Reasoning about Context in Ambient Intelligence Environments

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Overview

- **AmI @ FORTH**
- Experience with Context Reasoning
- AI for AmI

Introduction

- The vision of Ambient Intelligence assumes a shift in computing towards a multiplicity of communicating devices disappearing into the background, providing an intelligent environment, where the emphasis is on the human factor.
- Realizing this vision requires the integration of expertise from a multitude of disciplines.
- Despite the rapid advancement of these fields, existing approaches have difficulty in meeting the real-world challenges imposed by developing ambient information systems.

Context in AmI

- Aim of AmI systems
  - right information to the right users, at the right time, in the right place, and on the right device
  - Requirement:
    - thorough knowledge and understanding of context

- Context in Ambient Intelligence
  - ".. any information that can be used to characterize the situation of an entity. An entity is a person, place or object that is considered relevant to the interaction between a user and application, including the user and application themselves.." [Dey and Abowd, 1999]

Activities

- Creation of small-scale experimental AmI spaces
  - AmI Sandbox
  - Smart Office
- Building a new facility for R&D in AmI technologies
- R&D through competitive funded projects at national and European level

AmI Sandbox (1/3)

- An experimental space within ICS-FORTH
  - 6 rooms (~ $100m^2$)
- Installation, testing and integration of a large variety of technologies and applications
- Allows researchers from different domains to bring together and share their know-how and resources

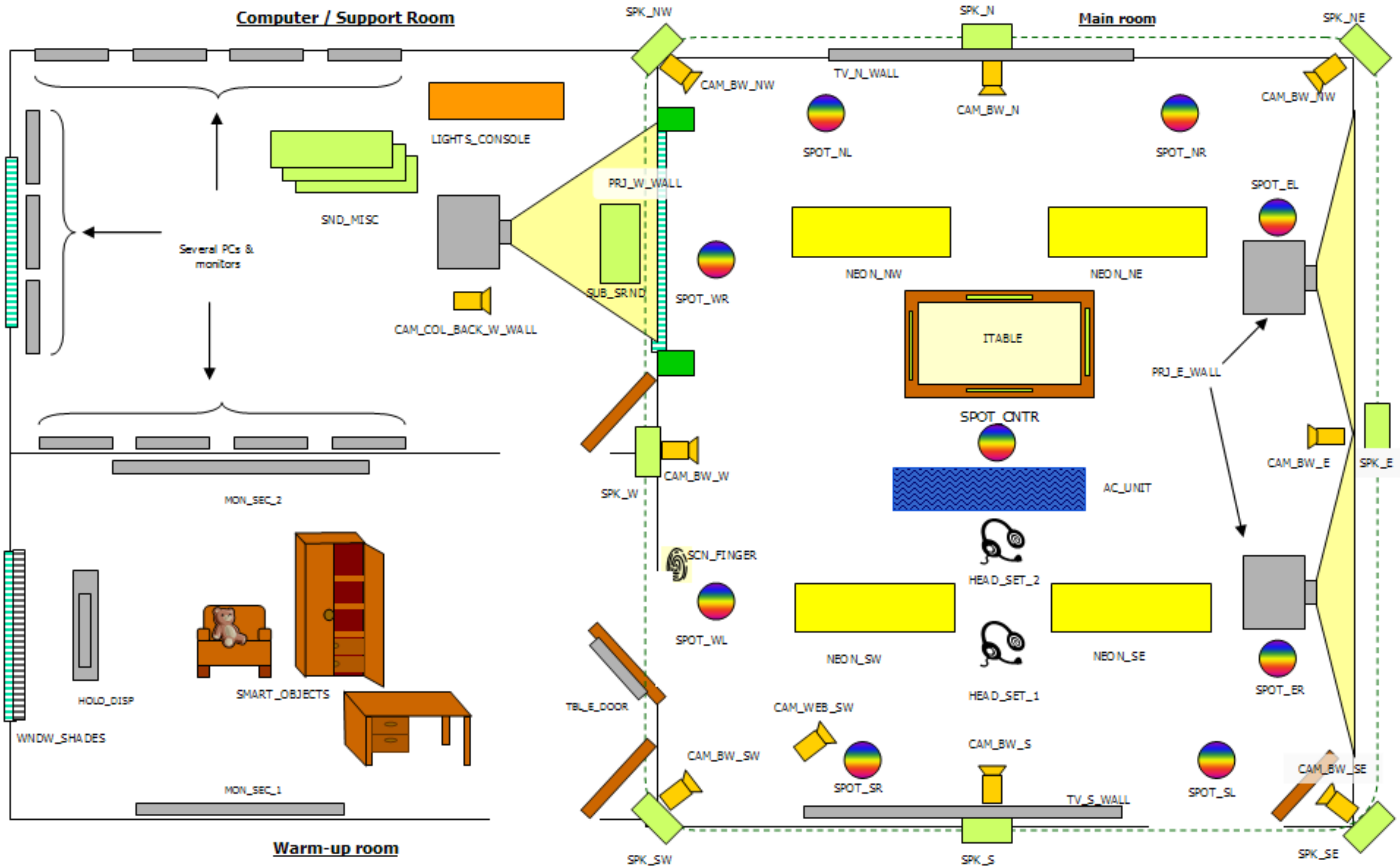
AmI Sandbox (2/3)

