Improvement of Sharing of Observations and Awareness in Nursing and Caregiving by Voice Tweets

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Abstract Nurses and caregivers provide care for patients using their hands and move around hospital wards, staff stations, operating rooms, residents' rooms and so on. They also read and write, sending and receiving a lot of information of various types in the course of their work. Therefore, nursing and the provision of care could be described as "physical and adaptive intelligent services." Several types of information systems and communication systems are used in "physical and adaptive intelligent services." But there is a striking mismatch between "physical and adaptive intelligent services" and conventional information systems whose interfaces are generally designed for deskwork. The mismatch is one of the significant causes of the fact that the quality and efficiency of information processing in nursing has not been improved as much as people would expect. In this paper, we describe how a voice interface improves the quality of the information processing in nursing, focusing on care recording. The smart voice messaging system for nursing makes it possible for nurses to input care records, take notes for themselves, and organize voice messages to other staffs in a unified way during care. The experimental evaluation performed in a nursing home for the elderly shows that the smart voice messaging system can contribute to improvement in the quality of care because care staffs can easily retain various observations and concerns that are often lost in the case of conventional care records.

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1 Introduction

More and more countries are experiencing population aging and a rise in the number of patients, and more and more time and money will be devoted to healthcare services. Therefore, improvement of the efficiency of healthcare processes is an important issue. Nursing and caregiving are an important aspect of health services. We focus on nursing care processes in this paper.

Nurses and caregivers provide care for patients using their hands and move around hospital and care facility wards, staff stations, operating rooms, residents' rooms and so on. They also read and write, sending and receiving a lot of information of various types in the course of their work. Since their work involves both physical action and information processing, it could be described as "physical and adaptive intelligent services."

Several types of information systems and communication systems are used in nursing such as telephones, mobile phones, PCs and papers. But there is a striking mismatch between "physical and adaptive intelligent services" and conventional information systems that are generally developed as tools for deskwork. Since care staffs' hands are occupied during the patient care and care staffs move around hospital wards, staff stations, operating rooms and so on, it is difficult for them to record by keyboard, to compose messages, to telephone other staffs and to take telephone calls from other staffs at the right moment.

Lemonidou, et al. show that care staffs spend much of their time on indirect care such as recording the provision of nursing, accepting medication orders, and messaging to other staffs [9]. Hollingsworth, et al. show that emergency physicians and care staffs spent almost half of their time on indirect care [6]. Hendrich, et al. show that care staffs devote 35.3 % of their time to documentation according to their time study of 767 care staffs [4]. The mismatch is one of the significant causes of the inefficiency of indirect care. Smartphones and tablet PCs have recently come into use in nursing and caregiving, but it is difficult to type messages during "physical and adaptive intelligent services" other than fixed inputs such as multiple-choice, autocompletion, and numeric inputs.

Uchihira, et al. [13] and Torii, et al. [11] have proposed a "smart voice messaging system" to overcome this mismatch. The smart voice messaging system provides a single semi-hands-free voice interface and enables nurses and caregivers to input nursing records, take notes for themselves, and compose voice messages to other staffs during the provision of care.

In this paper, we describe an experimental application of the smart voice messaging system in actual nursing processes in a nursing home for the elderly, and evaluate effects of the system on recording and sharing of observations and awareness of care staffs. The remainder of this paper is organized as follows. We

describe related works in the second section. The third section describes the overview of the smart voice messaging system. The fourth section describes the experiments using the smart voice messaging system in actual care processes in a nursing home for the elderly in Japan, and analysis of collected voice tweets is shown in the section six. In the last section, we present our conclusions. This research was approved by JAIST Life Science Committee (#25-001).

2 Related Works

Much research has been done on voice input interfaces and automatic speech recognition (ASR) for medical reporting [1, 3, 7, 8, 10, 12]. ASR technology was first adopted for radiology more than 25 years ago [1, 8]. The most common objective of introducing speech recognition in a radiology department is to reduce report turnaround time (RTT), i.e., the time interval between the examination and the finalized report digitally available in the hospital information systems (HIS) [1]. Kang, et.al. also show reduction in turnaround time of reporting about surgical pathology using speech recognition software [7]. Devine, et.al. evaluate accuracy of speech recognition softwares about dictation of medical records by physicians [3]. In these researches, it is assumed that users sit at their desks and use applications via laptop PC interfaces, typically a laptop screen, a keyboard and a mouse. So these systems are not necessarily applicable to "physical and adaptive intelligent services" such as nursing and caregiving.

