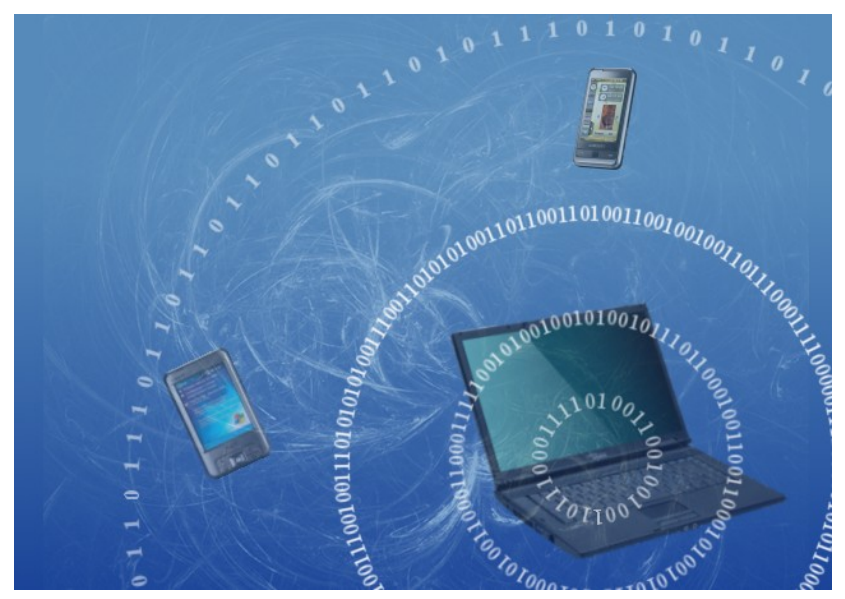


A Framework for Anomaly Diagnosis in Smart Homes - combining Autonomous Robot and Smart Environment -

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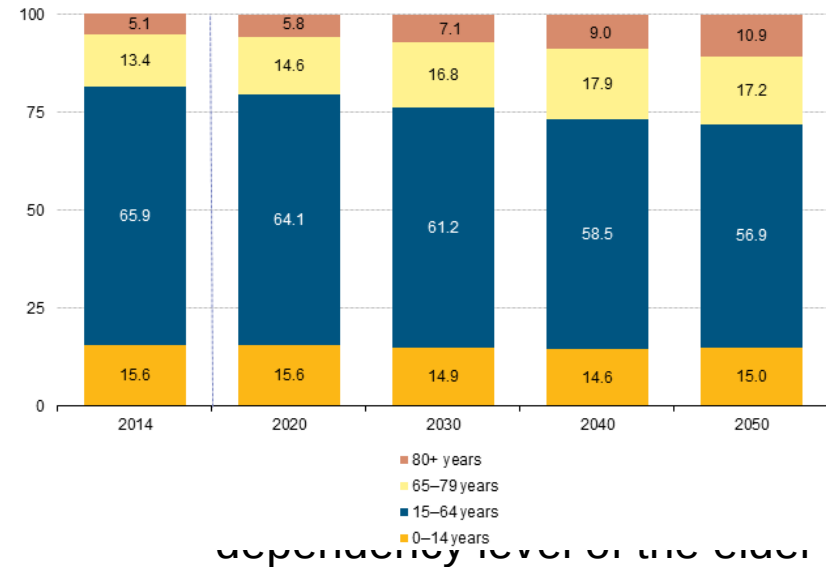
Context (1)

➤ People ageing occurs in over the world

- Around 2050, expected population
- 28% will be over 65 years
- 11% will be over 80 years

➤ Population ageing raises the people

- Home care
- Most people prefer to stay in their own home for as long as possible
- Residential care
- Expensive cost of these institutions
- Used for people who have no other option
 - Guarantee the quality and appropriateness of services
 - Guarantee their accessibility and sustainability



Context (2)

