CONTEXT-AWARENESS SIMULATION TOOLKIT
A Study on Secure Context-based Learning in Ubiquitous Computing

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Abstract: The study deals with the most important elements of ubiquitous computing, that is, the toolkit to acquire, express and safely use the context information. To do so, we introduce CAST(Context-Awareness Simulation Toolkit) and show how it works. CAST generates users and devices in a virtual home domain, designates their relation and creates virtual context information. The created context information is reused by the request of application and put into use for learning. Particularly, we have given a consideration to security in the process of context creation and its consumption. That is, we applied SPKI/SDSI to test if the created context information was valid information and if the application that called for the context had legitimate authority to do so. CAST not only captures virtual context information, but it also guarantees the safe sharing of the context information requested by the application.

1 INTRODUCTION

Context Awareness is the most important research area in ubiquitous computing, on which many researches are recently being done. It was because Mark Weiser, who first suggested the notion 'ubiquitous computing', noted that basically the following 4 should be reflected (Mark Weiser, 1993), (Mark Weiser, 1993) and (Mark Weiser, 1994): ① Human-friendly interface, ② Computing connection at anytime, anywhere, ③ Calm technology, ④ Dynamic service.

Like this, Context Awareness is very important to ubiquitous computing that is intended to enable natural and convenient computer use in everyday lives regardless of location and time.

Since Context Awareness is important, there have been lots of preceding researches on it. However, there are some limitations and our approach to the resolution of it is as follow:

- The vagueness of the definition of context
- Although there have been many preceding researches, there is no agreed definition of it yet. The main reason of it is that we generalize and then try to define all the domains. Here, we are going to focus on the context of just a certain domain of home.
- The difficulty in acquiring context
- In real world, context information is acquired by physical sensors. However many researchers have hard time in their getting context information since they have mostly majored in S/W part rather than H/W part. For the reason, the majority of the related researchers are apt to do their modeling and research context conceptually without the real context information. The study provides a Simulation Toolkit by which those researchers of Context Awareness in the S/W part may acquire context and share in their acquired context.
- The validity of acquired context information and its safe sharing

: Preceding studies on the things such as Context Toolkit have not given any consideration to security

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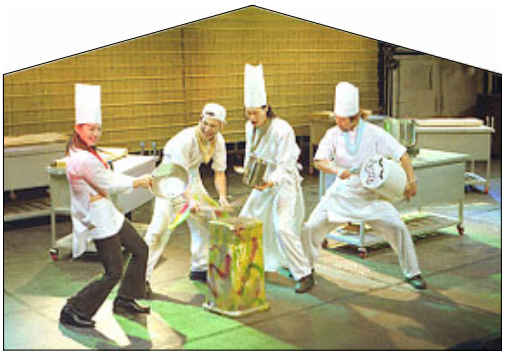


Figure 1: Korean musical named NANTA.

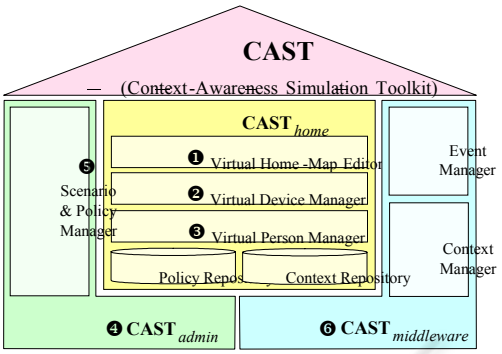


Figure 2: Architecture of CAST.

while acquiring context. That is, there have been no consideration to if the acquired context information was valid or if the application requesting the acquired context is duly authorized. The ubiquitous computing system should protect individual privacy from ubiquitous sensors. That was why we have considered security.

The development of CAST(Context-Awareness Simulation Toolkit) which the study suggests was motivated while the author was watching a play in the theater. Figure 1 is a scene from the featuring of famous Korean musical named NANTA. The performers(❸ of Figure 2) play with their all might and main in their gestures(❻) following the scenario(❺) of the playwright(❹) against the stage(❶) garnished with various stage properties(❷).

The CAST suggests will create a valid context information for us via a S/W agent concocted virtual sensor instead of a physical sensor. Just like the performers in the play moves us by their performance in their virtual lives, we are going to safely share and reuse the created context information and utilize it in the user adaptation by the context learning.