3 The Architecture of the Smart Voice Messaging System

Figure 1 adapted from [11] shows the outline of the architecture of the smart voice messaging system, which consists of a smartphone application and a Web server application. The voice interface of the smartphone application enables semi-hands-free messaging. Several sensors on the smartphone continuously collect data around the user in a background process, and the application periodically sends the data to the server of the system. Several estimators on the server estimate the state (context) of each staff who carries a smartphone. The states estimated by each estimator are called "tags". Tags are, for example, specific types of keywords included in a recognized voice, location and time when the staff makes a voice tweet, the task which the staff is executing at the moment of the voice tweet, and the staff ID.

Tags have two important functions. First, the tags improve comprehensibility of voice tweets for recipients. So, care staffs need not say everything about a voice tweet. For example, they can leave out context information (WHO, WHEN, WHERE) in their voice tweets. Secondly, the tags enable the system to decide the type of delivery of voice tweets and to deliver them to an appropriate destination

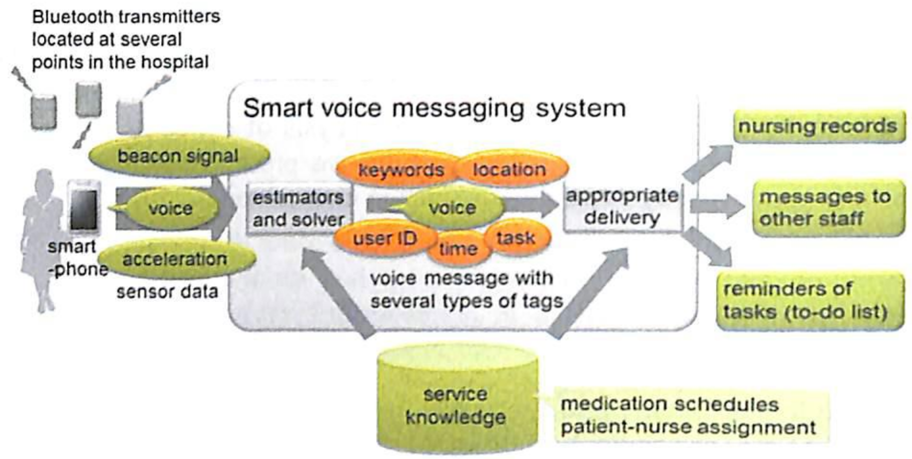

Fig. 1 Architecture of the smart voice messaging system (Adapted from [11])

automatically, for example a message to other staffs, a reminder of one's task, and inputting to an appropriate database of nursing records.

3.1 Automatic Tagging to Voice Tweets

Figure 2 illustrates the structure of "estimators and solver" in Fig. 1. There are three estimators in the server: voice recognition and keyword extraction, location estimator, and task estimator. The voice recognition in the server recognizes the voice and extracts keywords included in the recognized voice. For example, patient names and names of cares for the patients may be included in the keywords. To collect indoor location data with smartphones, Torii et al. developed a small Bluetooth transmitter that emits a beacon signal including ID of the Bluetooth device on the transmitter [11]. The smartphone receives beacon signals from the transmitters around it, and the application on the smartphone sends ID and RSSI (Received Signal Strength Indicator) of each signal to the server. The location estimator estimates the location of each staff at each time from the Bluetooth beacon signal. The task estimator estimates what task was executed at each time from acceleration sensor data and so on. These estimators generate candidates of tags with degrees of confidence. The tag solver in the server searches an optimal set of tags from the candidates using service knowledge such as medication schedules for patients and patient-nurse assignments. An optimal set of tags is a set of tags whose sum of degrees of confidence of tags is maximal among sets that satisfy the constraints derived from service knowledge. The server attaches the optimal set of tags to the voice.