- The provision of services in patients' homes is typically more cost-effective than in institutions
 - Expectations for home care have grown as new technology
 - Facilitates care coordination
 - Enables distant monitoring and more complex treatments in the home situation

- Require to integrate technology in patients' homes
 - Low cost and energy efficient network infrastructure
 - Wireless sensors and actuators
 - Access to new services through usual devices

Maintain dependent people at home

➤ Smart homes

- Static architecture
- Network infrastructure
- Fix sensors and actuators
- Ambient intelligence system
- Mobile devices
- Devices worn by the users

Room1 Study Kitchen

➤ Nowadays, smart homes offer the

- Monitoring and simple remote treatment
- Social services

Room2 Bathroom
following services

➤ To support a large number of dependent people and increase their quality of life

- Need assistive services
- Require new mobile devices

- => In a near future, autonomous robots would be an essential part of smart home

Different types of autonomous robots

➤ Fully autonomous

- Designed to integrate the best possible hardware and provide a large range of features
- Best assistive robot disregarding any financial constraints
- Effective for healthcare institution with large financial resources

➤ Semi-autonomous

- Can perform some tasks automatically
- Propose the main required functionalities to maintain people at home
- Provide basic assistive functions
 - Cognitive stimulation programs, training...
- To achieve complex tasks, they require to be controlled remotely
- => Although expensive today, we believe the cost of these robots could over time converge with that of tele-operated robots

Overall architecture

Caregivers or family

Internet

Room1

Study

Kitchen

Room2

Bathroom

Middleware – Ease the complexity of these systems

- 1) Heterogeneity of technologies and devices
 - Middlewares ease the exchange of the data

- 2) Limited resources
 - Some sensors cannot execute middlewares
 - Middlewares have to support the most common network protocols

- 3) Different middlewares
 - Smart home and robot middlewares are different

- 4) Anomalies can occur at any time
 - May put at risk the life of inhabitants
 - Anomaly management system has to be integrated into middlewares

Types of anomalies in smart home

Smart Home/AAL Anomalies

Hardware Anomaly

Software Anomaly

Network Anomaly

Operator Anomaly

Context Anomaly

➤ 5 types of anomalies

- Hardware
 - Problems encountered by physical devices
- Software
 - Problems encountered by the logical program executed on the physical device
- Network
 - Problems on the communication between at least two devices
- Operator
 - Problems related to human factor and may be made during system design, manufacturing, implementation, operation and maintenance
- Context
 - Problems that occur due to "good work but bad situation"

Anomaly management (1)

- Anomalies have to be detected as fast as possible
 - Get the system back to a stable state as quickly as possible

➤ Four steps

- Detection
- This relies on components' survey to trigger a warning about anomalies
- Warning
- Alert
 - Message which warns the system an anomaly has been detected
 - Emitted by any component able to detect the occurrence of an anomaly
- Report
 - Message which completes previous knowledge about the related anomaly
 - Emitted by any component which knows of an anomaly, and can provide
- Analysis
- Similarly to the report, the analysis completes previous knowledge
- Only authorized components can emit an analysis
- Response
- Instruction sent to mitigate the anomaly, to the point of resolving it if possible
 - Pseudo-program, an ordered tree of procedures to perform
- Emitted by authorized, well suited components

1. Detection

2. Warning

3. Analysis

4. Response

complementary information

about the anomaly

Anomaly management (2)

- Devices are connected to the smart home architecture
 - Information are exchanged between devices
 - Anomalies have to be sent to the ambient system
 - 1) Require to define an anomaly message

