Discourse Analysis of Voice-Based Computer-Mediated Communication in Distributed Work

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ABSTRACT

Computer-mediated remote voice communication among care providers is analyzed by a newly proposed discourse model. Nursing and care are central to healthcare services, and improvements in the quality and efficiency of healthcare processes are important issues. Effective communication support that does not interfere with normal operations is an urgent need. Here we examined a “smart voice tweet system” intended to overcome this problem by supporting collaboration across different sites. We field-tested this system at an elderly care facility in Japan for 5 days in 2013. We observed the activities of groups of care workers during residents’ lunch and dinner and collected data on use of the system. By discourse analysis based on the proposed model, we confirm the validity of the voice tweet system as a support for remote voice communication among staff collaborating to achieve tasks. The findings can be used to design rules for estimating the ongoing status of collaborations and classifying voice tweets by purpose to decide whether they should be sent or just recorded. This research is based on joint research conducted by the Toshiba Corporation, the Shimizu Corporation, and the Japan Institute of Science and Technology with support from the Japan Science and Technology Agency.

Keywords: Voice, Communication, Collaboration, Discourse, Model, Exchange structure

INTRODUCTION

The aging of Japan's population is a major issue, one urgent aspect of which is caring for elderly persons with disabilities. At present, care services are often provided through the devoted efforts of care staff at long-term care facilities. Care services are characterized by what we call "action-oriented intellectual services." Care staff makes many decisions regarding medical care that require specialized knowledge. They also assist elderly persons with disabilities in many activities of daily living. The care service staff is made up of many professions and specialties, and care services must operate at all hours all year round. Successfully doing so requires a high degree of information sharing among staff, such as ensuring that proper records of care are kept.

Lemonidou C., Plati, C., Brokalaki, H., Mantas, J., and Lanara, V. (1996) pointed out that medical staff spends a significant amount of time on indirect care, including recordkeeping and information sharing. Conventional IT systems are fundamentally designed for deskwork, however, and do not support hands-free and eyes-free operation suitable for action-oriented intellectual services.

Uchihira, N., Torii, K., Uchihira, N., Chino, T., and Iwata, K. (2011) and Torii, K., Uchihira, N., Chino, T., and Iwata, K. (2012) have proposed a "voice tweet system," which is being developed to overcome these problems. In that system, "voice tweets" spoken by a staff member are tagged with the staff member's location and motion, spoken keywords, and associations with background knowledge. On the basis of these tags, the tweets are automatically delivered to an appropriate staff member. This system provides semi-hands-free and eyes-free communication among medical and care staff. Developing such a system requires knowing what kind of speech communication will support cooperative work in the medical and care domains. We therefore performed field studies at an elderly care home in Japan to analyze cooperative work and speech interaction among care staff.

Chino, T., Torii, K., Uchihira, N., and Hirabayashi, Y. (2013a, b) reported on field studies in which the voice tweet system was used to support staff assisting with bathing tasks at an elderly care facility in Japan.

In this paper, we report the results of another field study and an analysis at the same site on another task, feeding assistance. A new discourse model is proposed to clarify the validity of the voice tweet system from the point of view of supporting computer-mediated remote voice communication among the staff.

The remainder of this paper is organized as follows. The second section gives an overview of the voice tweet system, and the third section proposes a discourse model. The fourth section describes the field study site and the tasks examined. The fifth section discusses the results of the field studies. Finally, the sixth section gives our conclusions and proposes some areas for future study.

VOICE TWEET SYSTEM

Overview

The voice tweet system consists of a smartphone application, which is run on smartphones carried by nurses and care staff, and additionally a supporting application running on a smart voice tweet server. This voice tweet system allows nurses and care staff to input care records, make memos for themselves, and compose voice messages to other staff.

Figure 1 shows an outline of the system architecture, which consists of a smartphone application and a server application. The voice interface of the smartphone application enables hands-free or semi-hands-free message composition. Several sensors on the smartphone continuously collect data around the nurse or care staff as a background process, and the application periodically sends the data to the system server. Several estimator processes on the server estimate the state (context) of each staff member who is carrying a smartphone. The states estimated by each estimator are called "tags." Tags include, for example, keywords included in utterances, the location where the staff member composed a voice tweet, the task the staff member was executing at the moment the voice tweet was made, the time, and the staff member's identity. Tags have two important functions. First, they improve comprehensibility of voice tweets, so that nurses and care staff need not vocalize everything in a voice tweet. For example, the staff member can leave out contextual information (who, when, and where). The system also uses tags to decide the type of delivery of voice tweets and to automatically deliver them to an appropriate destination according to whether they are a message for other staff, a reminder for oneself, or input to a database of nursing records.

