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Chapter 13 Temporal–Spatial Collaboration Support for Nursing and Caregiving Services

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Abstract An aging population is driving a tremendous need to improve both the efficiency and quality of nursing and caregiving. Toward this end, a collaboration support system would be useful because indirect operations such as recordkeeping and communication are a significant part of healthcare work. This chapter proposes an information supervisory control model for a collaboration support system targeted at nursing and caregiving service systems; furthermore, we have developed a smart voice messaging system based on this model. We then formulate hypotheses to be examined through field tests, virtual field tests, and simulation from the perspective of information supervisory control.

13.1 Introduction

Global demand for improvements to healthcare service systems is increasing rapidly. This is especially true in highly developed nations like Japan where the demographic ratio has shifted to more elderly to fewer young people in the population. As a consequence, higher quality and greater efficiency are needed in

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healthcare. From the viewpoint of service science, healthcare including nursing and caregiving is a typical service system (Chesbrough and Spohrer 2006), and an abundance of research and practical experience has been accumulated in this area (Berry and Bendapudi 2003; Saviano et al. 2010; Brailsford and Vissers 2011).

In this chapter, we focus on communication in nursing and caregiving, which are areas where new and less stressful human–computer interaction technologies are required. Moreover, service design and evaluation methodologies are also necessary for stepwise improvement of these service systems. To satisfy these requirements, we have developed a novel temporal–spatial communication system using smart voice messaging through an industry–government–academia collaborative project (Uchihira et al. 2011, 2012; Hiraishi et al. 2012).

Started in October 2010, this project involves an information technology company (Toshiba), a construction company (Shimizu), knowledge management researchers (JAIST), a hospital, and several care facilities, and is supported by the Service Science, Solutions and Foundation Integrated Research Program (S3FIRE) of JST.

This chapter is organized as follows. In Sect. 13.2, we define the problem to be investigated. In Sect. 13.3, we discuss the characteristic features of nursing and caregiving, and in Sect. 13.4, we give an overview of the methods and goals of communication. We propose an information supervisory control model in Sect. 13.5, and we explain a smart voice messaging system in Sect. 13.6. Section 13.7 discusses hypotheses to be tested and system evaluation. Section 13.8 discusses related research, and Sect. 13.9 gives our conclusions.

13.2 Workload in Nursing and Caregiving

A major problem faced by healthcare professionals is a heavy workload; thus, finding ways to improve efficiency is vital. Although most nursing and caregiving work directly involves patients and care recipients, indirect operations are also significant. In fact, it has been reported that 25–50 % of nursing work consists of indirect operations at some hospitals (Toriyama et al. 2007).

We conducted interviews with caregivers and nurses, and identified the following areas in need of support: recordkeeping using a healthcare information system, handoff at shift change, and collaboration between remote locations. Raising the efficiency of indirect operations will increase the time available for direct operations involving patients and care recipients, in turn leading to higher quality of service and increased customer satisfaction.

Several information systems including electronic medical recording and ordering have been introduced to increase the efficiency of administrative work. However, these systems sometimes increase the burden of indirect operations to be performed by nurses and caregivers because of cumbersome terminal input. Extensive research has been conducted on computer-supported cooperative work (Rodden 1991), but conventional PC-based support tools introduce problems of their own. PC-based support tools are not well suited to nursing and caregiving service systems which involve physical activities because using such tools creates an additional burden, both mentally and physically, on nurses and caregivers.

Table 13.1 Comparison between PAI service and software development

Feature	PAI service	SW development
Knowledge-based tasks	High	High
Adaptation	High	Low
Multitasking	High	Middle
Spatial tasks	High	Low
Collaboration	High	High
Recording	High	Middle

Therefore, new human–computer interaction technologies are required to improve nursing and caregiving service systems by lowering the burden imposed on the user. Moreover, new service design and evaluation methodologies are also necessary for stepwise improvement of nursing and caregiving service systems.

13.3 Nursing and Caregiving as Physical and Adaptive Intelligent Services

In this section, we discuss six characteristic features of nursing and caregiving.