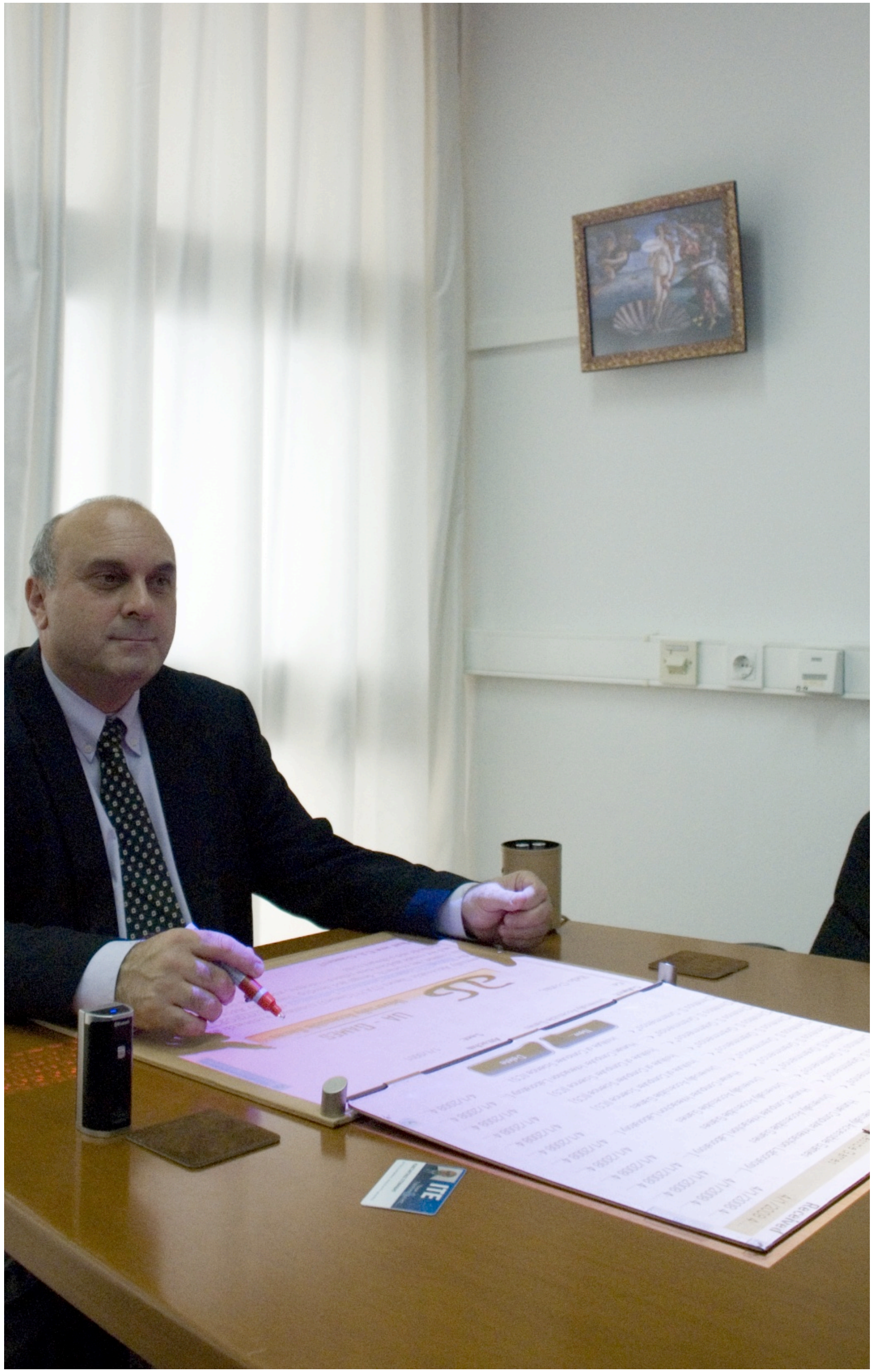
- Main goals
  - Experimentation in a creative, flexible and informal setting
  - Acquisition of hands-on experience
  - 1st step towards the AmI Facility

AmI Sandbox (3/3)

- Installed Technologies
  - Computer vision system, comprising 8 cameras
  - Surround speaker system with 8 speakers
  - Various computer-operated lights (neon, spot lights, floor and desk lamps) using both the DMX and X10 protocols
  - Computer-operated air-condition
  - Various screens and high definition TVs, including touch screens
  - One large front projection screen created by 2 ceiling-mounted short-throw projectors
  - One back projection screen
  - Several sensors (distance, temperature, etc.) and actuators
  - Desktop and mobile RFID readers
  - Interactive table
  - Access control systems (IRIS Scanner, RFID, …)
  - Positioning system through wireless access points
  - Various robotic systems

