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# Dealing with the need for Infrastructural Support in Ambient Intelligence

**2 June 2009 @ School of Computing and Mathematics, University of Ulster, Jordanstown campus**

**Dr. Diego Lz-de-Ipiña Glz-de-Artaza**
Faculty of Engineering (ESIDE), University of Deusto, Bilbao
dipina@eside.deusto.es
http://www.morelab.deusto.es
http://www.smartlab.deusto.es
http://paginaspersonales.deusto.es/dipina

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# Introduction

- What is the endemic problem(s) of AmI precluding its wider deployment?
  - Probably many factors but a very remarkable one is the ...
    - **"unfortunate" high demand on infrastructural support!!!**
      - Sensors
      - Actuators
      - Automation buses and protocols
      - Wireless communication links
      - Middleware
      - Context modelling and Reasoning engines
      - And so on and so forth ...

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# Research Motivation

- Given that AmI is not possible without infrastructure ...
  - **How do we alleviate this "unfortunate" need?**
- Our approach/research aim:
  - **Use and adapt low-cost off-the-shelf hardware infrastructure and combine it with intelligent middleware and interaction techniques to make "any" environment appear "intelligent"**
- **This talk describes several iterative research efforts addressing the infrastructure dependency issue**



# Talk Outline

- **Part 0:** Bird's-eye view of my research group and laboratory activities (5')
- **Part 1:** Review my previous research work on solutions to address "the need for infrastructure of AmI" (35')
  - **Iteration 1: Build your own sensing and reasoning infrastructure**
  - **Iteration 2: Concentrate on explicit user-environment interaction**
  - **Iteration 3: Leverage from Web 2.0 principles and map them to AmI**
  - **Iteration 4: Dealing with the heterogeneity, dynamic behaviour of existing instrumented environments**
  - **Iteration 5: Focus on a more specific application domain: AAL**
- **Part 2:** Review of current research lines & projects (10')

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## MoreLab Research Group & SmartLab Research Laboratory @ University of Deusto

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## University of Deusto, Bilbao

- Private Jesuits' University founded in 1886 in Bilbao, Basque Country, Spain
- It offers degrees on:
  - Business & Administration
  - Law
  - Psychology
  - Engineering
  - Social Sciences & Linguistics

- URL: http://www.deusto.es

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# Our Research Group:

mobility research lab

- Created in 2003, there are 3 lecturers and 12 researchers:
  - URL: http://www.morelab.deusto.es
  - Specialized on Mobile-Mediated Interaction, Internet of Things, Smart Objects, Semantic Middleware, AAL

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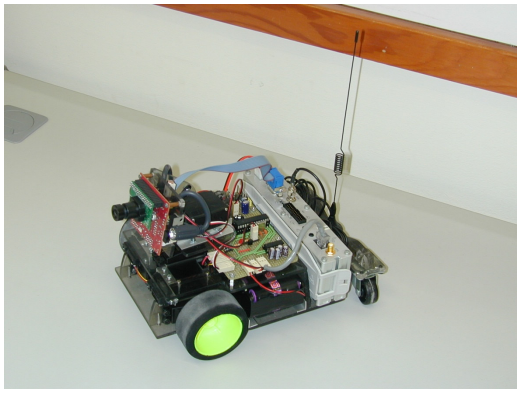
# Remote Control of Embedded Sensing Devices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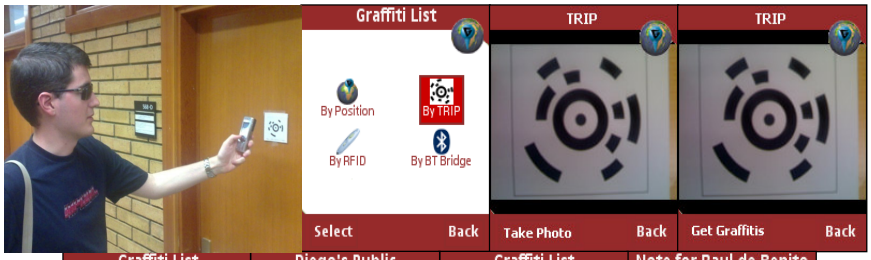
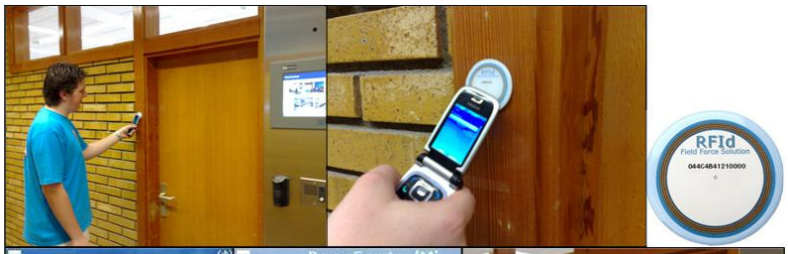
# Mobile-mediated Human-Environment Interaction