- *Knowledge-based tasks*: Nursing and caregiving require expert knowledge and skills in order to avoid malpractice.
- *Adaptation*: The conditions of patients and care recipients change, so it is necessary to adapt to such changes flexibly.
- *Multitasking*: Multiple tasks must be handled at the same time (e.g., call handling during regular care).
- *Spatial tasks*: Tasks must be performed at various locations, such as the hospital ward, nursing center, and pathology laboratory, necessitating considerable movement.
- *Collaboration*: Many tasks must be done collaboratively, for example, bathing assistance, pressure ulcer care, and transfer of a patient between a bed and wheelchair.
- *Recordkeeping*: Accurate records of patient condition and treatment must be kept.

We call service systems having the above features “physical and adaptive intelligent services” (PAI services). Traditional PC-based tools for computer-supported collaborative work are ineffective at supporting PAI services. Table 13.1 shows a comparison between PAI services and the software development as a typical PC-based collaborative work.

13.4 Communication in Nursing and Caregiving

Based on observations and interviews in a hospital and a care facility, which are participants in this collaborative project, the objectives and methods of communication in nursing and caregiving as PAI services are analyzed.

Table 13.2 Communication methods in nursing and caregiving (Sync: Synchronization, Async: Asynchronization)

Method	Media	Distance	Timing	Channel	Record	Direction
Face-to-face communication	Voice	Near	Sync	Many to many	None	Push
Memorandum	Paper	Near	Async	One to one	None	Pull
Phone	Voice	Far	Sync	One to one	None	Push
Bulletin board	Board	Near	Async	Many to many	None	Pull
Intercommunication system	Voice	Far	Sync	Many to many	None	Push
Mail	Text	Far	Async	One to many	Exist	Push
SNS	Text & Image	Far	Async	Many to many	Exist	Pull
Operator	Voice	Far	Sync+ Async	Many to many	None	Push

13.4.1 Objectives of Communication

The objectives of communication among nurses, caregivers, and other staff can be classified as follows.

- *Information sharing:* Nurses and caregivers communicate with others to share information about patients and care recipients (client information sharing) and information of the progress of tasks (process information sharing).
 - Client information sharing includes face-to-face communication at a shift-change meeting and PC-based communication via a healthcare information system for recording and viewing patient information.
 - Process information sharing is necessary for collaboration with colleagues at remote locations (e.g., a nurse in the nursing center confirms progress of bathing services in the bathroom).
- *Instruction and request:* Nurses and caregivers communicate with others to transmit instructions and make requests. Instructions and requests include the following forms of communication.
 - Transmitting instructions/orders to staff (e.g., medical instruction from a doctor to a nurse).
 - Real-time requests for transportation services (e.g., patient transportation between a patient's room and the operating room).
 - Batch (non-real-time) requests from clients and clients' families (e.g., requests for changes in meal service and meeting request from a client's family).

Table 13.3 Communication methods and objectives in nursing and caregiving

Method	Information sharing		Instruction and request		
	Client	Process	Instruction	Request (real time)	Request (Batch)
Face-to-face communication	+++	+	+++	++	++
Memorandum	++	+	+	–	+++
Phone	+++	+	+++	++	–
Bulletin board	++	+	+	–	+++
Intercommunication system	+++	+	+++	++	–
Mail	++	+	+++	–	+++
SNS	+++	++	+	–	++
Operator	++	+++	+	+++	+

13.4.2 Methods of Communication

Table 13.2 lists communication methods that are used in actual nursing and caregiving settings. In the table, “operator” indicates operator-controlled communication, analogous to radio dispatching of taxis and traditional telephone controlled by a switchboard operator. Human operators are effective but expensive, so automatic intelligent operators (communication supervisors) are required.

Table 13.3 shows the suitability of communication methods in nursing and caregiving for meeting communication objects. Because each communication method has particular advantages and disadvantages, they are used in combination to achieve communication objectives. However, it is hard for nurses and caregivers to carry many communication devices. Now smartphones show great promise for integrating multiple communication tools into a single device. We introduce a communication model called an “information supervisory control model” to explain these communication methods, including the operator, in an integrated fashion.

13.5 Information Supervisory Control Model

To design and evaluate a temporal–spatial collaboration support system, a communication model is required. Several studies on models of communication in nursing and caregiving have been reported (Avrunin et al. 2010). We have also modeled collaborative processes in nursing and caregiving by means of Petri nets and evaluated the efficiency of communication through computer simulation (Hiraishi et al. 2012). Here, we must model not only the communication system but also humans (the senders and receivers of information). However, the human behavior of nurses and caregivers is difficult to model. Accordingly, human behavior modeling of nurses and caregivers remains an important issue.

