Security Service Robot in Ubiquitous Environment based on Cognitive Robotic Engine

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Abstract. This paper proposes a security service robot that is working in ubiquitous environment. The system is organized based on TCP/IP communication and Cognitive Robotic Engine (CRE) for intelligent control. CRE, that is proposed by Sukhan Lee, et al [1], provides asynchronous and concurrent processing architecture, uncertainty control, and behavior selection for the accomplishment of missions. The traditional security systems are limited in their intelligence and the view where they can observe. Contrary to the conventional, the security robot can provide effect and active security service with low-cost. The authors have implemented the proposed system in mobile robot and shown that the robot have performed its mission very well.

Keywords: Ubiquitous, Security, Service Robot

1 Introduction

1.1 Intelligent Ubiquitous Robot

Since the end of the 20th century, the ubiquitous technology has been rapidly growing. Ubiquitous can be applied to lots of fields. In fact, the technology is expected to create 800 trillion won world market, according to the experts. On the other hand, robot technology is the one of new breakthrough in science technology [2]. There are plenty of researches being made for human-robot interaction (HRI). Among them, wireless robot control is important. Traditional isolated robot are able to interact with the surrounding world by seeing, touching, and moving, etc. These kinds of interactions are local and physical. But in contrast, ubiquitous robot's interactions are global and abstract. The robot can overcome the physical barriers through the network [3]. Taking account of such trend, service robots integrated with ubiquitous computing technology are expected to expand the both research fields. Many of research institutes in Korea are developing mobile robots based on wireless network. Ubiquitous Robotic Companion (URC) is one of the biggest robot projects by Korea government. Meanwhile, intelligent robot control for the integration of HRI components is critical issue. In previous work, one of the authors proposed Cognitive

Robotic Engine for optimal control of robot system [1]. CRE considers uncertainty of mission and invoke proactive actions to get more evidences. The main features of CRE will be detailed in chapter 2.

1.2 Security Service

Intelligent security systems are common in home, office, and other places, these days. They usually use fixed pan-tilt cameras, digital doors, and so on. However, the problem of those kinds of systems is that they are passive system. So anyone who knows well about particular system is able to incapacitate the security. Besides, the configuration of the system should be adapted from place to place. On the other hand, security service robot can be an active system. It can wander over the place and check the environment by itself, since all the system is installed in mobile platform. If the structure or environment of the place is changed, the robot would be simply adapted to new environment by the user's settings. Especially, the security robot with ubiquitous probably maximize its utility. The robot may inform the situation to supervisor through the media like internet. For this reasons, the authors propose the novel and intelligent security robot based on ubiquitous environment and CRE.

2 Cognitive Robotic Engine

2.1 Conceptual Overview

CRE is regard as a more general form of behavior based approach [4] that is extended to include perceptual behavior. It aims for dependable perception and integration by combination of imperfect perceptual processes and/or proactive actions. Imitating the human dependability in perception, the main features and procedures of CRE is conjectured as follows:

1) The spontaneous and self-establishment of ad-hoc perceptual missions in connection to particular sensing.
2) The choice of particular asynchronous and concurrent flow architecture of perceptual building blocks, out of a potentially huge number of possible flow architectures as the basis for deriving evidences to be fused together.
3) The incorporation of action blocks into the chosen asynchronous and concurrent flow architecture. This is a mean of proactively collecting new evidences for less uncertainty. The evidences trigger a dynamic reorganization of the flow.
4) The optimal process control at each sampling time, where the optimality is defined in terms of the time and computing resources for uncertainty reduction. Note that the control strategy may differ by individuals.

For the optimal control of CRE, the authors applied Bayesian Net in uncertainty calculation. The mission certainty is acquired below:

