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Topics：Strategic management of evidence-based health and medical care policy: How to use new Digital Big Data in health care system

＜Review＞

Management of medical staff utilizing sensing technology: Development of a nursing activities measurement method with ultrasound positioning

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Abstract

The ultrasound positioning technology used in this investigation makes it possible to collect data on nursing activities consecutively for 7 days in the respiratory disease center of Showa University Hospital. The total of 142 person-days and 1,464 person-hours of positioning data within the hospital ward floor were recorded; meanwhile, follow-up records on the nursing details of every nurse on duty were also collected. Nursing activities were visualized in motion pictures, and nursing movement patterns were visualized in charts and network models. The characteristics of nursing activities regarding the duration of stay in the nurses' station, patient rooms, corridors, and other locations; the frequency of visiting patient rooms; the frequency of traveling between rooms; and the length of direct nursing time were discussed. For nurses in different roles, the characteristic patterns of nursing activities were observed.

keywords: human behavior, nursing traffic line, nursing staff management, sensing technology, artifact link-chain

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I. Introduction

This paper first provides a brief introduction on the trend of sensing technology applied in human activities and its application on improvement of daily living. Afterward, the authors' research will be described in detail.

1. Motion sensing of human activities and its application

(a) "The weakest link"

Sensing technology has been applied to the investigation of human motion for research in IT, robotics, and other leading-edge fields. The extracted patterns are also important evidence for developing new measures to support daily activities. In a paper titled "Human, the Weakest Link," Kanade [1] claimed that no matter how the

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artificial elements correlated with each other to strengthen a designed system for human manipulation, the human factor is the weakest link to the other artificial elements to make the system operate well. The strength of links between every pair of elements within the connected system holds the key of the overall strength of such a system. That is to say, the weakness of connecting to the human factor is dragging down the design that is supposed to be supportive of human daily life. Here, for a human-manipulated system, the smoother the human factor could be incorporated into such a system, the better the performance that could be achieved.

In the research on designing a network of artificial elements, taking the connection of the human factor as the last frontier to success, various efforts has been made on sensing human actions for the innovation of artificial elements supportive of human-manipulated systems. For example, in automotive or aircraft design, erroneous driver or pilot manipulation can be detected in advance to forestall severe mishaps. Sensing technology is applied not only to warn drivers simply for leaving a door unlocked or a seatbelt unbuckled, but also adjustment of the operating program for safe driving by, say, detecting the driver's habits of stepping on the gas for optimal acceleration, forecasting a crash and braking in advance, and reading the driver's eyelid movement to sense drowsiness. Meanwhile, in the authors' field of concern, architectural elements such as a habitually occupied space have only slight sensing knowledge about when, where, or what its inhabitants are or how they behave within. As compared to the average usage of an automobile in tens of minutes per day, people spend much longer time inside specific built spaces. Despite the difference, there is obviously not a balanced effort to make daily habitual spaces more adjustable to their long term users. We might have been overlooking the importance of designing better habitual spaces that can sense and adjust themselves to fit human needs.

(b) Mortality statistics in home accidents and traffic-related deaths

In 2005 statistics show that home accidents caused the deaths of 12,781 people, a number that has been rising in recent years. Meanwhile, in 2012, traffic-related deaths stood at 4,612, which has been decreasing year by year. Mortality at home has been surpassing that caused on the road, showing the trend of a broadening gap.

The habit of taking baths may be the cause of the high drowning death rate in Japan. Around 7,000 people per year are found dead inside bathtubs. Inside a closed bathroom, it is difficult for a second person on the outside to confirm the bather's status or sense signs of an accident in time.