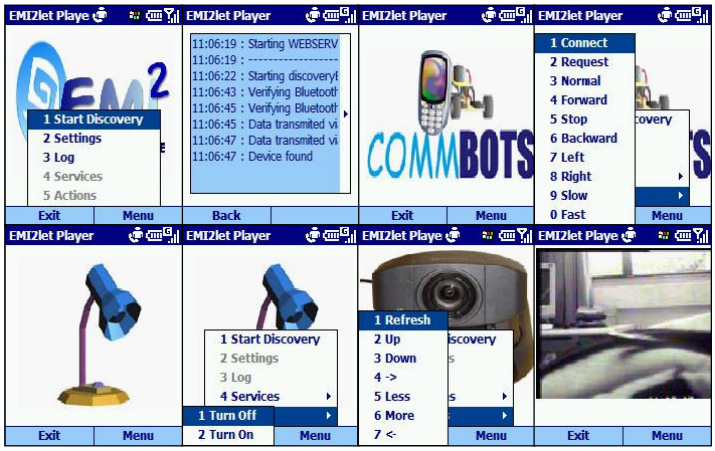


# Mobile-mediated Human-Environment Interaction



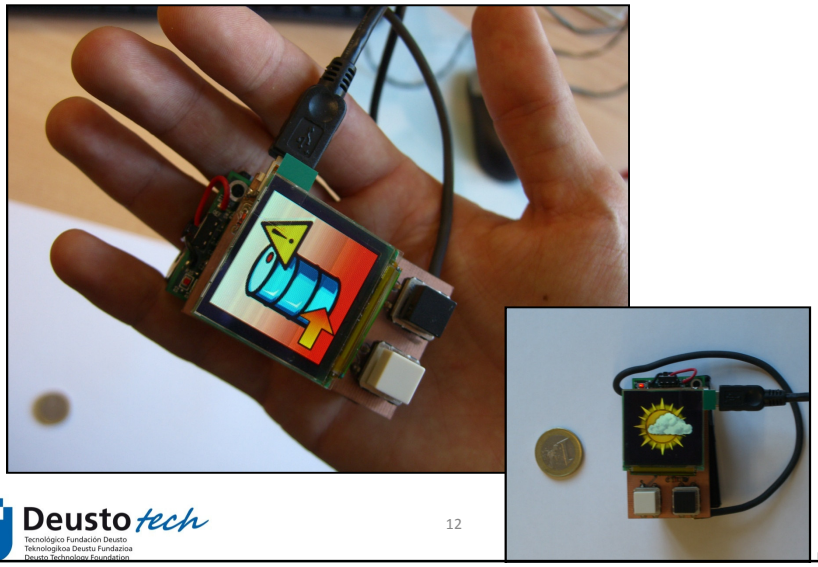



# Mobile-mediated Human-Environment Interaction

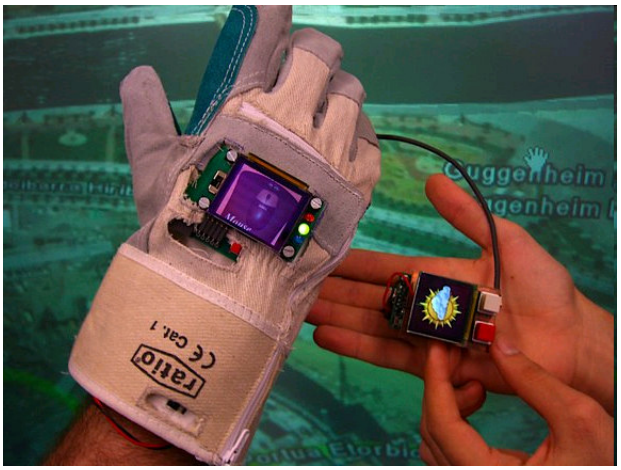





# RealWidget: desktop widgets for the real world

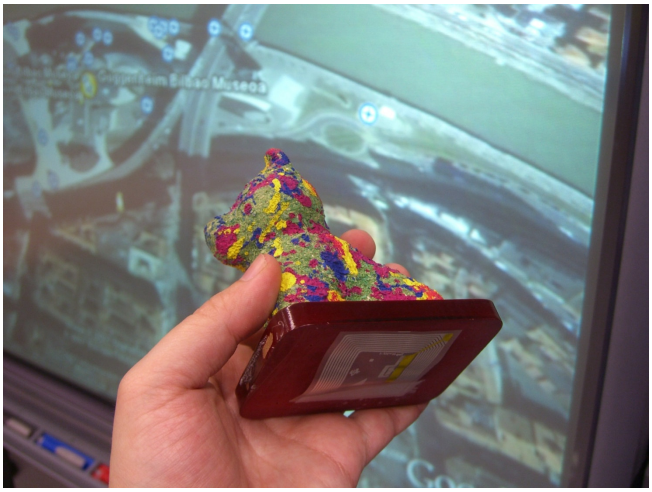


# RFID Glove (left) and RealWidget (right)

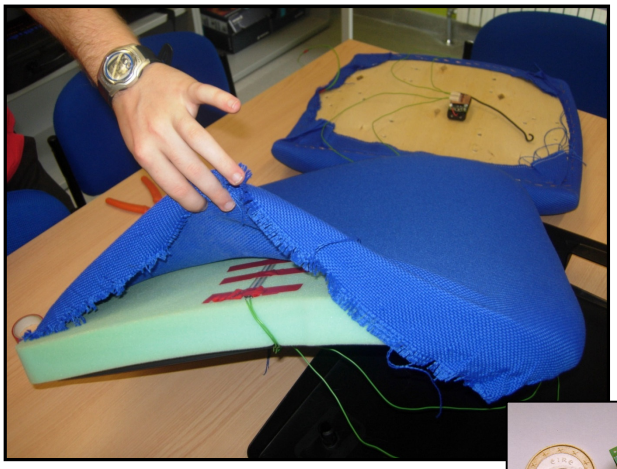


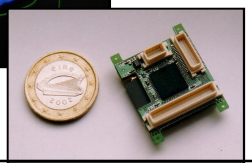


# Souvenir-aware Google Earth



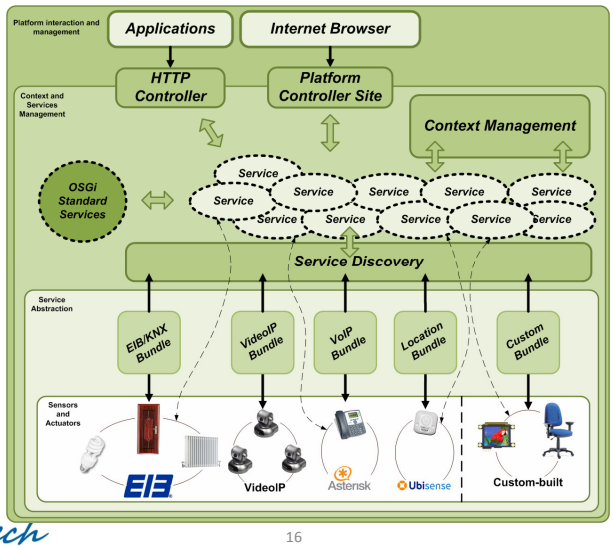
# Prototyping an intelligent chair (FlexChair) with an embedded wireless sensor node







# AmI-enabling Semantic Middleware



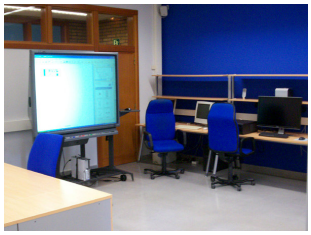
# Home control for AAL




# Our Research Lab: SmartLab

- A **research laboratory focused on AmI research**
- **Aim**: create an intelligent working space with a double purpose:
  - Provide infrastructure to host and attract research projects related to AmI
  - Assess the suitability of AmI as a mechanism to enrich and improve the working daily activities of a group of users
- URL: http://www.smartlab.deusto.es

# Our Research Lab: SmartLab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# Iteration 1: Build your own essential sensing and reasoning infrastructure

**PhD Dissertation: Visual Sensing and Middleware Support for Sentient Computing**



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# Iteration 1: Build your own essential sensing and reasoning infrastructure

- **Goals:**
  - build Sentient Spaces = computerised environments that sense & react
  - close gap between user and computer by using context
  - make ubiquitous computing reality through Sentient Computing
    - by **building your own low cost easily deployable infrastructure to make it feasible!!!**

- Developed during PhD research in University of Cambridge
  - http://www.cl.cam.ac.uk/research/dtg/
  - Supervised by Prof. Andy Hopper

Laboratory for Communications Engineering (LCE)
Cambridge University Engineering Department
England, UK


AT&T Laboratories
Cambridge


Basque Government
Education Department

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# Sentient Computing

- **Sentient Computing = computers + sensors + rules:**
  - distributed sensors capture context, e.g. temperature, identity, location, etc
  - rules model how computers react to the stimuli provided by sensors
  - 3 phases: (1) context capture, (2) context interpretation and (3) action triggering

- **PhD aim**: to make viable widespread adoption of Sentient Computing through:
  - location sensor deployable everywhere and for everyone
  - middleware support for easier sentient application development:
    - rule-based monitoring of contextual events and associated reactions
    - user-bound service lifecycle control to assist in action triggering

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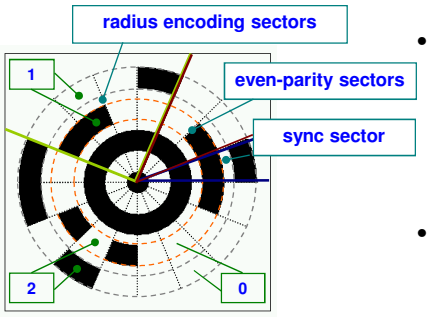
# TRIP: a Vision-based Location Sensor

**"Develop an easily-deployable location sensor technology with minimum hardware requirements and a low price"**

- TRIP (Target Recognition using Image Processing):
  - identifies and locates tagged objects in the field of view of a camera
- Requires:
  - off-the-shelf technology: cameras+PC+printer
  - specially designed 2-D circular markers
  - use of well-known Image Processing and Computer Vision algorithms
- Cheap, easily deployable → can tag everything:
  - e.g. people, computers, books, stapler, etc
- Provides accurate 3-D pose of objects within 3 cm and 2° error



# TRIPcode 2-D Marker



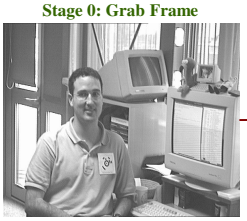

* 10 2011 221210001

TRIPcode of radius 58mm and ID 18,795

- 2-D barcode with ternary code
- Easy to identify bull's-eye:
  - invariant with respect to:
    - Rotation
    - Perspective
  - high contrast
- 2 16 bit code encoding rings:
  - 1 sector synchronisation
  - 2 for even parity checking
  - 4 for bull's-eye radius encoding
  - $3^9$ = 19,683 valid codes

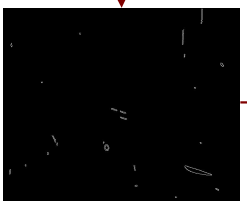
# Target Recognition Process

Stage 0: Grab Frame



Stage 1: Binarization

Stage 2: Binary Edge Detection



Stage 3: Edge Following & Filtering

**Ellipse params:**
x (335.432), y (416.361) pixel coords
a (8.9977), b (7.47734) pixel coords
θ (15.91) degrees

**Bull's-eye radius:** 0120 (15 mm)
**TRIPcode:** 002200000 (1,944)

**Translation Vector (meters):**
($T_x$=0.0329608, $T_y$=0.043217, $T_z$=3.06935)

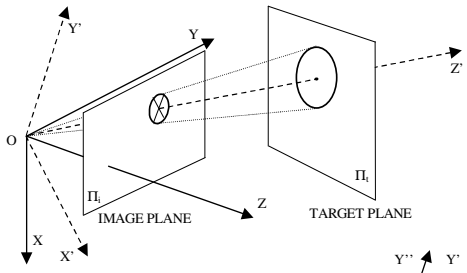
**Target Plane Orientation angles (degrees):**
( α=-7.9175, β=-32.1995, γ=-8.45592)

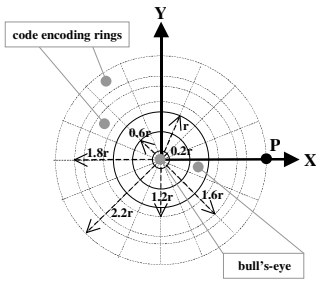
**d2Target:** 3.06983 meters

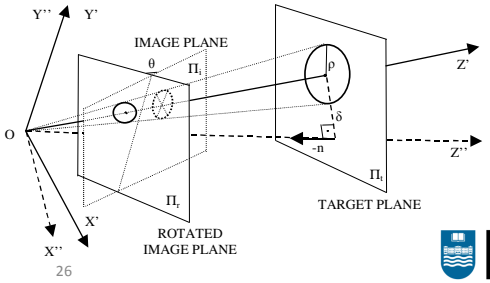
Stages 4-7: Ellipse Fitting, Ellipse Concentricity Test, Code Deciphering and POSE_FROM_TRIPTAG method



# Geometry POSE_FROM_TRIPTAG method



# A Rule Paradigm for Sentient Computing

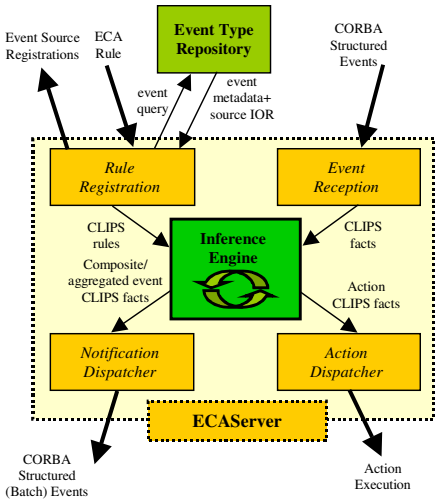
- **Sentient systems are reactive systems that perform actions in response to contextual events**
  - Respond to the stimuli provided by distributed sensors by triggering actions to satisfy the user's expectations based on their current context, *e.g.* their identity, location or current activity
- Issues:
  - Development of even simple sentient application usually involves the correlation of inputs provided from diverse context sources
- Observation:
  - ***Modus operandi* of sentient applications: Wait until a pre-defined situation (a composite event pattern) is matched to trigger an action**



# ECA Rule Matching Engine

- Sentient Applications respond to an ECA model:
  - monitor contextual events coming from diverse sources
  - correlate events to determine when a contextual situation occurs:
    - e.g. IF two or more people in meeting room + sound level high THEN meeting on
  - ineffective to force every app to handle same behaviour separately
- Solution → **ECA Rule Matching Service**:
  - accepts rules specified by the user in the ECA language
    `<rule> ::= {<event-pattern-list> => <action-list> }`
  - automatically registers with the necessary event sources
  - notifies clients with aggregated or composite events or executes actions when rules fire:
    - ***aggregated event*** = new event summarizing a situation
    - ***composite event*** = batch of events corresponding to a situation

# ECA Service Architecture






# Building a Sentient Jukebox with ECA Service

**"If it is Monday, a lab member is logged in and either he is working or it is raining outside, then play some cheerful music to raise the user's spirits"**

```
within 15000 {/* Enforce events occur in 15 secs time span*/
  query PCMonitor$logged_in(user ?userID, host ?hostID) and
  test(dayofweek = "Monday") and
  Location$presence(user ?userID) before
  /* a presence event must occur before any event on its RHS */
  ((PCMonitor$keyboard_activity(host ?hostID, intensity ?i) and
    test(?i > 0.3)) or
   (query WeatherMonitor$report(raining ?rainIntensity) and
    test(?rainIntensity > 0.2)))
=>
  notifyEvent(Jukebox$play_music(?userID, ?hostID, "ROCK"));
}
```

