A Design of Social Awareness for Ubiquitous Supervisory Systems

Hideyuki Takahashi†, Satoru Izumi†,‡, Takuo Suganuma†,‡,
Tetsuo Kinoshira‡,††, and Norio Shiratori†,‡
†Research Institute of Electrical Communication, Tohoku University, Japan
‡Graduate School of Information Sciences, Tohoku University, Japan
††Cyberscience Center, Tohoku University, Japan
{hideyuki, izumi, suganuma, norio}@shiratori.riec.tohoku.ac.jp, kino@riec.tohoku.ac.jp

Abstract This paper describes a ubiquitous supervisory system "uEyes" that considers actual situations and social aspects of users. For providing efficient supervisory services, the system needs to recognize the daily activities of a watched persons, associated with his/her physical condition. To achieve this, we introduce the function of Social Awareness. In this paper, we present the design of Social Awareness focusing on the ontology to represent temporal concept. We implemented a prototype system for supervising elderly people, and confirmed that the system could judge the situation and the level of privacy based on our Social Awareness effectively by using the temporal concept.

1 Introduction

Supervisory system using multimedia communication functions can be applied to various healthcare support systems such as health management system and supervisory system for live-alone elderly people. Studies are at the initial stage to deploy this system to the ubiquitous computing environment [1, 2]. The contribution of these studies is to increase the usability of the system. However, when some emergency situation such as the condition of the watched person's health worsens, or when he/she wants to keep privacy, it is expected to cope with these situations in supervising autonomously without any user interactions. In order to achieve a gentle and safe supervision, the actual situation of and around the watched person should be reasoned using limited sensing data from real world. We also have to cope with social relationships between observers and the watched person, such as family relations or friendship, to give adequate privacy level to the services.

To realize this concept, we have been investigating a ubiquitous supervisory system "uEyes". In uEyes, we introduce a distinguished feature for the supervision: Social Context Awareness [3, 4], or simply Social Awareness. Here the Social Context Awareness is a capability of the system that can recognize the actual situation of users and social relationship between users using common-sense knowledge on social aspects. We designed this feature by effectively combining environmental information acquired from real world and knowledge on social activities of people. This knowledge on social context includes human relationship, general behavior of elderly persons, life style of the watched person, and role of each living space in house. This feature is effectively used to infer the situation of the users, and it enhances the Social Awareness of the system to make it gentle and safe to the users. Based on the advanced feature, live video streaming system is autonomously constructed according to the users' situation in runtime.

In the previous work [4] we proposed the conceptual design of the Social Context Awareness. Subsequently, we gave the detailed design of it using ontology technology. We also demonstrated the total effects with the Social Context Awareness, as well as other components in uEyes [3]. In this paper, we extend the Social Context Awareness to enable to handle various real situations of the watched person. Actually, we introduce concepts to represent temporal facts into the ontology in order to describe repetitive behaviors of people in their daily life.

We performed some experiments using newly-expanded uEyes. For instance, we assumed a scenario where an elderly person is watched by his family and his neighbors in the local community. We confirmed that, by the extension of Social Context Awareness, uEyes can recognize his unusual activities and notify the situation to the related members. For example, when the elderly person is sleeping in the bedroom at midnight and he sleeps between 23:00 and 5:00 every day, his privacy is protected. However, when he is sleeping at lunch time, uEyes recognizes it as an unusual situation, e.g., he may be in bed with a cold, and the situation is informed to the members.

2 Related Work

Some research groups are working to apply real-time multimedia watching system to ubiquitous computing environment based on location information. Such studies use video streaming delivered from the selected camera closest to the target people [5, 6]. The other research direction is on flexible displaying that seamlessly plays video streaming from the nearest display to the watching person [7, 8].