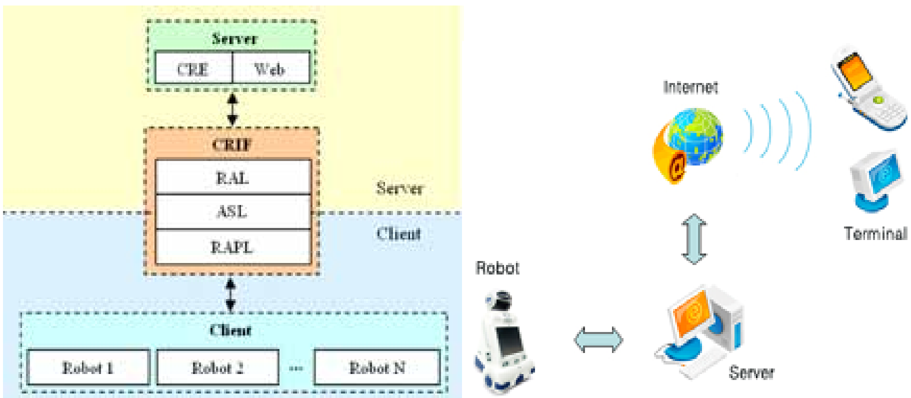
$$Mission\ \ Certainty = P(Mission \mid Evidences) = \frac{1}{1 + \dfrac{P(Evidences \mid \overline{Mission})P(\overline{Mission})}{P(Evidences \mid Mission)P(Mission)}} \qquad \textbf{(1)}$$

The advantage of Bayesian Net is that multiple evidences can be integrated naturally. The mission certainty is accumulated in time domain based on (1). Disadvantage of this approach is that the prior probabilities are hardly known. So some heuristics are needed. For more details see [1].

3 Security Service in Ubiquitous

3.1 Common Robot Interface Framework (CRIF)

Since there is no standard for development of robot, most of implementations for control, like functions and protocols, differ highly depend on the developers. This results in problems in compatibility. One program may not work in other robots because hardware dependent codes are embedded in it. To enhance compatibility of robot platform, Electronics and Telecommunications Research Institute (ETRI) has developed Common Robot Interface Framework (CRIF).



(a) (b)

Fig. 1. (a) CRIF concept. It covers both server and client. (RAL: Robot API Layer, ASL: API Sync Layer, RAPL: Robot API Presentation Layer) (b) The concept of ubiquitous service robot.

CRIF provides TCP/IP wireless connection so that robot is able to communicate to other Server PC or PDA. This is important for ubiquitous robot because developers are able to put complex programs in server computer and make robot lighter. Fig. 1 (a) represents the conceptual structure of CRIF. As seen in the figure, there are server and client. The client means robot here. If the robot is changed, the developer doesn't have to implement the program again. Instead of that, hardware controlling program should be changed only. CRIF is covering both the robot and the server so that they can communicate to each other. Once an application program orders to control a robot, CRIF in server part sends it. And then, the counter-part CRIF in client decodes it and makes the robot to do it. In (b), by web server, client robot can pass information to internet. From the web service, the user is entitled to access the server, make events, and use multimedia. The web part in server is organized using Apache HTTP server, so that monitoring is available from 80 port. Data which are pictures, packets, and time, transmitted from the robot is saved in MySQL. The user can see the data real-time by web with PHP that is server side script. Additionally, he/she also can make event by keyboard or mouse and control the robot directly using web event.

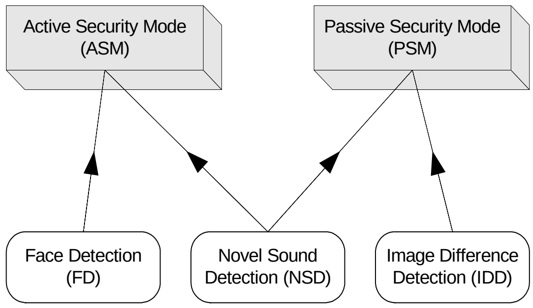


Fig. 2. The relation for two security missions and three perceptual processes.

3.2 Configurations for Security Service

Basically, the authors set two missions for security. The first mission let the robot to stay in certain place so that it can observe door or windows like traditional security systems. The second one is active mission. The robot will be wandering and try to find something strange. To perform missions three perceptual processes are defined. Face Detection (FD) Process, Novel Sound Detection (NSD) Process, and Image Difference Detection (IDD) Process. The relation between perceptual processes and missions are represented in Fig. 2. Any of sensing cues will report its results to CRE control, and then the mission will be managed. Individual perceptual process has its behavior recommendation. The definitions of behaviors are listed in Table 1. In Table 1, two categories of behaviors are defined first. Behaviors in action category are for an invader. Security reporting behaviors are stronger gestures of robot. Recommend behaviors from each process are described in Table 2.