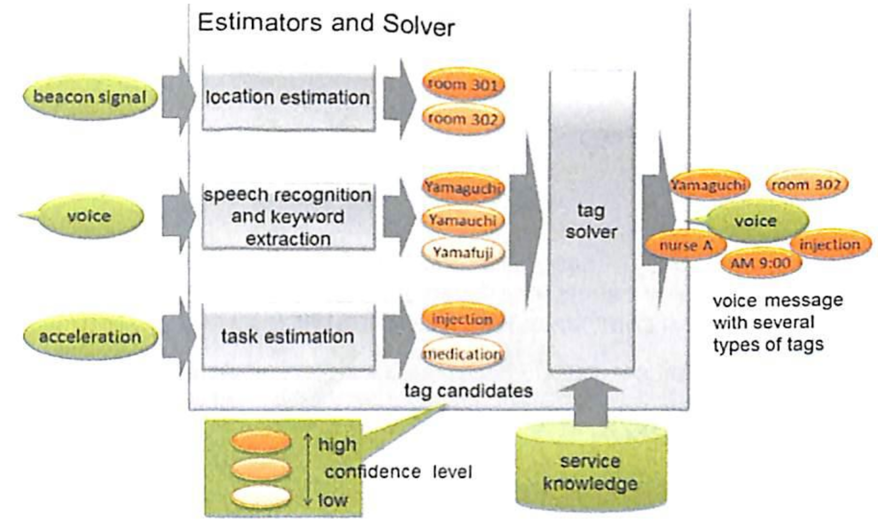

Fig. 2 Architecture of the module for automatic tagging to voice tweets (Adapted from [11])

3.2 Delivery of Voice Tweets to Appropriate Destinations

The system estimates the types of delivery of each tweet according to the attached tags, and decides appropriate destinations of voice tweets (Fig. 1). Messages are delivered to the staffs who actually need the messages. Reminders by a care staff are sent to herself/himself at the right time. Nursing records are reported to an appropriate database. Details of the estimators are explained in [11].

Figure 3 illustrates typical use cases of the smart voice messaging system. Care staffs are able to compose voice tweets such as a patient's pain complaints, a patient's questions about care processes and several observations of concern about a patient only by one hand at a patient's bedside. Tags are automatically attached to the voice tweets. For example, a voice tweet about a patient's pain complaint is delivered to the care staff who cares for the patient in the bathroom, and then the care staff is able to easily grasp the patient's pain, and can appropriately assist the patient to bathe. Since the tweets with tags are categorized automatically, care staffs can efficiently hand over information about patients.

4 Field Studies in a Nursing Home for the Elderly

We performed field studies at a nursing home for the elderly in Japan. Several "physical and adaptive intelligent services" are provided in the nursing home as shown below.

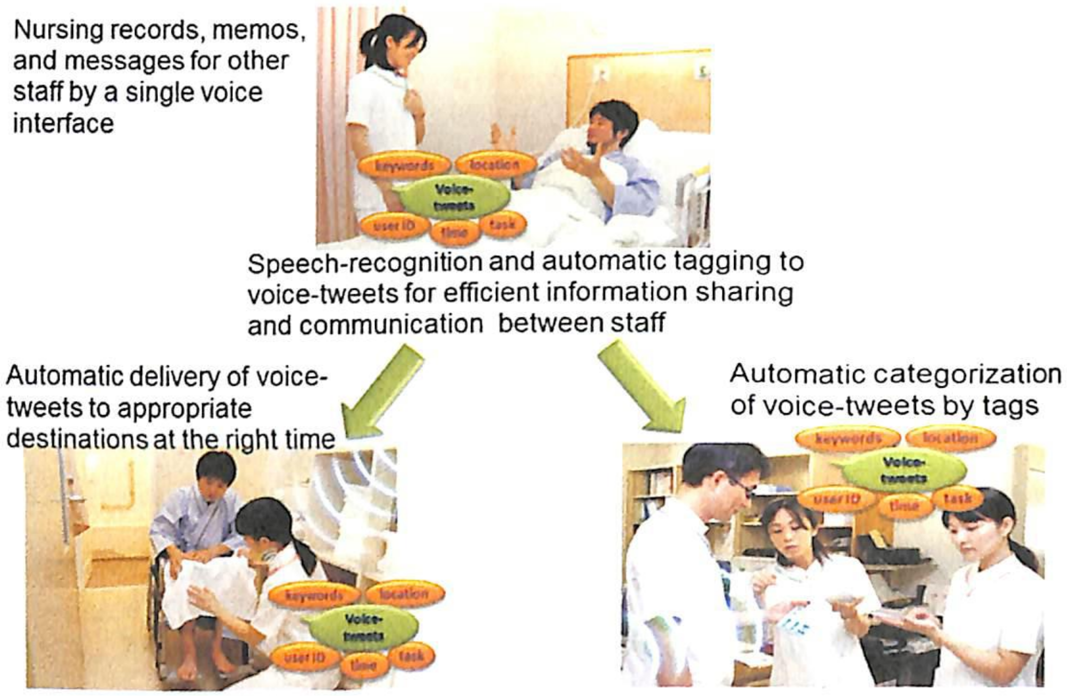

Fig. 3 Use cases of the smart voice messaging system (Adapted from [11])