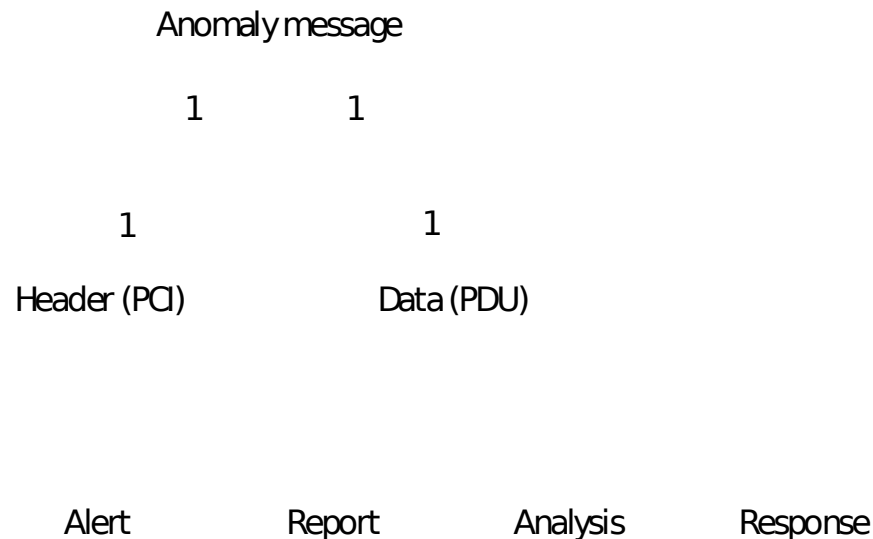
- Abstract the heterogeneity of technologies and device's capacities
 - Anomaly information has to be represented uniformly whatever the device is
 - 2) Require to base the anomaly description on ontology

- Middlewares are used and integrate in smart home's devices
 - Facilitate cross-application or component communication
 - 3) Require to integrate an anomaly management framework into middlewares
 - Ease the development for anomaly management applications

1) Anomaly message

➤ Composed of two parts

- Header
 - Provide basic useful information about the rest of the message
 - Type of PDU, time of the anomaly detection...
- Data
- Anomaly information related to one of the four anomaly management's steps



2) Ontology to describe anomalies

- Heterogeneity of networks and device's capacities
 - Increase the complexity to exchange information
 - Ambient intelligence system need a same representation of the information
 - In order to monitor the context appropriately
- Semantic Web technologies are good candidates
 - To provide data interoperability between these devices
 - To classify information and formally describe concepts
 - To increase the inferring power of the ambient intelligence systems
- We propose an anomaly ontology
 - Based on the Web Ontology Language (OWL)

Component description

➤ A component is a part of the system

- The system being what is studied or used, with its relevant dependencies
- E.g., basic smart home's system are composed of
- The devices (sensors, actuators), the network, the home itself (including its furniture), the dependent people and any other inhabitant