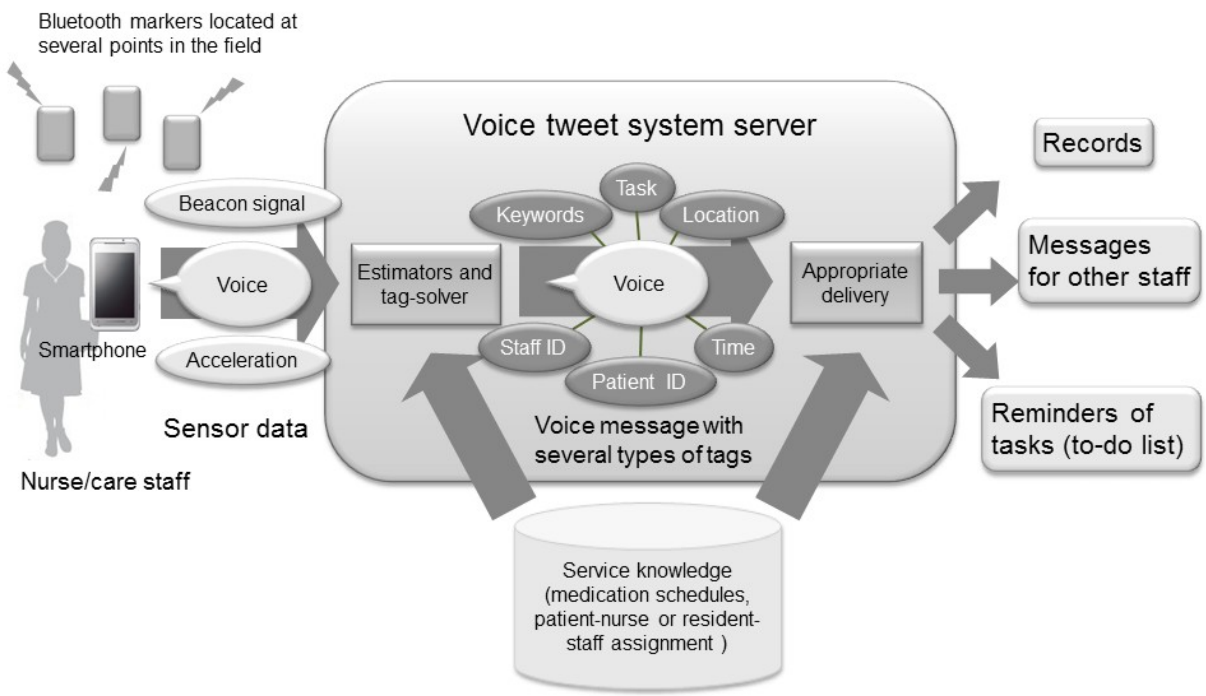

Figure 1. Architecture of the voice tweet system (Adapted from Torii et al., 2012)

Typical use cases

Figure 2 illustrates typical use cases for the voice tweet system. Nurses and care staff can compose voice tweets regarding topics such as patient pain complaints or patient questions about care processes by using a single hand at the bedside. Tags are automatically attached to the voice tweets. For example, a resident's question regarding bathing can be delivered to the care staff member who bathes the patient, allowing staff to easily provide appropriate assistance. Since tweets are automatically categorized according to tags, nurses and care staff can efficiently deliver the required information.

The aim of the voice tweet system is to support the work of staff in the medical and care domains. Because the system is used by staff, not by patients or care recipients, problems such as developing a computer–human interface for elderly persons are beyond the scope of this research.