The AmI Sandbox

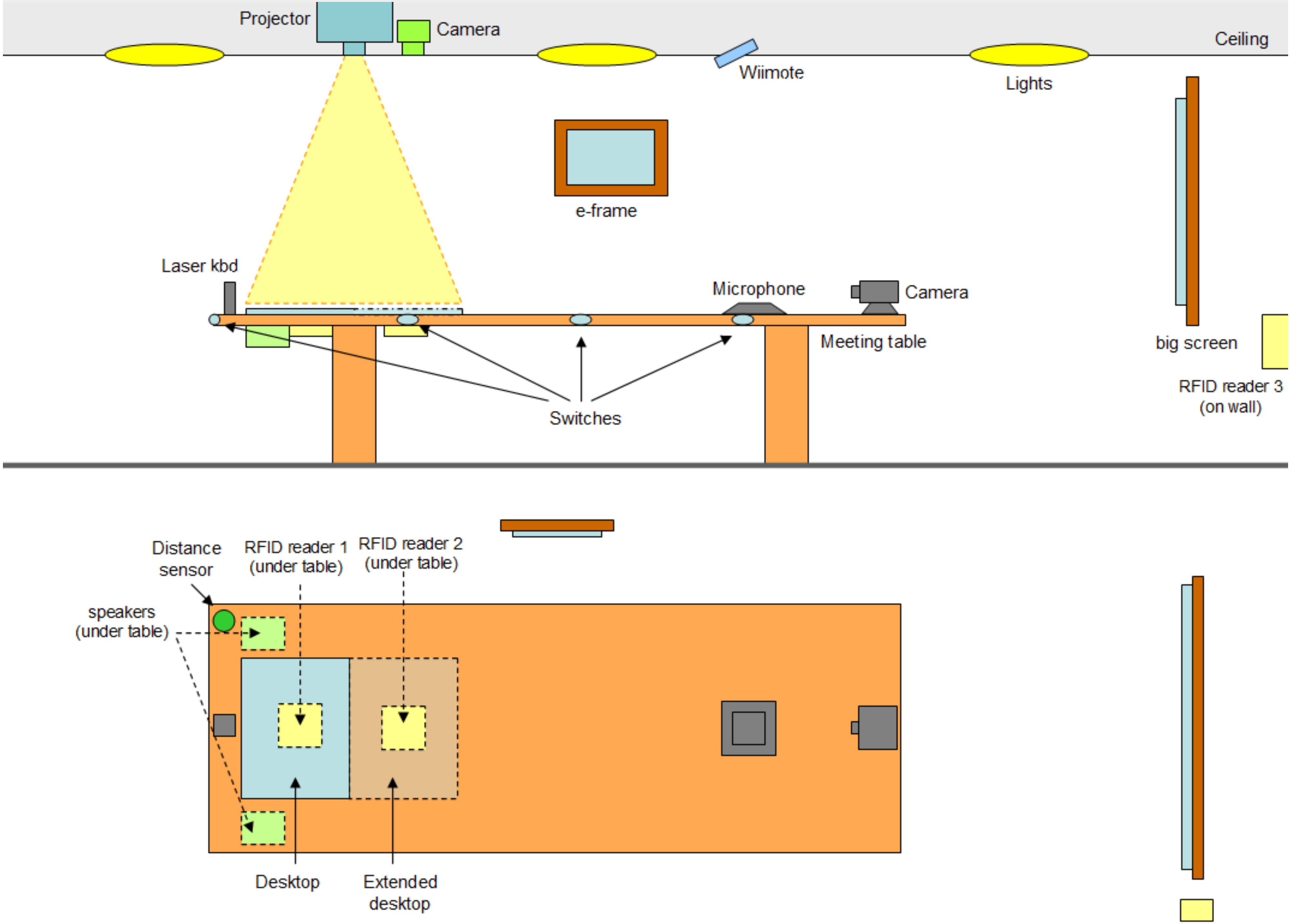




Smart Office

- Augmenting an existing office space with AmI technologies
  - Multiple interconnected displays
    - Large screen
    - e-Desktop
    - e-Frame
  - Smart table
  - Controllable lights
  - Computer vision camera
  - e-pens
  - Distance sensor
  - Laser keyboard