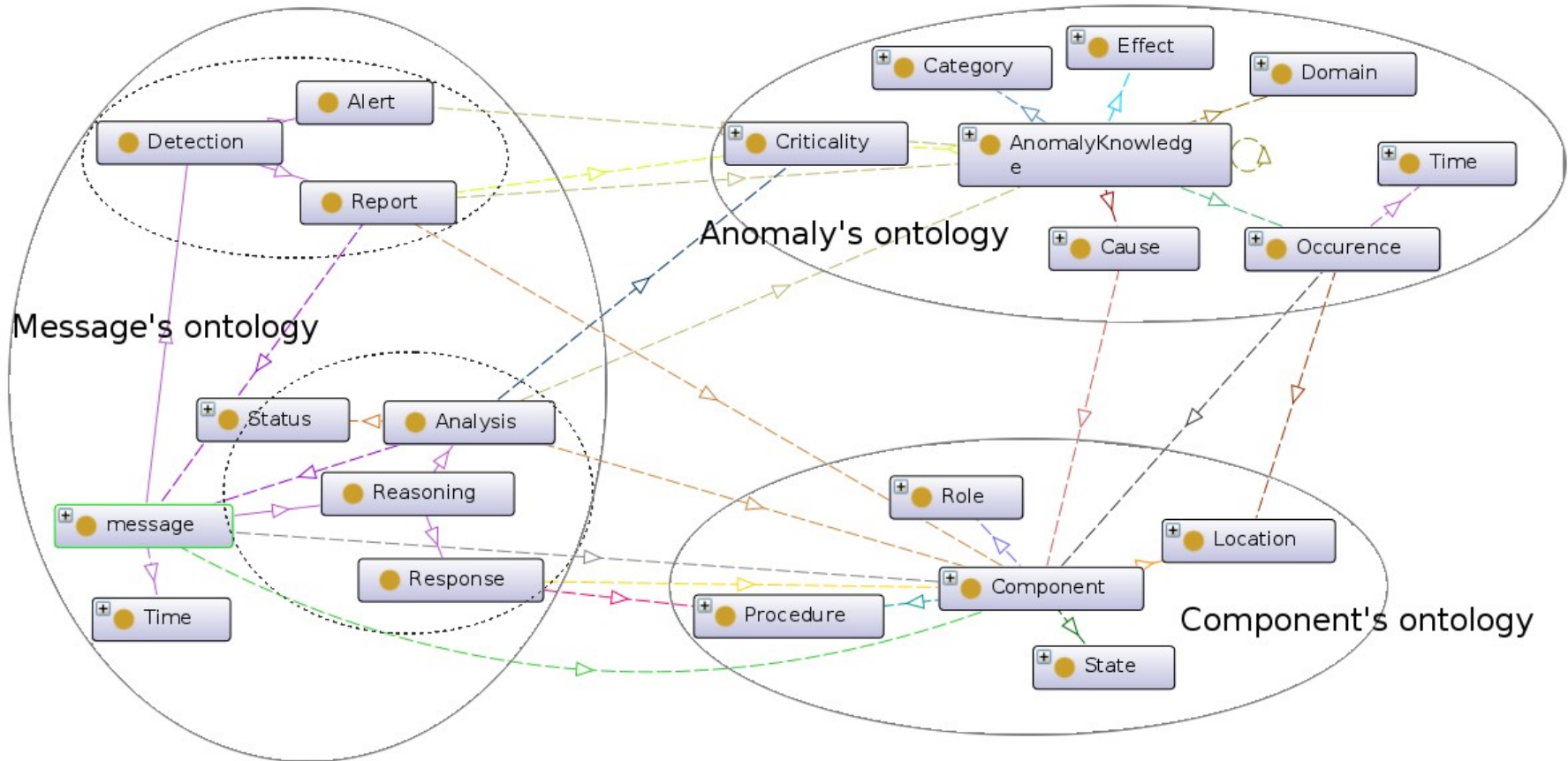
➤ A component has the following properties

- An identification key
- Permit to uniquely identify a given component.
- A role
- Defines what can be expected of the component (a node, an authority, a resource)
- A location
- Refer to some system's known areas
- A state
- Defines both the component's Finite State Machine's state (on, off, etc.), and how well does it perform (is it broken?)

Anomaly description

- Anomaly's description expresses which part of the system is affected by what.
- An anomaly has the following properties
 - A set of effects
 - Each effect describes one aspect of the observed phenomenon
 - A set of causes
 - Each cause refers to a component suspected to be the source of the anomaly
 - A set of occurrences
 - Each occurrence refers to where and when which component observed the anomaly
 - A criticality
 - It is a time dependent worth attributed to the anomaly management system
 - A set of domains
 - Each domain relates to a specific kind of consequence of the anomaly
 - A category
 - An anomaly can happen once (transient), periodically (recurrent) or definitively (permanent).

