A Location Model for Ambient Intelligence

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Outline

1. Motivation
2. Approach
3. Location Model
4. Design and Implementation
5. Applications
6. Conclusion

Background

- Location is an essential part of contextual information in ambient intelligence.
  - Many location-based services have been developed based on the underlying location-sensing systems.
  - They cannot be reused with other location-sensing systems, which they do not support initially.
- A solution to this problem is to construct a general-purposed location model independent on the underlying systems.
  - Existing location models are not always available in ambient intelligence.

Location-based information services on mobile computers

Personalized information services on public terminals

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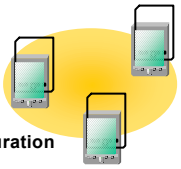
Problems in Existing Location Models

Existing models have problems:

- In ubiquitous computing environments any database servers, e.g., relational database systems, may not be available.
  - But, existing location models need to be maintained in centralized database servers.
- Computing devices may be dynamically organized and deployed in the physical world.
  - But, these models can maintain only the locations of physical entities and places but not the locations of computers and software for defining the services.



dynamic configuration

Non-relational database system

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Requirements

A location model for context-aware services indoor-smart spaces.

- **Unified view**
  The model must maintain the positions of computers and services as well as the positions of physical entities and spaces.
- **Availability**
  It must be able to discover and execute suitable services on suitable computers at suitable locations according to changes in the real world and the computers' capabilities.
- **Adaptability**
  Software for defining services should be dynamically deployed at computing devices only while they are wanted.
- **Extensibility**
  It can be maintained by multiple computers, which can be dynamically connected to, in an ad-hoc manner.

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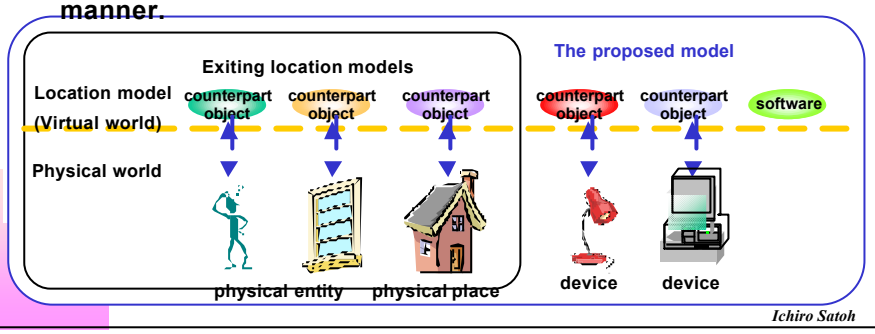
Approach

This location model is based on the symbolic approach.

- The model provides virtual counterpart objects, called components, with physical entities and places.
- The model maintains not only the positions of physical entities and places but also those of computers and services
- It can be managed by multiple computers in a self-organizing manner.



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Components

The model is constructed as a tree structure of components:

- **Virtual counterpart component** is a digital representation of an physical entity or space in the physical world.
- **Proxy component** is a proxy of a computing device that can execute service components or provide its own services.
- **Service provider component** is a software module that defines application-specific services associated with physical entities or places.
- **Link component** is a proxy of the computer that maintains a tree structure of components.

In the current implementation, all components are defined as Java-based mobile codes or objects (agents).

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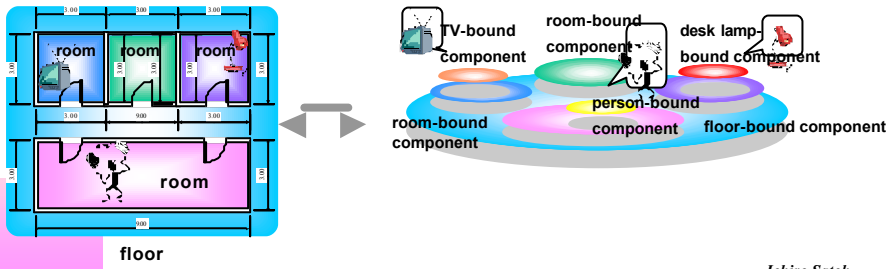
Virtual Counterpart Components

- A person, physical object, or place can have more than one virtual counterpart component.
- The model spatially binds the locations of entities and places with the hierarchy of their virtual counterpart components.
- When they move to other locations, it deploys their components at the destinations' counterpart components.