Table 1. The list of behaviors and their definitions

Category	Name of Behavior	Definition
Action	Wandering (WA)	Moving constant velocity with obstacle avoidance
	Turning (TU)	Turn to intended direction
Security	Capture Image (CI)	Image capture for security
Reporting	Report User (RU)	Send image and report the status

Table 2. Recommened actions from individual perceptual process

Name of Process	Certainty Level		
	L	M	H
Face Detection	WA	CI	RU
Novel Sound Detection	TU	CI	RU
Image Difference Detection	CI	RU	RU

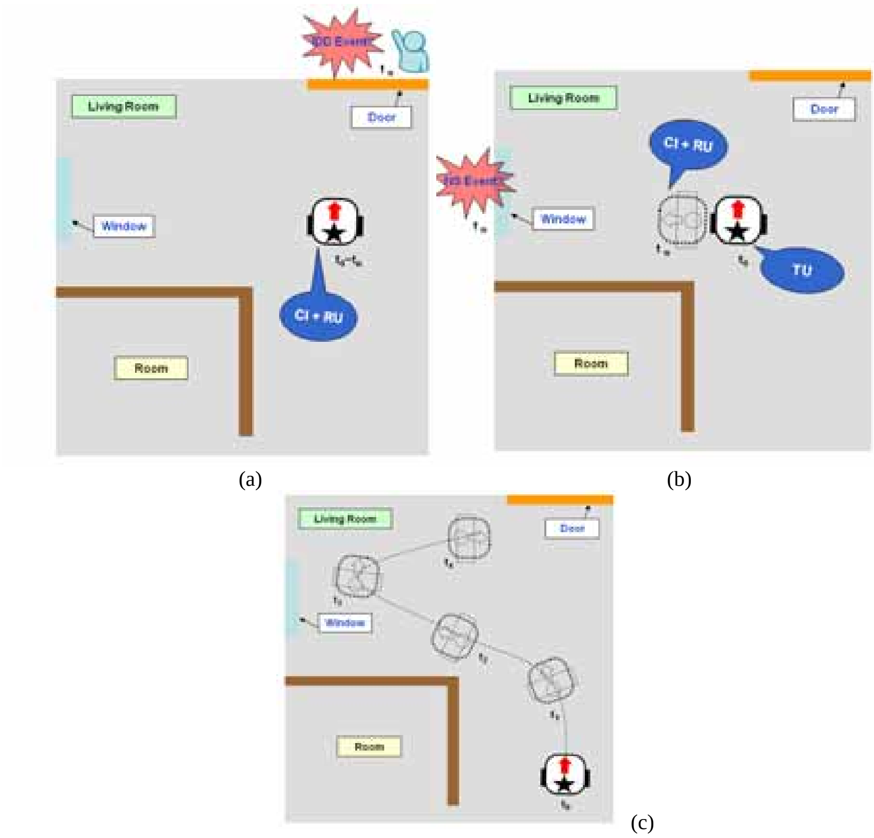


Fig. 3. Three scenarios of security mission. (a) and (b) is in PSM, and (c) is in ASM.

Fig. 3 shows the example scenario of security robot. In (a), robot was staying in front of the door. When unexpected person came to the door and open it. The robot may detect the difference of image. Since he/she is not an owner, it will capture the image and report it through web. In (b), initial state is same as (a), but the event occurred beyond the robot's sight. However, the novel sound invoked the robot. It will probably turn to the direction and do the same job as in (a). In (c), the robot wanders so that it may find unexpected situation.