Anomaly ontology



3) Anomaly management framework

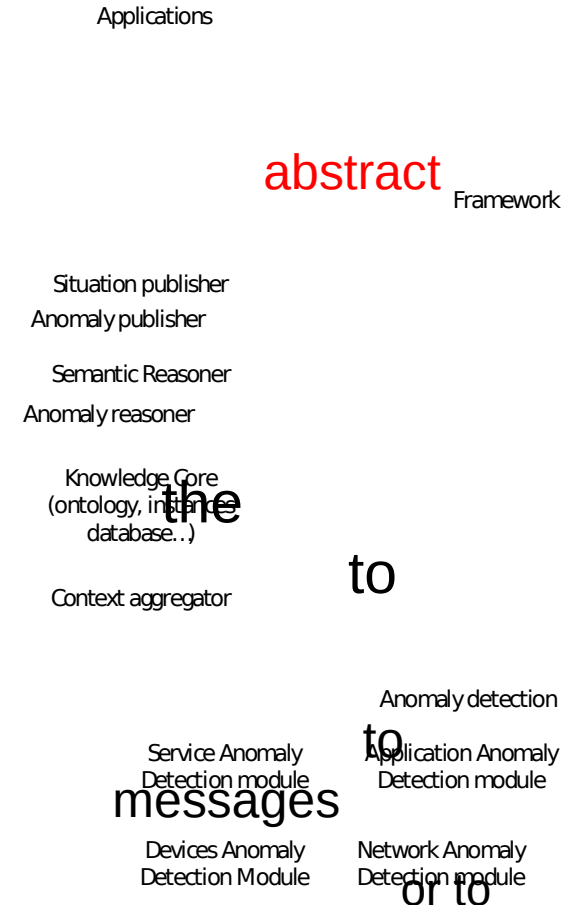
➤ Smart home middlewares manage only a subset of the expected anomalies

- It is time consuming to manage anomalies

=> it is necessary to have method to manage them

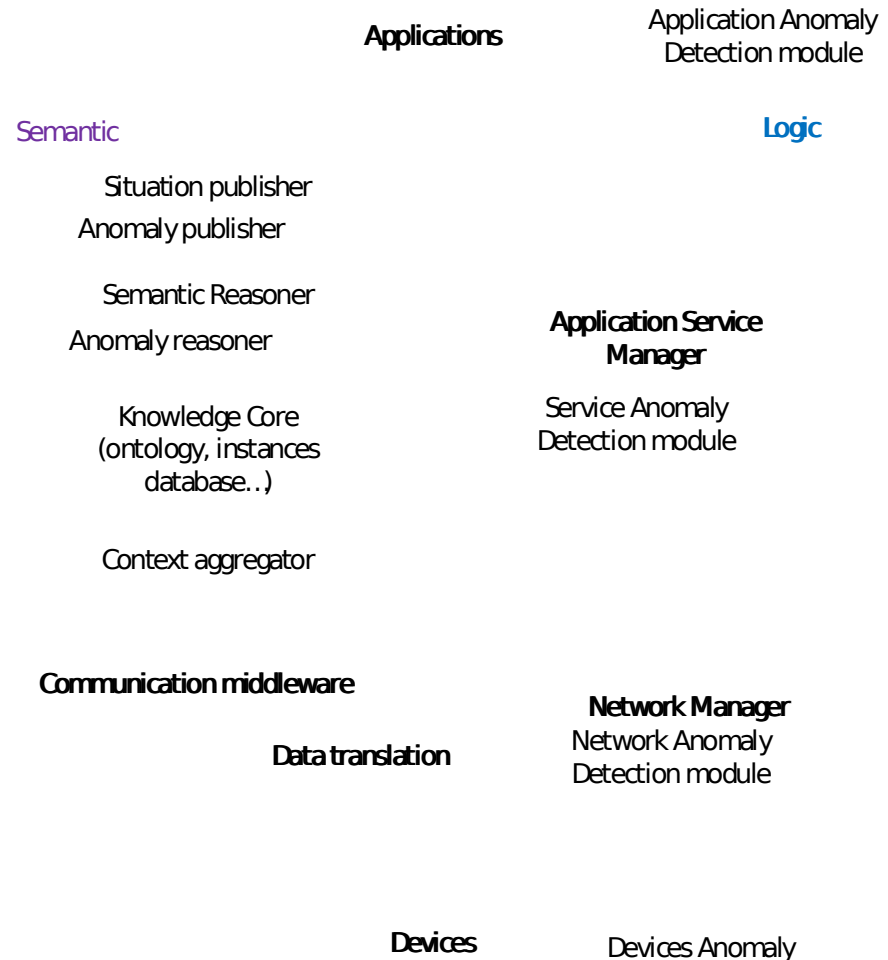
➤ Our framework eases developers' work related anomaly management