Japan has entered a period of a super-aging society, the likes of which no country has ever experienced with such speed and context. According to the Statistics Bureau of Japan, the projected aged population, those age 65 and over, will reach the 34 million range; every 2 people in the working-age group, ages 15 to 64, will be supporting the life of one person in the aged group. The number of the elderly with dementia will reach 3.2 million [15]. The number of elderly households will reach 18.43 million, 37% of the total number of households, within which 6.8 million, or 13.5% of all households, will be single-person elderly households [16]. The risk of home accidents is rising as the elderly losing their physical and cognitive functions. Similarly, there exists an increasing probability of unnoticed deaths when bathing at home among the elderly who live alone.

(c) The Potential of sensing technology

If a built space is designed with the function to observe human motion and sense abnormalities, it is possible to help prevent everyday home accidents and help provide inhabitants with more efficient environmental controls for safer and easy-to-control daily living.

Taking the bathing case by way of explanation, if there are sensors to detect abnormal drowning movements within the bathtub, or sensors to continually check the bather's heartbeat, bathing time versus water temperature for the adjustment of a safer bathing environment, it is possible to reduce the risk of death caused by unnoticed drowning, heart attack, or other accidents.

In the case of an unexpected disaster like an earthquake or tsunami, it is believed that motion sensing technology would be of great assistance to those people with mobility disability who come to top priority.

Last summer, the worldwide heat wave led to the rise of heat-related deaths around the world. The global warming trend continues. By the end of the 21st century, a further rise of 6 degrees in the average temperature is predicted. For human beings inhabiting the earth, an efficient indoor environment-controlling system to provide habitable space against severe climate changes will become necessary.

Crime in multistory apartments has been increasing. The automatic dweller identification innovation is one possible crime-prevention measure.

In northern Europe, where services for the senior society are advancing, the shift of terminal care in hospices to care at home has been observed. Home-care technology plays another important role in supporting patient care and the family's needs.

(d) Nursing activities in hospital acute care wards

The social issues of an aging population, changes in disease structure, patients' attitudes toward medical care, and advancing medical technology make nurses' daily duties complicated and busy. In today's turbulent health care environment, there is rising concern about the quality of care and patient safety, particularly in demanding acute care wards. The strain of the current situation is believed to be expanding rather than reducing. As one strategy to effectively distribute the limited medical resources, we are attempting to search for improving solutions in regard to ward floor planning and the nurse staffing model. There is existing research that has attempted to visualize the nursing workload for efficient staffing. As mentioned above, we succeeded in developing a research methodology that utilizes sensing technology for tracing nurses' movement tracks in real time for further analysis. We aim to establish a model for optimal nurse staffing on the wards.

II. Background and the aim of the research

1. Literature review and the importance of the research

Numerous studies have shown many findings in relation to nurses' duties and path tracing within and outside Japan since the 1950s [2-14]. Most of these findings provide evidence aiming for quality care and efficiency. To achieve similar aims, there is research related to architectural floor planning for patient wards. These findings have contributed to planning strategies such as shortening traveling distances between patients and nurses, improvement of accessibility to nursing care, and increasing direct nursing care hours.

The related study began with a series of precedent studies outside Japan. In the Japanese context, it was led by research by Yoshitake [2] in which nursing duties were first observed and basic information was collected. Other observational research followed that focused on the duties of night-shift nurses, recorded consecutively by one-on-one researchers [5]. Another study collected data by nurses completing forms themselves and the researchers simultaneously recording the frequency of patient ward visits and the extent of patient care [6]. The characteristics of nurses' traveling paths were analyzed in another paper in a follow-up survey on the progression of nurses' duties [7]. In a similar follow-up survey on other research, it was shown that the "personal nursing base" strategy has an effect on nurses' duty routines [8, 9]. Prediction of nurses' traveling paths was also tentatively attempted in past studies [10, 11] by recording the actual tracks traveled.