4.1 Overview of the Nursing Home for the Elderly

Figure 4 shows the sketch map of the nursing home where we performed field studies. The nursing home is a four-story building. Thirty residents live in the nursing home. Each resident has his/her private room. There are two dining rooms, one on the first floor and the other on the second floor. The care staff station is next to the dining room on the second floor. PCs for accessing care records are in the care station.

4.2 "Action Oriented Intellectual Service" Provided in the Nursing Home for the Elderly

Several "physical and adaptive intelligent services" are provided in the nursing home. Feeding assistance care is a typical one as shown below. All the residents take meals together at a dining room on the first floor or at a dining room on the second floor. During the provision of feeding assistance care, nurses and caregivers not only assist residents in taking meals, but also give them medicines and help them brush their teeth and use the lavatory. Furthermore, since many of the residents have physical or cognitive difficulties with walking, caregivers attend residents moving between their rooms and the dining rooms. Care staffs also

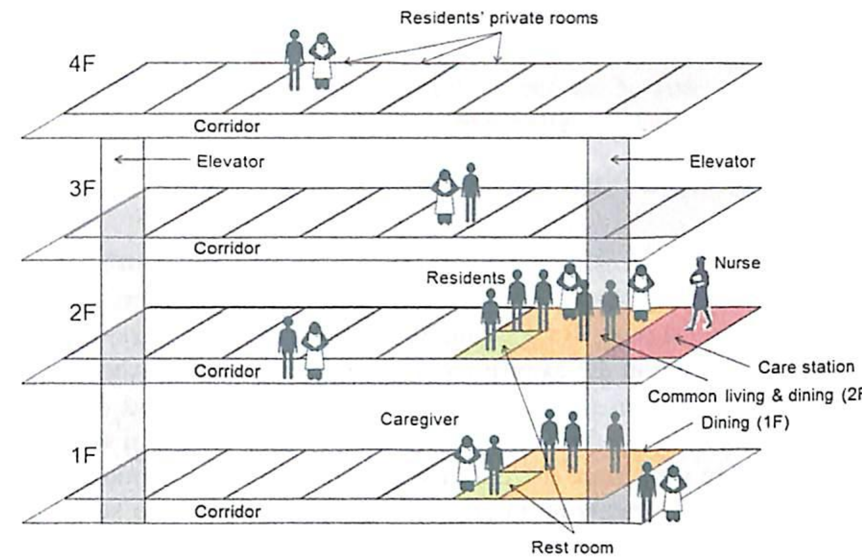

Fig. 4 Sketch map of the nursing home for the elderly

process several types of information. For example, during the provision of feeding assistance care, they check whether the meals for each resident are served correctly, check which residents have been prescribed which medicine after a meal or before a meal, and record how much each resident ate of each dish. They also observe behaviors and conditions of residents.

Experienced care staffs are aware of slight behavioral abnormalities of residents, and slight but significant changes of physical and mental conditions of residents. Such observations often include information helpful for evaluating and revising care plans for residents. For example, in the feeding assistance care, if a resident spills food from her/his mouth during a meal, the resident might have a problem concerning the swallowing function. Or the behavior might be symptomatic of dementia. Then other nutritional strategies such as jelly to ease deglutition might be examined and training in swallowing might be planned. In bathing assistance, care staffs observe the skin condition of each resident while washing his/her body, and a care staff assesses whether bedsores are developing on his/her skin and examines whether pressure ulcer care is appropriate for the resident. Some care staff may become aware of problematic states of facilities during care. For example, they may find an obstacle on a corridor that could cause residents to fall.

These observations and awareness should be recorded and shared with other staffs and managers. But it is difficult for them even to take notes on slips of paper, much less record the events on a PC because both hands are occupied in providing care or they are moving around in the nursing home. Therefore, they must remember all those important events. But no small part of the memory is lost before they have the opportunity to sit and record at a desk. The smart voice messaging system provides care staffs with a single semi-hands-free voice interface for both recording and immediate messaging to other staffs. The system enables care staffs to take notes of such awareness and observations during care.