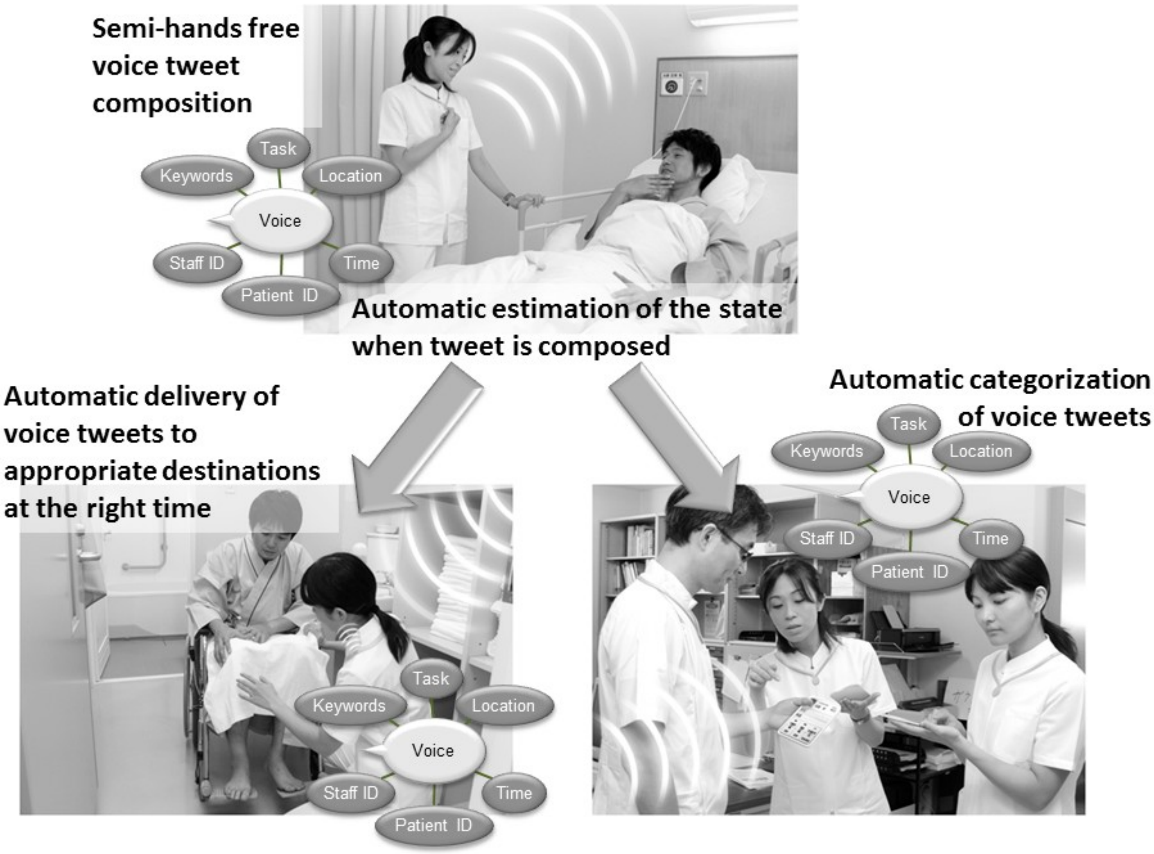

Figure 2. Typical use cases of the voice tweet system (Adapted from Torii, Uchihira et al. 2012)

DISCOURSE MODEL

Exchange structure

Sinclair and Coulthard (1975, 1991) proposed a discourse model called *exchange structure* to investigate the structure of classroom interactions. In this model, discourse in the classroom is analyzed by using multiple layers (*lesson*, *transaction*, *exchange*, *move*, and *act*). Although it can be regarded as a powerful descriptive tool for discourse analysis, as Coulthard and Brazil, (1981, 1991) pointed out, the original model was too specific to pedagogy and too complex for wider use. For example, the model introduced 26 acts, some of which are difficult to distinguish among because of ambiguities in the original definitions. Coulthard et al. (1981, 1991) proposed a revised and simplified model to address these problems.

Based on the work of Sinclair et al. (1975, 1991) and Coulthard et al. (1981, 1991), we propose a new discourse model for analyzing computer-mediated remote communication among multiple staff (participants) in action-oriented intellectual services work distributed across multiple work fields.

In our model, there are only three elements of discourse: *exchange*, *move*, and *discourse act*. *Exchange* is the basic unit of interaction among participants (here, staff). An *exchange* consists of a sequence of more than one *moves* by participants. A *move* corresponds to one utterance in a face-to-face communication or one computer-mediated voice message in a remote communication. A *discourse act* corresponds to one intention, or speech-act. Therefore, multiple discourse acts can be realized in one *move*. In the following subsections, the details of these elements are described.