The methodology, duration of survey, survey objects, and other research conditions of each of the above research studies are sensitively tailored for the respective aims, type of wards, nursing duties, staffing models, patient care level, and so on; and most were conducted in one day's time on a limited number of target nurses. There is a limitation shown in the traditional observation methods used to collect consecutive data of longer duration and a larger number of survey objects. Here, our group shows the practicability of an advancing survey method to collect nursing activity records for all the nurse members in one care ward for a time period of 7 consecutive days. The scale of the amount of data being collected has not been achieved before in any hospital under full operation [*1]. In the overall project, we aimed to accumulate a series of basic data in a consecutive period of time for further investigation of the nurse staffing model and floor planning for hospital wards. This report, as part of the project, is aimed to focus on the affirmation of the practicability of recording real-time nurses' duty movements for comparatively long duration, in a format that is technically comprehensible and easy to revisualize.

Table 1 Summary of precedent studies.

	Methodology	Research Duration	Objects
Yoshitake, etc. (1952) [2]	Fixed point observation	1 day (Day shift 8:00～17:00)	2 hospitals 14 + 7 ppl
Tomokiyo, etc. (1976) [3]	Fixed point observation	1 day (Day shift 8:00～17:00)	2 hospitals 19 + 12 ppl
Nagasawa (1983) [5]	Follow-up survey	1 day (Night shift 16:00～9:00)	5 wards, Night shift 5～8 ppl each
Yanagisawa, etc. (1984) [10]	Self-record, Fixed point observation, Follow-up survey	1 day (00:00～24:00)	Hospital staffs
Taniguchi, etc. (1984) [11]	Follow-up survey	1 day	6 wards Day shift 6 ～11 ppl
Nagasawa (1986) [6]	Self-record, Fixed point observation, Follow-up survey	1 day (from start of day shift to the end of night shift)	10 wards Day 13～17 ppl Night 6-8 ppl
Zhou, etc. (2004) [6]	Fixed point observation, Follow-up survey (One day each)	1 day (from start of day shift to the end of night shift)	Day 2 ppl Early Night 2 ppl Mid-night 2 ppl
Toriyama, etc. (2007) [7]	Follow-up survey (non-participant observation)	1 day (from start of day shift to the end of night shift)	4 wards Day 5～7 ppl Night 3 ppl

III. Methodology of the survey on nursing activities

1. Survey target and duration

The targeted hospital (see table 2) has been actively undergoing reforms to continually strive for better nursing services. We focused on the nurse staff, including registered nurses, assistant nurses, clerks, and on-demand nurses from other wards (here called "relief nurses") who are working in the most demanding ward in the hospital. If it is possible to accurately record nursing activities in this demanding and complicatedly staffed ward, it is proved that the survey method is also applicable to other situations.

Table 2 Data of hospital ward under investigation.

Ward Detail	The Respiratory Disease Center, 11/F, the Showa University Hospital
Building Detail	17 floors above ground +2 floors underground, Gross floor area㎡
No. of bed	55 beds(Single bed: 5 rooms; Double: 5; 3 beds: 2; 4 beds: 1; 6 beds: 5)
Nurse Staffing Model	2 shifts, patients assigned to 2 teams in charge

The one-week survey, which included the weekend, lasted from the day shift that started at 8:30 a.m. on Thursday, January 19, 2012, until the night shift that ended at 11 a.m. on Wednesday, January 25, 2012.

2. Survey methods

(a) Nursing activities traced by an ultrasound positioning system

Ultrasound positioning technology uses ultrasound transmitting tags to emit a real-time 40 kHz signal to ultrasonic receivers fixed in various locations. The position of a specific tag is determined by the trilateration algorithm calculation of the distance data based on the time delays of the ultrasound signals reaching the 3 nearest receivers (fig. 1). Here we use the name "tag transmitters" (fig. 2), which are attached to each nurse on duty, and "receivers" (fig. 3), which were attached in advance below ceiling boards in various strategic locations within the targeted ward (fig. 4) [*2]. The ultrasound signal has a few merits over light and radio waves. The transmission speed of ultrasound is slow, and therefore the time delay for the signal to reach multiple receivers is obvious, and a more accurate position can be calculated. Furthermore, the weak ultrasound waves do not have adverse effects on the human body or medical equipment.