These studies include functions to select existing displays and cameras based on user's location information, and contribute to provisioning of the care-support services anytime and anywhere. However, from viewpoints of contexts of the actual situation of the supervising, there are some limitations in these studies. For instance, when a tag is recognized to be located in low position, these systems cannot judge the situation as either the watched person is sleeping in the bed room as usual, or he/she is lying in emergency situation. This is because these systems judge the situation of the watched person according to only the user's location information. This kind of deep analysis of the situation affects to the supervision directly. For example, in case of emergency, the live video streaming should be sent to as many watchers as possible with reasonable video quality. In the contrary, when the watched person is sleeping, the video should be sent with privacy concerns. To solve these problems, we need knowledge representation techniques to introduce the knowledge into the system to express various situations of the entities. As the one of the techniques, some researches use the knowledge representation using ontology [3, 4, 9].

In previous work, we propose a watch-over system introducing "Social Context Awareness" [3, 4]. Here, the ontology is used to express the knowledge about watching over. Chen et al. describe an ontology for supporting pervasive context-aware systems [9]. This ontology is a collection of ontologies for describing places, agents, and events and their associated properties in an intelligent meeting-room domain. However, these ontologies in the previous researches are limited to express temporal concepts. The temporal concepts are important to represent social knowledge.

From this viewpoint, some researches introduce temporal concepts into the ontology [10, 11]. In the literatures [10], authors attach time labeling to a triple in RDF and define that the triple is valid only the interval notated in the time labeling. In [11], the knowledge about time is expressed using the ontology. Furthermore, Chen et al. [12] are also trying to incorporate the temporal concepts to ontology in ubiquitous and pervasive application domain. By using these ontologies, we can express relations between time-lines of human behaviors, and also we can represent when person takes some actions. However, we cannot express repetitive behaviors of people such as "the person takes a meal at eighteen every day." The ubiquitous computing environments are closely linked to daily life of people. Therefore, we need to represent knowledge about repetitive behaviors that express the life style of people using ontology with temporal concepts.

3 Overview of uEyes

Fig. 1 shows our target supervision. The community of watching persons cooperatively watches over a target person. We call this kind of watching task as "Community-based supervisory task." The purpose of uEyes is to solve the problem described in Sec. 2 in this supervisory task. To achieve this, it is necessary to introduce mechanism where entire system configuration that consists of various system elements is dynamically selected and organized according to the states of the system, users, situation around the users, and social aspects. To do this, the following three awarenesses are newly introduced:

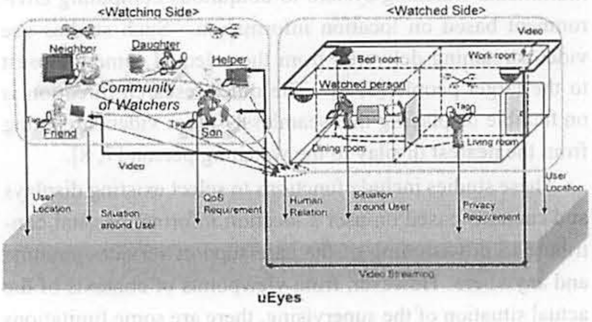

Fig. 1: Concept of uEyes

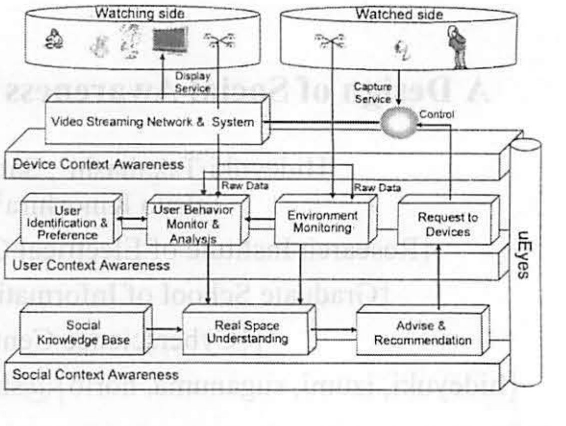

Fig. 2: Functional model of uEyes

(S1) Device Context Awareness: uEyes effectively handles and coordinates multiple contexts of ubiquitous devices for provisioning of appropriate QoS of watching systems. The contexts involve not only user location, but also status of display/camera device, available resources of PCs and handheld devices, available network access and bandwidth, etc.