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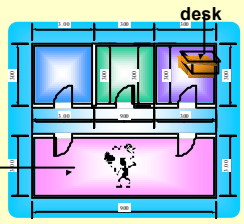
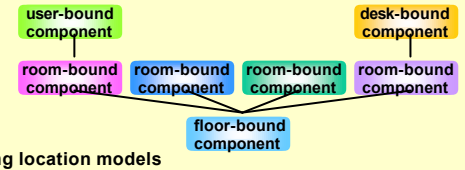
Component Hierarchy

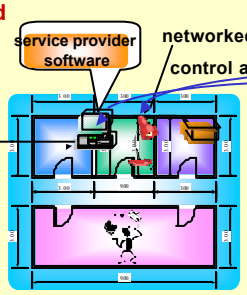
Existing location models

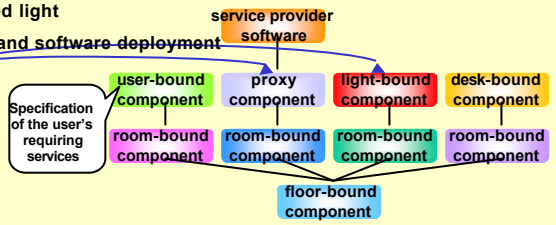




Existing location models maintain only the location of physical entities and places.

Proposed location model





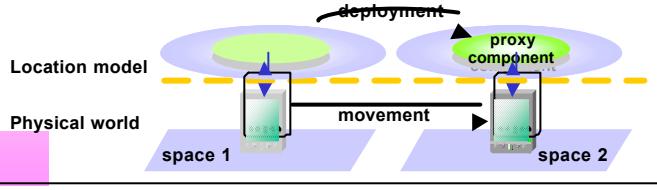
The model also maintains the location and capabilities of computers and the relocation of software.

Proxy Components

The model provides devices for two types of proxy components.

- Proxy components for remote-controllable devices that can provide their own services.
  - e.g., TV and X10-aware appliances
- Proxy components for computing devices that can download and execute deployable software (i.e., service components).
  - e.g., networked computers

If devices are in spaces, their proxy components are contained in the virtual counterpart components of the spaces.



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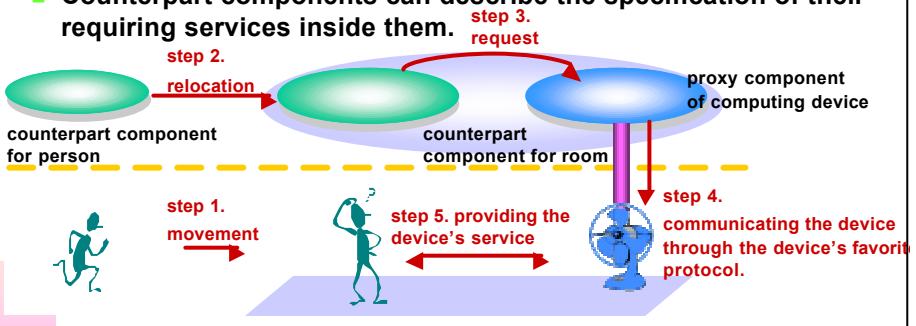
Proxy Components for Service-provider Devices

- When a proxy component receives requests, it controls and monitors its target device through the device's favorite protocols.
- Counterpart components can describe the specification of their requiring services inside them.



The current implementation provides X10-enabled proxy components to control legacy appliances through power-line

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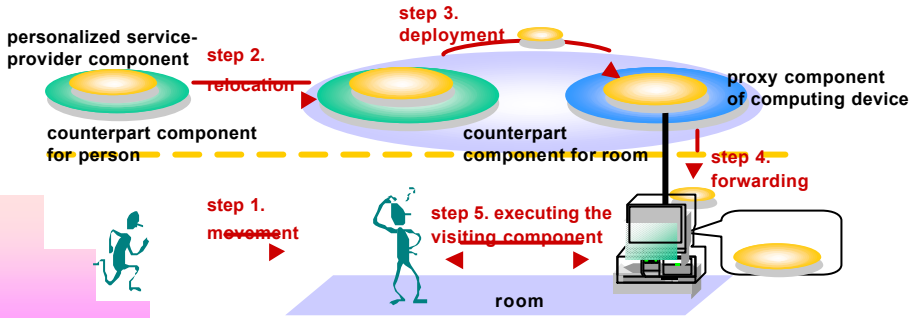
Proxy Components for Service-executor Devices