4 Hardware Configuration and Implementation

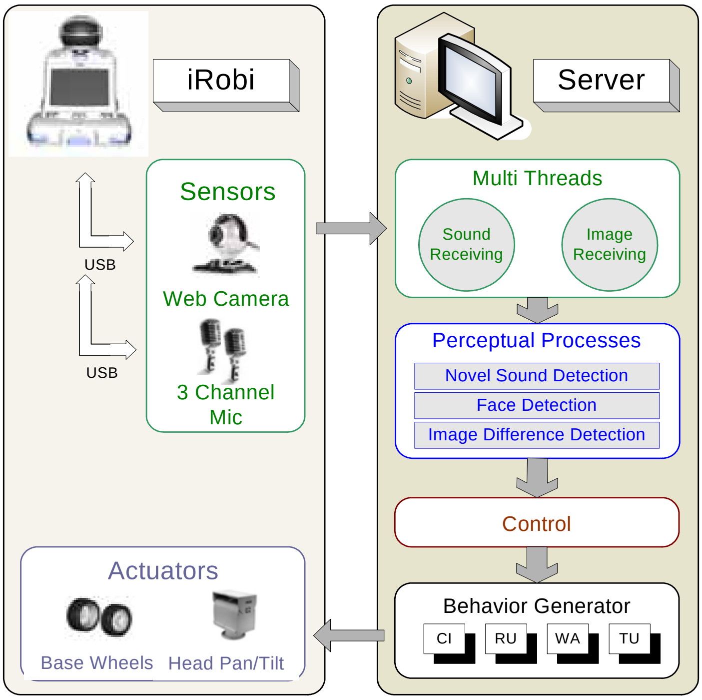


Fig. 4. The design of robot security system.

In Fig. 4, single-board-computer in the robot has Intel Pentium mobile processor 1.4GHz, 1GB RAM, and 40GB hard disk. Web camera as imaging sensor has approximately 60° horizontal-field-of-view (HFOV), and 320*240 square pixels at 30Hz. Robot/hardware dependent procedures are implemented in the server so that CRE system could be adapted to another platform easily. The server computer has CRE application which provides security. Two multi threads in the server requiest image and sound asynchronously and concurrently. A perceptual process is called when a thread get sensing information from robot. All the results from perceptual processes are reported by the packet form. And the control estimates the certainty of mission. It immediately requests a behavior, if it is needed. Note that communications between two systems are done by CRIF. Last, Fig. 5 shows the interface for user report. This way of reporting programs can be applied to PDA, PC, and etc.

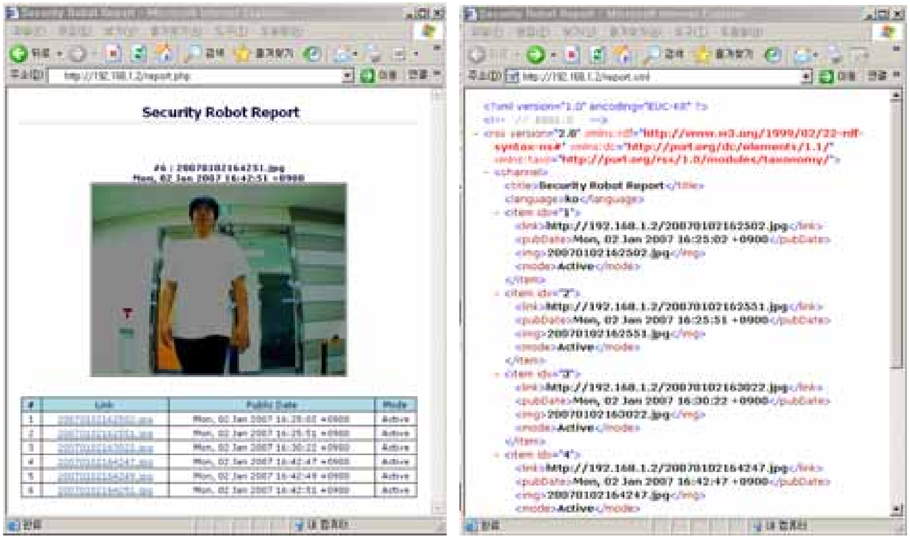


Fig. 5. Reporting web page and xml codes for the implementation

5 Experimental Results

5.1 Experiment Condition

The experiment results below show the robot behaviors and captured image from the robot when the robot mode is “Passive Security Mode (PSM)” or “Active Security Mode (ASM).” Y-axis in the graph indicates robot behaviors (WA, TU, CI, RU), and x-axis in it indicates time sequences (sec). These results demonstrate security service robot motions when a trespasser breaks into the area especially.

5.2 Passive Security Mode (PSM)

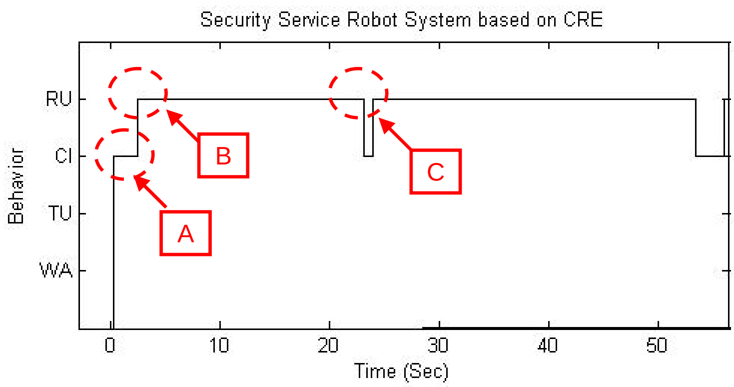


Fig. 6. The records of robot behaviors when the robot's mission is PSM.