Supervisory control is a well-studied model of a discrete-event system in which events occur concurrently and collaboratively (Ramadge and Wonham 1987). In

traditional supervisory control, a supervisor controls the target system by permitting the occurrence of events in order to satisfy a given specification. We call the traditional supervisory control “event supervisory control.”

The controlled objects in event supervisory control are machines, not humans, and thus human behavior modeling of nurses and caregivers requires the following additional considerations.

- The information processing capability of humans is limited.
- Humans finally make decisions and take action based on available information.
- Humans use tacit knowledge to decide upon actions in addition to available information, but a complete model of tacit knowledge is impractical.
- Human behavior differs between individuals according to their mental and physical condition.
- Humans can inquire about information and verify it, if desired.

We introduce information supervisory control as an alternative to event supervisory control. In the proposed control scheme, a supervisor indirectly controls the target collaborative system, including humans, by controlling the information distribution flow. Here, indirect control means that humans ultimately decide upon and implement actions autonomously, and only the provided information is controlled. In information supervisory control, the necessary information (*what*) is distributed to the right person (*who*) at an appropriate time (*when*) and an appropriate place (*where*) by a suitable means (*how*). In other words, information supervisory control acts as if it were a responsive administrative assistant. Figure 13.1 depicts event supervisory control and information supervisory control. In previous research, the blackboard model and the agent model have been proposed, in which processes and

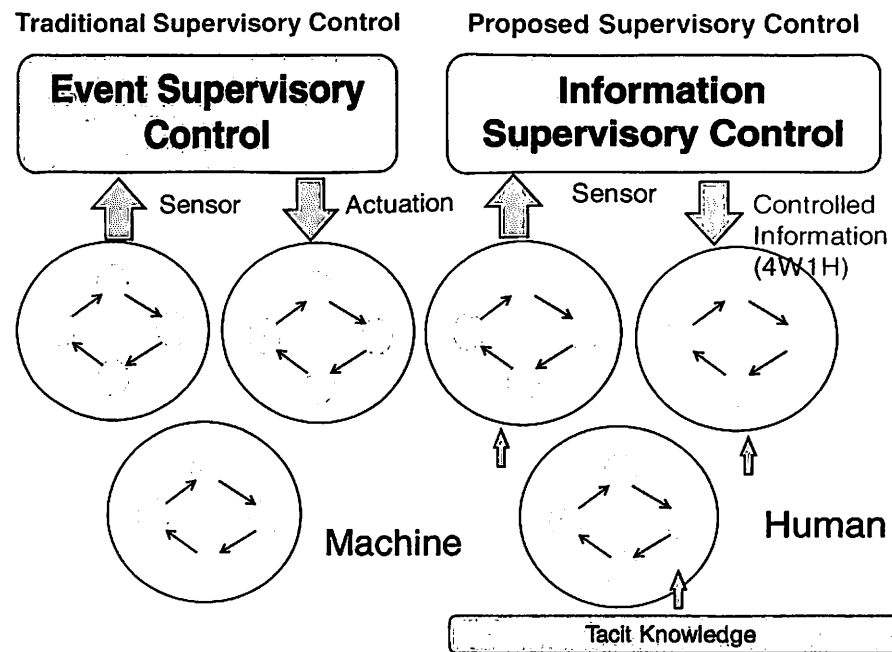


Fig. 13.1 Information supervisory control

agents autonomously operate on the basis of the information provided. In those models, however, information flow control is not explicitly adopted.

Information supervisory control features the following specific information control items.

- *Who*: Information is distributed to only the person who needs it, thus avoiding interruptions caused by unnecessary information (spam). This control is designed to accommodate the limited information processing capability of humans.
- *What*: Information is distributed after customization based on the recipient’s context, according to which some information may be added or deleted.
- *When*: The timing and recipient priority of information distribution are controlled in order to minimize ambiguity. For example, ambiguity occurs when a nurse call request is sent to several nurses simultaneously.
- *Where*: Information is distributed with consideration given to the recipient’s context. For example, low-priority information is sent after, not during, important work in a patient’s room or in the operating room.
- *How*: The mode of information distribution is changed according to the objective. For example, there are several modes including “urgent,” “regular,” and “reference.” Furthermore, supporting the cultivation and utilization of tacit knowledge is also important for better collaboration.

13.6 Smart Voice Messaging System

In accordance with the information supervisory control model, we have developed a smart voice messaging system (Fig. 13.2), which provides a handsfree communication method for temporal–spatial collaboration among nurses and caregivers.