# Mapping of Rules to CLIPS

```
(assert (rule (ruleID 0) (ruleRegTime 1005472984621)))
(defrule rule0
  (PCMonitor$logged_in (user ?userID) (host ?hostID)
                       (timestamp ?time0#))
  (test (eq (dayofweek) "Monday"))
  (Location$presence (user ?userID) (timestamp ?time1#))
  (test (> ?time1# 1005472984621))
  (test (> ?time1# (- (curtime) 15000)))
  (or (and (and (PCMonitor$keyboard_activity (host ?hostID)
                                (intensity ?i) (timestamp ?time2#))
                (test (> ?time2# 1005472984621))
                (test (> ?time2# (- (curtime) 15000)))
                (test (> ?time2# ?time1#)))
           (test (> ?i 0.3)))
      (and (WeatherMonitor$report (raining ?rainIntensity)
                                  (timestamp ?time3#))
           (test (> ?rainIntensity 0.2))))
=>
  (bind ?currentTime# (curtime))
  (bind ?factID0# (assert (Jukebox$play_music# 0 ?currentTime#
                                               ?userID ?hostID "ROCK")))
  (notify-event ?factID0#))
```



# LocALE Framework

- Need to provide **support for reactive behaviour of sentient systems**:
  - e.g. user-bound service activation after aggregated event arrival
- **LocALE = CORBA-based solution to object lifecycle & location control:**
  - hybrid of CORBA's Object LifeCycle Service and Implementation Repository
  - addresses location-constrained service activation, deactivation and migration
  - adds mobility, fault-tolerance and load-balancing to objects in a location domain
  - generates permanent object references (independent of object network location)
  - undertakes transparent client request redirection upon object's location change
  - useful for third-party object location controllers:
    - e.g. "migrate the TRIP parser to another host when the used host owner logs in"

# Location-constrained Object Lifecycle Control

- Why is CORBA location transparency not always desirable?
  - sometimes want to control where objects are first located and then relocated
    - e.g. load-balancing or follow-me applications

- **LocALE provides apps with location-constrained object lifecycle-control**:
  - apps specify on distributed object creation its initial location:
    - within a host, e.g. `hostDN("guinness")`
    - any host in an spatial container (room), e.g. `roomID("Room_1")`
    - in any location domain's host, e.g. `hostDN("ANY")` or
    - in one of a given set of hosts, e.g. `hostGroup("heineken", "guinness")`
  - … and restrictions under which an object can later be moved and/or recovered:
    - `LC_CONSTRAINT(RECOVERABLE | MOVABLE)` # any host of location domain
    - `LC_CONSTRAINT(RECOVERABLE_WITHIN_ROOM | MOVABLE_WITHIN_ROOM)`

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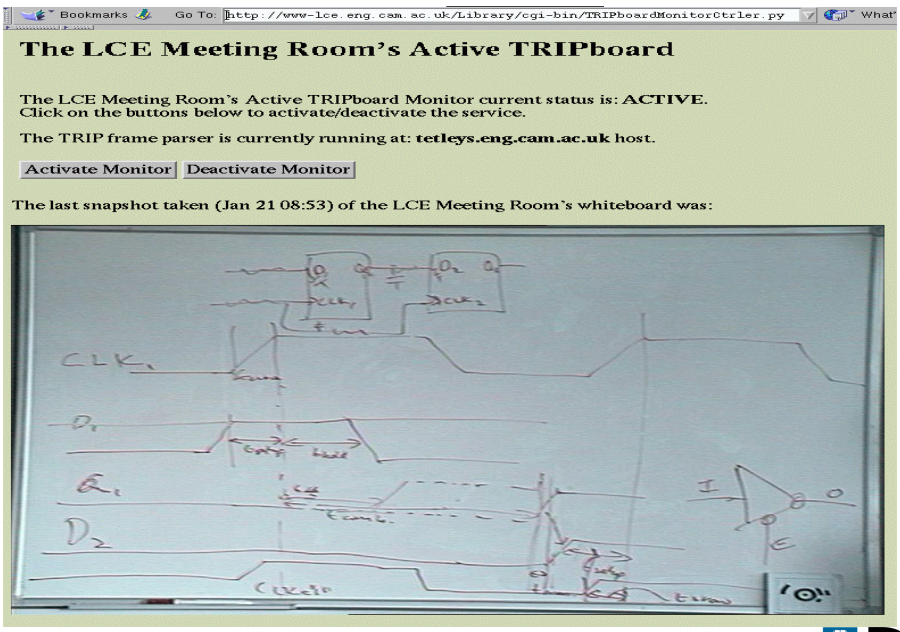


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# Follow-Me Audio

- Provides mobile users with music from the nearest set of speakers
- MP3 decoder and player follow the user to his new location.
- Uses TRIP as a real-time location and music selection device
- Uses ECA Service to register contextual situations to be monitored
- Uses LocALE's migration support

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# Iteration 2: Concentrate on explicit user-environment interaction: profit from what you already have in your hands!

**EMI2lets: a Reflective Framework for Enabling AmI**

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# Iteration 2: Concentrate on explicit user-environment interaction

- Latest mobile devices used mainly for communication, entertainment or as electronic assistants
- However, their increasing:
  - Computational power
  - Storage
  - Communications (Wi-Fi, Bluetooth, GPRS)
  - Multimedia capabilities (Camera, RFID reader)
  - Extensibility
- Makes them ideal to act as intermediaries between us and environment:
  - Aware (Sentient) Devices
  - Powerful devices
  - Always with us anywhere at anytime
- **Our mobile devices can turn into our personal butlers!!!**



# Motivation


- **Build Smart Spaces** and **transform mobile devices into Universal Remote Controllers** of Anything Anywhere at Anytime
  - Mobile devices equipped with Bluetooth, cameras, barcode, GPS or RFID are sentient devices
    - http://www.ctmd.deusto.es/mobilesense
  - A **Smart Space** is a container, either indoors or outdoors, of Smart Objects
  - A **Smart Object** is an everyday object (e.g. door) or device augmented with some computational service.
- Definition of suitable AmI architectures may be a good starting point to make AmI reality

# EMI²lets Platform I

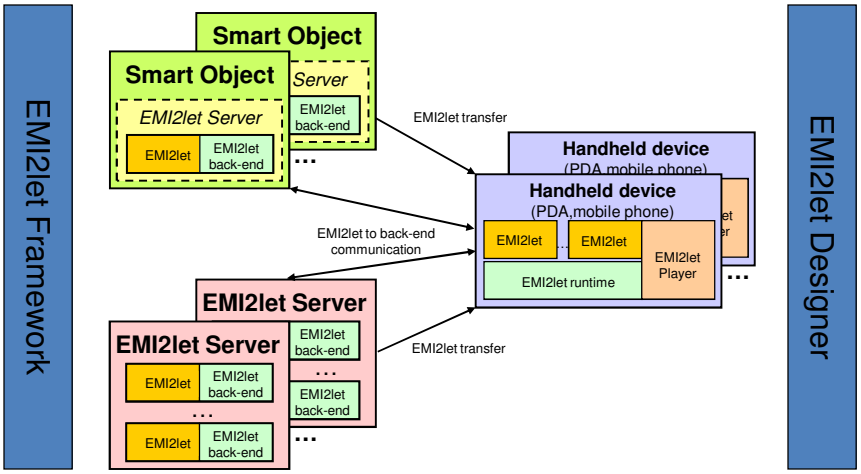
- **EMI²lets** is a middleware to facilitate the development and deployment of mobile context-aware applications for AmI spaces.
- **Software platform** to:
  - **convert physical environments into AmI spaces**
    - augment daily life objects with computational services
  - **transform mobile devices into Smart Object remote controllers**



# EMI²lets Platform II

- EMI²lets is an **AmI-enabling middleware**
  - **addresses** the **service discovery and interaction** aspects required for **active influence** on EMI²Objects
- Follows a Jini-like mechanism and Smart Client paradigm
  - once a service is discovered, a proxy of it (an EMI²let) is downloaded into the user's device (EMI²Proxy).
  - An **EMI²let** is a mobile component transferred from a Smart Object to a nearby handheld device, which offers a graphical interface for the user to interact over that Smart Object

# EMI²lets Deployment

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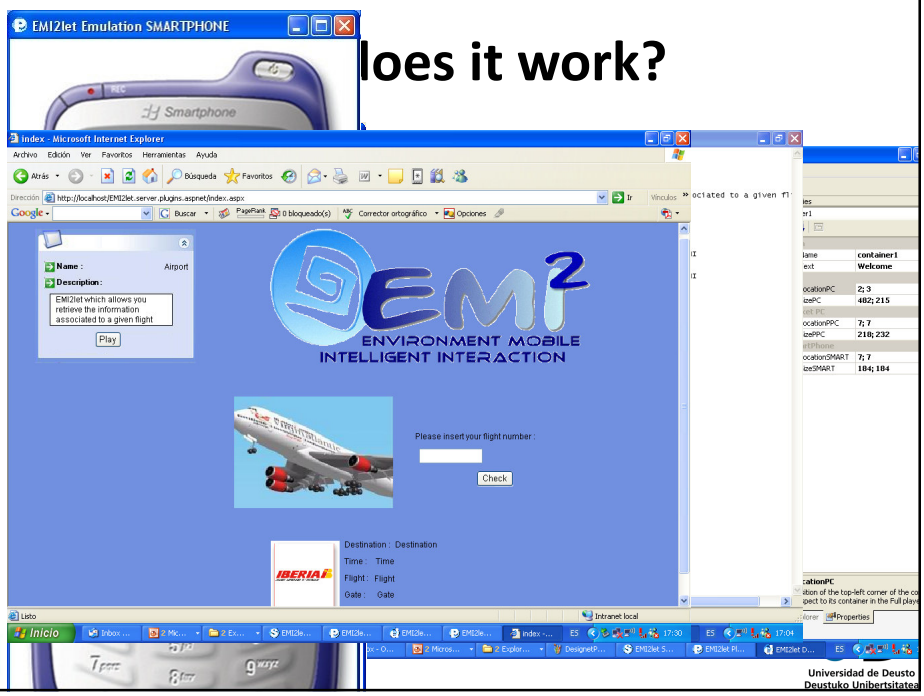
# loes it work?