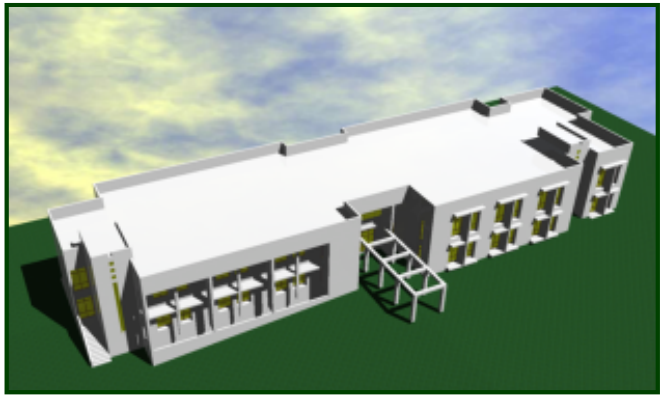
The Smart Office

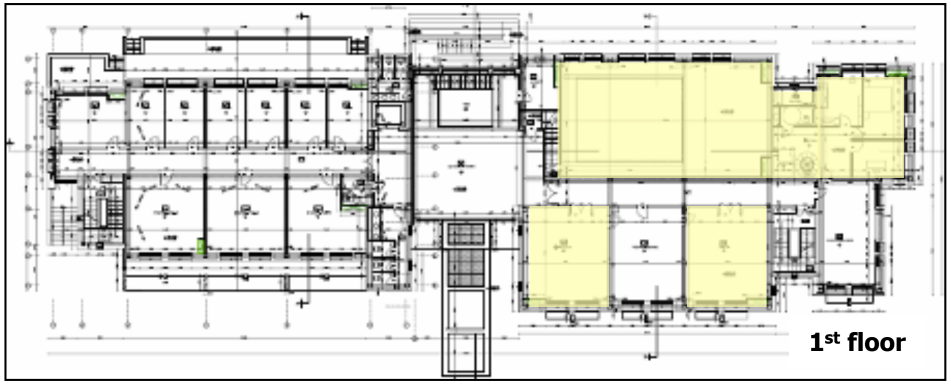


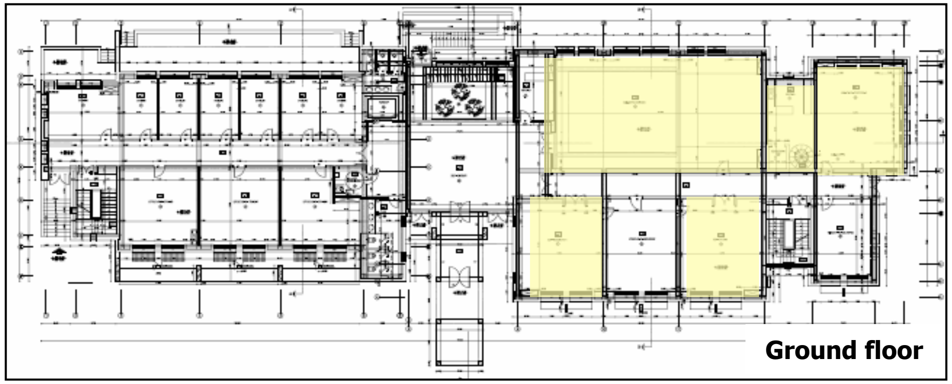
AmI Facility

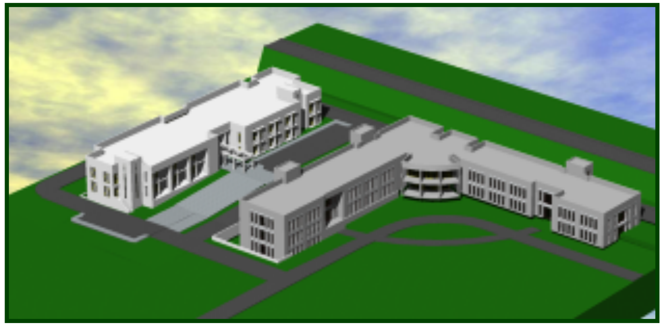
- New building (~ 3.000m^2)
  - Basement, ground floor, 1st floor
- Fully accessible by people with disabilities
- Includes:
  - Simulation spaces
  - Laboratories for R&D in AmI technologies
  - Offices
    - Permanent research staff & visitors

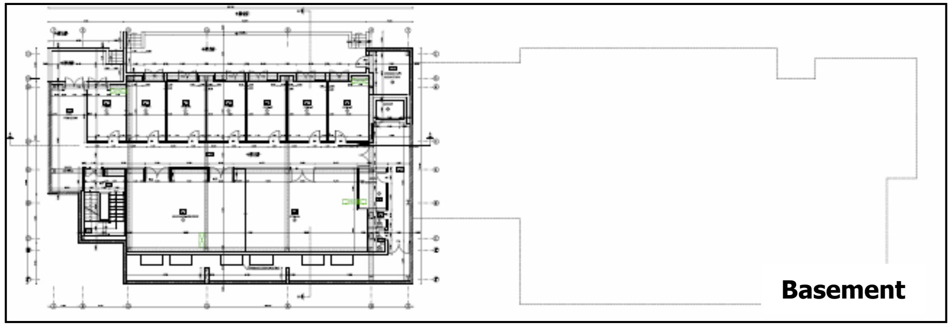
AmI Facility – Blueprints











AmI Facility – Simulation Spaces

Simulated home environment

- 2 floors (staircase + elevator)
  - living room
  - Kitchen
  - house office
  - 2 bedrooms
    - adults & children
  - 2 bathrooms
- Scenarios
  - local, remote and automated home control
  - safety and security
  - health monitoring
  - independent living
  - (tele)working
  - entertainment
- Fully accessible by the elderly & people with disabilities

Components under development

- AmI software and hardware architectures
- Middleware
- Context management and reasoning
- Environment sensing technologies & sensor fusion
- Access control, information and communications security
- Seamless and intuitive user-environment interaction
- Speech recognition and speaker localization
- Computer vision subsystem for multiple user localization and gesture recognition
- Dynamic surround sound playing system
- Environmental control

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Contextual Reasoning in Ambient Intelligence

- Challenges
  - Imperfect nature of the available context information
    - **Unknown, ambiguous, imprecise, erroneous**
  - Special characteristics of ambient environments
    - Agents with different goals, computing and perceptive capabilities, and vocabularies
    - Highly dynamic and open environments
    - Distributed context knowledge
    - Unreliable and restricted wireless communications
- Limitations of current AmI systems
  - No formal model for reasoning with imperfect context
  - Centralized architectures → No support for distributed reasoning

Motivating AmI Scenario

Dr. Amber is located in the ‘RA201’ university classroom reading his e-mails on his laptop. It is Tuesday, the time is 7.50 p.m., and he has just finished with a lecture for course CS566. His context-aware mobile phone receives an incoming call, but it is not in silent mode.

Dr. Amber’s phone is configured to take decisions about whether it should ring in case of incoming calls based on its context and Dr. Amber’s preferences:

- –The phone should ring, unless it is in silent mode or Dr. Amber is busy with some important activity.
- –A lecture at the university is one such important activity.

