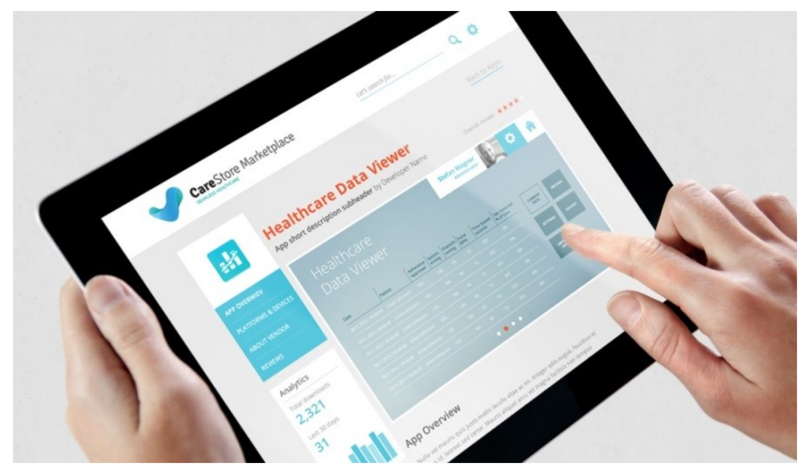
OPEN CARE SERVICE ENGINE

› Middleware (MAF/WS/ICE) based communication infrastructure broker



… or combine your own components





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SPINE

SPINE (Signal Processing in Node Environment) is a software Framework for the design and fast prototyping of Wireless Body Sensor Network (BSN) applications. SPINE enables efficient implementations of signal processing algorithms for analysis and classification of sensor data through libraries of processing functionalities. It also embeds an application-level communication protocol.
(Bellifemine et al. 2010)

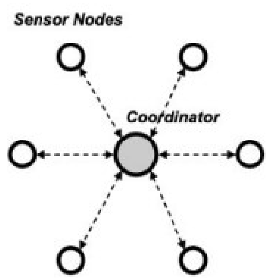

Figure 1. SPINE network architecture.

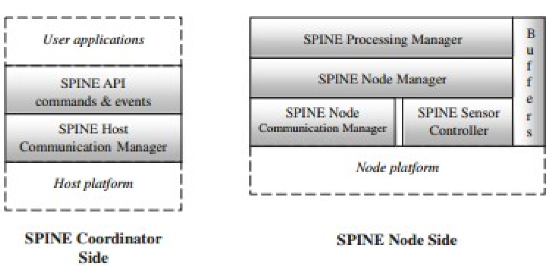

Table I. Comparison among the available approaches for BSN application development.

	Application-specific code	Domain-specific framework	General-purpose middleware
Code			
Reusability		√	√
Rapid prototyping		√	√
Ease of debugging		√	√
Code efficiency	√	√	
System interoperability		√	√
Specific support to flexible sensing operations		√	
Specific support to in-node signal processing		√	

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SPINE

Table II. Common tasks supported by BSN applications at node-side.

TASK	DESCRIPTION
SAMPLING	The sensor sampling process represents the first step for developing a BSN application. Selecting the appropriate sampling time to satisfy the application requirements is important because the amount of data generated and processed, and under certain degree the energy consumed depend on it.
FEATURE EXTRACTION	Classifier algorithms very rarely use raw data. Instead, attributes (or features) are typically extracted on data windows and used to detect events and classify activities. Extracting features directly on the wireless nodes also allows the reduction of the radio usage, as aggregated results are sent instead of several raw data values.
QUERIES	Support for selective queries on the available sensors of a node is important because application requirements can change over time and not all the sensors are necessarily involved for algorithms execution at any time.
NODE SYNCHRONIZATION	In a WBSN, nodes should be kept synchronized when sampling the sensors and processing data, because data gathered from multiple wearable nodes must refer to the same time interval to be aggregated to recognize correctly e.g. physical activities or other events of interest.
DUTY CYCLING	Duty cycling is a mechanism for handling the radio status (idle, on, off) to reduce power consumption of a sensor node and therefore its battery lifetime. In particular, radio duty cycling must be tuned very carefully, reducing as much as possible the active time (transmitting, receiving, and listening).