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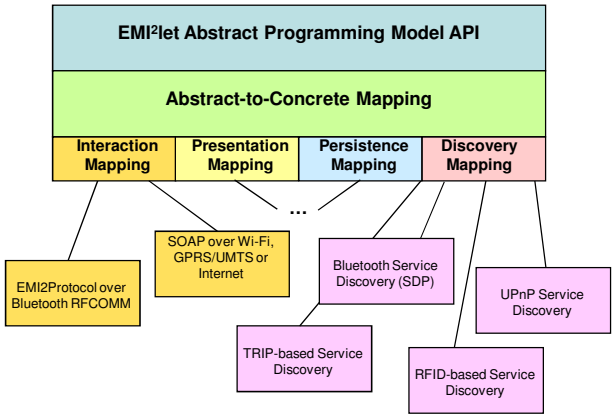
# EMI²lets Internal Architecture

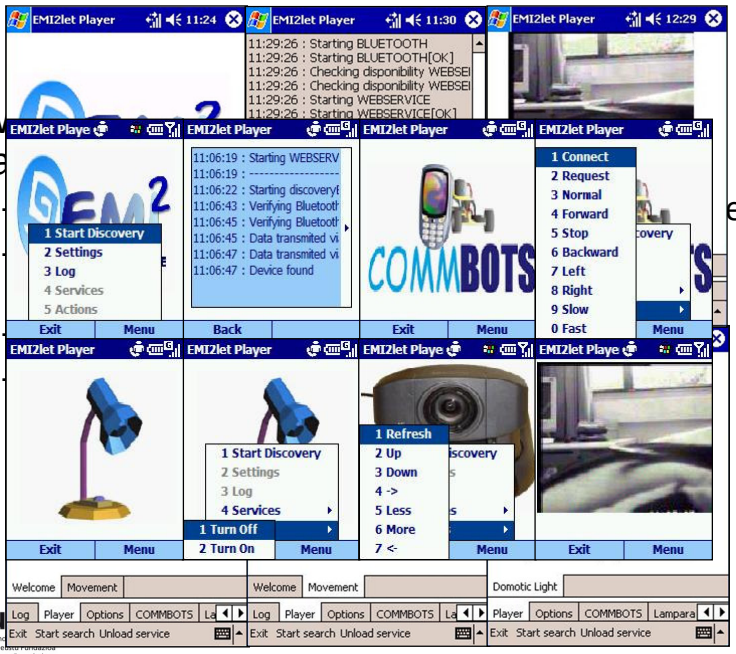





# EMI² Internals

- 3-tier software architecture
- EMI² framework defines **4 programming abstractions**:
  - Discovery
  - Communication
  - Presentation
  - Persistency
- An **EMI2let plug-in** = abstraction implementation
  - Common plug-ins: Bluetooth, Wi-Fi, UPnP
  - Special purpose: TRIP (Target Recognition using Image Processing)
- **Assembly fusion** at runtime
  - Reflection does the magic!!!

- V
  a
  e)




# Conclusion

- **EMI²lets = middleware providing universal active influence to mobile devices over Smart Objects**:
  - Transforms mobile devices into universal remote controllers.
  - Enables both local and global access to those Smart Objects (anywhere/anytime).
  - Independent and extensible to the underlying service discovery and interaction, graphical representation and persistence mechanisms.
  - Enables AmI spaces using conventional readily-available hardware and software.
  - Follows a “write once run in any device type” philosophy

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# Iteration 3: Easing AmI! Leverage from Web 2.0 principles and map them to AmI

**A Web 2.0 Platform to Enable Context-Aware Mobile Mash-ups**



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# Iteration 3: Easing AmI! Leverage from Web 2.0 principles

- **Issues impending AmI wide deployment remain:**
  - AmI is possible if and only if:
    - Environments are heavily instrumented with sensors and actuators
  - Besides, to develop AmI apps continues being very hard!
- Still, mobile devices enable interaction anywhere at anytime
  - User-controlled (explicit) & system-controlled (implicit)
- **Is AmI possible without heavy and difficult instrumentation (or infrastructure-less)?**
  - YES, IT SHOULD if we want to increase AmI adoption!!!

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# Research Aim

- **Aim**
  - Lower the barrier of developing and deploying context-aware applications in *uncontrolled global* environments
    - Not only my office, home, but what about my city, other companies, shopping centres, and so on
- **HOW?**
  - Converging mobile and ubiquitous computing with Web 2.0 into **Mobile Ubiquitous Web 2.0**
    - Adding context-aware social annotation to physical objects and locations in order to achieve AmI



# Sentient Graffiti

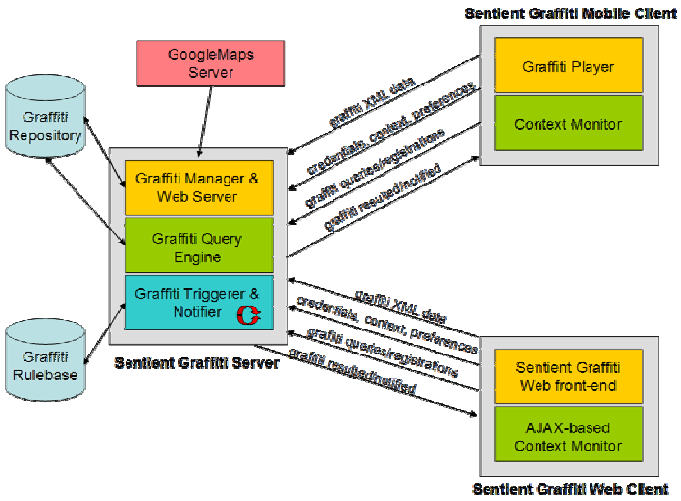
- **What does it do?**
  - Annotate every physical object or spatial region with info or services
    - Both indoors and outdoors
  - Filter annotations associated to surrounding resources based on user context and keyword filtering
  - Enable user interaction with the smart object and spatial regions both in a PUSH and PULL manner
- **Requirement**
  - Participation in a community of users interested in publishing and consuming context-aware empowered annotations and services

# Functionality

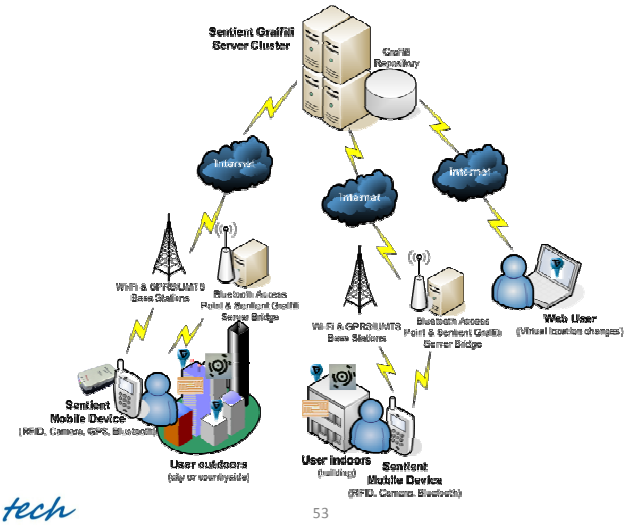
- **User's view**
  - Graffiti annotation
    - Descriptions, keywords, contextual attributes
  - Graffiti discovery and consumption
    - TRIP, RFID, NFC, GPS
- **System's view**
  - Context-Aware Folksonomy
    - Tag/keyword-based
  - Context-Aware Mash-up
    - GoogleMaps + our server back-end



# Architecture



# Deployment Scenarios



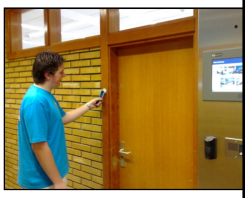



# Multi-modal Interaction

- Sentient Graffiti simplifies human-to-environment interaction through **four mobile mediated interaction modes**:
  - **Pointing** – the user points his camera phone to a bi-dimensional visual marker and obtains all the graffitis associated with it
  - **Touching** – the user touches an RFID tag with a mobile RFID reader bound to a mobile through Bluetooth (or NFC mobile) and obtains the relevant graffitis
  - **Location-aware** – mobiles equipped with a GPS in outdoor environments obtain the relevant nearby graffitis in a certain location range
  - **Proximity-aware** –the device retrieves all the graffitis published in nearby accessible Bluetooth servers when it is in Bluetooth range

# Sentient Graffiti & NFC

- **Near-Field-Communication (NFC)** is a combination of contact-less identification and interconnection technologies enabling wireless short-range communication between devices and smart objects.
  - Range about 20 cm, 13.56 MHz band
  - Enables 3 types of services:
    - **Service initiation and configuration**
    - P2P (peer to peer) data sharing and communication
    - Payment and ticketing
  - **Key enabler for the upcoming Internet of Things**



- **How does Sentient Graffiti leverage from NFC?**
  - **Touching interaction through NFC**
    - MIDP 2.0 Push Registry and NFC are combined to prevent users from starting mobile client before interacting with RFID augmented objects
  - **Proximity-aware interaction through NFC**
    - Nokia NFC 6131 and Bluetooth SG servers are bound by simply touching an RFID tag with a mobile

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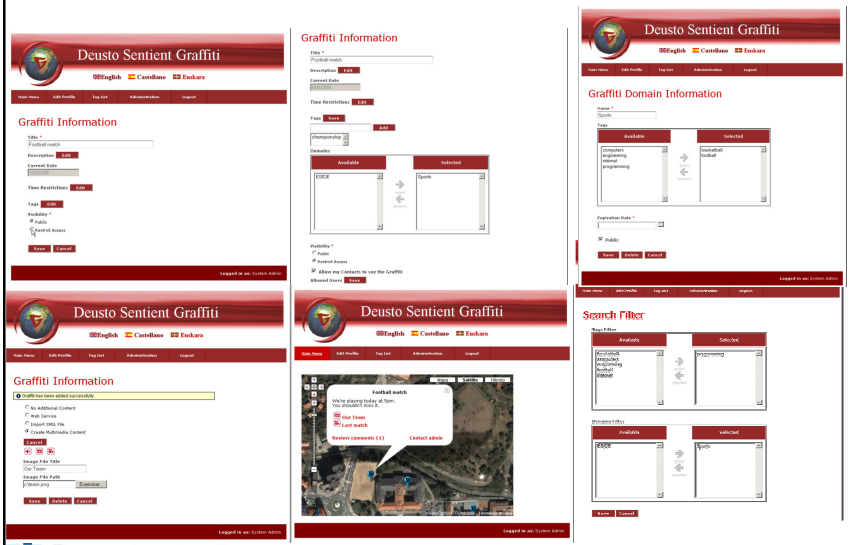
# Sentient Graffiti Web Client