In the proposed smart voice messaging system, voice messages can be automatically distributed to the right person at the right time and place in the right way (*who, what, when, where, and how*) without cumbersome input operations. To do so, the automatic voice message distribution engine uses tags appended to the voice messages.

Figure 13.3 shows the voice message distribution engine. Voice message tags annotate the message and indicate contextual information about the message. These tags are generated from keywords (voice recognition) and location and acceleration (from sensor data) (Torii et al. 2012).

Typical use cases of the smart voice messaging system in nursing and caregiving are given below.

- *Regular information transfer*

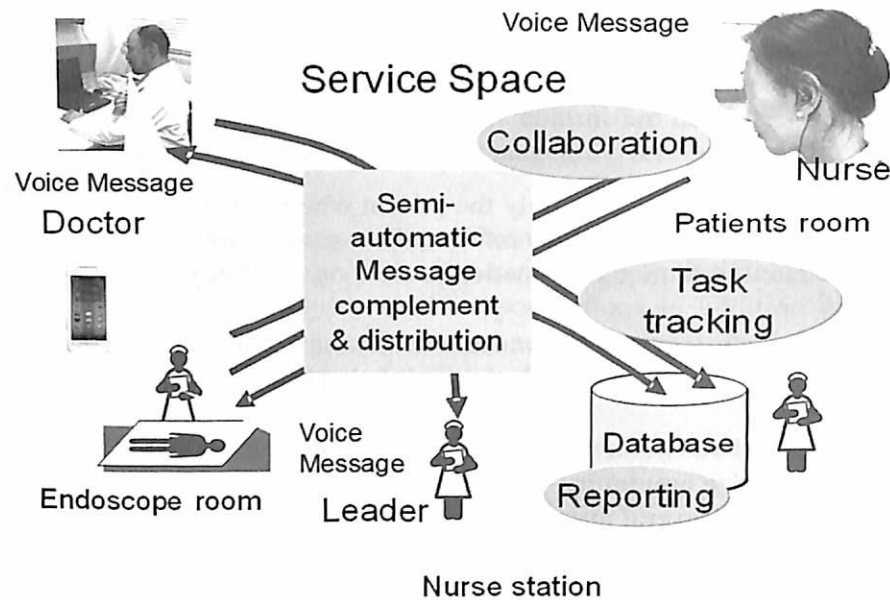


Fig. 13.2 Smart voice messaging system

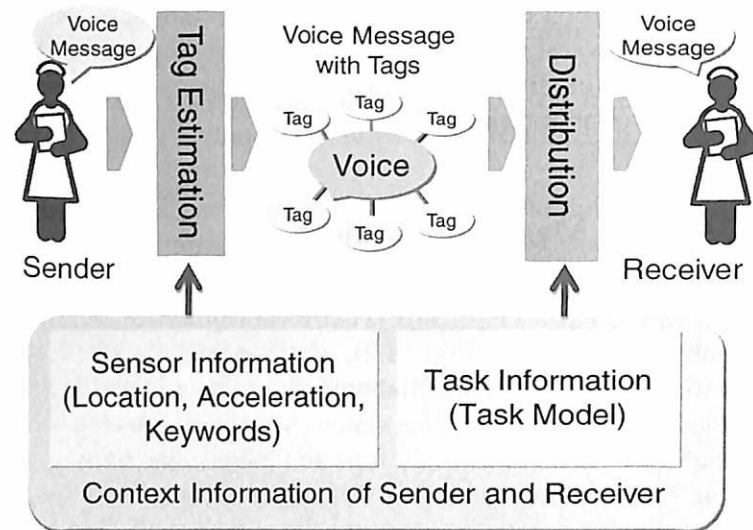


Fig. 13.3 Message distribution engine

Nurses and caregivers record voice messages of information observed about patients and care recipients during work. The messages are then used at the shift-change meeting.

- *Voice sticky note*

Nurses and caregivers record voice messages of tasks to be done. Afterward, a reminder about the task is given.

- *Task progress sharing*

Nurses and caregivers report and share their progress status. Then, appropriate actions and support can be adaptively implemented in collaborative work.

Figure 13.4 shows an example of voice message distribution. A nurse speaks with Patient X during a round and records the following messages about the patient.