(S2) User Context Awareness: uEyes closely associates with user's requirement for watching tasks in the best possible way. For example, where a watcher requires the video streaming so that he can vividly view the facial color of the watched person, high quality and zoomed picture should also be appeared in the nearest display.

(S3) Social Context Awareness: uEyes deeply considers social relationship between watched person and watchers, and keeps adequate privacy according to the situation. For instance, in case of normal situation, watched person's privacy should be protected, however in case of emergency, the privacy level would moderately be lowered.

Our previous papers [13, 14] discuss (S1) and (S2), and we omit the details of them here. We proposed the basic concept of (S3) in [4]. In this paper, we concentrate on the detailed design and implementation of (S3) Social Context Awareness of uEyes.

A functional model of uEyes is shown in Fig. 2. Device Context Awareness consists of a set of components for video streaming system and sensor devices for capturing raw data from real world. User Context Awareness is for capturing user's behavior and conditions around the user. Moreover Social Context Awareness is for recognizing social relationship between watched and watching person. It also understands the current presence and situation of the user. The three mechanisms have some functional modules as shown in Fig. 2, and these modules cooperatively work to support the supervisory task described in the previous section.

4 Mechanism for Social Context Awareness

4.1 Real Space Understanding Mechanism

In order to realize safe and convenient supervisory system, it should recognize user's actual requirements from "situation of users" and "human relationship" without any burden in system operation. To obtain the users' situations, available sensing data is limited due to its installation condition. Moreover to get the human relationship, users do not want to open all their personal information to keep their privacy. Therefore, it is difficult to precisely judge the situation and relationship of users from the limited information from real space. To resolve this problem, we take an approach to enhance the social context awareness of our system. We introduce "Social Knowledge" to perform inference to recognize the situation of users and human relationship, as well as a method to create quality/privacy request to video streaming system from the recognized results.

We propose "Real Space Understanding Mechanism" to infer the situation and relationship of users by combining sensing information and Social Knowledge. The sensing information is the data of environment acquired from real space. It includes user's physical location and temporal change of it. On the other hand, the Social Knowledge involves common-sense knowledge on human relation, human behavior, structure of living space, etc. This mechanism consists of "Human Relation Recognition" function and "Situation Recognition" function as shown in Fig. 3. The Human Relation Recognition gets user's identifier, preference, profile, etc. and puts the strength of relationship between watched person and watching person. The Situation Recognition gets user's location, environmental data, etc. and derives the user's situation such as "during dinner", "while sleeping", and "while taking a bath".

These recognized information is utilized to create QoS advice in "Advice & Recommendation" mechanism. This mechanism produces user-oriented QoS requirement to video streaming system based on the recognized results. For example, when the user requirement of high quality of video is derived in the situation where the watcher is worrying about the watched person's health condition; the mechanism creates request of high quality in video encoding. When it requires keeping high level of privacy, it issues request to degrade the