5 Experiments in a Nursing Home for the Elderly

We performed experiments using the smart voice messaging system in the nursing home 7 times for feeding assistance care on 4 days in September, October, and November 2012, and 10 times for feeding assistance care on 5 days in May 2013. The system configuration in the experiments is shown in Fig. 5. Twenty caregivers and nurses used this system in the provision of care at lunch and dinner on the 9 days. About 6 staffs cared for residents during each provision of feeding assistance care. Each care staff wore a wired headset connected to a smartphone when they started attending residents moving to dining rooms. The care staffs push the switch of the headset and articulate their observations or messages whenever they observe events to be recorded about residents or they have messages for other staffs during the provision of feeding assistance care. Input voice tweets are sent to the managing server on the internet via Wi-Fi or 3G. The ASR server recognizes the voice of each tweet and returns the result to the managing server. The managing server adds tags to each tweet and processes it appropriately. The voice and other data are transferred through a secure channel.

Each care staff usually fills in important observations for the nursing records after the completion of feeding assistance care for all residents. In the experiments,

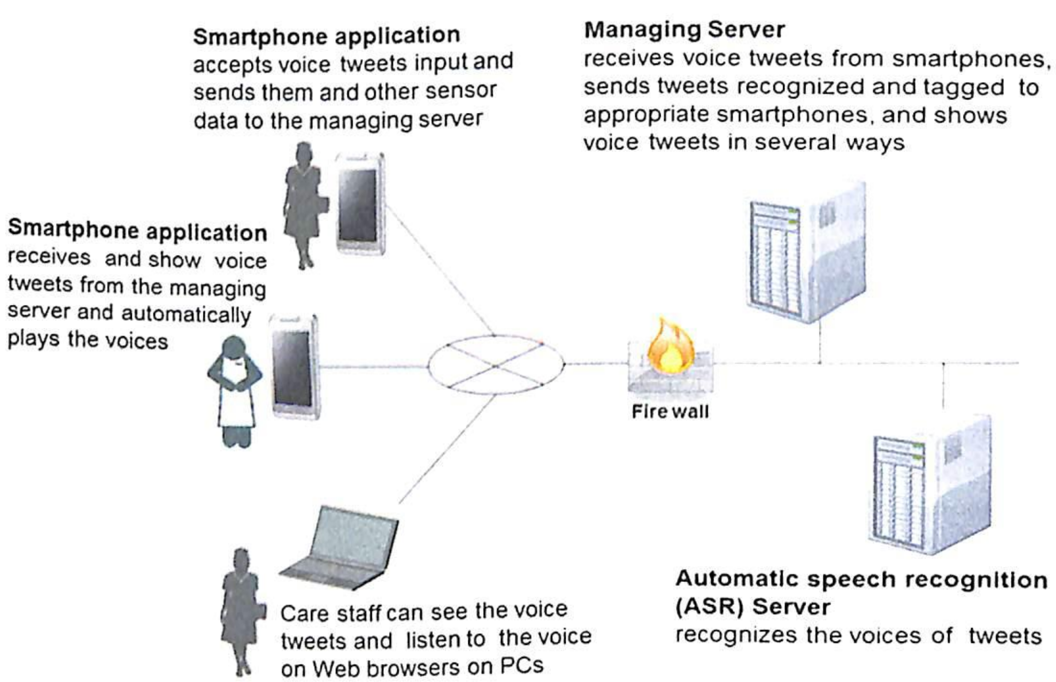

Fig. 5 The experimental voice messaging system

the care staffs made nursing records as usual without reviewing their voice tweets spoken during the provision of feeding assistance care, in order to evaluate how many tweeted observations are recorded or lost in the case of the conventional provision of feeding assistance care and recording.

6 Experimental Results

As shown in Tables 1 and 2, 330 voice tweets were collected in the experiments in 2012, and 720 voice tweets were collected in the experiments in 2013. Thus, 1050 voice tweets were collected during the provision of feeding assistance care at lunch and dinner 17 times on 9 days.