The study is composed of the following. In section 2, it will take a look at related research and in section 3, it will introduce CAST. In section 4, it will discuss the feasibility and its comparison with existing research by a proposed prototype of CAST. Finally, in section 5, it will present the conclusion and the direction of future studies.

2 RELATED WORK

There have been lots of preceding researches on Context-Awareness. Except the Context Toolkit of A.K.Dey (G. D. Abowd, 1999) and (A. K. Dey et al., 2000), All preceding researches acquire context information through physical device in H/W part (Seiie jang et al., 2004) and (N. Davis et al., 2001).

2.1 The Context Toolkit of Dey et al.

The approach of the Context Toolkit by Dey et al (G. D. Abowd, 1999), (A. K. Dey, G. D. Abowd, 2000), (A. K. Dey et al., 2001) and (Dey, A.K. et al., 2001) origins from the area of location-aware services. Its main focus is to provide a comprehensive conceptual framework together with a toolkit for representing and processing context information independent of an application, thus establishing an external customisation architecture.

The context toolkit which realises only a subset of the frameworks' concepts has been implemented using Java and XML (W.S. Means and E.R. Harold, 2001) Various applications have been developed on basis of the toolkit, including, e.g., an in/out board for indicating those persons which are inside a building, a personalised information display which shows the user in front relevant information and a context-aware mailing list sending emails only to those subscribed users which are currently in a certain building.

2.2 The CIVE of Seiie Jang et al.

The CIVE(Context-based Interactive system for distributed Virtual Environment) is a system that connects real world with virtual world by sharing user's context (Seiie jang et al., 2004).

It consists of ubi-UCAM for generating user's context, NAVER for managing virtual environments, and Interface for linking ubi-UCAM with NAVER. Interface transforms contexts or commands into events that influence virtual environment, and converts events into contexts for context-based services in real environment.

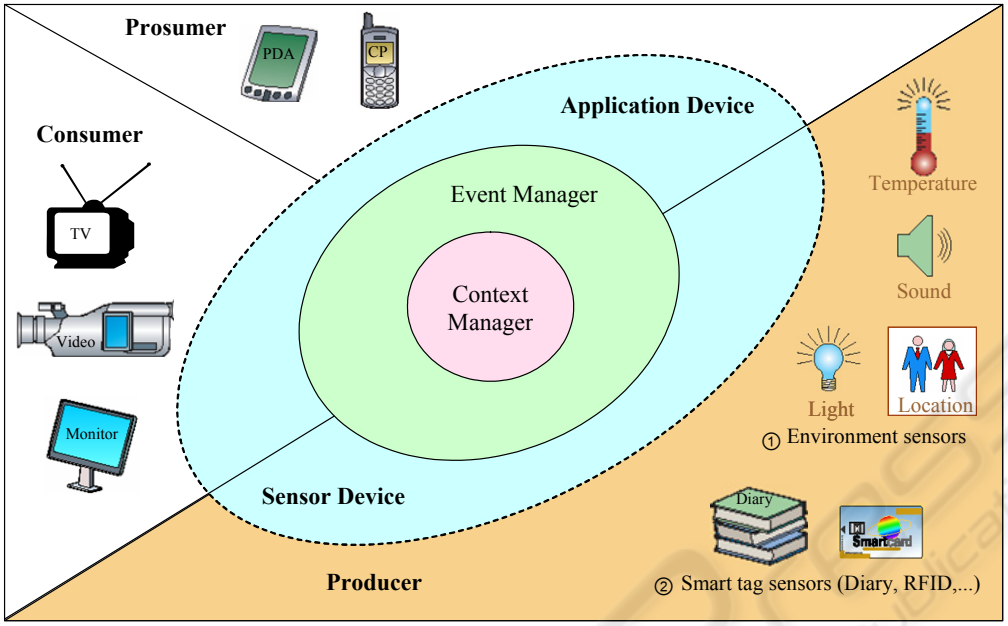


Figure 3: Virtual Devices of CAST.