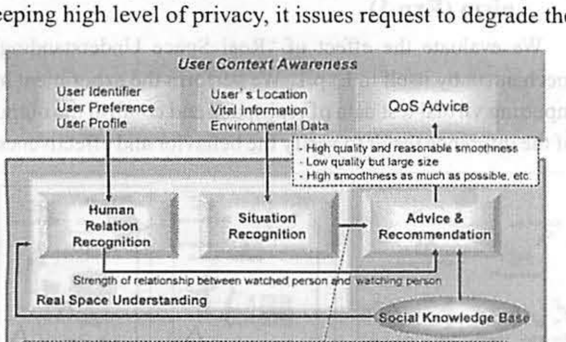

Fig. 3: Relationships among mechanisms in Social Context Awareness

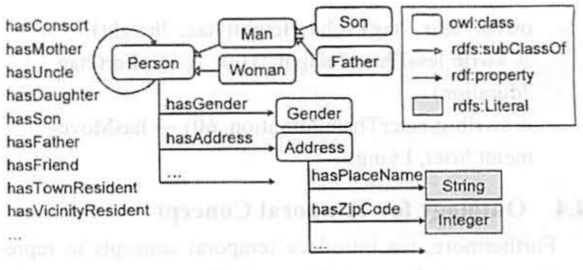

Fig. 4: Human relationship ontology

quality of the video. Moreover, in case of emergency of the watched person, it produces request the reasonable quality of video that is delivered to as many watchers as possible.

We employ ontology as knowledge description scheme to represent Social Knowledge and environmental information. The ontology can express conceptual entity of target domain and relationship among the entities. Gu et al. define context ontology in [15]. The context ontology is an ontology to express knowledge for ubiquitous computing. The ontology consists of User, Location, Activity, and Computational Entity, and these elements have relations. In our system, we define the properties, subclasses, and individuals (instances) to each basic element, focusing on the supervisory system domain.

4.2 Function of Human Relation Recognition

The Human Relation Recognition function derives human relationship between watching person and watched person, such as family relation, friendship, and block association relation. To conduct these relations, knowledge, as shown in Fig. 4, is introduced as ontology in this system.

The block association relation can be acquired from address given to each user. The family relation can be derived from each user's information of sex, partner, and children, using ontology and the rules [16].

Our system can automatically complement the missing information. In the current version of this function, only the direct friendship is given statically, however it would be dynamically obtained through the socialization in the local community activities.

4.3 Function of Situation Recognition

The Situation Recognition function infers the situation of users, especially in watched person side, in detail, by combining sensing data on real space such as user's location, current time, and social knowledge. Fig. 5 shows a part of ontology used in the Situation Recognition function. We added some essential knowledge for supervision domain to the basic four elements on the context ontology described in Section 4.1. This ontology expresses semantic relationship between concepts of devices, location, life space, human activities, persons, etc., related to the supervisory task. Using these classes and their instances, facts occurred in this domain can be represented. Applying this ontology and rules, this system recognizes the actual situation of users from the acquired sensing data. For example the following rule is knowledge to obtain behavior of a user. This rule represents that "if a user has a tag, the tag is at 100 mm high from the floor, and it is staying for 60 seconds, then the user is lying on the floor".

owns(?user, ?tag) ∧ hasHeight(?tag, ?height)
∧ swrlb:lessThan(?height, 100) ∧ stayFor(?tag, ?duration)
∧ swrlb:greaterThan(?duration, 60) → hasMovement(?user, Lying)

4.4 Ontology for Temporal Concept

Furthermore, we introduce temporal concepts to represent repetitive behaviors of the user. This extension provides powerful description ability to the basic ontology by introducing temporal concepts of human activities. Especially, we can represent a lifestyle habit of the user using the ontology with temporal concepts. Fig. 6 shows our temporal concepts to represent repetitive behaviors of the user. By using the ontology in Fig. 5, user's activities are expressed by rdf:subject, rdf:predicate, and rdf:object (triple). We can add temporal information to the triple using "temporal" property. Temporal class has two properties: "hasRealTime" and "hasCycle," which express the current time when the user is doing the specific activity, and how often the user does the activity, respectively. This representation allows to describe the user's lifestyle habit explicitly. Instant means a certain point of time (e.g., year-month-day and clock time), and Interval means an length of a time frame (e.g., from one day to another day and for hours). TimeEntity is a class which expresses time. It can express date and time, e.g., "May 25, 2008" and "10:20." The concepts of Instant, Interval, and TimeEntity are similar to those presented in [10, 11, 12]. In addition, we introduce "Cycle" class to express a periodic time. This intends to represent repetitive behaviors of the user.