(a) (b) (c)

Fig. 7. Captured Images from the robot - situation (a), (b), and (c), for the time sequences.

Fig. 6 shows the robot behaviors when the robot mode is PSM. In that mode, the robot stays in a certain place and stares doors or windows for security. At this point, if someone comes into the robot vision or the robot hears novel sound, it will capture current image for intended direction. (a) in Fig. 7 shows CI. Since there were continuous evidences according to a human moved, the robot captured (b), and (c). The system reported the alert messages and captured image to the user which is RU. 'C' in Fig. 6 shows sudden change of behavior. Actually, the human wasn't moving for a while. Despite the fact, the robot could find some differences in the image, and captured image (See (c) in Fig. 7). In this situations, the robot works like conventional security system. This means that if the user put the robot some place, it can provide a normal security service. Moreover, it should not be embedded in ceiling.

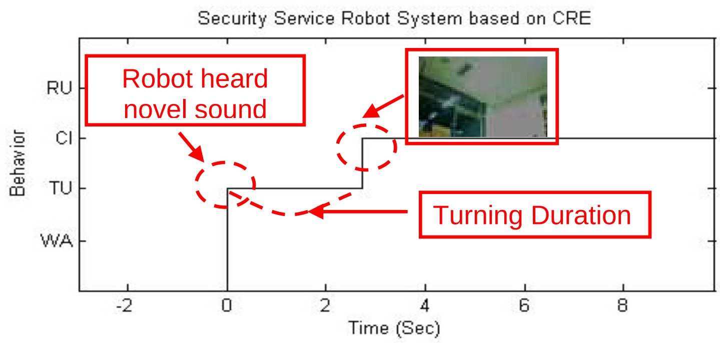


Fig. 8. Capture image from the robot with the novel sound.

The other side, Fig. 8 shows other situation in PCM. If the robot heard novel sound, the robot may turn to the sounds direction and captures image (CI). But if the robot does not find any image differences at that direction, the robot probably not take any other behavior (RU).

5.3 Active Security Mode (ASM)

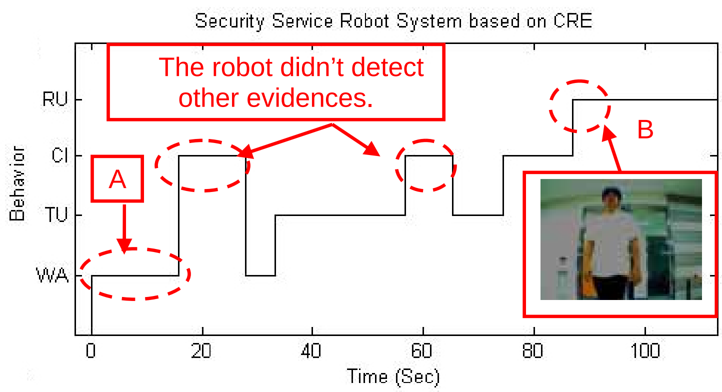


Fig. 9. The records of robot behavior when the robot's mission is ASM.

Fig. 9 represents the experiment in ASM. Firstly, WA behavior is invoked by any evidences or user's inquiry. Accumulations of evidences made CI twice, but there was no more evidences. At last, the certain invader made the robot to report the situation by internet. Situation B indicates the robot detected the trespasser using FD, and NSD process. The results show a good possibility for new security system using mobile robot.

6 Conclusion

We have developed a security service robot as an application of ubiquitous technology. The ubiquitous systems are implemented based on CRIF which provide TCP/IP wireless communication. Using the system, the robot, the server, and the user could naturally communicated for the service. The robot intelligence is implemented using CRE. In particular mission, the evidences from perceptual processes invoked robot behaviors. For the experimentations, the authors implemented proposed systems. Although, the processes were not excellent components, we could see the experimental results have shown that the security robot is able to provide both active and passive service which is conventional.

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