The mobile phone is not aware of Dr. Amber’s current activity. It attempts to infer the activity using two rules:

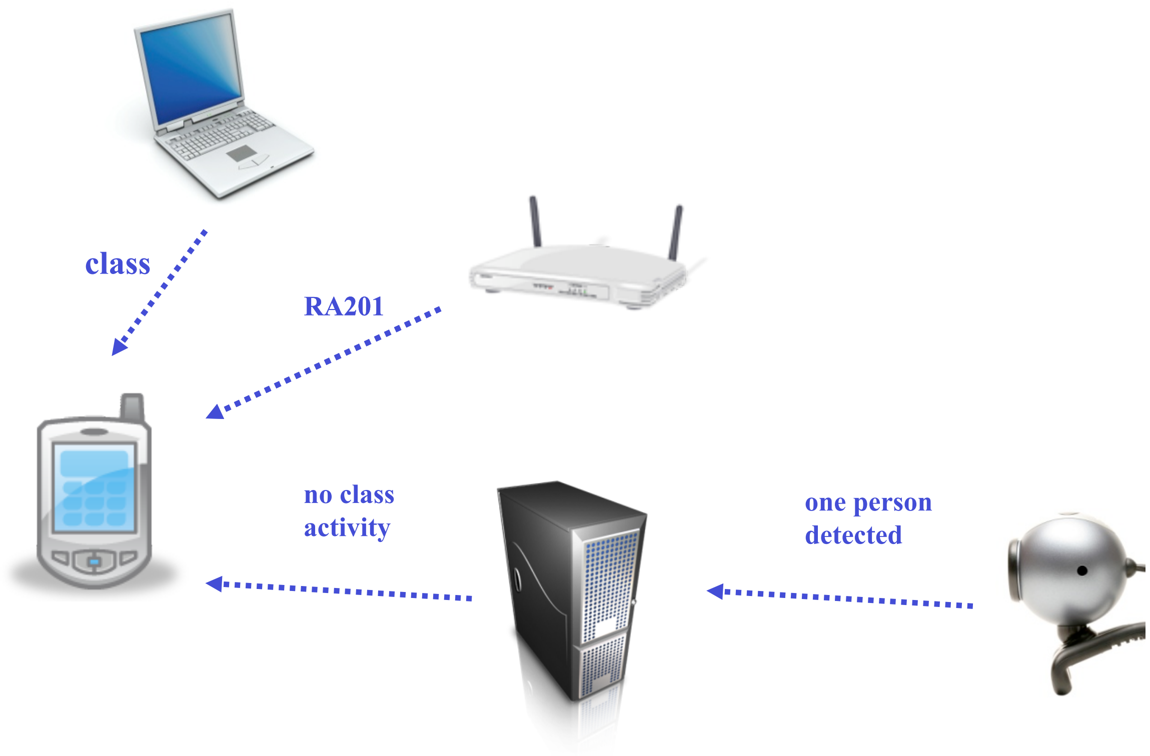
- –If there is a scheduled lecture for a course at this time, and Dr. Amber (actually his mobile phone) is currently located in a classroom, then Dr. Amber is possibly giving a lecture.
- –If Dr. Amber is located in a classroom, but there is no class activity taking place in the classroom, Dr. Amber is rather not giving a lecture.

Motivating AmI Scenario

Information about scheduled events is imported from Dr. Amber’s laptop. According to his calendar, there is a scheduled class event for Tuesdays from 7.00 to 8.00 pm.

The localization service possesses knowledge about Dr. Amber's current position. In this case it 'knows' that Dr. Amber is currently located in 'RA201'.

Motivating AmI Scenario



The classroom manager 'knows' that the classroom projector is off, and imports knowledge about the presence of people in the classroom from an external person detection service; in the specific case the service detects only one person (Dr. Amber) in the classroom. Based on this information, the classroom manager can infer that there is no class activity in the classroom.

Motivating AmI Scenario

Based on the context information imported from the laptop and the localization service the phone infers that Dr. Amber is giving a lecture. The information from the classroom manager leads to a contradictory conclusion.

The knowledge of the classroom manager is considered more accurate than the knowledge of the laptop, so the phone determines that Dr. Amber is not currently giving a lecture, therefore it reaches to the 'ring' decision.

Scenario Characteristics

- Assumptions
  - available communication means (wireless network)
  - each agent aware of the type and quality of imported knowledge
  - each agent has some computing and reasoning capabilities
  - each agent willing to disclose part of its local knowledge
- Challenges
  - context is incomplete, imprecise, ambiguous
  - restricted computing capabilities
  - distinct vocabulary used by each agent
  - light communication load for making quick decisions

Modeling the AmI scenario

- Phone (P_1)
  - Local facts and rules

$$r_{11}^{1}: \rightarrow incoming\_call$$

$$r_{12}^{1}: \rightarrow normal\_mode$$

$$r_{13}^{1}: incoming\_call, normal\_mode, \neg important\_activity \rightarrow ring$$

$$r_{14}^{1}: lecture \rightarrow important\_activity$$

  - Mapping rules

$$r_{15}^{m}: \quad scheduled(CS566)_2, location(RA201)_3 \Rightarrow lecture$$

$$r_{16}^{m}: \quad \neg class\_activity_4 \Rightarrow \neg lecture$$

  - Preference relation

$$T_1 = [P_3, P_4, P_2]$$

P_2 : laptop, P_3 : localization service, P_4 : classroom manager

Modeling the AmI Scenario

- Laptop (P_2)