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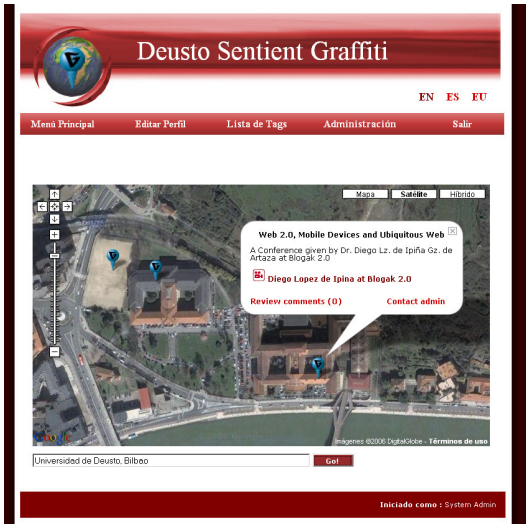
# Sentient Graffiti Web Client

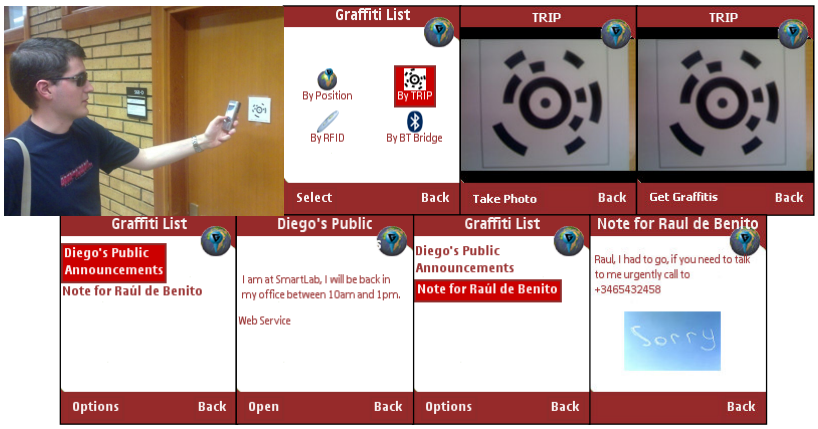





# Application Types & Examples

- **Available prototypes:**
  - **Marker-associated Graffitis**: Virtual Notice Board
    - Public/private graffitis, expiration time, remote review, user participation
  - **Bluetooth-range Graffitis**: University Services Booth
    - Individual, group and private graffitis, tag-based (OPEN_DAY)
  - **Location-range Graffitis**: Bus Alerter
    - Third-party SG clientes
- **Other possible applications:**
  - City Tour: `Bilbao_tourism` Graffiti Domain
  - Conference: `AmI-07` → feedback, expiration after conference
  - Publicity: Graffiti expiration after N times
  - Friend meetings
  - Disco/stadium/office blogs

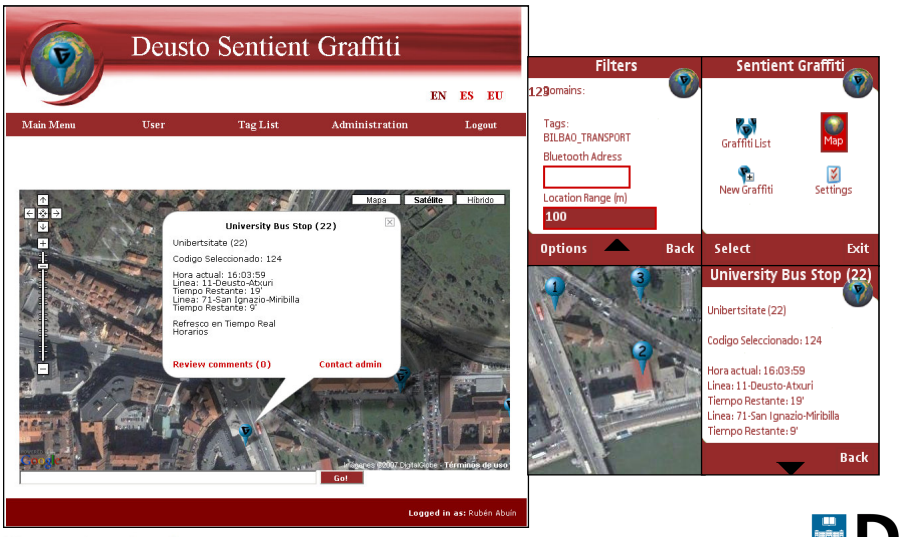
# Marker-associated Graffitis: Virtual Notice Board






# Bluetooth-range Graffitis: University Booth

# Location-Range Graffitis: Bus Alerter






# Third-Party Mobile Application using Sentient Graffiti HTTP API

# Conclusions

- Sentient Graffiti is a **platform which promotes a more extensive adoption of AmI in global environments** (cities, cars, hospitals, homes) without imposing deployment and maintenance hassles, offering the following features:
  - **Context-aware** to filter and select most appropriate smart objects' content and services for users
  - Encourages the **creation of third party context-aware mash-ups** through its HTTP API
  - Based on **standard web technologies** lowering its adoption barrier
  - Enables **multi-modal interaction between users and environment** through generic mobile client

- **Further work:**
  - Evaluate SG in a mobile social software community
  - Adopt Semantic Web context modeling



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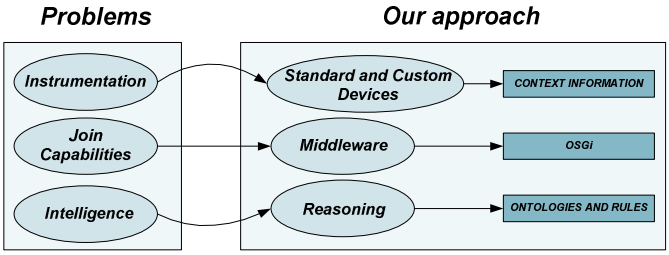
# Iteration 4: Dealing with the heterogeneity, dynamic behaviour of existing instrumented environments, using available standards

**SmartLab: Semantically Dynamic Infrastructure for Intelligent Environments**

# Iteration 4: Dealing with the heterogeneity, dynamic behaviour of existing instrumented environments

- **Middleware support for intelligent environment provision:**
  - Monitoring context
  - Determine the user activity and high level context
  - Adapt the environment to the user

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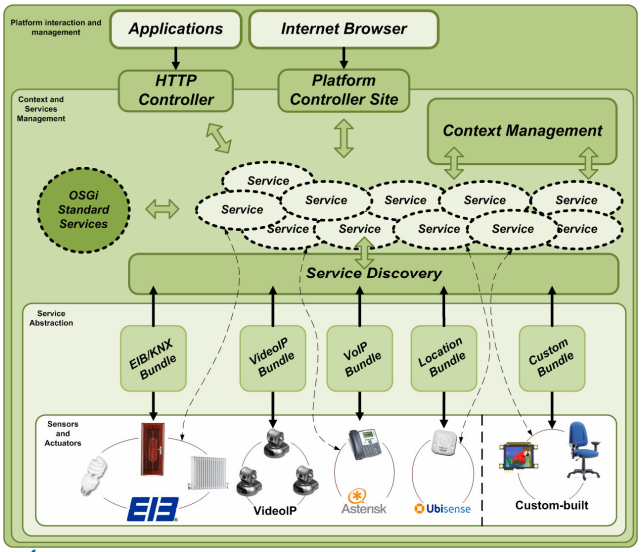
# SmartLab Architecture

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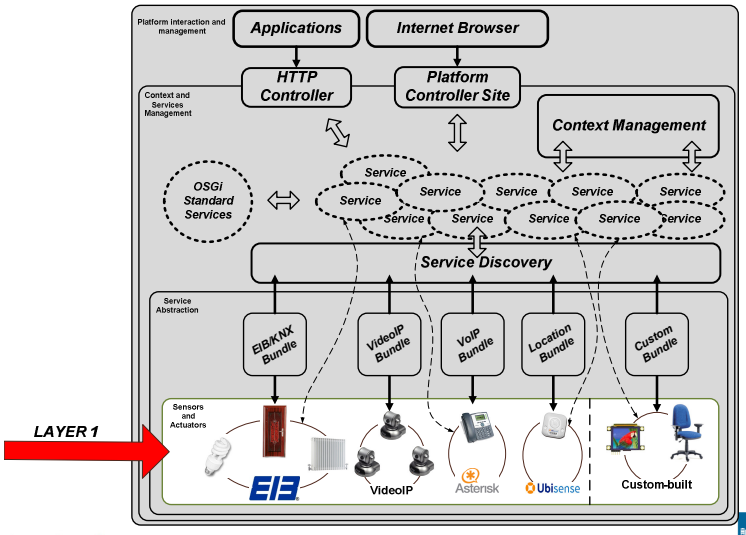
# Layer 1: Sensors and Actuators

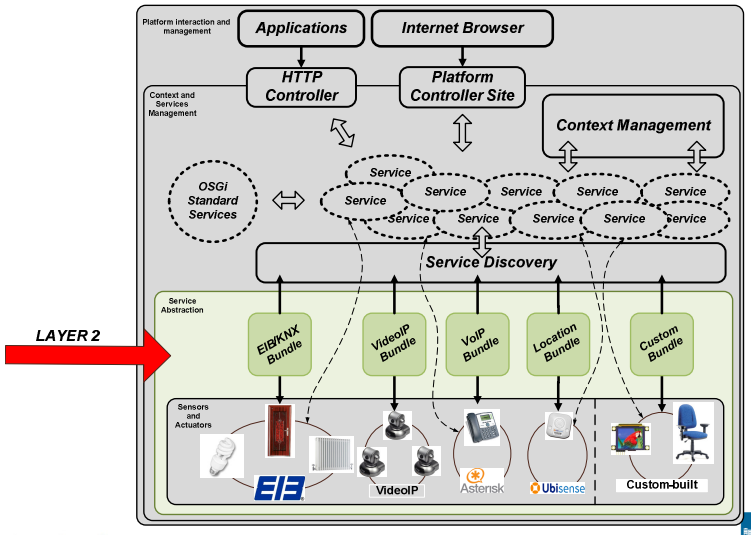





# Layer 1: Sensors and Actuators

- Device assortment common in intelligent environments:
  - EIB/KNX
  - Asterisk VoIP
  - VideoIP Cameras
  - Indoor Location System (Ubisense)
  - People wandering devices (Gerontek)
  - Custom-built Devices (WSN)
    - Chair
    - Display bracelet
    - Container
- Every system has its own control interface
  - How do we interconnect all of them?