5 Application: A Supervisory System for Elderly People

We are developing an application of uEyes to supervise elderly people at home. We use some USB cameras for capturing live video of the watched person. For the watchers, PC displays is used to play the live video. The live streaming is realized by applications of JMF. We use sensor systems to obtain location information of users in the rooms. We use Zone Positioning System (ZPS) for ultra sonic sensors, and an active RFID system.

In the implementation, we used DASH, a multiagent-based programming environment [17]. To implement the ontology and the rule, we describe in OWL and SWRL respectively, then convert them to Jess. This conversion is needed due to performance concerns.

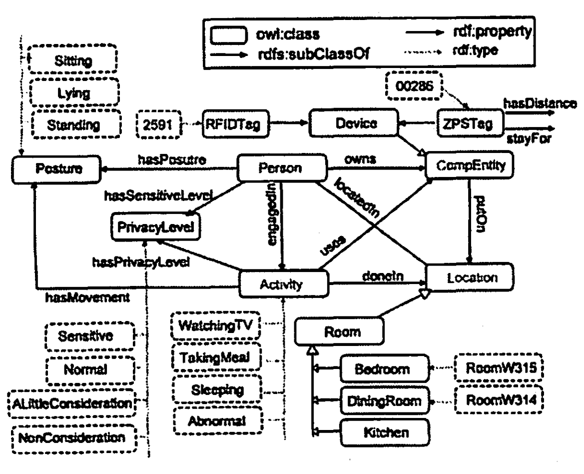

Fig. 5: Ontology to represent situation of users

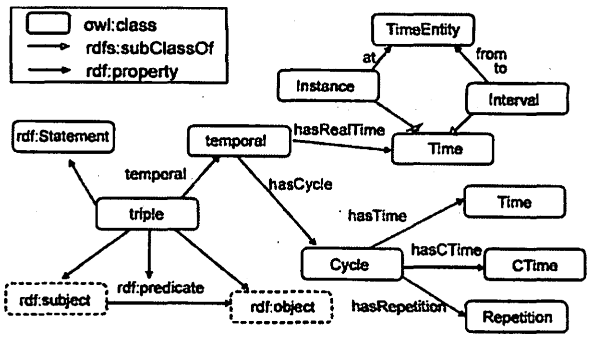

Fig. 6: Temporal concept ontology

6 Experiments and Evaluation

6.1 Experimental environment

In the application scenarios to evaluate feasibility and effectiveness of our system, we consider a situation where the elderly person is supervised by four people having some kind of relation to the person - his son, a relative, a neighbor, and a friend living in the same block. We have two experimental rooms in the watched site; a bed room and a dining room. Fig. 7(B) shows the setting of the rooms in this experiment in the watched site. ZPS ultra-sonic sensor is used in both the rooms as location sensor. We also set up a room for watching site as shown in Fig. 7(A). In this watching site, RFID system is used to obtain location of the watcher.

Here, suppose that the elderly person who is the watched object here with id "user-A", is in the bed room (B-1) or in the dining room (B-2). In this situation, our system will select the most appropriate camera and PC with reasonable network connection in these rooms. Then suitable quality of live streaming video is captured and displayed to a PC on the watching side.

We perform two kinds of experiments. The first experiment (Exp.1) is for evaluating effectiveness of the Real Space Understanding Mechanism. The second experiment (Exp.2) is to confirm the effect of Social Context Awareness in uEyes.