2.3 The GUIDE of Cheverst et al.

The GUIDE system of Cheverst et al. (N. Davis et al., 2001), (K. Cheverst et al., 2000), (Mitchel and N. Davis, 2002) (N. Davies et al., 2001) stems from the area of location-based services. The focus is to provide tourists with up-to-date and context-aware information about a city via a PDA.

3 CAST

CAST that we suggest defines context with our focus on a specific domain of home, unlike the preceding researches with wide-range definitions of context. The domain can be a school, a hospital, an office or the like.

- Context_{home}: Context is the information that can particularize the conditions of all entities constituting home and be put into use in decision-making. The entity includes people, place and all objects in the actual world.

3.1 CASThome

We have used by Macromedia's Flash MX 2004 in laying out a home environment with virtual people and devices (J. Kaye and D. Castillo, 2005) and (Craig Swann and Gregg Caines, 2002). We chose the technology because it's quite useful with its visual convenience and easy interface. It also has a big merit of its ability to be interlocked with external programs (M. L. Liu, 2004) since it supports the inter-communication function with the programs such as JAVA, C++, C# via the XMLsocket Class provided by Flash.

3.1.1 Virtual Device Manager

We have realized virtual S/W devices by using the Flash MX 2004 (J. Kaye and D. Castillo, 2005) and (Craig Swann and Gregg Caines, 2002) as well as the JAVA sockets. The devices are classified in their production and consumption of virtual context as Figure 3.

- Sensor device(=Producer): This is a device, with no calculation capability, that only generates context information and that is classified as the following:

  ①Environment sensors: This is a sensor that produces physical environmental information that is exposed to everybody.

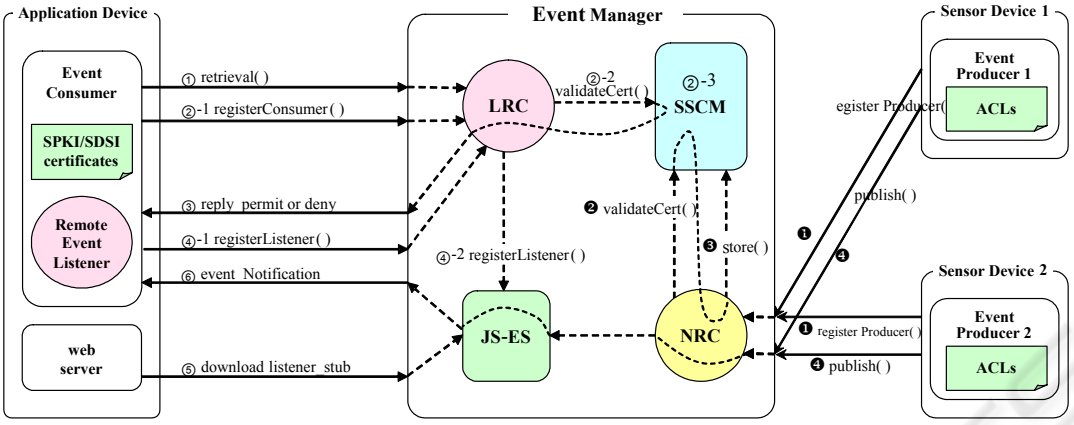


Figure 4: Event Manager process realized authentication and authorization.

(temperature, sound, light force, location etc.)

② Smart tag sensors: Smart tag sensor connected to private information.(Diary, RFID etc)

• Application device: A device with calculation capability with itself. Classified as the following:

①Consumer: A device that just asks Context manager for context and consumes context. (TV, video, monitor, etc)

② Prosumer: A device that not only asks Context manager for context to consume it, but also is able to update its private information-related context.(PDA, cellular phone, etc)

3.1.2 Virtual Home-Map Editor

It generates a virtual home environment as the domain of CAST. A virtual home, like a home in real world, may consist of rooms, a living room, bath room and kitchen. Also, the Sensor and, Application devices generated by Virtual Device Manager will be put into appropriate places in the virtual home.(Figure 6)

3.1.3 Virtual Person Manager

This generates family members that belong to the virtual home environment. The profile of each member will be stored in their cellular phones and will be updated at all times. The profile will be written in SOUPA(Standard Ontology for Ubiquitous and Pervasive Applications) (Harry Chen et al., 2004), (Harry Chen et al., 2004) and (H. Chen, 2003) and includes the information of their respective domain homes as well as the application device.