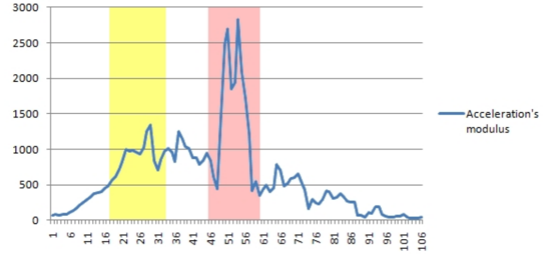
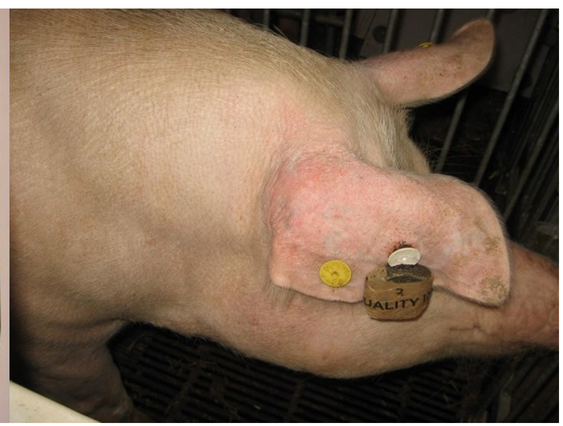


Fig. 4. Acceleration's modulus calculated for backward fall.

SPINE USAGE

› Activity tracking of humans
› Fall detection
› Farrowing behavior of pigs



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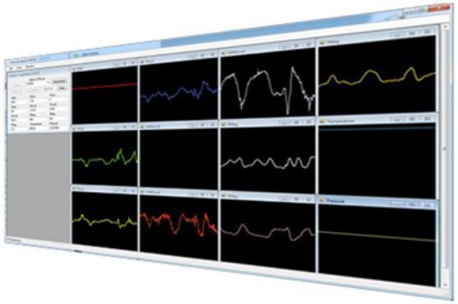
SHIMMER3

X	Y	Z	X2 + Y2 + Z2	SQRT(D)
-0,1992188	1,021484	0,1601563	1,108767733	1,052980405
-0,3476563	0,9580078	0,06445313	1,042798054	1,02117484
-0,2226563	0,9580078	0,04882813	0,969738959	0,984753248
-0,2636719	0,9609375	0,04882813	0,995307936	0,99765121
-0,2607422	0,9609375	0,04394531	0,993318564	0,996653683
-0,2529297	0,9589844	0,04296875	0,985470826	0,992708832
-0,2509766	0,9423828	0,02636719	0,951769824	0,975586913
-0,2988281	0,9433594	0,04492188	0,981243166	0,990577188
-0,2539063	0,9560547	0,03125	0,979485561	0,989689629
-0,2646484	0,9501953	0,02636719	0,973605112	0,986714301
-0,2587891	0,9570313	0,03710938	0,984257814	0,992097683
-0,2587891	0,9599609	0,03613281	0,989802308	0,994888088
-0,2646484	0,9521484	0,03515625	0,977861313	0,988868704
-0,265625	0,9541016	0,02148438	0,981328082	0,990620049
-0,2685547	0,9521484	0,04785156	0,980997974	0,990453419
-0,2626953	0,9550781	0,04589844	0,983289665	0,991609633
-0,2626953	0,9599609	0,04785156	0,992823522	0,9964053
-0,2519531	0,9589844	0,03710938	0,98450855	0,992224042
-0,2519531	0,9589844	0,04394531	0,985062634	0,992503216
-0,2744141	0,9521484	0,04199219	0,983653018	0,99179283
-0,2548828	0,9550781	0,02929688	0,977997726	0,988937675
-0,2822266	0,9521484	0,0390625	0,987764308	0,993863325
-0,2666016	0,9570313	0,04101563	0,988667604	0,994317658
-0,265625	0,9589844	0,03808594	0,991658259	0,995820395
-0,265625	0,9541016	0,04199219	0,982629848	0,991276877
-0,2714844	0,9492188	0,04296875	0,976566423	0,988213754
-0,2685547	0,9550781	0,04199219	0,986059148	0,99300511
-0,2763672	0,9501953	0,0390625	0,980775816	0,990341263
-0,2773438	0,9521484	0,05175781	0,98618503	0,993068492