# Layer 2: Service Abstraction

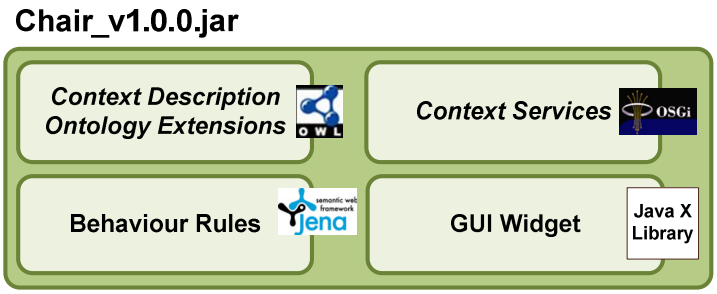





# Layer 2: Service Abstraction

- Every device or system provides certain functionalities that we must transform into software services inside OSGi.
  - **Each device must *provide* a control *bundle* acting as a proxy inside the OSGi platform.**
  - All the native services of each device are wrapped in OSGi services.
    - *EIB/KNX Bus → BinaryLight, DimmableLight, Alarm, DoorSensor*
    - *VideoIP HTTP Cameras → CameraController*
    - *VoiceIP Asterisk Server → AsteriskController*
    - *Gerontek Server → GerontekController*
    - *Ubisense COM Server → UbisenseController*
    - *Custom-Built Devices → SmartChair, SmartContainer*

# Layer 2: Semantically-enhanced OSGi Bundles

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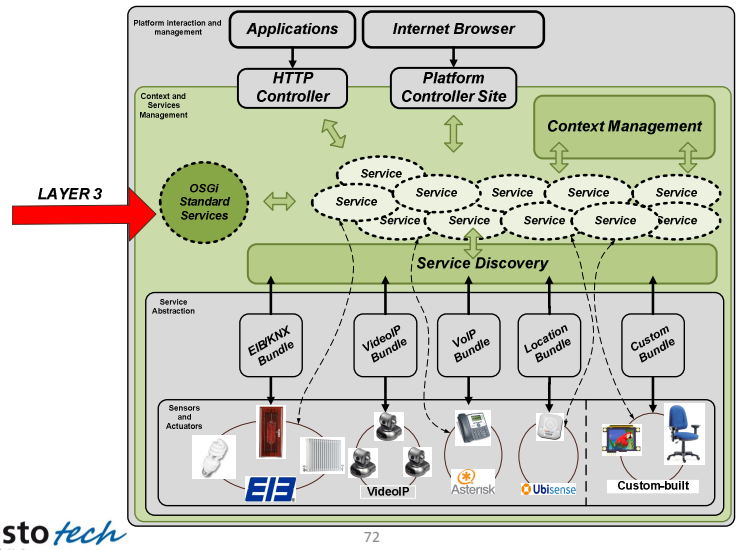
# Layer 3: Service and Context Management

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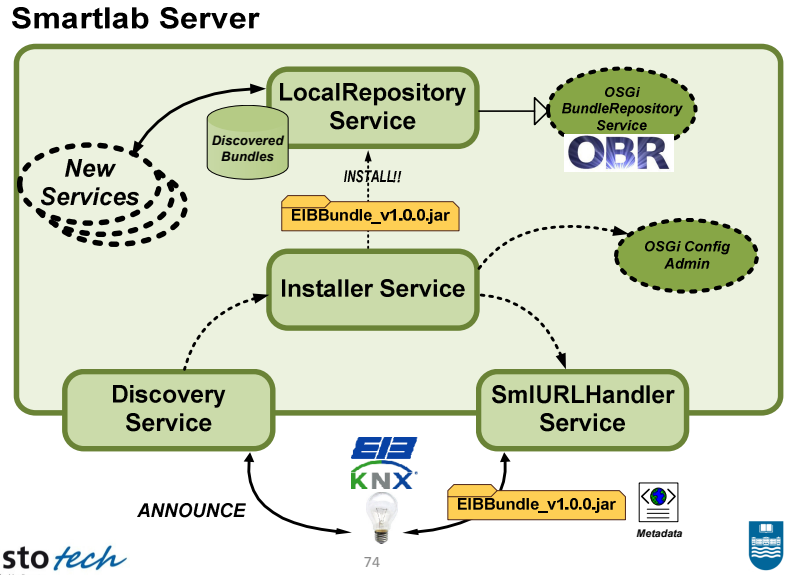
# Layer 3: Service Management

- **Discovery service**
  - Simple multicast protocol to obtain the bundles automatically.
- **Installer service**
  - Decides whether the bundle should be installed or not.
- **Local Repository service**
  - Extends the OBR service to provide a local cache for the discovered bundles.



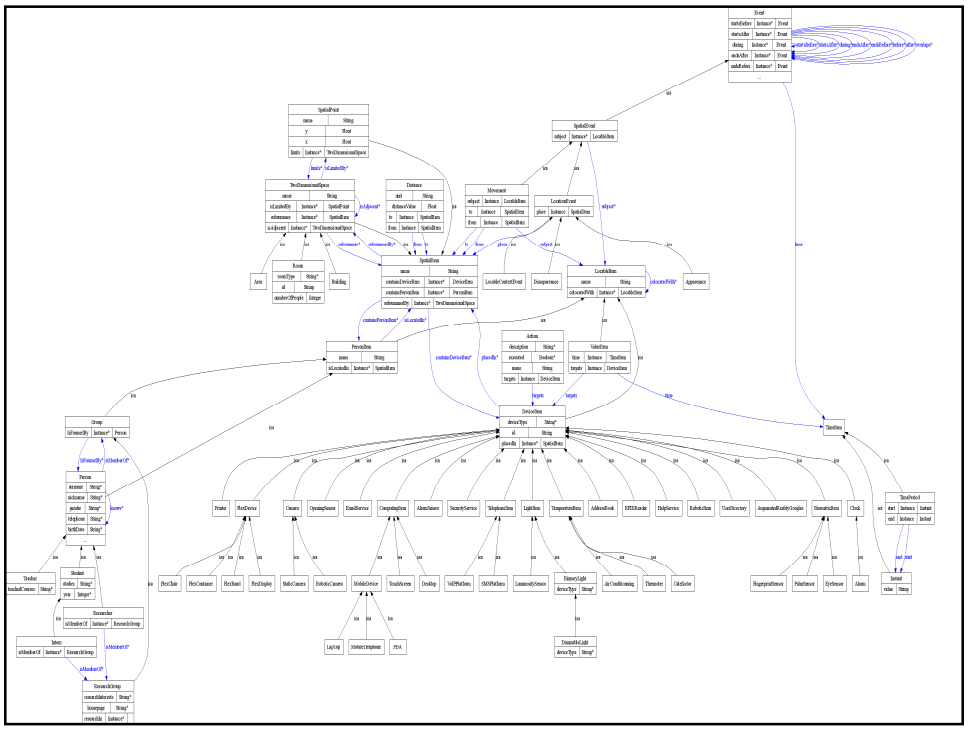
# Example: Service Management



# Layer 3: Context Management

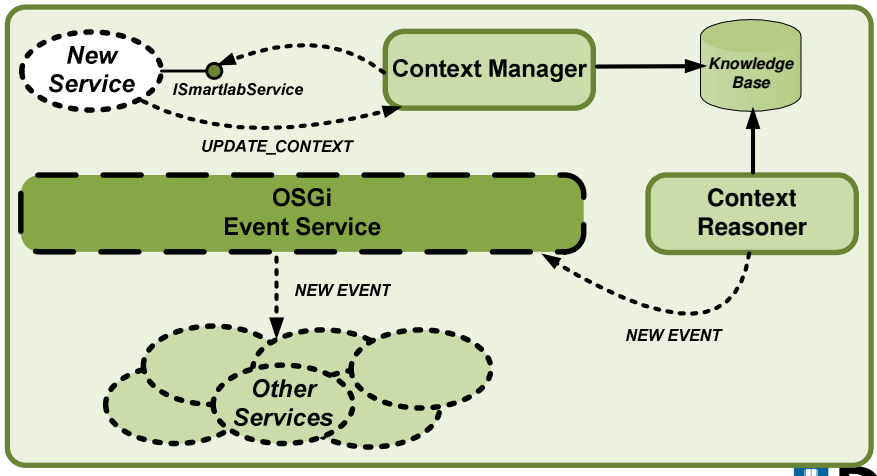
- Context information modelled with an ontology
  - Base core
  - Time and space relations
  - Events
- **New services might extend the knowledge base**
  - **Classes and instances**
  - **Behaviour rules**
- Converts inferred information into OSGi events to which the different services can register.
  - React accordingly to specific events.