The following shows a partial ontology descriptiion of the person Kim In-su:

```
<per:Person>
 <per:firstName
    rdf:datatype="&xsd;string>Kim</per:
 firstName>
 <per:lastName
          rdf:datatype="&xsd;string>In-
su</per:lastName>
 <per:gender rdf:resource="&per;Male"/>
 <per:birth
    rdf:datatype="&xsd;string>04041974<
/per:birth>
 <per:homepage
   rdf:resource="http://www.cyworld.com
   /agisong"/>
 <per:email
  rdf:resource="mailto:agisong@lsrc.jnu
  .ac.kr"/>
 <per:hasHomeContact
   rdf:resource="#InsuHomeContact"/>
</per:Person>
<per:ContactProfile
rdf:ID="InsuHomeContact">
 <per:address
rdf:datatype="&xsd;string">
            LSRC,300,Yongbong-dong,Puk-
gu,Gwangju,Korea
 </per:address>
 <per:phone rdf:datatype="&xsd;string">
   +82-62-530-3714</per:phone>
</per:ContactProfile>
<dev:SamsungCellphone>
  <dev:hasUser>
    <foaf:Person>
      <foaf:homepage
      rdf:resource=http://www.cyworld.c
      om/agisong"/>
        </foaf:Person>
  </dev:hasUser>
   <dev:modelNumber
rdf:datatype="&xsd;string>
                    SCH-
E120</dev:modelNumber>
   <dev:serialNumber
rdf:datatype="&xsd;string>
                    R24W114948</dev:seri
alNumber>
   <dev:phoneNumber
rdf:datatype="&xsd;string>
```

```
                    017-365-
8477</dev:phoneNumber>
</dev:SamsungCellphone>
```

3.2 CASTmiddleware

$CAST_{middleware}$ performs the communication role among the virtual people and devices set in $CAST_{home}$. It is composed of Event Manager and Context Manager. Their respective roles are like the following.

3.2.1 Event Manager (YoungLok Lee et al., 2005)

Ubiquitous services must appropriately adapt to the context information of the user. In need of privacy protection and proper adaptation, context information should be generated from the accurate event information and only right possessor of the authority about the event should utilize it. The ad hoc network environment introduces fundamental new problems. One is the absence of an online server, and another is secure transient association. Authentication and Authorization are the most interesting security problems in ad hoc networking, because much of the conventional wisdom from distributed systems does not quite carry over. For solving these problems, we use SPKI/SDSI(Simple Public Key Infrastructure/Simple Distributed Security Infrastructure) certificates. (YoungLok Lee et al., 2005) and (M. L. Liu, 2004)

- ACL and SPKI/SDSI Certificate

: The consumer of events will have the following Name Certificate(<Issuer, Local Name, Subject, Validity>) and Authorization Certificate(<Issuer, Subject, Delegation bit, Authorization-tag, Validity>) (YoungLok Lee et al., 2005). The event consumer sends Name Certificate and Authorization Certificate bundled together to LRC when registering event listeners.

ACL includes security policy which event producer endows the beneficiary event consumer the authority and is expressed as the Authorization Certificate.

The following explains S-expression of Authorization Certificate. Bob grants subject, called InSu Kim in his local name space, its authority, “get notification 2” from Nov.20,2005 to June.18,2006.

```
(cert (display plain)
(issuer (public-key (rsa (e
#010001#)
      (n |APsREOm+tJQsyS6f7ddzrY4A
...|)))))
(subject (name InSu Kim))
(tag “get notification2”)
(valid (not-before "2005-11-
20_06:51:33")
      (not-after "2006-6-
18_21:51:33"))
(comment "test certificate"))
(signature (hash sha1
|aj5Le4mGJ1BltdNdhU...|)
(public-key (rsa (e #010001#)
      (n
|APsREOm+tJQsyS6f7ddzrY4ACM9fmQC
...|)))
(rsa-pkcs1-sha1
|mSWhfa2GBJ3YKwkEYL/7yCP...|))
```

- SPKI/SDSI Certificate Manager

: SSCM(SPKI/SDSI Certificate Manager) includes “ Certificate Chain Discover” algorithm which carries out the work of retrieving from its certificate cache authority certificates and name certificates provided to verify the authority for the consumer to perform the given calculation(②-3 of Figure 4) (YoungLok Lee et al., 2005).