- Offer a high level interface trigger anomaly related
- Sent to specific components/services all of them



Integration of the framework inside middlewares

- Our framework can easily be integrated into a context aware middleware
- Modifications are quite light
- The different anomaly detection modules are placed in their expected place
- Their respective manager in the middleware or their related component



Implementation

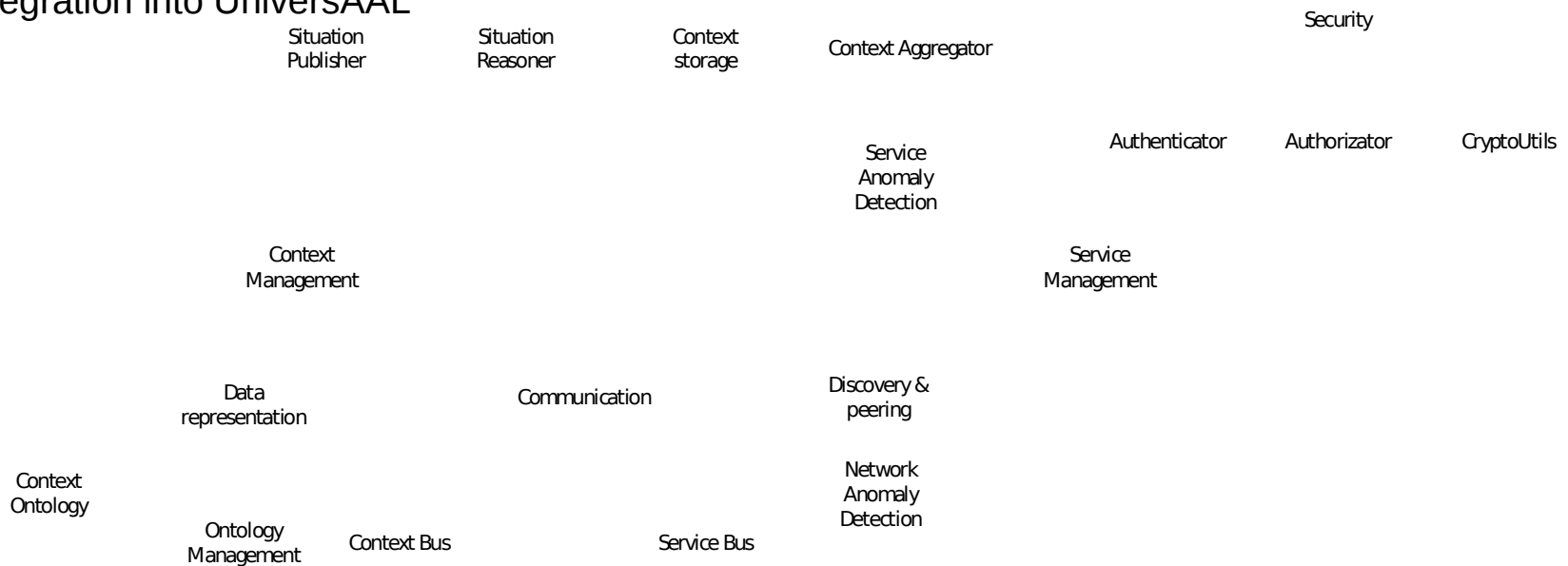
➤ Our anomaly management framework is incorporated into UniversAAL middleware (uAAL)