- When a proxy component receives downloadable software, it automatically forwards the software to its target device to execute the software on the device.
- An entity's counterpart component can carry software to the proxy components of computing devices in its current space.



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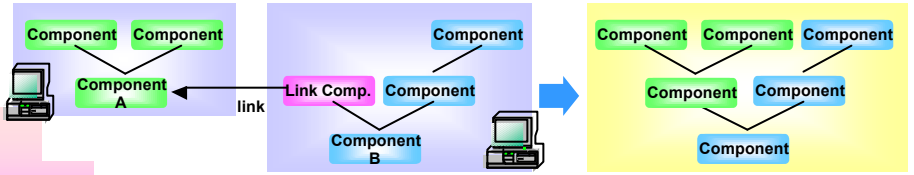
Distributed Model Management

This model is a composition of sub-trees, which may be maintained in different computers.

- Each sub-tree has its own proxy, called link component.
- The model can relocate link components according to the containment relationships of the spaces that they refer to.
- Each link component forwards control messages and visiting components to the root component of its target sub-tree.



The space that component A refers to is contained by the space that component B refers to.

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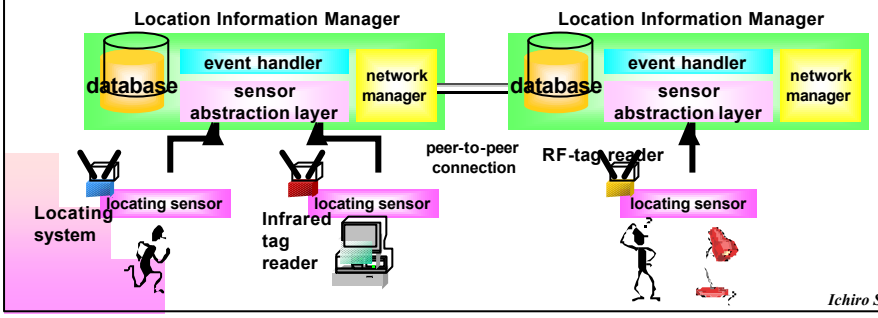
Location Model Management

The model enables its containment hierarchy to be configured through users or location sensing systems.

- A location information manager monitors more than one location-sensing system.
- Each manager can be in an external or internal computer.



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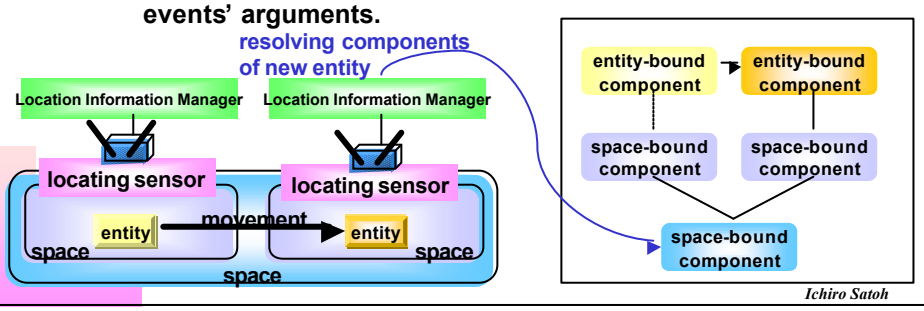
Location Model Management

- When a manager detects a new physical entity or computer, it discovers components bound to the entity or computer in the tree by using a breadth-first-search approach.
- If sensors can measure geometric locations, the location information of entities are mapped into the name of the space that contains the entities.
  - The information can still be notified to components as events' arguments.