6.1 Types of Voice Tweets in the Feeding Assistance Care

All the voice tweets are classified in two types of "record" and "message" according to their contents. Two hundred and fifteen voice tweets (74 of 2012 and 141 of 2013) are of record and 785 voice tweets (256 of 2012 and 579 of 2013) are messages to other staffs. Voice tweets of recording are for example "Mrs. A leans to left side when she eats," "Mr. B exhibits agitation behaviour after dinner," and "Mrs. C is putting too much food in her mouth at once." And voice tweets of messaging are for example "Mrs. A has finished dinner, now I take her to her room," and "Some residents are getting agitated. Please come to the dining room to help."

Table 1 The results of the count of voice tweets in the care assistance in the 4 days experiments in 2012

	Record	Message	Total
Lunch	46	180	226
Dinner	28	76	104
Total	74	256	330

Table 2 The results of the count of voice tweets in the care assistance in the 5 days experiments in 2013

	Record	Message	Total
Lunch	90	337	427
Dinner	51	242	293
Total	141	579	720

6.2 *The Occurrence of Voice Tweets in the Feeding Assistance Care*

Figures 6 and 7 show the occurrence of voice tweets in the experiments in 2013. Usually lunch care starts at about 10:00 or 10:30, and finishes at about 13:00. Dinner care starts at about 17:00 and finishes at about 19:30 or 20:00. For lunch, care staffs start tweeting from about 10:00 and finish at about 13:00. For dinner, they start tweeting from about 17:00 and finish at about 20:00. It can be seen from these figures that voice tweets of records occur throughout the provision of care. Since care staffs usually can finally input nursing records after all the feeding assistance care is completed, the data on the time at which nursing records input into the current information system without using the smart voice messaging system might be distributed to the right end of these figures.

Figures 8 and 9 show cumulative relative frequency of voice tweets of records during the provision of care assistance at lunch and dinner over time axis in all the experiments. Fifty-four percent of voice tweets of records for lunch care occur before 11:50. And 52 % of voice tweets of records for dinner care occur before 18:15. These results mean that about half of observations and events that could be recorded occur 1 or 2 h before all the feeding assistance care is completed and care staffs have the opportunity to make records at desks.

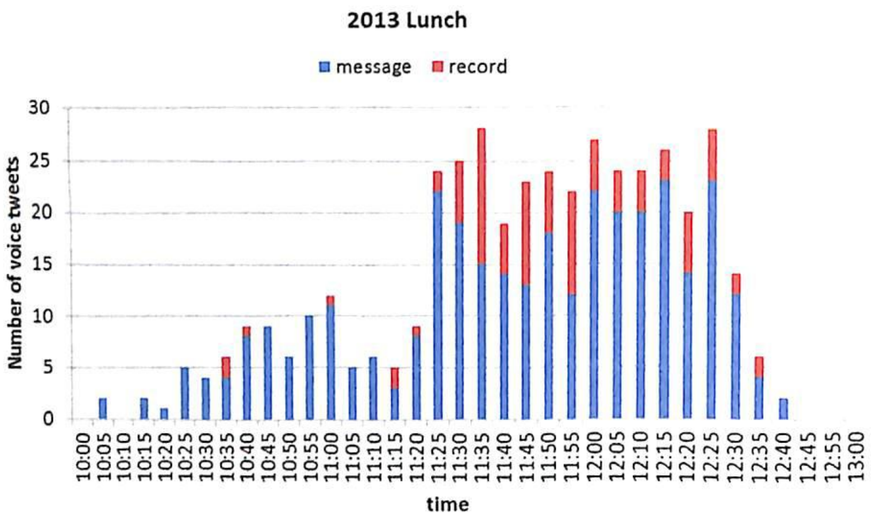

Fig. 6 The occurrence of voice tweets in the lunch care assistance in the 5 days experiments in 2013