Moves

Moves are classified into 3 types: *Initiation (I)*, *Response (R)*, and *Feedback* (F) in our model with some extensions. An *exchange* is defined as a sequence of *moves* of the types, in order, *Initiation–Response(s)–Feedback(s)*. We also introduce subtypes of each type of *move*. All *moves* are also classified as one of two subtypes according to whether a response is required *(rq)* or optional *(op)*. Therefore, the following six combinations of types and subtypes are possible.

- *Initiation (I)*: A *move* spoken by a speaker (an initiator speaker, *Si*) to initiate a communication with the others in an *exchange*.
    - *I(rq)*: an *initiation move*, with *response(s)* required.
    - *I(op)*: an *initiation move*, with a *response(s)* optional.
- *Response (R)*: Arbitrary numbers of *move(s)* by speakers other than *Si* (*So(s)*) in response to the *initiation move* from *Si*.
    - *R(rq)*: a *response move* that was requested by the corresponding *initiation move*.
    - *R(op)*: a *response move* that was not requested by the corresponding *initiation move*.
- *Feedback (F)*: Arbitrary numbers of *move(s)* spoken by *Si* to give feedback to the responses from *So(s)*.
    - *F(rq)*: a *feedback move* in reply to a corresponding *response* move that was requested by the *initiation move*.
    - *F(op):* a *feedback move* in reply to a corresponding *response* move that was not requested by the *initiation move*.

Discourse act

Each *move* can contain (or realize) an arbitrary number of *discourse acts*. We define the following four *discourse acts*:

- *Eliciting (elc)*: to request verbal responses; to seek information from the intended hearer(s).
- *Directing (dir)*: to request non-verbal responses; to affect actions of the intended hearer(s).
- *Informing (inf)*: to provide new information to intended hearer(s).
- *Acknowledging (ack)*: to confirm, deny, or evaluate the corresponding move spoken by the intended hearer(s).

As summarized in Table 1, an *exchange* always starts from a single *initiation move* spoken by an initiator speaker (*Si*), followed by arbitrary numbers of *response moves* from other speakers (*So(s)*). Each *response move* may be followed by arbitrary numbers of *feedback moves* by *Si*. No *feedback moves* need to be followed by any *moves* in the *exchange*. Only limited combinations of the *move* types, subtypes, requirement for responses and *discourse acts* specified in Table 1 are possible. Given a combination of *move* type, subtype, requirement for responses, and *discourse act*, there is a prediction preference (no: not permitted;, weak: possible; or strong: likely) for the next discourse act, as shown in Table 1.

Table 1: Summary of proposed discourse model

Table 1.
Summry of elemnets of proposed discourse model,i.e. exchange, move types (I=initiation, R=response, or F=feedback type) , speaker(Si=an initiator, speaker, or So=other speaker(s) than Si), order of move types, requirement for responce moves (op=optional or rq=require), and discourse acts (inf=informing, elc=elicitating, dir=directing or ack=acknowledging).

Elements of discouse model										
	Move					Discourse act				
	Type	Speaker	Order of move types		requirement for response(s)	Possible discouse acts	Predicted (following discourse acts)			
			proceeding	following			ecl	dir	inf	ack
Exchange	I	Si	-	R(s)	op	elc	no	no	strong	weak
					rq	dir	no	no	no	strong
						Inf	no	no	no	weak
	R	So(s)	I	F(s)	op	inf	no	no	no	weak
					rq	inf	no	no	no	weak
						ack	no	no	no	weak
	F	Si	R(s)	-	op	ack	-	-	-	-
					rq	ack	-	-	-	-

STUDY LOCATION

Care facility

We performed field studies at a Japanese elderly care home over 5 days during May 2013. The building has four stories, about 40 private resident rooms, 1 common living room, and 2 dining rooms (one is on the first (i.e., ground) floor and the other is on the second floor), 1 care station, 1 bath area, and various other rooms and spaces. Corridors, elevators, and stairways connect the rooms. About 35 residents were living in this building during our field study. We selected feeding assistance as the task to study.

Residents with disabilities

We classify residents into the following groups.

- Residents with slight disability are independently mobile with the aid of a device such as a cane, walker, or wheelchair, and can eat without assistance. They eat lunch and dinner in the first-floor dining room.
- Residents with moderate disability require a wheelchair and staff assistance to move around, but can eat without assistance. They eat lunch and dinner in the first-floor dining room.
- Residents with severe disability require a wheelchair and staff assistance to move around and cannot eat without assistance; they therefore require full assistance from a staff member. They eat lunch and dinner in the second-floor dining room.
- Bedridden residents cannot eat ordinary meals and receive individual care in their own rooms.