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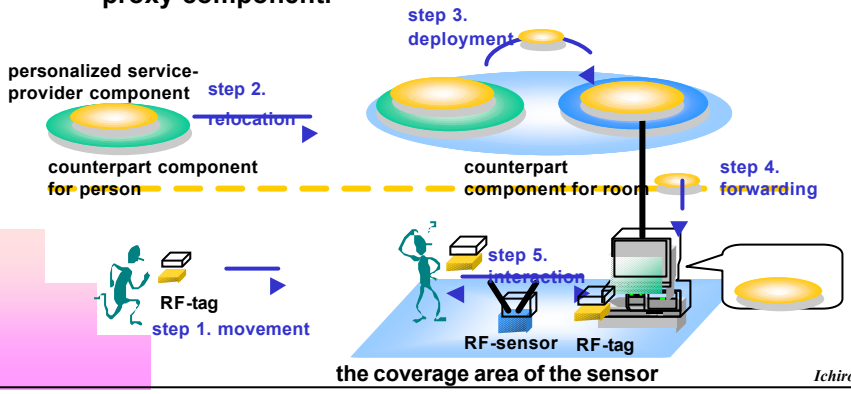
Example: Follow-me Services

A proxy component of a PC is located in the counterpart component corresponding to the coverage area of RF-reader.

A user's counterpart component carries its user's assistant agent to the area's component and then it migrates the agent to the proxy component.



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Example: Follow-me Services

The current implementation tracks the movement of a user by using Active RF-tag technology.

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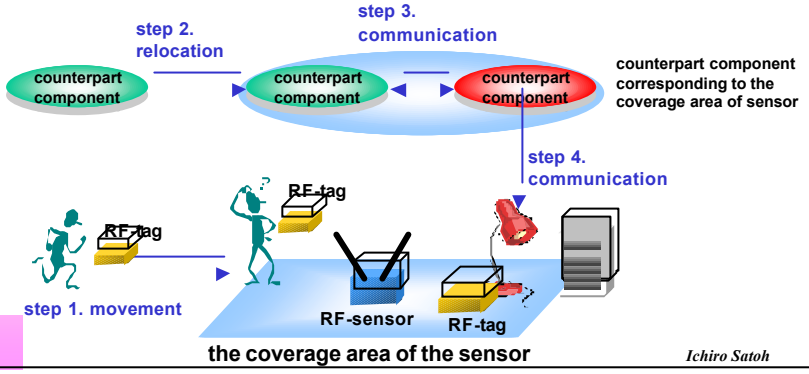
Example: Proactive Lamp

- A desktop-lamp bound component communicates with X10-based servers to switch the desktop-lamp on or off.
- A user's component can be relocated to the area's component and then requests the lamp's component.



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Conclusion

Service discovery and location model are inherently indivisible in a pervasive computing environment.

- but, existing approaches have been explored independently.

- The proposed model can maintain not only the location of physical entities and places but also the location of computers and software as unified components.
- It can be managed by multiple computers in an ad-hoc manner.
- A prototype system of the model was implemented.

Future Work

- Meta-descriptions about services and query languages
- Programming-language independent implementation
- Policy-based deployment of services
- Enhancement of security mechanisms, including protection of user privacy
- Component resolution mechanisms for large-scale systems
- Component caching mechanisms for scalability

Q&A

Thank you

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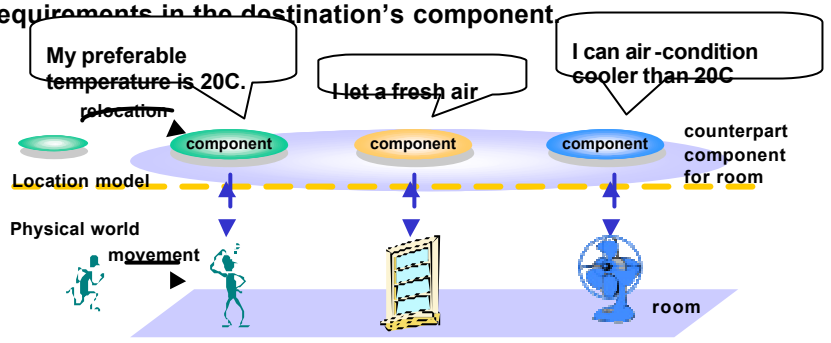
Service Discovery