- One of the main European middleware for AAL systems
- It is an EU FP7 project middleware

➤ UniversAAL properties

- Communication layers are abstracted
- Applications receive only messages for which they registered
- Changes are expressed as context events and operations are translated into service requests
- Both are ontology's instances

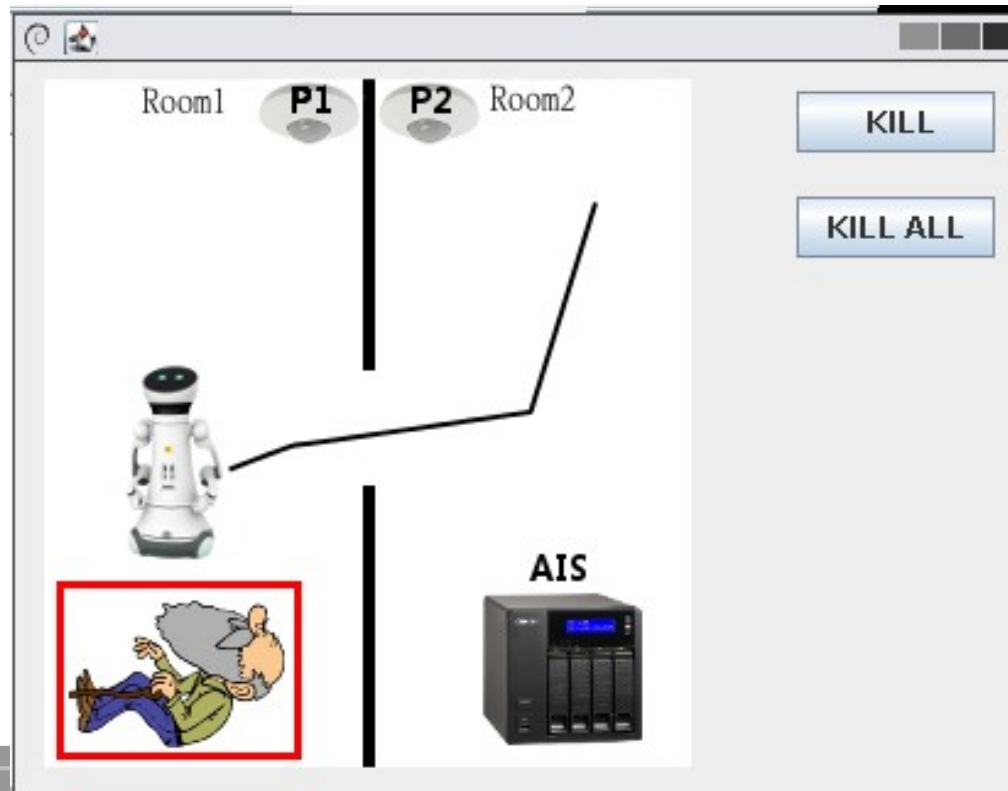
➤ Integration into UniversAAL



Proof of concept

➤ Composed of two parts

- Static smart home installation
 - Mobile devices (an autonomous robot and a fall detection sensor worn by the elder)
1. Normal situation
 2. The fall detection sensor alerts the AIS of the elder fall
 3. The AIS commands the robot to check for false alarms



Conclusion

- Lot of middlewares have been proposed to abstract hardware components
 - They are integrated to all devices of smart homes
 - From the basic sensor to the autonomous robot
- These middlewares do not take into account the anomalies that a system may encounter
 - The potential failures of the system have to be taken into consideration
 - To prevent health and security risk
- Anomaly management systems
 - Become an indispensable part of the overall architecture
- We propose a new anomaly management system
 - Ease the design of applications and anomaly detection modules
 - Ensure interoperability
 - Our framework is based on Semantic Web ontology to describe an anomaly