Care teams and target tasks

A team of 5 to 8 care staff members, including a staff leader, performs the following routine around lunch time and dinner time.

1. Residents with slight disability come to the first-floor dining room without assistance.
2. One care staff member goes to the room of each resident with moderate disability to help them to the first-floor dining room.
3. One or more care staff members go to the room of each resident with severe disability to help them to the second-floor dining room.

4. Two or more care staff members provide mealtime assistance to residents with slight or moderate disabilities in the first-floor dining room.

5. Three or more care staff members, including the staff leader, provide feeding assistance to residents with severe disabilities in the second-floor dining room.

6. One or more care staff members take individualized meals to the room of each bedridden resident and provide individualized care.

7. Two or more staff members assist residents with slight or moderate disability as they move from the first-floor dining room to the second-floor living room for relaxation after the meal.

8. All staff members assist any resident who requires movement help from either of the dining rooms or the living room to their own private rooms after their meal or relaxation, and staff members assist with oral health care after lunch and dinner, and with night care (e.g., changing into sleepwear) after dinner.

METHODOLOGY

Data collection

We asked all participating staff to carry a smartphone with a voice-tweet-system client application and a headset device during feeding assistance. All voice tweet inputs and estimated location data with participant identifier and time information are automatically recorded by the server application of the voice tweet system. Human observers were also monitoring the activities of the participants.

Instructions and system settings

We asked the participating staff to use the voice tweet system to communicate with other staff members during tasks. We did not restrict conventional communication among staff (face-to-face conversation, phone calls, memos, mail, etc.). We instructed participants on a small number of key phrases to control distribution of their voice tweets to other staff members. For example, if a participant says “please” at the last part of their voice tweet input, then the voice tweet will be distributed to other staff members. Almost all linguistic variations of the underlying key phrases are automatically categorized into the appropriate key phrases.

Topologies of communication network

Two topologies of communication network, shown in Figure 3, were tested. In the star topology, all voice tweets of staff members are distributed to only the staff leader, and voice tweets uttered by only the staff leader are distributed to other staff members. In the fully connected topology, all voice tweets are distributed to all staff.

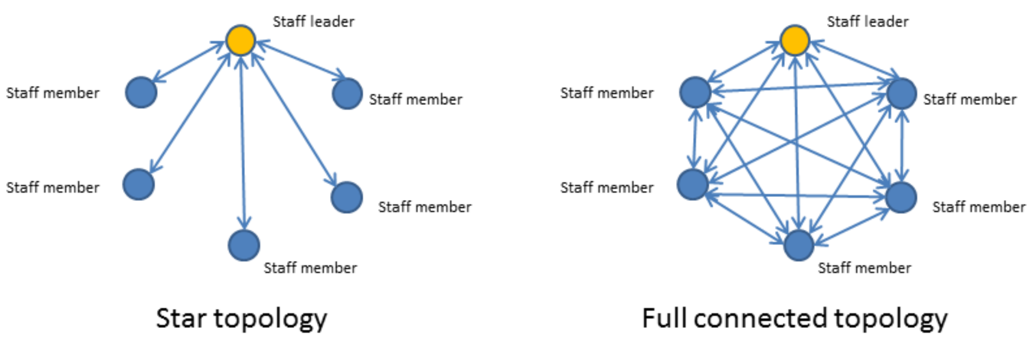

Figure 3. Topologies of communication networks

DISCUSSION

Collected voice tweets

Table 2 summarizes the trials and conditions. During our field studies at the care facility, 10 trials of more than 22 hours by 62 participants (1,267 person-hours in total) were performed: 5 trials during lunch time and 5 trials during dinner time. The star topology was used for 4 trials, and the fully connected topology was used for 6 trials. Each trial involved 5 to 8 participants. In all, 62 participants took part in the experiment. The elapsed times of trials vary from just over 1.5 hours to nearly 3.5 hours, depending on how busy each meal was. Table 2 also summarizes the collected voice tweets, with 636 voice tweets automatically collected by the tested voice tweet system. The average number of voice tweets per person during a meal time was 10.3. The average interval between voice tweets was about 2 min. The computer-mediated remote communication by the voice tweet system during the lunch time trial on the day 3 can be regarded as the most active, since it had the highest average number of voice tweets per participant (14.6) and the shortest average intervals (1 min 3 s). The influence of topology on the collected voice tweets was relatively smaller than the difference between lunch time and dinner time. We conclude that the fully connected topology is better suited to the tested situations (i.e., tasks, physical environment, number of users, duties and distribution of staff, etc.).