  $r_{21}^{1}: \rightarrow day(Tuesday)$

  $r_{22}^{1}: \rightarrow time(19.50)$

  $r_{23}^{1}:\ day(Tuesday), time(X), 19.00 < X < 20.00 \rightarrow scheduled(CS566)$

- Localization Service(P_3)

  $r_{41}^{1}: \rightarrow location(RA201)$

- Classroom Manager (P_4)

  $r_{41}^{1}: \rightarrow projector(off)$

  $r_{42}^{m}: \rightarrow detected(X)_5, X<2, projector(off) \Rightarrow \neg\, class\_activity$

- Person Detection Service(P_5)

  $r_{51}^{1}: \rightarrow detected(1)$

Algorithm Characteristics

- Variation of defeasible logic
  - Lightweight NMR
  - Cycle detection
- Argumentation semantics
- Complexity analysis
- Reasoning variants depending on application characteristics
  - E.g. privacy concerns

Running the Scenario

- In the AmI Sandbox
- Using cameras, localization etc. through middleware services
- Running the algorithms on small devices (e.g. mobile phone) in a distributed fashion
- Implementation based on lightweight Prolog system

Approach

- Mobile DR-Prolog
  - Application implemented in J2ME (Java 2 Micro Edition)
  - Runs on Cell Phones & PDAs supporting J2ME (almost all nowadays)
- Defeasible Reasoning Capabilities
  - Integrates foreign prolog interpreter
  - On top of which runs DR-Prolog

Reasoning Engine

- TuPrologME
  - Prolog Interpreter
    - Implemented using Java 2 Micro Edition (J2ME)
    - Lightweight implementation for performance
    - Provides API for application integration
    - http://www.alice.unibo.it/xwiki/bin/view/Tuprolog/TuprologMe
- DR-Prolog
  - Defeasible Reasoning capabilities
  - Using a lighter version of the DR-Prolog metaprogram
    - Written in Prolog & loaded to the TuProlog Engine

Technologies Used

- Interconnection with other devices through:
  - WiFi 802.11b/g
  - Bluetooth
  - Internet Connection (e.g. 3G, GPRS etc.)

- Java sockets use the above connections where available to connect with servers, URLs or other mobile devices implementing the Mobile DR-Prolog Service.

Technologies Used

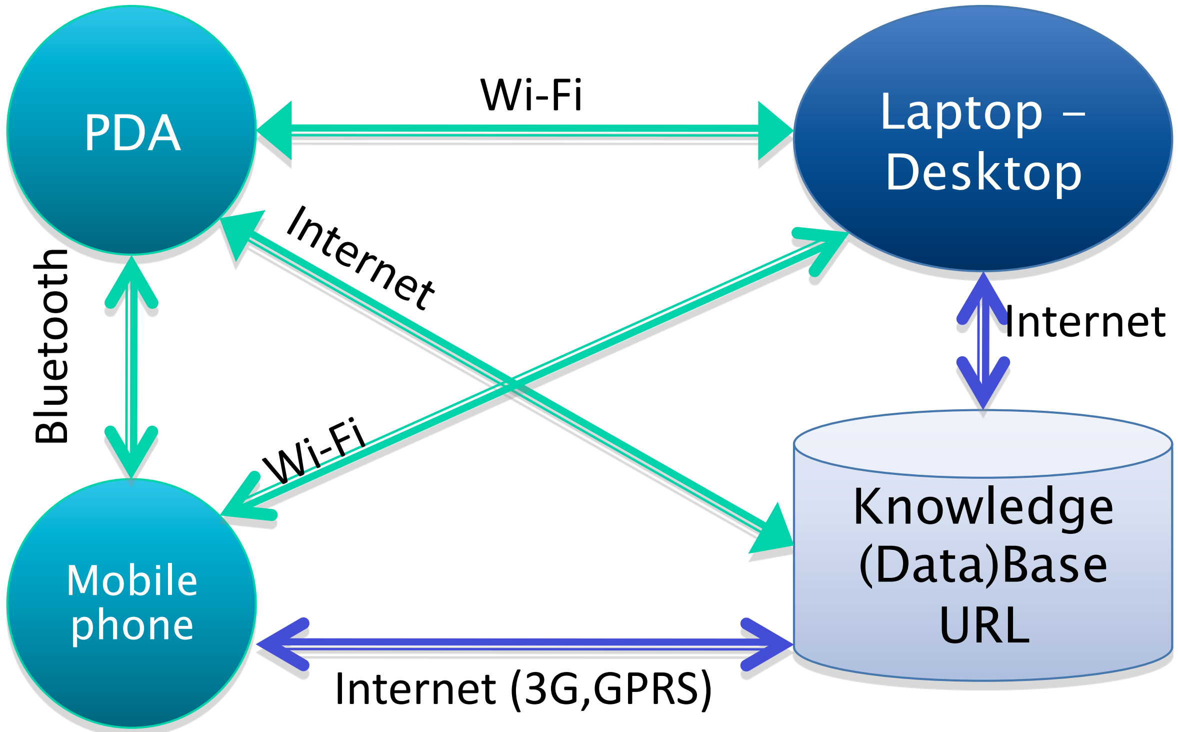
- Bluetooth is important because it provides
  - Discovery of Devices in Proximity
    - Bluetooth range 10-15 meters
    - Up to 100 meters (class A devices)
  - Service Discovery capabilities
    - On the discovered devices
  - Widespread use on almost any electronic device
    - Mobile phones
    - Pda
    - Laptops, desktops
    - Sensors, gps etc.