(b) Nursing activities record by follow-up survey

In addition to the ultrasound positioning tracing survey, a follow-up survey was conducted simultaneously by having every nurse followed by an individual surveyor to record his or her nursing activities in detail. There are a couple of purposes for conducting the follow-up survey. First, the location and time data in the written follow-up records are used to counter-check against the ultrasound positioning data in order to verify the accuracy of the data retrieved by the ultrasound positioning system and calculations. Second, in addition to the movement paths, the record details (see table 3) can help ascertain the content and progression of nursing activities.

(c) Survey procedures

The survey was conveyed in the following procedures:

(i) Nursing activities tracing by ultrasound positioning

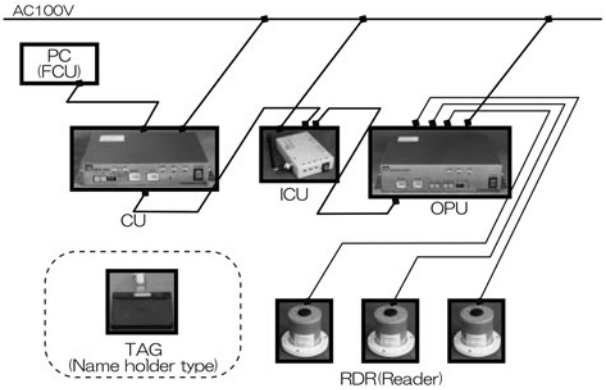

Fig. 1 The structure of ultrasound positioning system.

Fig. 2 Transmitter (TAG)

Fig. 3 Receiver (RDR).

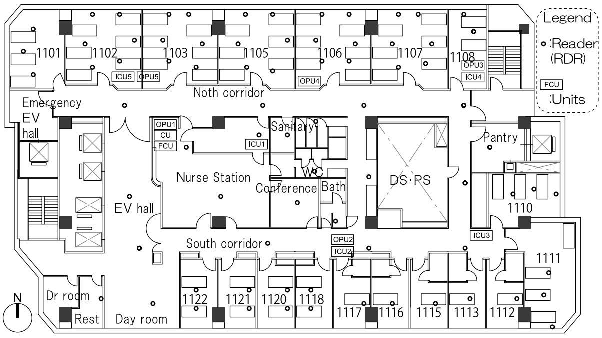

Fig. 4 Locations of the ultrasound receivers and other devices on the ward floor plan.

Table 3 Details of nursing activities record.

1.	*Time*	Record in 1 minute interval
2.	*Location Code*	The place or the patient room where the nursing act was taken place
3.	*Patient name*	Full name of patient whom was receiving the nursing care
4.	*Nurse Call*	Content of each nurse call
5.	*Activities*	Technical term of nursing act
6.	*Activity Code*	Code Nursing act, categorized according to the Table of nurse act [*3]
7.	*Remark*	Record of exceptional situation

system

1. Nurse duty begins. Surveyor puts the tag on the nurse, records the tag number and starting time.

2. Check the real-time position of the nurse against the positioning data shown in the system while on duty.

3. Nurse duty ends. Surveyor takes off the tag, records the tag number and ending time.

(ii) Nursing activities record by follow-up survey

1. Document distribution to surveyor, briefing, Q&A session

2. Synchronize surveyor's timing device

3. Allocation of targeted nurse. Introduce surveyor to designated nurse. Recording starts.

IV. Results

1. Data properties

(a) Daily nurse staffing and patients' conditions in the survey period

Table 4 shows the summary of nurse staffing and patients' conditions in the survey period. From the table, it is obvious that according to changing patients' conditions, nurse staffing was flexibly adjusted daily for the optimal provision of nursing care through the addition of assistant nurses and relief nurses.

(b) Visualization of nursing trips within the hospital ward

The tracing data of the group of nurses is organized in a timeline for visualization by a program development environment [*4]. The nurses' movement is animated over the ward floor plan (fig. 5). The post of each nurse is represented with a code for recognition. The overall perspective of the temporal nurse activities within the ward can clearly be visualized.