Table 2: Summary of trials, conditions, and collected voice tweets

Table 2.
Summary of trials and cconditions (day, lunch or dinner, star topology or full connected topology, and number of participants, and experiment durations), and statictics of collected voice tweets.

Trials and conditions					Collected voice tweets		
Day	Lunch or dinner	Topology	Number of participants	Duration	Number	Average number per perticipant	Average intervals
Day 1	lunch	star	6	2:28:16	64	10.7	0:02:19
	dinner	star	5	2:05:28	31	6.2	0:04:03
Day 2	lunch	star	6	1:33:16	76	12.7	0:01:14
	dinner	star	6	3:23:53	47	7.8	0:04:20
Day 3	lunch	full	8	2:03:06	117	14.6	0:01:03
	dinner	full	6	2:11:13	80	13.3	0:01:38
Day 4	lunch	full	7	2:34:03	61	8.7	0:02:32
	dinner	full	6	1:58:32	58	9.7	0:02:03
Day 5	lunch	full	6	1:58:24	63	10.5	0:01:53
	dinner	full	6	1:52:19	39	6.5	0:02:53
All 5 lunch trials			33	10:37:05	381	11.5	0:01:40
All 5 dinner trials			29	11:31:25	255	8.8	0:02:43
All 4 star topology trials			23	9:30:53	218	9.5	0:02:37
All 6 full connected topology trials			39	12:37:37	418	10.7	0:01:49
All 10 trials			**62**	**22:08:30**	**636**	**10.3**	**0:02:05**

Extracted elements of exchange structures

Table 3 summarizes the elements of exchange structures extracted from the 636 collected voice tweets. Because each voice tweet corresponds to a move in our model, 636 moves were extracted, as well as 735 *discourse acts*. Thus, each *move* contains 1.16 *discourse acts* on average. Almost all *moves* (95.1%) were classified as *initiation*. Most of the other *moves* (4.5% of total) were classified as *response*, and *feedback* was rare (0.4% of total). Although only a few (3%) of *initiation moves* without response required received one or more *responses*, almost half (46.4%) of *initiation moves* with response required received at least one *response*. This can be regarded as evidence for the validity of the voice tweet system in this task situation (i.e., computer-mediated remote voice communication among staff performing feeding assisting tasks at an elderly care facility). Almost all *feedback moves* appear as replies to *response moves* when no response was required, or as replies to additional (2nd or later) *response moves* for an *initiation move*. This may mean that the *feedback move* was used to express appreciation for the extra effort by the voluntary responders. In addition, all *feedback moves* were from a staff leader. Some of them may be positive rewards for extra efforts by responders.

Table 3: Summary of extracted exchange structures, moves, and dialogue acts

Table 3.
Average number of extracted elements of exchange structures, i.e. move (I=initiation, R=response, or F=feedback type) , requirement for responce moves (op=optional or rq=require), and discourse acts (inf=informing, elc=elicitating, dir=directing or ack=acknowledging) per trial and

Trials conditions	Average number of extracted elements of exchange structurs per trial								Average number of discourse acts	
	Initiation moves (I)			Response moves (R)			Feedback moves (F)			
	op	rq		op	rq		op	rq	per participant	per move
	I (op/inf)	I (rq/elc)	I (rq/dir)	R (op/inf)	R (rq/inf)	R (rq/ack)	F (op/ack)	F (rq/ack)		
Lunch trials	81.6	1.8	1.2	2.6	1.8	0.4	0.2	0.4	13.6	1.18
Dinner trials	52.6	0.6	2.0	1.4	0.0	0.4	0.0	0.0	9.8	1.12
Star topology trials	69.8	0.3	1.8	1.5	0.3	0.5	0.0	0.0	12.9	1.36
Full connected topology trials	65.3	1.8	1.5	2.3	1.3	0.3	0.5	0.0	11.3	1.05
All trials	**67.1**	**1.2**	**1.6**	**2.0**	**0.9**	**0.4**	**0.1**	**0.2**	**11.9**	**1.16**
Distribution (all trials)	91.3%	1.6%	2.2%	2.7%	1.2%	0.5%	0.1%	0.3%		
		3.8%			1.8%		0.4%			
	95.1%			4.5%						

Examples of extracted exchange structures are shown in Table 4. Ten voice tweets (*moves*) uttered by two participants (staff leader A and staff member C) during 1 hour of lunch on day 4 are extracted. There are two *initiation moves* from A, 6 *Response moves* from C, and 2 *feedback moves* from A. Two sequences of *initiation–response–feedback*, and four sequences of *initiation–response* are formed by these 10 *moves*.