- Listener Registration Controller

(The first security challenge: Authorization)

: LRC(Listener Registration Controller) registers only the event listener of authorized consumer(Application Device) to JS-ES(②-1). LRC sends the event type and certificate bundle which it received from consumer to SSCM for authority probation(②-2) and decides by the feedback whether to register the event listener(③)(Philip Bishop and Nigel Warren, 2002) and (W. Keith Edwards, 2000).

- Notification Registration Controller

(The second security challenge: Authentication)

: NRC(Notification Registration Controller) registers only the events of authenticated

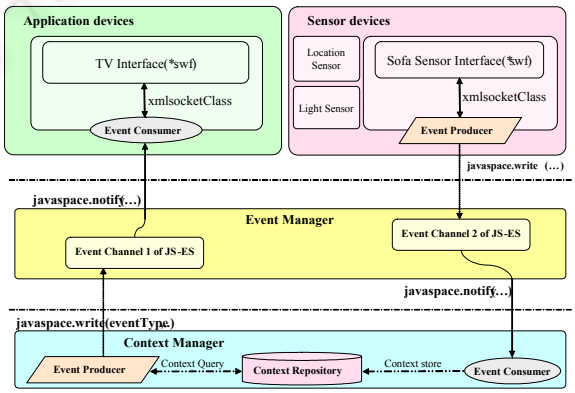


Figure 5: Overall architecture of our prototype.

producer(=sensor device)(❶, ❸) and produces valid context(❹). It tests the event type registered by producer and checks for any error for ACLs and for any overlapping of the event registered(③)(Philip Bishop and Nigel Warren, 2002) and (W.Keith Edwards, 2000) and (W. Keith Edwards, 2000).

• extended JavaSpace-based Event Service (③)(Philip Bishop and Nigel Warren, 2002) and (W.Keith Edwards, 2000).

: JS-ES(extended Java Space-based Event Service) takes the stub of the Remote Event Listener for the communication with the event consumer through web server(⑤). If sensor 1(=Event producer 1) produces a context information, Event producer 1 publishes it on NRC of Event Manager. Through JS-ES, NRC notifies the event(=context information) published by ❹ to Event Consumer of Application device(⑥).

3.2.2 Context Manager

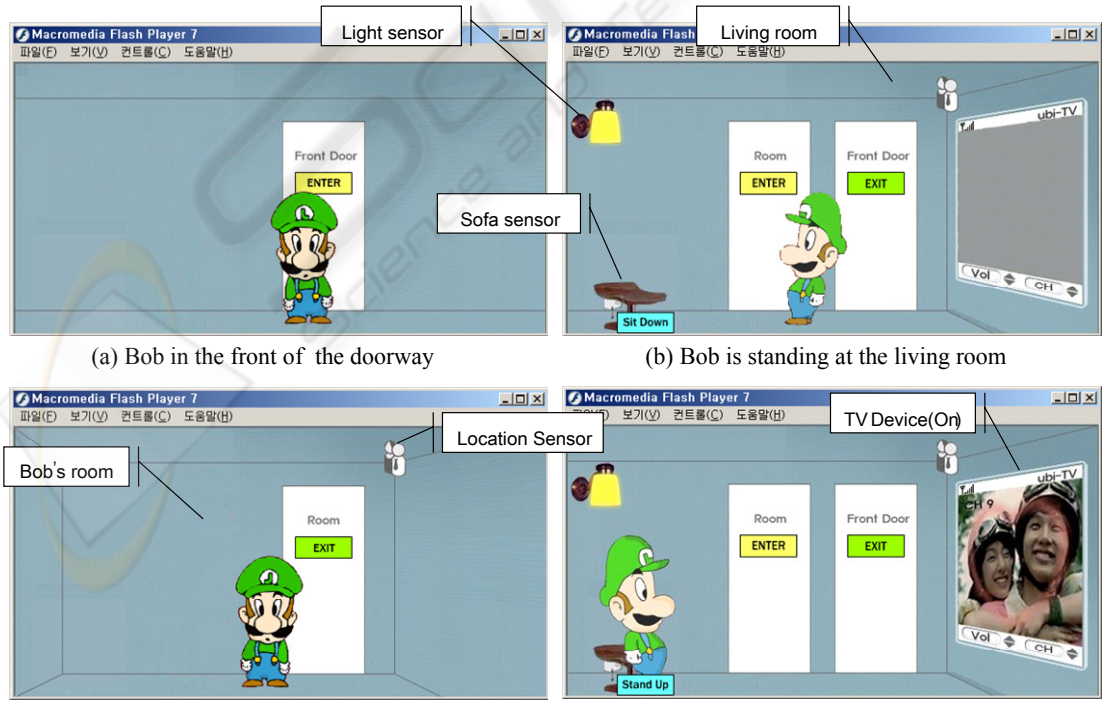
The context manager processes context information coming from sensors, stores it, and converts it into high layer's context information according to the inference policy. The context information, stored in the database, is reused later in the study of user sign or when the application demands. This context information is the events which application devices want, so to inference those events the context manager provides GUI for setting the inference policy. On the account of limited space in the thesis, we omit the explanation for this.