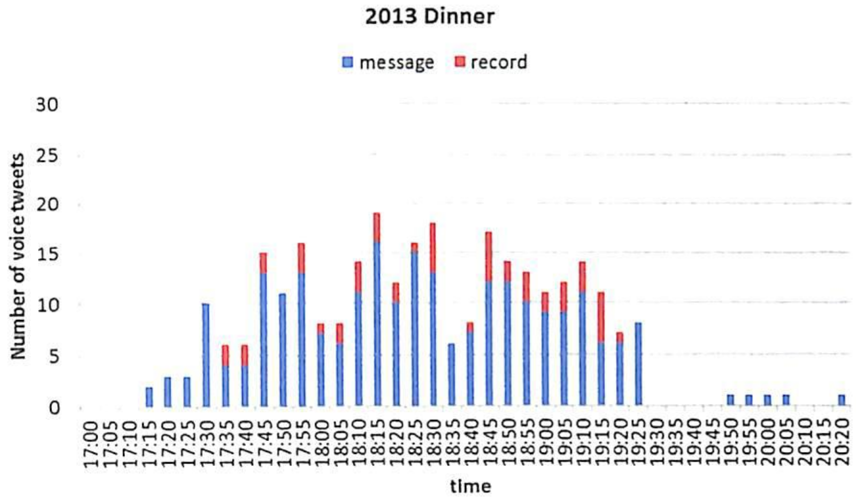

Fig. 7 The occurrence of voice tweets in the dinner care assistance in the 5 days experiments in 2013

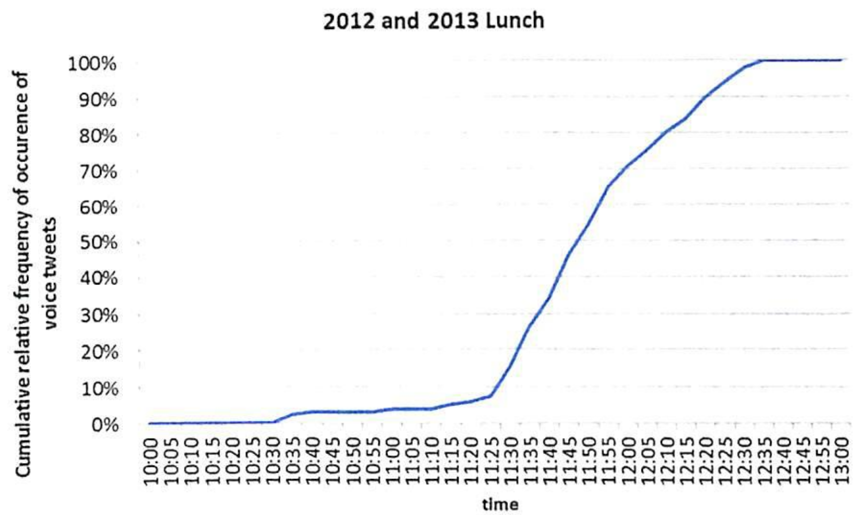

Fig. 8 Cumulative relative frequency of voice tweets of records in the lunch care assistance over time axis

6.3 *Analysis of Voice Tweets of Records*

Seventy-four voice tweets of records in the experiments in 2012 and 141 voice tweets of records in the experiments in 2013 were classified into four categories according to the following two criteria.

1. Every voice tweet was classified into either of two groups, "recorded" and "unrecorded," depending on whether a corresponding topic was written for the care record.

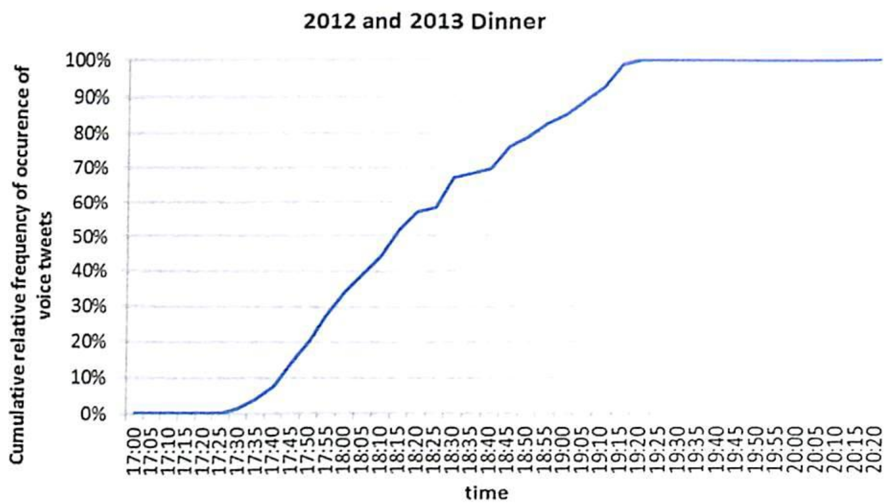

Fig. 9 Cumulative relative frequency of voice tweets of records in the dinner care assistance over time axis

Table 3 The result of the classification of tweets of records in the experiments in 2012 by care staff A

	Important	Unimportant	Total
Recorded	11	5	16
Unrecorded	41	17	58
Total	52	22	74

Table 4 The result of the classification of tweets of records in the experiments in 2012 by care staff B

