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A Platform for Interoperability via Multiple Spatial Views in Open Smart Spaces

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Outline

• Goal
• Our solution: Space Integration Services
• Real scenario
• Conclusions
Smart Spaces: overall challenge

- Open & Large-scale smart spaces: integration of heterogeneous devices, systems and services

- How to support integration and interoperability?
Our approach

• Approach: reification of a few widespread concepts in a concrete framework

• Space-awareness: the system capability of localizing information in physical or logical spaces and of behaving according to localized information
  – A person is
    • located in a room
    • plays a role in an organizational space
    • is associated with an RFID tag in an identifier space
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Space Integration Services (SIS)

• An architectural framework where components can
• define **multiple spaces**
• define **mappings among spaces**
• localize and obtain information on/from multiple spaces
• considering the mappings
Space: concepts

• **Core spatial model**: it defines a space typology
  – a space typology specifies how locations are defined
  – currently focus on intrinsically finite spatial typologies only
  – *graph-spatial model*, locations: nodes and edges
  – *grid spatial model*, locations: (i,j) cells
  – *name spatial model*, locations: names

• **Environment space**: an instance of a core spatial model
  – a collection of locations
  – what is a location is defined by the related spatial model

• **Thematic information** can be localized in several locations of different spaces
Multiple information localization

- Room 44
- Room 43
- Room 45

:GraphSpace
  spaceName = aBuilding

:Node
  nodeId = room45

:Element
  j = 12
  i = 7

:GridSpace
  spaceName = aFloor

:ThematicInfo

O1 :Component
«views»

O2 :Component
«views»
Mappings

- Unidirectional associations among locations of different spaces
Mapping & indirect localization

- aBuilding : GraphSpace
- L1 : Node
  - nodeId = room45
- L2 : Element
  - j = 12
  - i = 7
- aFloor : GridSpace
- aPerson : ThematicInfo
- aBuilding «views» O1 : Component
- L1 «views» indirect localization
- L2 «views» direct localization
- aFloor «views» O2 : Component
Spatial Context

• A specification of one or more locations of an environment space
  – enumerative form
    • <spaceName, locationID+>
  – wildcards
    • <spaceName, *>
  – work-in-progress extension for declarative specification
Space-aware publish/subscribe
Matching rules

- A publication context PC matches a subscription context SC if
- 1) **direct match**: the intersection of the sets of locations in SC and PC is not empty
Direct match example

Component C2

publish(theInfo, <aFloor, <12,7>>)

Component C1

subscribe(<aFloor, <12,7>>)

notification

theInfo

SIS

aFloor
Direct match example

• C1 will be notified with a Matching structure
  – <theInfo,
  – 08:39:02-2010-06-07
  – <aFloor, <12,7>>

• A notification contains the thematic info plus
  – 1)the emission time of the thematic information
  – 2)the publication contexts associated to the thematic info that match the subscription context
Matching rules (2)

- **indirect match**: the set of locations in PC includes a location L which is mapped to a location L’ in SC, by considering the *restricted transitive closure* of the mappings
  - Restricted transitive closure of a mathematical relation R: the relation T containing all the pairs
    - (a,b) belonging to R
    - (a,c) where (a,z) and (z,c) belong to T for some z, and c is not equal to a
Indirect match example

Component C1: subscribe(<aBuilding, room45>)

Component C2: publish(theInfo, <aFloor, "12,7">)

theInfo

mapping

room45

room44

aBuilding

SIS
Indirect match example

- C1 will be notified with the following Matching structure
  - <theInfo, 08:39:02-2010-06-07
  - <aFloor, <12,7>> <aBuilding, room45>>

- A notification contains the thematic info plus
  - 1) the emission time of the thematic information
  - 2) the publication contexts associated to the thematic info that match the subscription context...
  - 3) ...and those which are explicitly or implicitly mapped from them according to the restricted transitive closure of the mapping relation (*context completeness*)
Prototypal implementation

- Core: Java + JESS rule engine
- Environment spaces, mappings and matching rules turn into JESS facts and rules
- Environment spaces are defined through XML descriptors which are used by SIS in the initialization phase
- The interaction primitives are exposed as Web Services
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Real scenario: Smart Building (1)

- Suppose that a building is enriched with sensing and responding technologies providing users with smart services
  - Sensing: RFID and “Wireless” localization systems
  - Responding: light control system
  - DISCo-UniMiB GAS-Intelligent Building project scenario

- Users are identified by their names together with their organization roles (Director, Full Professor, Ph.D. student, etc.)