3.3 CASTadmin

$CAST_{admin}$ defines the relations between the Device deployed in the $CAST_{home}$ as a domain and the Person belonged to it, and generates policy and scenario. The defined relations and policy are to decide who can own and use which device. And person actually behaves following the scenario, then the subsequent virtual device is going to produce or consume context via the communication with $CAST_{middleware}$. The detailed explanation of it is omitted due to space consideration here.

4 IMPLEMENTATION AND ANALYSIS

To probe the feasibility of the suggested CAST, we implemented in Linux/Windows OS, Macromedia's Flash MX 2004 (J. Kaye and D. Castillo, 2005) and (Craig Swann and Gregg Caines, 2002), JDK 1.3 and Jini 1.2 development environment (❷)(Philip Bishop and Nigel Warren, 2002) and (W. Keith Edwards, 2000). We set up a scenario, and subsequently observed that virtual certified device produce valid context information in accordance with the scenario and that authorized device TV share and consume it.



(a) Bob in the front of the doorway

(b) Bob is standing at the living room

(c) Bob is standing at the his room

(d) Bob sit on the sofa in front of the TV device

Figure 6: Demo of our prototype .

4.1 Scenario

We chose TV for an example of the application. It was because, though with an infamy of being a fool box, it is one of the media that have the greatest impact on contemporary lives. In addition, more than anything else, in the prospect of the technologically converging trend of broadcast and telecommunication, it will become the most influential media in the future. We realized the prototype scenario as the following:

Table 1: Result of Analysis.

Approach	Representation of Context		Acquisition of Context						Sharing of Context
			Automation			Dynamicicity		Security	
Kind	Abstraction	Reusability	manual	semi-automatic	automatic	static	dynamic	Device Authentication	Authorization
CAST	o	o	-	-	o	-	o	o	o
CIVE	o	-	o	o	-	-	o	-	-
Context Toolkit	o	o	-	-	o	-	o	-	o
GUIDE	o	-	o	o	-	-	o	-	-

"On July 5, 2005, PM 6:00, Bob heads for home after work. In the way, he stops by a grocery store to buy some fruits. When he arrives home, the light goes on and after certification, he enters home. First, he changes his clothes in his home, then he has a brief dinner and sits on the sofa. The context manager, detecting his sitting on the sofa, turns on the TV to a channel based on Bob's appetite. Bob runs out to the grocery store to retrieve his wallet that he had mistakenly dropped there, with the TV on. When Bob came back, the TV is off, but turns on to the same channel that he viewed when he sits on the sofa."

4.2 Prototype Implementation

4.2.1 Scenario Process

The Figure 5 explains the communication flow between $CAST_{device}$ and $CAST_{middleware}$ that takes place once Bob sits on the sofa. The information generated by the sofa sensor is transmitted to Context Manager through JS-ES of Event Manager and stored there. Since the acquired information is the one that is called to turn the TV On/Off, it is automatically transmitted to the TV through JS-ES of Event Manager. Of course, the information of whether the TV has the authority to use the context information generated will be transmitted only when it is probed in SSCM of Event Manager.