6.2 Effect of Real Space Understanding Mechanism (Exp.1)

We evaluate the effect of "Real Space Understanding" mechanism by itself in Exp.1. We perform the experiment by inputting virtual test data of real space and confirm the output of the inference result to verify the behavior and effectiveness

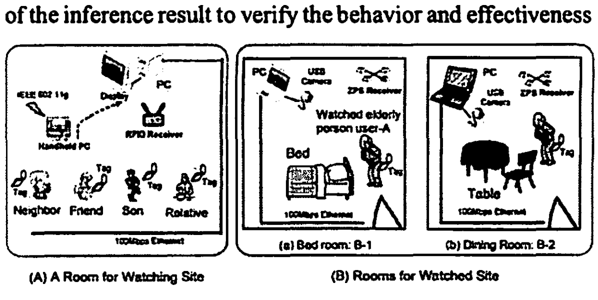

Fig. 7: Experimental room settings

of the proposed mechanism. We give some patterns of the test data, considering actual situation of an elderly watched person. The given data consists of tag ID, room ID where the tag is located, height of the tag from floor, staying duration, and current time.

Considering a situation where the watched person, suppose user-A is sleeping, we give the following data as an input of the mechanism: Tag-ID:Tag1, Tag-Position:B-1, Tag-height:100 mm, Staying-duration:300 seconds, Current-time:23:00. The result shows in Fig. 8. Without this mechanism, the given data would pass through to the output as it is. This means that the recognized results should read as "A tag with ID #1 is in the room B-1 at 23:00 and it is staying at 100 mm high for 300 seconds." On the other hand, using our mechanism, the output result is obtained as "Elderly person user-A is sleeping in the bed room as usual." To recognize this situation, we use the knowledge described in top-right text box shown in Fig. 8.

This result shows that Social Knowledge such as common-sense of human behavior and house structure is used to create meaning on the environmental information obtained from real space. In this scenario, there was no conflict in two inference results on posture of the persons, between environmental information and Social Knowledge. Both were indicating that the user-A is lying. This fact leads to the final judgement.

6.3 Effects of Social Context Awareness (Exp.2)

We have performed experiment to verify the effect when Social Context Awareness is introduced to uEyes. It is expected that it can achieve the supervision by community of two or more people, because understanding of the interpersonal relationship and recognition of the situation can be done by the Social Context Awareness.

Fig. 9 shows the example of the display in the emergency situation when the watched person collapses onto the floor. The "Situation Recognition" function judges it as a state of emergency such as the falling down etc., using elderly person's location information obtained from real space, and the "Social Knowledge" concerning the structure of the house. The display is changed so that many people may know the situation by lowering the privacy level. Concretely, an untouched video image is delivered to his son and his relative. His neighbor with a good relation receives a low quality

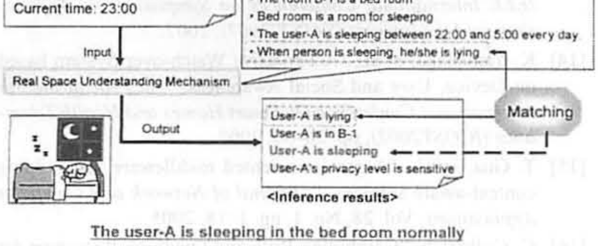

Fig. 8: Experimental result of Exp.1: A normal situation (the user is sleeping)

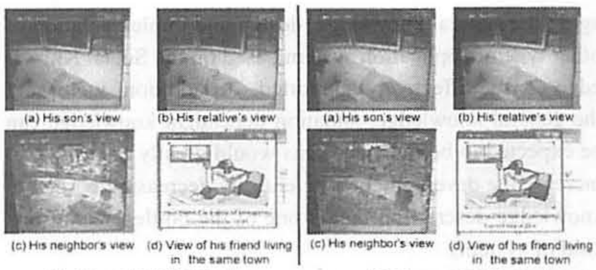

Fig. 9: Experimental result of Exp.2(1): Effect of Social Context Awareness in case that of watched person in emergency.

video and a person in his same block is notified by emergency message with picture image.

The system could judge the emergency in both cases (Fig. 9(A) and Fig. 9(B)) using temporal concepts in addition to relation of ontology about activity and location. The reason was that the watched person never lies down on the floor in the dining room without emergency situation.