	Important	Unimportant	Total
Recorded	10	6	16
Unrecorded	36	22	58
Total	46	28	74

Table 5 The result of the classification of tweets of records in the experiments in 2013 by care staff A

	Important	Unimportant	Total
Recorded	53	6	59
Unrecorded	60	22	82
Total	113	28	141

2. Two administrative care staffs (A, B) of the nursing home classified every voice tweet into either of two groups, "important" and "unimportant," according to the effectiveness for care planning. The voice tweets that include information helpful for assessing the care levels of some residents or for revising the care plans for some residents were classified as "important" voice tweets, and the others were labelled as "unimportant".

The results of the classification by the two administrative care staffs are shown in Tables 3, 4, 5 and 6.

Table 6 The result of the classification of tweets of records in the experiments in 2013 by care staff B

	Important	Unimportant	Total
Recorded	48	11	59
Unrecorded	56	26	82
Total	104	37	141

Fifty-two voice tweets out of a total of 74 voice tweets of records in 2012 were classified as "important" by care staff A, but 79 % of them (41/52 in Table 3) were not recorded in the care records. Also 78 % of the voice tweets classified as "important" by care staff B (36/46 in Table 4) were not recorded.

With regard to 2013, care staff A classified 113 voice tweets out of a total of 141 voice tweets of records as "important", but 53 % of them (60/113 in Table 5) were not recorded in the care records. In addition, 54 % of the voice tweets classified as "important" by care staff B (56/104 in Table 6) were not recorded.

These results show that important observations made by care staffs and events seen by them during the provision of care are often lost and not shared with other staffs and managers. According to the interviews of care staffs who participated in the experiments, they observe many residents' behaviours while providing care that are a cause of concern. It is impossible for them to make records at a desk during the provision of care. They try to take notes of the events when they can use their hands. But they often become involved in providing care for other residents before they are able to take notes about their observations. Some care staff omits recording of observations according to the subjective criteria.

Even in the case that these observations remain in the memories of care staffs, it is difficult for them to remember the exact time when each event occurred, and so nursing records tend to be inaccurate. For example, residents with dementia often sleep during the provision of feeding assistance care. The duration of the time when the resident's eyes are closed could be important for revising the care for the residents to provide better nutrition.

Too much tweets could be easily made and disturb care staffs. But the system prints the time and the location where each tweets is made, and also automatically extracts keywords such as patient's names and terms related to care or nursing from the tweet. Such meta-information is displayed attached to each tweet. The meta-information would enable care staffs to grasp the summary of each tweet and to process piles of tweets efficiently.

7 Conclusions and Future Works

In this paper, we describe a smart voice messaging system and its application to "physical and adaptive intelligent services." The smart voice messaging system makes it possible for care staffs to input care records, take notes for themselves, and deliver voice messages to other staffs with a single voice interface of a smartphone application during the provision of care.

We performed experiments in an actual nursing home for the elderly, and collected voice tweets by care staffs during the provision of feeding assistance care. The evaluations of the voice tweets shows that important observations and awareness during the provision of care are often lost and not shared. Recording and sharing of these observations and awareness are indispensable for assessing the care levels of residents accurately or for revising the care plans for residents appropriately. The smart voice messaging system can contribute to improvement of the quality of care records because staffs can easily retain various observations and awareness during the provision of care.

The limitation of the paper is that experiment in a nursing home was done for a short period and it is too short to evaluate care quality improvement in addition to evaluation that a smart voice messaging system can catch more awareness shown in this paper.

Subjects for future work will include:

- Complete stress-free interface
- Speech recognition with higher accuracy
- Reduction of the time required to make nursing records using a smart voice messaging system
- Long term experiment and evaluation using refined smart voice messaging system
- Improvement of the quality of contents of voice tweets. Standardization of observations during the provision of care and corresponding voice tweets between care staffs is indispensable for this issue. This will increase the ratio of important tweets and improve the quality of nursing records.
- Assessment of physical and mental states of residents by utilizing accumulated voice tweets about residents. And evidence-based care planning according to the assessment.

Although we focused on nursing records by voice tweets in this paper, the smart voice messaging system has another important aspect: messaging to other staffs [2, 5, 14]. Improvement of collaboration among care staffs by means of the voice tweet messaging is also included in the research targets.

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