# Example: Context Management

## Smartlab Server






# Context Management

- Two knowledge generation methods in SmartLab:
  - **Ontological reasoning**
    - Makes use of RDF (rdf:domain), RFS (rdfs:subPropertyOf) and OWL (owl:TransitiveProperty) predicates
    - Allows to infer implicit knowledge
  - **Rule-based reasoning**
    - Allows defining relationship among entities in ontology
- Three types of inference:
  - **Semantic rules** – enable making ontological reasoning based on RDF and OWL theoretical models
  - **Knowledge extraction rules** – extract new knowledge from ontology's implicit one
  - **Event-inferring rules** – generate aggregated events from the context in the knowledge base

# Event-inferring Rule Example

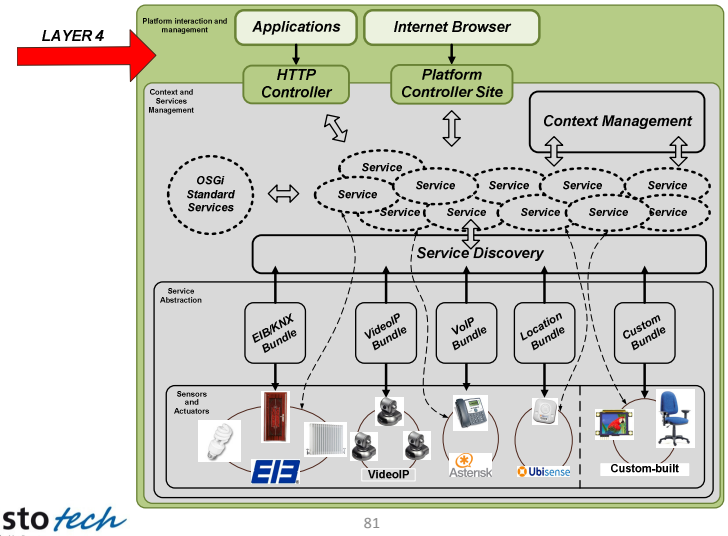
```
[EVENT-Meeting:
(?meetingArea rdf:type
   <http://deusto.es/smartlab.owl#MeetingArea>),
(?meetingArea <http://deusto.es/smartlab.owl#containsPersonItem>
   ?p1),
(?meetingArea <http://deusto.es/smartlab.owl#containsPersonItem>
   ?p2),
 (?p1 <http://deusto.es/smartlab.owl#name> ?name1),
 (?p2 <http://deusto.es/smartlab.owl#name> ?name2),
notEqual(?name1, ?name2),
makeTemp(?meetingEvent)
->
(?meetingEvent
   rdf:type<http://deusto.es/smartlab.owl#LocableMeetingEvent>),
(?meetingEvent <http://deusto.es/smartlab.owl#place> ?meetingArea),
(?meetingEvent <http://deusto.es/smartlab.owl#name> ?name1),
(?meetingEvent <http://deusto.es/smartlab.owl#name> ?name2)
]
```



# Performance Results

| | 5 Devices | 10 Devices | 20 Devices | 50 Devices | 100 Devices |
|---|---|---|---|---|---|
| **Average Inference Time Jena (ms)** | 1854 | 2620 | 3671 | 9944 | 27827 |
| **Average Inference Time SWRLTab+Jess (ms)** | 922 | 1063 | 1391 | 3953 | 12844 |
| **Average triples Jena** | 866 | 965 | 1164 | 1656 | 2329 |
| **Average triples SWRLTab+Jess** | 3259 | 3464 | 3874 | 5104 | 7154 |
| **Average classes Jena** | 112 | 123 | 143 | 203 | 303 |
| **Average classes SWRLTab+Jess** | 127 | 127 | 127 | 127 | 127 |
| **Average individuals Jena** | 66 | 84 | 121 | 194 | 269 |
| **Average individuals SWRLTab+Jess** | 83 | 103 | 143 | 263 | 463 |
| **Average rules Jena & SWRLTab+Jess** | 29 | 35 | 45 | 75 | 125 |

# Layer 4: Service programmability, Management and Interaction

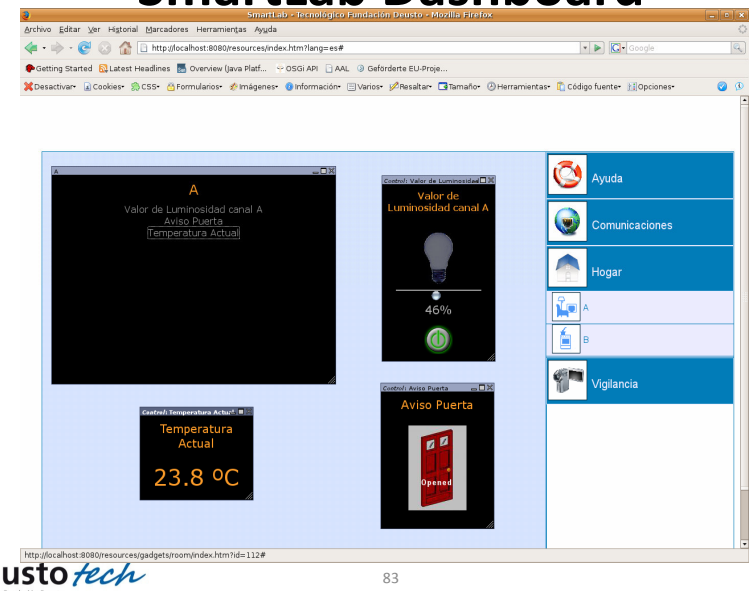





# Layer 4: Service programmability, Management and Interaction

- **Implicit interaction**
  - Context management generates events and some services are invoked automatically.
- **Explicit interaction**
  - HTTP interface inside OSGi to invoke any service that exposes remote methods
  - Dashboard-like GUI based on widgets (javascript cross-browser library) that are loaded when the services are active.

# SmartLab Dashboard






# Conclusions

- **Several extensions to the OSGi framework to support intelligent and evolvable environment instrumentation** have been presented:
  - Devices or environment services expose a special **semantic control bundle**.
  - OSGi bundles are discovered and act as a proxy providing semantic enhanced services.
  - These services populate the system with new context information in order to infer new knowledge and generate events.
  - Different services can register to receive context events and react to them accordingly.
  - The platform knowledge has been modelled using ontologies and rules that can be extended and updated dynamically.
  - For explicit interaction we have a HTTP interface or a Dashboard GUI based on widgets that can be used to interact with the platform.
  - **Semantic reasoning is powerful but costly computationally!!**

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# Iteration 5: Focus on a more specific application domain: AAL

## ZAINGUNE: Infrastructural Support for Ambient Assisted Living



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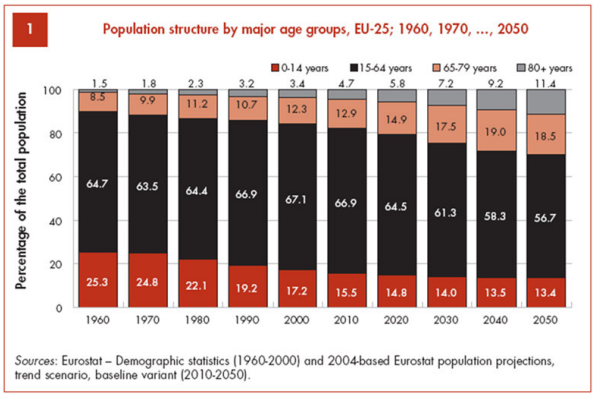
# Iteration 5: Focus on a more specific application domain: AAL

- Some facts:
  - **By 2020, 25%** of the EU's population will be **over 65**
  - **Spending** on pensions, health and long-term care is expected **to increase by 4-8% of GDP in coming decades**
    - Total expenditures tripling by 2050
  - **Older Europeans are important consumers** with a wealth over €3000 billion
- **Ambient Assisted Living (AAL)** is a European Union initiative to address the needs of the ageing European population
  - Elderly people should be able of living longer in their preferred environments, to enhance the quality of their lives
  - Costs for society and public health systems should be reduced
    - **http://www.aal-europe.eu/**
- **To make AAL reality** → important to devise new easily-deployable middleware and hardware infrastructure

# Motivation






# The ZAINGUNE Project

- **Aims to provide the software/hardware infrastructure (platform) required to easily deploy assistive services for elderly people @home**
  - **http://www.tecnologico.deusto.es/projects/zaingune**
- **HOW?**
  - With an **OSGi gateway powered by a rule-based reasoning engine** which allows the coordination and cooperation of the home sensing and actuation devices

- Consortium composed by:

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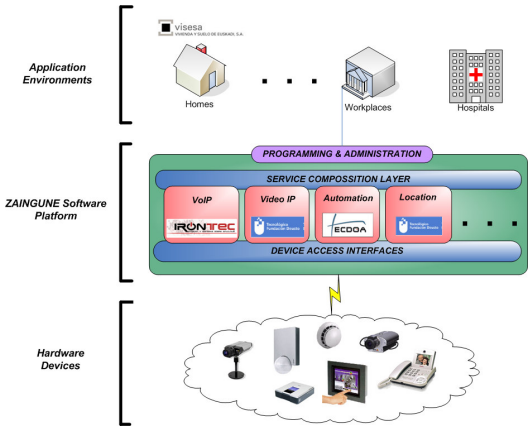
Internet y Sistemas sobre GNU/Linux

# ZAINGUNE Goals

- **Heterogeneous device support:**
  - Agotek's gerontek, Asterisk IP phones, IP cameras, KNX-EIB devices, …
- Model **assistive environments** as a set of **cooperating services**
- **Programmability through** a **SOA**-based approach.
- **Apply natural explicit interaction mechanisms**:
  - Easy to use gadget-based and secure front-end, phone-mediated interaction, …



# ZAINGUNE Multi-layered Architecture



# Multi-layered Architecture

1. The **hardware device layer** is composed of the sensors and actuators which populate an environment
2. The **software platform layer** transforms the functionality provided by the devices managed by Layer 1 into software services (**bundles**) which can be combined to give place to more advanced services
   - Every device within an AAL environment (home, residence, hospital) is encapsulated as a bundle or execution unit within our OSGi environment.
   - It includes two **core bundles**:
     - **ZainguneController** – core component of ZAINGUNE server, manages and controls access to the components (OSGi bundles) supported by ZAINGUNE.
     - **ZainguneServlet** – behaves as an **Web Service/OSGi gateway** exporting the OSGi bundle functionality through Web Services and **generates web front-ends** (based on JavaScript X library) of every bundle
3. The **applications environment layer** includes all the possible application scenarios for the ZAINGUNE infrastructure
   - **Public housing flat for disabled or elderly people**, hospitals, residences and so on