- *Message A*: “Patient X reports foot pain. Please be careful at bath time.”
- *Message B*: “Patient X hopes to change his meal service from rice porridge to normal rice.”

Message A will be distributed to a bath caregiver at bath time in the bathroom. Message B will be distributed to other nurses during a shift meeting at the nursing station. These messages are automatically classified and distributed without any smartphone operations.

The smart voice messaging system can store past records of traces and voice messages of nurses and caregivers. We have developed a service space visualization and evaluation system that utilizes these records (Fig. 13.5). This tool enables the evaluation of operational efficiency and of the burden on nurses and caregivers, and is intended to support managers in redesigning work processes and the spatial layout of patients, staff, and equipment and in designing new hospitals or care facilities. This tool is also useful for the education of nurses and caregivers through retrospective analysis. In particular, tacit knowledge can be effectively externalized and shared among staff, which provides “Ba” and SECI processes (Nonaka et al. 2008).

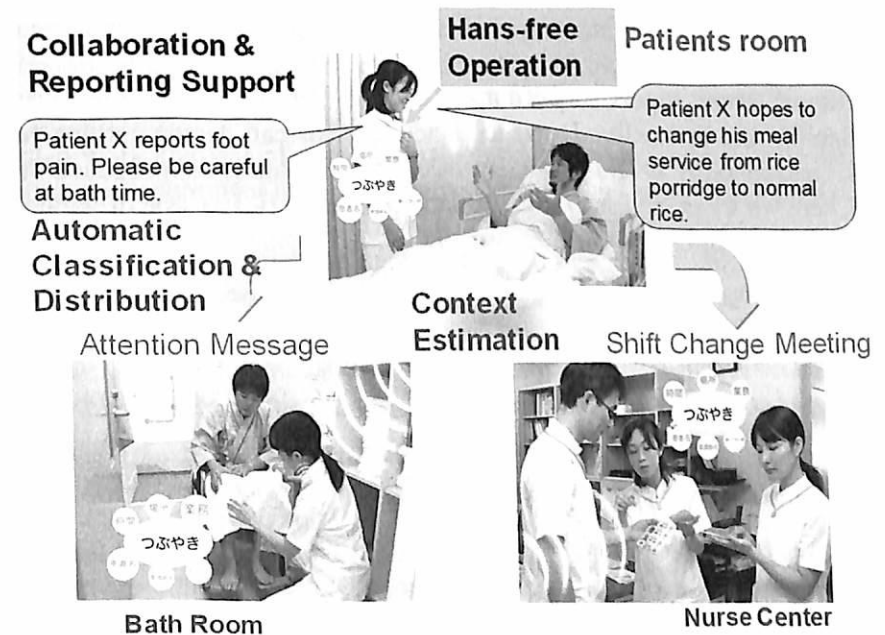


Fig. 13.4 Example of smart voice messaging

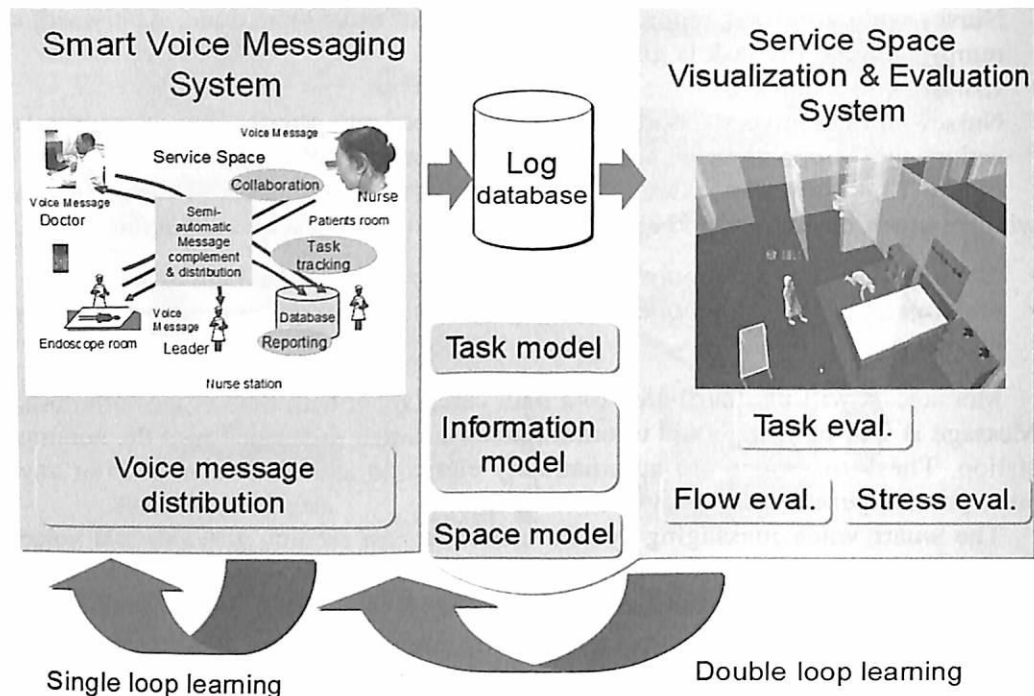


Fig. 13.5 Service space visualization and evaluation tool

13.7 Hypothesis and Evaluation

13.7.1 Hypothesis

In traditional event supervisory control, a basis for evaluating the system is controllability and optimality. However, since humans can decide actions autonomously, controllability is an insufficient basis for evaluating the proposed system. Instead, here we adopt the following evaluation items (I, II, III), one of which is the conventional item of efficiency improvement (I).

- I. *Efficiency improvement*: Reducing moving distance/time and working hours in nursing and caregiving.
- II. *Quality improvement*: Minimizing malpractice and maximizing client satisfaction.
- III. *Employee satisfaction improvement*: Reducing physical and mental burdens.

To determine whether the smart voice messaging system will achieve the intended benefits according to the above evaluation items, we will test the following hypotheses.

- **H1** The system makes collaboration smoother and more efficient by reducing ineffectual and redundant actions through appropriately distributed information. → I, III
- **H2** The system lessens the harmful effects of information overload. → I

- **H3** Using tacit knowledge enables a higher level of performance in comparison with using explicit information only. → I, II