Fig. 10 presents the displays when the watched person is sleeping in the bed room. Fig. 10(A) expresses the situation where the watched person is sleeping but is unusual because of a conflict between the current time when he is sleeping and his lifestyle habit. The "Situation Recognition" function judges it as an unusual state, e.g., he may be in bed with a cold. Therefore, the privacy level is lowered a little bit. The son can watch the video with high quality, and the relative and the neighbor receive a low quality video. The person in the same block gets message that announces the watched person's state is unusual. The situation where the watched person is sleeping normally at night is shown in Fig. 10(B). The "Situation Recognition" function judges it as normal situation and keeping his privacy. The son and the relative get a low quality video, and the others receive a message that he is sleeping.

In our previous work, whenever the watched person lies on the bed, the system recognize the person is sleeping usually and can not detect an unusual situation such as the person may be in the bed with cold. However, by introducing temporal concepts into our Social Awareness, our system can detect the unusual situation like Fig. 10 considering the person's lifestyle habit.

As mentioned above, we confirmed the advancement of the Social Awareness by the effects of temporal concepts.

6.4 Evaluation

(1) Real Space Understanding Mechanism: The effectiveness of our proposal was confirmed through the experiments described in previous sections. The experimental results show that we can create meaningful conclusions from environmental information got from real space based on the Social Knowledge. Therefore, we can infer many types of situations that is hard to recognize only from analysis of environmental data.

More general knowledge such as common-sense can be employed not only in supervisory application domain, but also in other domains. Namely, by accumulating and managing the general knowledge, design and implementation of other type of application system based on the Social Knowledge can be effectively supported. In addition, increasing the general knowledge, situation dependent knowledge can be expected to be reduced. This would greatly contribute to increase the development efficiency by decreasing burden in knowledge description that is one of the bottlenecks of this kind of systems.

(2) Temporal Concepts for Social Awareness : We confirmed the effect of temporal concepts for Social Awareness from the experiments. uEyes can recognize the actual situation considering the lifestyle habits of the watched person based on the temporal concepts. By introducing the temporal concepts, it enables to express the repetitive behaviors of the user adequately. This aspect leads to an improvement of existing Social Awareness.

uEyes can recognize relationship between people in real world and detailed situation of the watched person by employing this awareness with the temporal concept. uEyes can autonomously handle the implicit requirements on QoS parameter and privacy level in an adequate level based on the information on daily activities of the watched person. The significant point of this system is its automatic acquisition of user requirement. It would be very difficult for elderly people to properly manipulate the system. Moreover, the watched person cannot do anything in the emergency situation. This feature would enable safe and secure supervisory services to especially help non-expert users.

7 Conclusion

This paper presented a supervisory system for ubiquitous healthcare support. In this system, situation of users and environmental information around him/her are effectively handled to provide the supervisory services. Social Context Awareness such as human relationship is also considered to increase sense of safety in the supervision. We build an application of supervisory system supposed to be provided for elderly people at home, and confirmed the effectiveness of the idea with some initial experiments.

We are planning to extend the ontology of temporal concepts and construct a new method to detect person's lifestyle habits. Also we will continue the case study based on different scenarios. Additionally, we are trying to measure the user's satisfaction in quantitative manner. Moreover, we plan to carry on field tests to deeply investigate the effects and

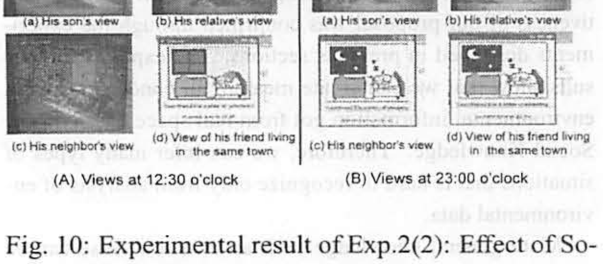

Fig. 10: Experimental result of Exp.2(2): Effect of Social Context Awareness in case that watched person is sleeping in bed room.

issues of our system in practical use.