	Standing	Running	Lying	Walking
Mean	1,00	1,51	1,00	1,09
Median	0,99	1,57	1,00	1,01
Std Dev	0,02	0,64	0,00	0,35
Sample Variance	0,00	0,42	0,00	0,12
Minimum	0,95	0,00	0,99	0,48
Maximum	1,17	2,79	1,00	2,67
Count	108	108	108	108



IE SENSOR CHALLENGES

- **Sensors**
  - Which types are relevant for current activity recognition?
  - How many?
    What cost?
  - Problems with interference and network topology needed
  - Autonomous or connected
  - Power consumption
  - Active vs. Passive
  - Communication
  - Time to interface

- **Networking**
  - Wired vs. Wireless
  - Protocol(s)
  - Bandwidth
  - Power consumption
  - Range
  - Topology

IE CONTEXT MODEL CHALLENGES

- Data storage
- Size
- Query rate
- Active vs. Passive
- Decision-making
- Communication

- Prediction and Decision-Making
- Dynamic/static, learning algorithms / temporal patterns
- Data relevance
- Sensor fusion
- Real-time
- Autonomy

IE SYSTEM CHALLENGES

- System architecture
  - Agent-based vs. monolithic
  - Hierarchical vs. flat
  - Distributed vs. centralized control
  - Open vs. closed

- Systems integration
  - Plug-n-play
  - Existing appliances

- Use frameworks
  - (JCAF, SPINE,)
  - Build your own framework

- Privacy and Security
  - Unwanted surveillance
  - “Break-ins”

CASE STUDY

- **Calm Ambient Medication Reminder System**
- Use a PIR sensor for detecting user presence
- Use a medication box sensor for detecting medication taken
- Only remind the patient to take medication after “grace” period
- Ensure patient only takes his medication once per day
- Use calm reminders
- Use speech as an interface
- Consider how to reuse sensors for other purposes?

FOCUS FOR ORAL EXAM

- Read about **Intelligent Environments, Smart Spaces, and Smart Homes**
- Make sure to **couple** todays manuscripts **to the ubiqutious computing, calm computing, and context toolkits and frameworks** (especially **JCAF and the Context Toolkit**) literature
- Make sure to **read about ADL** and how this **can be quantified using distributed context sensor** technology
- Make sure to read about **fall detection** – and how this can be classified
- Go back to the **distributed context sensor lesson** – and check for **specific sensor technologies** that may be used as "enabling technologies"
- Make sure to **read about types of ubicomp user interfaces** for Intelligent Environments
- Make sure to **read about SPINE** – and figure out whether it is a better approach than manual **Shimmer3/TinyOS programming** – e.g. for fall detection – or just using a SmartPhone
- Do not focus on the SVM model – or other approaches to context reasoning or feature extraction. These topics will be covered by Christian (though not SVM) – and we will not ask you to pay close attention to SVM and other reasoning models from the current papers
- Make sure to **note most of the IE challenges** and even elaborate on them if relevant

2013 EXAM QUESTION

Q6: Intelligent environments and smart spaces

1. Explain the principles behind intelligent environments and smart spaces
2. Present selected frameworks and enabling technologies, including user interface and sensor technology
3. Discuss specific and selected usages of intelligent environments and smart spaces, including in the ambient assisted living domain