4.2.2 TV On/Off Class and Algorithm

The event class that the virtual TV device is going to use will be the following:

```
public class TvOnOffEvent extends
  JSEvent {
 public Boolean flag;//
  False:TvOn,True: TvOff
 public Integer counter;//number of
  the family
 public String[] living;//family in
  living room
 public String[] sofa;  // family in
  sofa
 public TvOnOffEvent(Integer family,
  Boolean s) {
   counter = family;//total number of
  family
   flag = s;//current TV's On/Off
  State
   living = new String[counter];
   sofa = new String[counter];
 }
}
```

The TV On/Off adaptation algorithm of event consumer after receiving TVs On/Off events is as follows:

```
Algorithm: TV Adaptation(TvOnOffEvent
  tvevent)
Input: tvevent //    TV On/Off Event
  Type
Method:
begin
switch(tvevent.flag);//TV's state
  begin
    Case FALSE://in the case of TV Off
  event
      if((tvevent.livingroom ∩
  tvevent.sofa) ≠ Φ)
         TvOn( );
    Case TRUE://in the case of TV On
  event
      if((tvevent.livingroom ∪
  tvevent.sofa)=Φ)
         TvOff( );
    End
End
```

4.2.3 Demo

Bob moves left("Home" key) or right("End" key) by Keyboard and his home consists of living room, Bob' room. Location, light, sofa, TV device are put

into living room in Bob's home and only location device is put into his room.

In Figure 6-(a), Bob stands in front of door. When Bob enters into living room by clicking "ENTER" button of Front Door in Figure 6-(a), the location sensor detects his presence and turns the light on. But the TV does not go on by the Rule designated by the TV On/Off Adaptation Algorithm(Figure 6-(b)). If Bob enters into his room by clicking "ENTER" button of Room in Figure 6-(b), the location sensor detects his presence(Figure 6-(c)). In Figure 6-(b), If Bob sits on the sofa by clicking "Sit Down" button of sofa in living room, by the rule, the TV goes on(Figure 6-(d)).

4.3 Analysis

We have compared and reviewed CAST realized by a prototype and preceding studies, focusing on the following (Gerti Kappel and Birgit Proll, 2003). As a result, we could find a big merit of guaranteed security in the aspects of context acquirement(The first security challenge) and sharing(The second security challenge) in Table 1.

The comparison detail would be the following (Gerti Kappel and Birgit Proll, 2003):

- Automation. Concerning the acquisition of context, first it has to be defined who is in charge for gathering appropriate context information, be it either a human(manual acquisition) or the system(automatic acquisition) or a combination thereof(semi-automatic acquisition).
- Dynamicity. Another important aspect is when context acquisition takes place. Considering the frequency of context changes, context can be either static, i.e., determined once at application start up(e.g., the device used to select the appropriate interaction style), without considering any further changes or dynamic, i.e., determined on every change during runtime(e.g., the bandwidth to adapt the resolution of an image on the fly).
- Abstraction. According to the level of abstraction where context properties are represented it should be distinguished between physical context and logical context. Whereas physical context is at a very low level of abstraction which can be directly sensed from the environment, logical context would enable to enrich its semantics thus making it meani ngful for customisation purposes.
- Authentication. It means which context information acquired from certain types(manual, semi-automatic, automatic) is valid, that is, if the context is attained from certified source.(The first Security challenge)
- Authorization. It means whether it provides the acquired context information to only the application with due authority.(The second Security challenge)

5 CONCLUSION & FUTURE WORK

The study suggested CAST for the purpose of acquiring, expressing and safely using context information in the previous sections and probed its feasibility by a Demo of a realistic prototype. In particular, CAST acquires valid context and supports the function of sharing it with only authorized applications. This is significant because it provides virtual experimental environment to the S/W-major context researchers who find it difficult to fabricate physical sensors.

Future studies are called for the following area.

First, the automation of CAST components is necessary. For the present prototypes, only Device interface, agent and $CAST_{middleware}$(Event Manager, Context Manager) have been realized. In the future, through the automation of all the components, a more useful CAST will be developed and be open to the context researchers. Second, the extension of domain is necessary. Later studies will include other such various domains as schools and hospitals besides home in their research. Finally, it is expected to have a study on context modeling that is more typical and acceptable as the standard performed at the same time.

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