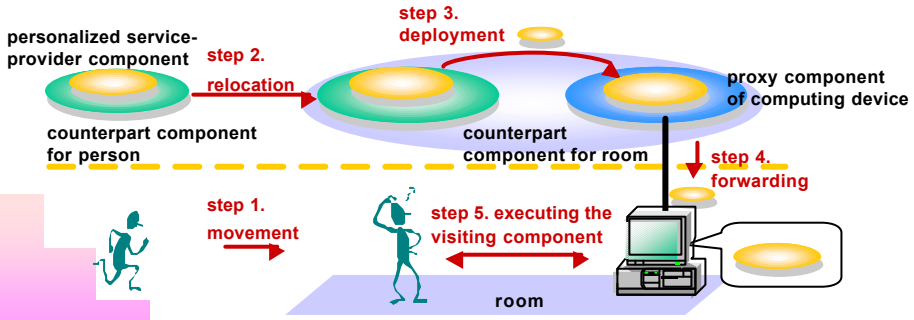
- Each virtual counterpart component can describe the specification of its requiring services.
- When a component moves to the destination component, it tries to discover the proxy components that can satisfy its requirements in the destination's component.



Service discovery management is operated as communications between components on the model, instead of between devices.

Proxy Components for Service-executor Devices

- When a proxy component receives software, it automatically forwards the software to its target device to execute the software on the device.
- An entity's counterpart component can carry software to the proxy components of computing devices in its current space.



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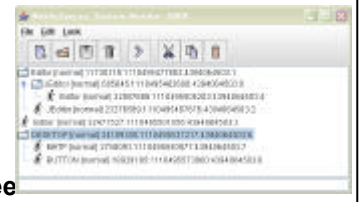
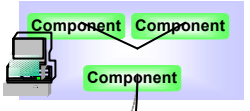
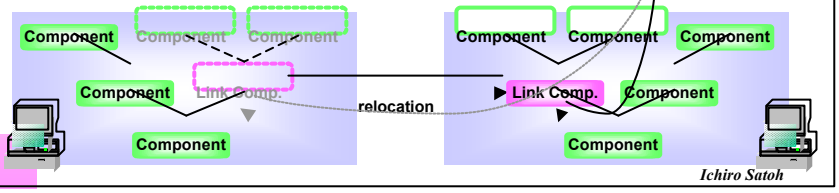
Dynamic Configuration

- When a space specified as a subtree maintained by a computer moves, the link component of the subtree is relocated as the same way of the relocation of counterpart components.
- When a computer maintaining a subtree meets another computer maintaining another subtree, these subtrees are relocated according to the locations of the spaces that the subtrees refer to.







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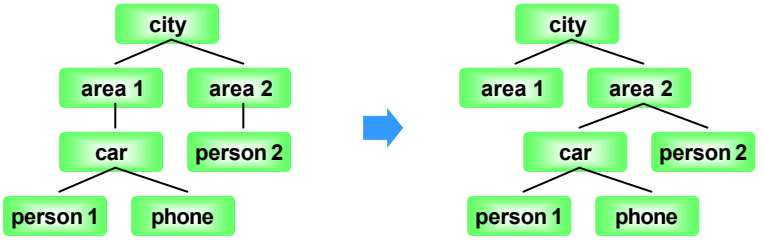
Component Model

- Each component can contain one or more components inside it.
- It can move between components as a whole with all its inner components.
- It can access services explicitly provided by its ancestors, i.e., its outer components.



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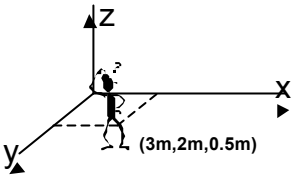
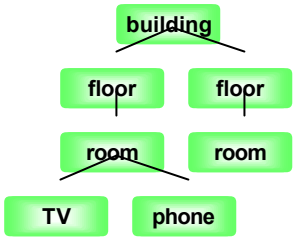
Existing Location Models

- Physical location model
  - The position of people and objects as geometric coordinates.
  - It is suitable with only a few outdoor-applications like moving-map navigation.
- Symbolic location model
  - Sets or hierarchies of locations' names.
  - It is suitable with indoor context-aware services.





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