Table 4: Examples of extracted exchange structures.

Table 4.
Examples of extracted exchange strucutures during 10:30- 11:30 on day 4. The original Japanese utterances are transcribed and translated into English. The phrases "please" at the end of the utterances are predefined key phrases to distriute the message to other staffs.

Voice tweet ID	Speaker	Extracted elements of exchange structures			Ttranscription (in Japanse) and translation (in English)
		Move type	Requrement for responses	discouse act	
Ta1:I(rq/ecl)	Staff leader A	I	rq	elc	U歯科の様子教えてくださよろしくお願いします。 “Report the progress of Dentist_U. Please.” (The last “Please” is a signal to send the message.)”
Tc1:R(rq/inf)	Staff member C	R	rq	inf	今、Vさんが治療に入ってまして。あとをWさん、Xさん 口腔ケアでYさんとZさんが残ってます。お願いします。 “Now, treatment for Mr. V is in progress. Ms. W is waiting. Ms. X, Ms. Y, and Ms. Z are also waiting for dental care. Please.”
Ta2:F(rq/ack)	Staff leader A	F	rq	ack	わかりました。よろしくお願いします。 “Ok. Please.”
Tc2:R(rq/inf)	Staff member C	R	rq	inf	今、Wさん治療に入りました。お願いします。 “Treatment for Ms. W has just started. Please.”
Tc3:R(rq/inf)	Staff member C	R	rq	inf	これから、Xさん治療に入ります。お願いします。 “Treatment for Ms. X will be starting just now. Please.”
Ta3:F(rq/ack)	Staff leader A	F	rq	ack	了解しました。よろしくお願いします Understood, Please.
Tc4:R(rq/inf)	Staff member C	R	rq	inf	口腔ケアのYさんが今から入りました。お願いします。 “Dental care for Mrs. Y has started. Please.”
Tc5:R(rq/inf)	Staff member C	R	rq	inf	口腔ケア最後のZさんが入りました。お願いします。 “Ms. Z, the last for dental care, is being treated. Please.”
Ta4:I(rq/elc)	Staff leader A	I	rq	elc	本日のXX、えーと、診察はこれで終わりでしょうか。よろしくお願いします。 “Today’ s dental care, umm, treatments are all finished, yes?, please”
Tc6:R(rq/inf)	Staff member C	R	rq	inf	はい全て終了です。お願いします。 “Yes, all set. Please.”

Figure 4 describes the same example of extracted exchange structures with the estimated physical movements of each staff member in the study field. The horizontal axis represents time of day, and the vertical axis represents the estimated location of each staff member. Short dotted lines denote physical movement of each staff member during the displayed time. Large red triangles denote *initiation moves*, large red circles denote *response moves*, and large red squares denote f*eedback moves*. Long red dotted lines denote each sequence of moves that forms an exchange structure. As can be seen, in some included cases, the effect of one *initiation move* may persist for a relatively long time and initiate multiple exchanges. Especially in such cases, the positions of participants in one exchange structure may change during the course of the exchange. The voice tweet system is designed as a semi-real-time (i.e., asynchronous) communication system because the network connection quality between the server and each staff member may vary by location. In these examples, however, 2 *feedback moves* are sent almost immediately after a r*esponse move* (within about 1 min).