Technologies Used

- Interconnection with other Devices can be supported easily
  - GPS Receiver
    - Bluetooth enabled
  - Various Sensors
    - Eg RFID
  - Parse messages from these devices to extract knowledge such as
    - coordinates, sensor measurements etc.
  - Conversion into DR-Prolog Facts & loading in KB

Infrastructure

- Circles are mobile devices
- Oval nodes are server computers, eg. Desktop versions of DR-Prolog
- Cylinder nodes are computers or websites with Knowledge Base Data, Theories, etc in DR-Prolog syntax.
- Connections: Message exchange (Blue: queries & their results, Red: facts)
  - Bluetooth, wifi, or through Internet using 3G, GPRS etc.



Social Scenario 1

- User with Bluetooth enabled cellphone passing by a classroom
- Bluetooth Server with lecture and lesson information for that classroom attempts to connect to cellphone
- Cellphone based on profile information either notifies the user or rejects the info
  - E.g. based on course registration etc.
- Based on the above Cellphone should inform user for this announcement

Social Scenario 2

- User with Bluetooth enabled cellphone sitting at ICS lobby; profile entry e.g.
  - hobby(‘tennis’).
  - hobby(X),tournament(X,…) => notifyUser(activity,X…)
  - Lobby computer eg:
    - tournament(‘tennis’,’location’,’date’)...
  - Based on the above
    - Cellphone should inform user for this activity
  - Send the ‘event’ to closeFriends via SMS
    - Based on profile entries of the reciever he will be notified or not! (reasoning on sms data received on certain port from the DR-Prolog mobile application)

Lessons Learnt

- A lot of non-logic related work required
  - Infrastructure
  - Middleware
  - Need for Facility!
- Technical difficultues
  - Scenario with SMS, not calls
- Performance no challenge for small applications
  - Combination with large portions of knowledge from (semantic) Web will be the challenge

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AI for AmI

- Context representation
- Context reasoning
- Privacy
- Planning
- Coordination

Context Representation

- Use semantic web languages to model
  - User profiles
  - Devices
  - Rooms
  - Activities
- Challenge: the usual one
  - tradeoff between expressivity and efficiency

Context Reasoning

- Distributed
- Heterogeneous
  - Different types of information call for different reasoning methods
- Inconsistency and imperfection tolerant
- Dynamic
  - E.g. reasoning about stream input
- Efficient

Privacy

- A major concern!
- Lightweight access control languages
- Blend in other languages/operations
  - E.g. in our context reasoning algorithm

Planning

- Reasoning about action is a well-formed subfield of AI.
  - But the classical planning problem adopted a number of restrictive assumptions to delimit the domain.
- The AmI environment is open and highly dynamic.
- World knowledge in AmI is incomplete.
- Plan generation must preserve a level of uncertainty.
- Exogenous events occur in AmI environments.

Coordination

- A device-rich environment that places users in the center of attention.
- Devices need to coordinate their actions, cooperate in generating plans and collaborate during execution.
- A decentralized self-organizing infrastructure is a non-trivial challenge for the realization of the AmI vision.

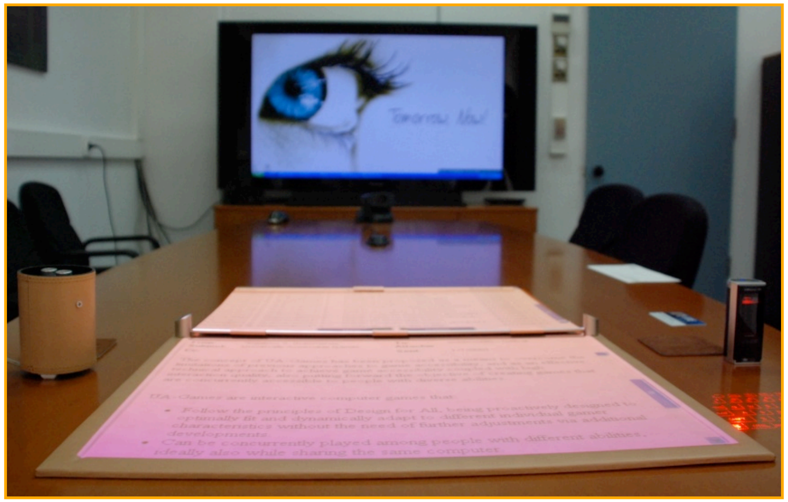
Tomorrow, Now!

ICS-FORTH AmI Programme

APPENDIX

Smart-desktop

- Leather desktop
  - Extendable interface (when opened)
- Input
  - RFID-augmented objects
  - Vision-based left/right switches
  - Distance sensor for up/down motion
  - IR pens (using the Wiimote)
  - Vision-based object position tracking
- Output
  - Projection (on the desktop)
  - 2 speakers
  - Sounds + speech synthesis
- Used for:
  - Logging in the system
  - Running applications