(c) Correction of raw positioning data for analysis

Positioning data is recorded in text tables in the formats shown below in table 5. Visualization of the overlapping of a series of raw positioning data for a specific nurse in consecutive intervals of time on the floor plan is shown in figure 5.

It shows a discrepancy in the positioning data that trips oscillate in straight lines between the rooms over the partitions without accordingly passing along the corridor. Theoretically, the receiver catches ultrasound signals and therefore records positioning data for each nurse in approximately 2-second intervals. In the actual situation, the tag signals may be blocked by unexpected obstacles, or they may transmit to multiple receivers when the nurse, wearing the tag on the shoulder, turns his or her body only slightly. Therefore, the tag signals reach the receivers in intervals that vary from a couple of seconds to a few

Table 4 Summary of the nurse staffing and the patients' condition on each survey date.

Date	*Day Shift*	*Day Staffing (Post : ppl)*	*Night Shift*	*Patients' Condition (State : ppl)*
Jan 19 Thu	17 ppl	Charge Nurse(S):1, Clerk(C):1, Assistant nurse(H):3, Team 1: 7 (Chief Leader (T):1), Team 2: 5 (Leader(L):1, #EarlyLeave:1)	4 ppl	Admission: 2, Discharge: 2, Fr other hospital: 1, Room Change: 6, Extra Care: 4, Observe: 16, Stay-out:1
Jan 20 Fri	18	S: 1, Senior Nurse: 1, C: 1, H:3, Team 1: 8 (T:1) Team 2: 4 (L:1)	4	Admission (Emergency): 1, Discharge: 3, Fr other ward: 1, Room Change: 4, Extra Care: 5, Observe: 17, Stay-out: 4
Jan 21 Sat	11	H: 1, Relief Nurse(R): 1, Team 1: 6 (L:1), Team 2: 3 (T:1)	4 Relief: 2	Fr other hospital: 1, Discharge:5, Room Change: 4, Extra Care: 4, Observe: 16, Stay-out:4
Jan 22 Sun	10	Team 1: 5 (L:1) Team 2: 4 (T:1), R: 2	4 Relief: 2	Severe: 1, Extra Care: 4, Observe: 19, Stay-out: 4
Jan 23 Mon	18	S: 1, C: 1, H: 3, Team 1: 6 (T:1) Team 2: 7 (L:1)	4 Relief: 1	Admission: 1, Discharge: 1, To other ward: 1, Room Change: 3, Severe: 3, Extra Care: 3, Observe: 20, Operation: 1, Stay-out: 1
Jan 24 Tue	18	S: 1, C: 1, H: 3, Team 1: 8 (T:1) Team 2: 5 (L:1)	4	Admission (Emergency): 1, Discharge: 3, Fr other ward: 2, Room Change: 6, Severe: 2, Extra Care: 3, Observe: 18
Jan 25 Wed	17	S: 1, C: 1, H: 3, Team 1: 6 (T:1) Team 2: 6 (L:1)	4	Admission (Emergency): 1, Discharge: 3, Fr other ward: 1, Room Change: 3, Severe: 1, Extra Care: 6, Observe: 21
Total	109 man day		3 man day	

Table 5 Format of positioning data.

1/Date	2/Time	3/Tag Number	4/Coordinates	5/Position Parameter
yyyy/mm/dd	hh:mm:ss.000	4 digit ID	(X,Y,Z)	Parameter

Fig. 5 A single shoot of the animated nursing paths on the hospital ward floor plan.