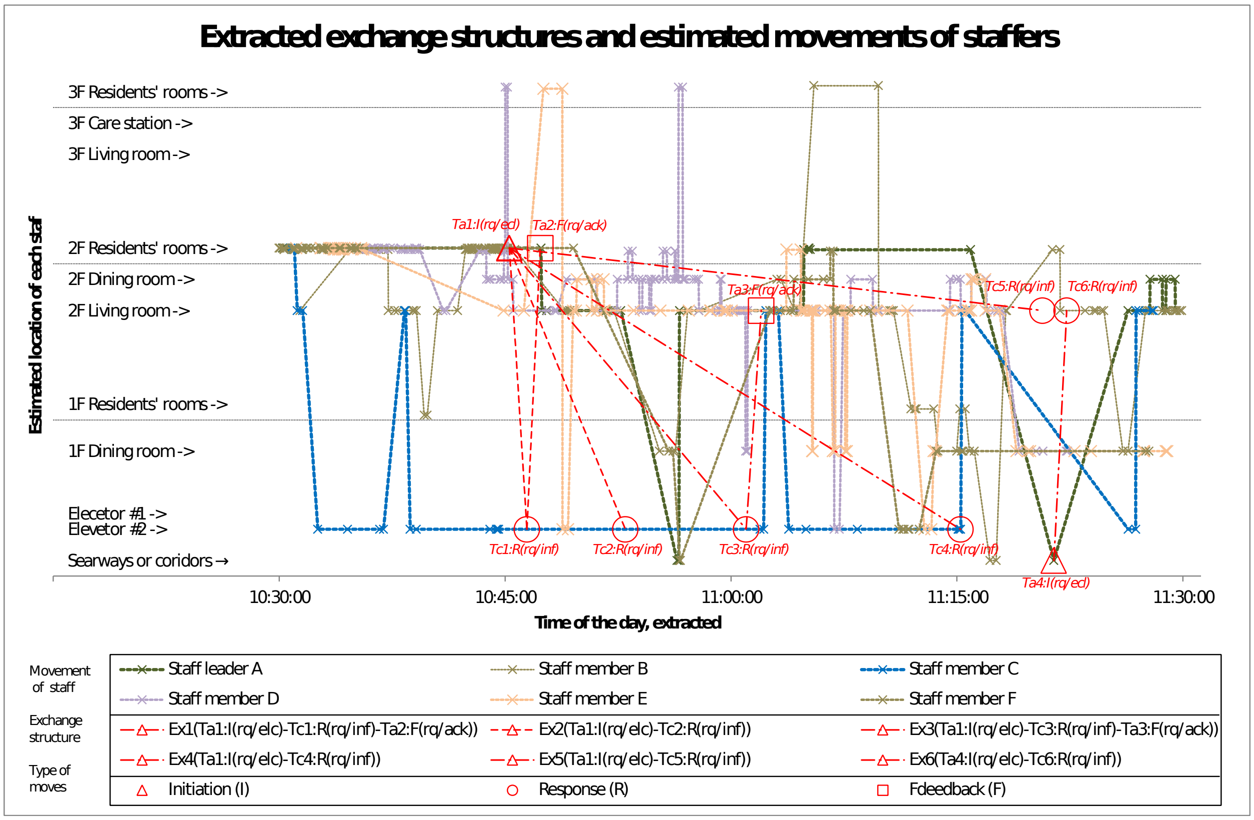

Figure 4. Example of extracted exchange structures and estimated movements of staff

CONCLUSIONS

This paper is one in a series about field studies at an elderly care facility in Japan. In this study, our voice tweet system was tested as a computer-mediated remote voice communication support system for staff. During the trials, the staff assisted with feeding tasks and sent voice tweets via the system to communicate with other staff members. During 10 trials at lunch and dinner times, 636 voice tweets were automatically collected by the system.

A new discourse model based on exchange structures is also proposed for use in analyzing the computer-mediated remote voice communication among the staff. The following insights were found by using the proposed model to analyze the collected voice tweets. Almost all moves (voice tweets) initiated an exchange. Most other moves served as responses. Moves were only rarely used for feedback. Some portion of responses and feedback may have been given in the usual face-to-face manner, rather than through the computer-mediated voice message system, because the staff members moved around the work site and had chances to meet. While only a few *initiation moves* without a response required received at least one *response*, almost half of *initiation moves* with a response required received *responses*. This can be regarded as evidence for the validity of the voice tweet system in this task situation (i.e., computer-mediated remote voice communication among staff performing feeding assistance at an elderly care facility). The usability of the proposed discourse model is also confirmed by finding complex sequences of computer-mediated remote voice communication that allowed achieving collaborative activities among the staff participants in the study.

FUTURE WORK

An integrated analysis to gain other insights and collect data such as staff interviews may be a useful project for future work. Application of the proposed discourse model to data acquired from other tasks, in this domain and in other domains, is another candidate for enlightening future work.

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