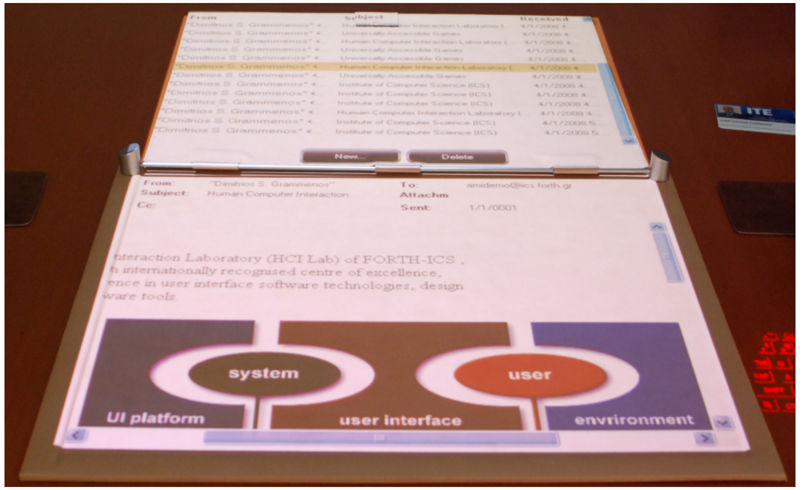


Ambient presentation

- Uses standard PowerPoint slides
- Coordinated slide change
- Replicated drawing on the current slide
- Can adapt to the current state / size of the smart desktop
- Can change the lighting conditions
- Output
  - Multiple screens
    - desktop, large LCD, laptop
- Input
  - Start/stop: RFID tag (ICS-FORTH leaflet)
  - Next / previous: right/left gesture
  - Drawing: IR pen (can change pen color using the pens' RFID tag)

E-mail

- Shows the e-mails of the person who logged in
- Can adapt to the current state / size of the smart desktop
  - Standard size: mails' list
  - Extended: mails' list + selected mail's content
- Output
  - Smart desktop
- Input
  - Start: RFID tag (envelope)
  - Next / previous mail: right/left gesture
  - Use slider: distance sensor
  - Buttons press: IR pen (click)
  - Send predefined e-mail: RFID tag (photo or ID card)

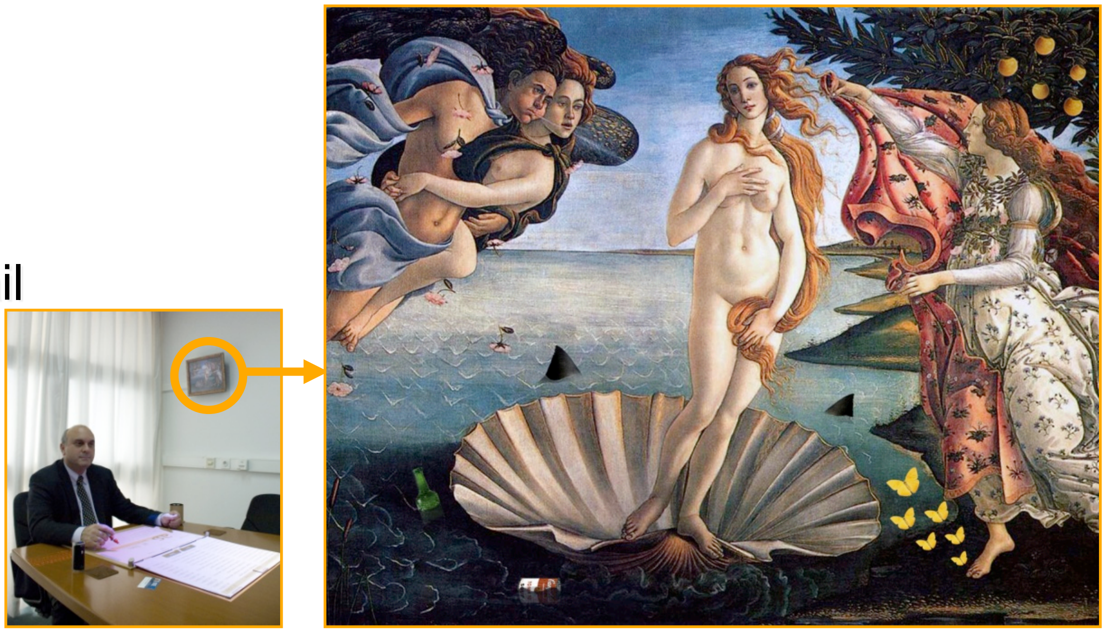


Mobile photo

- Get photo using the mobile phone and drag it on any display
- Output
  - Smart desktop, LCD screen, Archie
- Input
  - Mobile phone recognition: RFID tag (envelope)
  - Mobile phone position: Vision
  - Photo drag: IR pen

Archie: Interartive display

- Monitor e-mail account and visualise e-mail semantics
  - Number of e-mails
  - Number of e-mails from specific people
- Junk e-mail
  - Virus-infected e-mails
  - Unsent drafts
  - Receipt of specific e-mail
  - Urgent e-mail
- Output
  - Archie
- Input
  - E-mail account
  - Touch



Video conference

- Video conference
- Button presses around the table result in the camera turning to face the button's position
- Output
  - Large screen
  - Smart desktop
- Input
  - Camera
  - Multidirectional microphone
  - Buttons

High noon: Multiplayer Game

- 7-player game
- Gun fighting duel
- 2 opponents / teams
  - Left/right side of table
  - 3 buttons each (up, down, fire)
- 1 moderator (optional)
  - Undead
  - 1 button (show up / fire)
- Output
  - LCD screen
- Input
  - Buttons around the table

One-button start

- Turn on all devices
  - TV, PCs, projector, monitors, RFID readers, ..
- Connect devices via Bluetooth
- Run required processes / applications in each PC
  - In the appropriate order