- Example of “simple” smart feature: “increase the lightning of any room if the Director goes in”
SIS-based Architecture

SIS

Binding
Thematic Info

Location
Space

Mapping

Sensing component
Applicaton component
Actuator component

Binding

subscribe
notify
subscribe

publish
SIS-based Architecture

- Sensing component
- Application component
- Actuator component

Binding
Thematic Info
Mapping

Location
Space

publish
subscribe
notify
subscribe
notify

Thematic Info
Smart Building spaces

Actuators
- LightManager

Roles
- Director
- TechChief
- Full Prof.
- Associate

People
- Brown
- White
- Green

Building
- Room1
- Room2
- Room3
- Room4
- Room5
- Room6

WiIDs
- 3491234
- 3381236
- 335789

WiFloor

Tags
- 1234
- 1236
- 1235

RFIDs
- rf1
- rf2

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Smart Building mappings

Actuators

Roles

People

Tags

RFIDs

WiIDs

Building
Feature realization (1)

Application Component

subscribe(<Roles, Director>)

WiIDs

People

Brown
White
Green

Roles

Director

WiFloor

Building

Room2
Room3
Room4

SIS
Feature realization (1)

Wireless component

Application Component

Roles

People

WiFLOOR

WiIDs

Building

Director

subscribe(<Roles, Director>)

notification

..<WiFLOOR, “1,3”>, <Building, Room4>

publish(thematicInfo1, <WiIDs, 3381236> <WiFLOOR, “1,3”>)
Feature realization (2)

```
publish(thematicInfo2, <Tags", 1234><RFIDs, rf2>)
```

```
subscribe(<Roles, Director>)
```

```
notification
```

```
..<RFIDs, rf2>, <Building, Room4>..
```
Feature realization (3)

Building

Room2

Room3

Room4

Actuators

LightManager

subscribe(<Actuators, LightManager>)

Light Manager

SIS
Feature realization (3)

publish(“increase lighting”, <Actuators, LightManager>, <Building, Room4>)

subscribe(<Actuators, LightManager>)

notification...

command

command

Application Component

Light Manager

LightManager

Actuators

Building

Room2

Room3

Room4

SIS
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SIS: advantages

- Environment spaces support individual views of the overall environment
  - The same piece of data can be viewed by different mapped spaces, like role hierarchies or 3D physical spaces

- Information flows are transparently created through multiple spaces and mappings
  - Components can ignore the presence of other components

- It supports the creation of information flows among heterogeneous components
SIS: what semantics?

- SIS does **not** provide a general semantic model

- Spatial contextualization
  - widespread and reusable concepts
  - lightweight framework

- Semantic of Thematic info: out of scope
Extension and Future Works

• Space-based data-sharing
• Declarative context specification
• Filters to constrain the context completeness
• Experiments: efficiency and scalability
Ongoing Experimentations

- F.I.R.B. Integrated Systems for Emergency project - SIS for space-based information flows
- DISCo GAS Intelligent Building - SIS as integration platform
- Augmented classroom
  - with UniMiB DISCo IT IS Lab - Prof. Simone
- Integration of SIS and 3D visualization components
  - with UniMiB DISCo IVL Lab - Prof. Schettini
- Engineering of adaptive lighting systems based on Cellular Automata computational model
  - with UniMIB CSAI Center - Prof. Bandini
  - Acconci Studio, NY, USA, Interactive Art & Architecture
- Interactive art installations distributed over different sites
  - Luca Carrubba, esterotips.net