Acknowledgement This work was partially supported by Sendai Intelligent Knowledge Cluster and the Ministry of Education, Culture, Sports, Science and Technology, Grants-in-Aid for Scientific Research, 19200005.

References

[1] L. M. Camarinha-Matos, and H. Afsarmanes, " Infrastructures for collaborative networks - An application in elderly care, " in *Proc. of the 2005 Symposium on Applications and the Internet (SAINT'05)*, pp. 94–101, 2005.

[2] S. Consolvo, et al., "The CareNet Display: Lessons Learned from an In Home Evaluation of an Ambient Display, " in *Proc. of the Sixth International Conference on Ubiquitous Computing (Ubicomp2004)*, pp. 1–17. 2004.

[3] T. Suganuma, et al., "A Ubiquitous Supervisory System based on Social Context Awareness, " in *Proc. of the 22th International Conference on Advanced Information Networking and Applications (AINA2008)*, pp. 370–377, 2008.

[4] T. Suganuma, et al., "A Ubiquitous Watch-over System based on Environmental Information and Social Knowledge, " in *Proc. of the 4th International Conference on Ubiquitous Intelligence and Computing (UIC2007)*, pp. 1108–1120, 2007.

[5] M. Takemoto, et al., " Service-composition Method and Its Implementation in Service-provision Architecture for Ubiquitous Computing Environments, " *IPSJ Journal* Vol. 46, No. 2, pp. 418–433, 2005.

[6] G. C. de Silva, et al., "Experience Retrieval in a Ubiquitous Home, " in *Proc. of the 2nd ACM Workshop on Capture, Archival and Retrieval of Personal Experiences 2005 (CARPE2005)*, pp. 35–44, 2005.

[7] Y. Cui, et al., "Seamless User-level Handoff in Ubiquitous Multimedia Service Delivery, " *Multimedia Tools and Applications Journal, Special Issue on MobileMultimedia and Communications and m-Commerce*, Vol. 22, No. 2, pp. 137–170, 2004.

[8] M. Lohse, et al., "Dynamic Media Routing in Multi-User Home Entertainment Systems, " in *Proc. of the Eleventh International Conference on Distributed Multimedia Systems (DMS'2005)*, 2005.

[9] H. Chen, et al., "An ontology for context-aware pervasive computing environments, " *The Knowledge Engineering Review*, Vol. 18, No. 3, pp. 197–207, 2003.

[10] C. Gutierrez, et al., "Introducing Time into RDF, " *IEEE Trans. on Knowledge and Data Engineering*, Vol. 19, No. 2, pp. 207–218, 2007.

[11] J. H. Hobbs, and F. Pan, " An Ontology of Time for the Semantic Web, " *ACM Trans. on Asian Language Information Processing* , Vol. 3, No. 1, pp. 66–85, 2004.

[12] H. Chen, et al., "SOUPA: Standard Ontology for Ubiquitous and Pervasive Applications, " in *Proc. of The First International Conference on Mobile and Ubiquitous Systems: Networking and Services (MobiQuitous2004)*, pp. 258–267, 2004.

[13] H. Takahashi, et al., "uEyes: A Ubiquitous Care-Support Service based on Multiple Contexts Coordination, " in *Proc. of IEEE International Conferences on Symposium on Applications and the Internet (SAINT'2007)*, 2007.

[14] K. Yamanaka, et al., "A Pervasive Watch-over System based on Device, User and Social Awareness, " in *Proc.of the 5th International Conference On Smart Homes and Health Telematics (ICOST2007)*, pp. 20–30, 2007.

[15] T. Gua, et al., "A service-oriented middleware for building context-aware services, " *Journal of Network and Computer Applications*, Vol. 28, No. 1, pp. 1–18, 2005.

[16] C. Golbreich, "Combining Rule and Ontology Reasoners for the Semantic Web, " LNCS 3323, pp. 6–22, 2004.

[17] http://www.agent-town.com/dash/index.html