- **H4** Recording voice message is easier than writing messages by hand. → I, III
- **H5** Many tiny awareness of patient's and care recipient's condition is easily recorded by simple information input in smart voice messaging. → II
- **H6** Adequate feedback promotes utilization of recorded information. → II, III
- **H7** The system provides functions of an internal communications system, mail, and a social networking service in an integrated fashion, as well as easy-to-use face-to-face communication and telephone in a complementary manner. → III

13.7.2 Triangulation for Service Evaluation

Our research and development project has conducted several field experiments in collaboration with a hospital in Kanagawa and two care facilities in Tokyo and Ishikawa. Although actual field experiments are effective for identifying real-world targets and potential needs, a quantitative and objective evaluation is difficult for the following reasons.

- Authorized standard work in hospitals and care facilities takes precedence over field experiments. An experiment is not permitted to interfere with care. Interfering with the experiment is basically not allowed.
- Worker activities depend on situational demands which change day to day; thus, control of experimental conditions is not feasible.
- Habituation to the system has a great influence on the experiment.

One way to overcome these obstacles is to use a virtual field experiment and computer simulation to complement a field experiment. We have developed a triangulation environment for service evaluation (Fig. 13.6).

- *Field Experiment*
First, a work analysis of current nursing and caregiving operations is performed by using measurement hardware (voice, location, and acceleration) and conducting interviews with workers. Then, a developed system (prototype) is tested to identify real-world targets and potential needs (Torii et al. 2012).
- *Virtual Field Experiment*
A virtual field (virtual hospital, virtual care facility) is constructed by using lecture halls and university students to simulate typical field operations. In this virtual field, experimental conditions can be iteratively changed to perform a number of variations on an experiment (Choe et al. 2012), thus enabling the above hypotheses to be tested qualitatively and objectively.
- *Computer Simulation*
A virtual field is simulated on a computer by modeling humans and the communication among them. This computer simulation makes it possible to reduce the service design space and the search design parameters (Hiraishi et al. 2012).