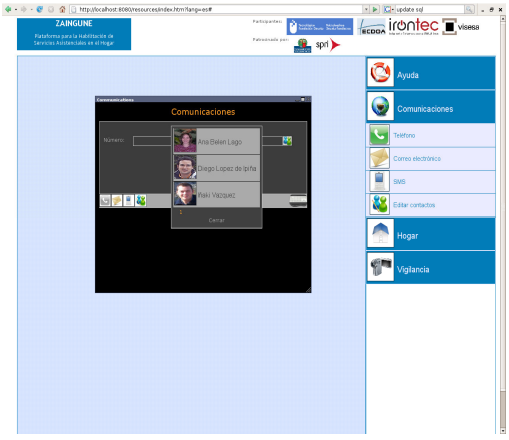
# Multi-modal Environment Interaction

- **Web gadget-based interaction** – an easy to use web gadget-based environment controller divided into the following sections:
  - **Help** – single button to request help
  - **Communications** – call by photo, email and SMS
  - **Home control** – control of every device by container
  - **Surveillance** – both local and remote IP camera control
- **Phone touchpad- and voice-based interaction** – the integration of Asterisk in ZAINGUNE provides:
  - feedback through phone speakers,
  - house control through keystrokes and
  - voice commands
- **Alert bracelet-based interaction** – special purpose device designed for assistance seeking and alert notification

# Multi-modal Environment Interaction




# Multi-modal Environment Interaction



# ZAINGUNE Alert Bracelet

- A **custom-built device combining** an **organic screen** (µOLED-96-G1 of 4D Systems) with a **WSN mote** based on Mica2DOT capable of displaying messages broadcasted by nearby motes.
- Every inhabitant may carry an alert bracelet for:
  - **Assistance seeking**
  - **Alert notification**
- A future work option is to add living signal monitoring sensors (e.g. Nonin 4100 Avant Module) to such device

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# Intelligence through Rule-Based Reasoning

- The adoption of a **rule-based engine** in ZAINGUNE offers two main advantages:
  - **Decouples environment configuration from programmability**
  - **Enables environment-initiated proactive reactions**
- **Environment intelligence is encapsulated as a set of rules which trigger when certain sensorial situations are matched**
  - LHS represents sensing conditions whilst RHS depicts actions to be undertaken when the LHS situations are matched
- This rule-based paradigm is employed to configure the reactive behaviour of a ZAINGUNE-controlled environment:
  - efficient management of energy resources
  - security at home or
  - danger situation prevention

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# Rule-reasoning Example

```
rule "Flooding Event"
   no-loop true
   activation-group "eib"
   salience 10
   when
      event: ZainguneEvent()
      houseInfo: ZainguneHouseInfo()
      eventSender: EventSender()
      eval(event.getTopic().equals("es/deusto/tecnologico/osgi/eventadmin/eib/VALUE_CHANGE"))
      eval(houseInfo.checkDeviceType((String)event.getProperty("name"), "FloodingSensor"))
      eval("On".equals((String)event.getProperty("newValue")))
   then
      String topic = "es/deusto/tecnologico/zaingune/emergency/send";
      Hashtable<String, String> properties = new Hashtable<String, String>();
      ZainguneDeviceInfo deviceInfo =
    houseInfo.getDeviceInfoByName((String)event.getProperty("name"));
      ZainguneRoomInfo roomInfo = houseInfo.getDevicesRoom(deviceInfo.getName());
      properties.put("location", roomInfo.getName());
      properties.put("emergency_type","flooding");
      properties.put("message", "Flooding in room " + roomInfo.getName());
      Event outputEvent = createEvent(topic,properties);
      eventSender.sendEvent(outputEvent);
      retract(event);
end
```



# Conclusions

- ZAINGUNE provides several **easily-deployable ICT infrastructure contributions for their progressive adoption** at elderly people's homes
- Our **main outcome** is an **OSGi platform powered by a rule-based reasoning engine which integrates** a **KNX/EIB** automation bus, **VoIP** and **VideoIP** infrastructure to configure more aware and reactive homes.
- An **assortment of multi-modal explicit interaction mechanisms** to request services from the environment have been shown:
  - Touch screen-based web gadget-based dashboard
  - An alert bracelet or
  - VoIP phone-mediated interaction

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# Review of currently active Research Activities

## Mobile Prosumer, Personal Mobile Sensing, Embedded Service Infrastructure, AAL Devices



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# Prosumer Concept: mIO!

- **mIO!**: personal, 'm': mobile, 'IO': input – output (consumer – producer)'!': immediate
- mIO! aims to develop technologies which help providing ubiquitous services within an intelligent environment adjusted to each user and his context
  - The mobile will be used as an interface both with services offered by companies as well as micro-services created and provided on the move, directly by users themselves
- URL: http://www.cenitmio.es

# mIO!: Summary

***Ambient Intelligence** Interaction*
**Context management and service discovery**, taking into account user preferences
Personalization: services adaptation and filtering

*New Mobility **User Experience***
New **interfaces**, exploring access technologies to use devices on the mobile phone or near to it. Real and virtual information mixing

***User Generated Mobile** Services*
User generated services "on the go" (**Prosumer** paradigm): light services and mashups created easily on the mobile
**Mobile Open APIs:** The mobile as main door to services which help the user

***Real Time Enterprise** on the move*
Mobile Context Services for **Enterprises/Governmental Org.**
Cities and Companies as intelligent environments

***Communication and Connectivity** Technologies*
Prospection of the underlying communication and connectivity technologies

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# Prosumer Concept: MUGGES

- **MUGGES: Mobile User Generated Geo Services**
  - A new approach for exploiting innovative GNSS-based mobile LBS applications, personal, social or professional: the mobile prosumer concept.
  - A new location model combining GNSS-based positioning and user-provided social positioning in order to support more significant location-based services.
  - A new business model, with the "mobile as the service platform", the "user adds value" and the "very long tail" as the three main pillars.
  - A new GNSS-based application paradigm driving to a new service infrastructure and platform tools.
- URL: http://www.mugges-fp7.org

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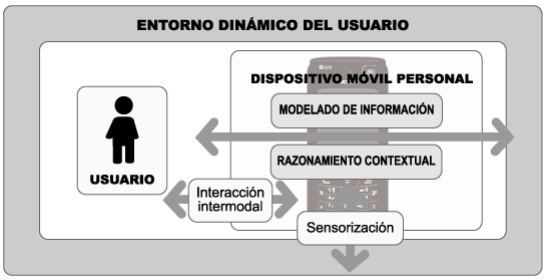
# Personal Smart Sensing Mobile Devices: PIRAmIDE

- PIRAmIDE aims to transform our mobile devices into a 6th sense which aids and mediates on our behalf easing and improving our daily interactions with everyday objects and locations
  - An important aspect is to address the needs of visually impaired
- URL: http://www.piramidepse.com

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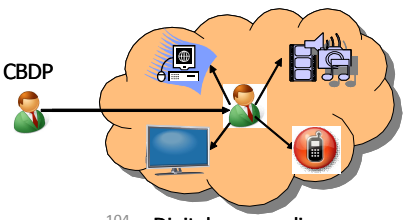
# CBDP: Context-Based Digital Personality

- Creation of a context-based digital personally (DP) which acts as an enabling proxy between digital surroundings and the final user.
  - DPs will benefit from mobile technologies for context-creation, maintenance and usage; and from semantic technologies for formal decisions and verifications.
  - Usage of DP will simplify everyday interaction between users and their surrounding digital environments.
- URL: http://projects.celtic-initiative.org/cbdp/

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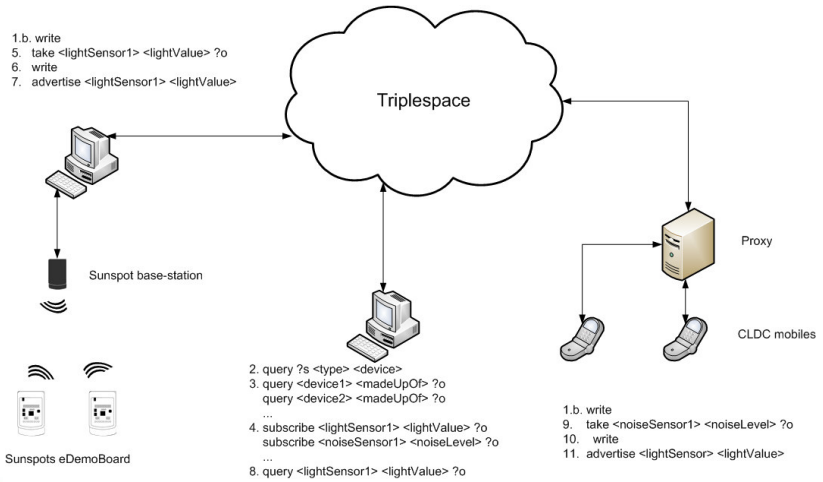
# Service Infrastructure for Embedded Wireless Devices: ISMED

- Aims to provide the required software infrastructure to develop and deploy cooperative intelligent environments equipped by heterogeneous wireless embedded devices
  - Adopts **Triple Space Computing** for the communication/coordination/cooperation needs of the project



# Service Infrastructure for Embedded Wireless Devices: ISMED



# AAL Devices

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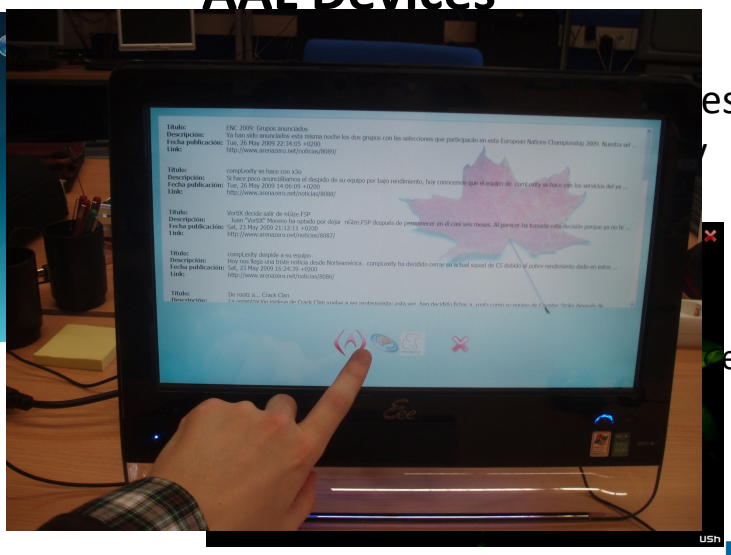



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# Dealing with the need for Infrastructural Support in Ambient Intelligence

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**Dr. Diego Lz-de-Ipiña Glz-de-Artaza**
Faculty of Engineering (ESIDE), University of Deusto, Bilbao
dipina@eside.deusto.es
http://www.morelab.deusto.es
http://www.smartlab.deusto.es
aginaspersonales.deusto.es/dipina

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