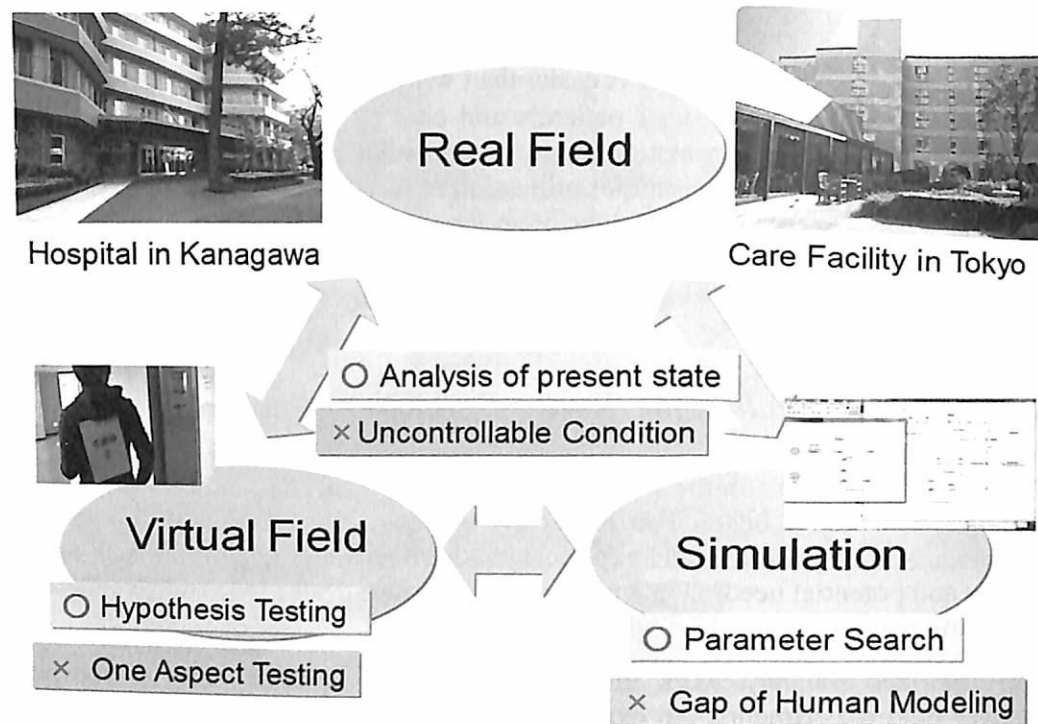


Fig. 13.6 Triangulation for service evaluation

13.7.3 Experimental Results

We have conducted four field experiments and three virtual field experiments, as well as computer simulation of the virtual field experiments. In each virtual field experiment, three or four sets of unit experiments were performed under different conditions (Choe et al. 2012).

To test hypothesis H1, we compared traditional communication using face-to-face meetings and mobile phones, and communication using the proposed smart voice messaging system and face-to-face meetings.

We received both positive feedback and negative feedback from nurses who participated in the virtual field experiment.

- Positive Feedback
 - The smart voice messaging system enables easy information sharing, whereas a traditional mobile phone is used for important communications only.
 - Making inquiries to others is easy because their situation can be recognized by the smart voice messaging system. It is possible to ask questions about patients who are assigned to other staff without going back to the nursing station.
- Negative Feedback
 - It is difficult to hear voice messages during conversations with patients and during intensive work.

- Compared with a mobile phone, the smart voice messaging system lacks interactivity due to the distribution delay.

We have also conducted a quantitative comparison between traditional communication and the smart voice messaging system in the virtual field experiments. We will present these results in the near future after modifying system and experiment environment to remove noise in the data and obtain more sets of results.

13.8 Related Works

Tang's group has intensively investigated hospital communications (Tang and Carpendale 2007a, b; Tang et al. 2010; Lee et al. 2012). They have analyzed the impact of new communication technology (the *Vocera® Communication System*¹) introduced into a hospital. They introduced the *InfoFlow* framework, which considers six interrelated factors: information, spatiality, temporality, personal, artifacts, and communication mode.

According to this framework, Tang and coworkers also reported a fishbone diagram for visualizing and analyzing the findings (positive and negative) on the deployment of *Vocera communications systems* in a hospital. Their method is useful when analyzing and evaluating communications systems in a healthcare setting. However, the *Vocera communication system* and *InfoFlow* framework do not consider information supervisory control that employs information on *who*, *what*, *when*, *where*, and *how*.

13.9 Conclusion

With the aim of improving the efficiency and quality of nursing and caregiving service systems as physical and adaptive intelligent services, this chapter proposed an information supervisory control model and a smart voice messaging system based on the model. We also formulated hypotheses to be tested for evaluating the system. The proposed service space visualization and evaluation tool can be used for hypothesis testing. Our project was funded through the *JST S3FIRE* program until September 2013. Based on triangulation for service evaluation, we plan to implement hypothesis testing.

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¹<http://www.vocera.com>

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