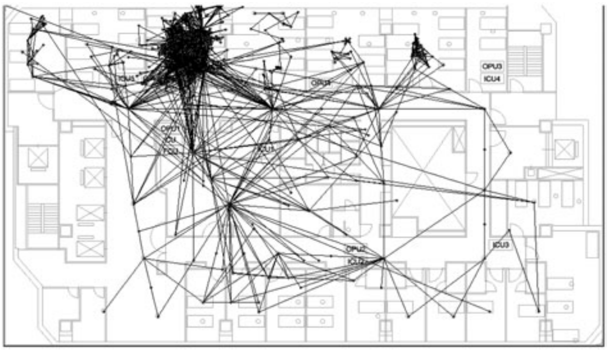

Fig. 6 The visualization of the positioning data of certain nurse in a certain interval of time

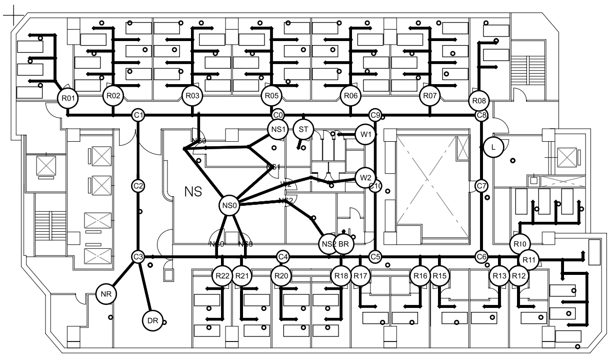

Fig. 7 The estimated network of travelling routes.

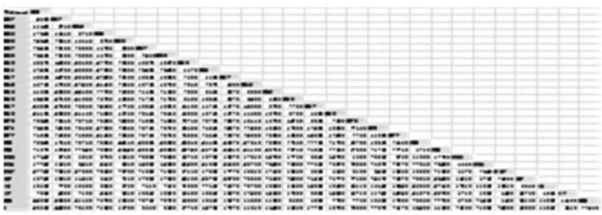

Fig. 8 The distance matrix among the defined locations.

minutes, and consecutive coordinates are not spatially continual.

The aim is to extract from the positioning data for further analysis some basic movement properties such as the distance of travel, duration of stay in patient rooms, and frequency of visits to patient rooms. Nonconsecutive positioning data must therefore be processed to rectify the missing trips between rooms. That is to say, when the raw positioning data shows that a specific nurse moved from one point to another, the path and the distance between the two points are not necessarily represented by a straight line linking the two points. It is therefore necessary to assign the possible trip for travel between specific pairs of points. The estimated routes of traveling within the ward are defined and shown in figure 7.

When the data shows that a certain nurse moved from one point to another, it is assumed that she or he had walked in or out of the room through the door opening, passing through the middle of the corridor to reach the destination. The coverage of each room or each section of corridors is defined by a range of coordinates. The travel distance from one of these locations to another is defined by the shortest path calculated from the route along the network, and the distance matrix is set up and shown in figure 8.

2. Data analysis

(a) Accuracy of ultrasound positioning data

The accuracy of the ultrasound positioning data is verified by comparing the ultrasound data with the recorded locations in the follow-up survey. The length of time when the position does not match is extracted, as summarized in table 6.

There are human mistakes simply due to the recording of the wrong room number in the follow-up records. These kinds of human mistakes are corrected manually and are not considered positioning mistakes caused by the system setup. It can be summarized that the ultrasound positioning data mismatches or repetitive position changes (position jumping repetitively among 2 or more locations within the interval of a couple of seconds) mostly occurs between the nurses' station (NS) and its nearby corridor areas, as well as the patient rooms and the adjacent corridor area. It is

Table 6 Total duration when positioning error occurs

Basic data	*Duty duration*	*Duration with positioning errors*	*% of error*
Jan 19, Day Shift, Tag ID:3	9 hours 31 mins	20 mins 17 sec	3.5%
Jan 19, Day Shift, Tag ID:4	9 hours 16 mins	23 mins 24 sec	4.2%
Jan 19, Day Shift, TagID:10	9 hours 15 mins	24 mins 40 sec	4.4%

predicted that rapid changes in positioning data were caused by the change of orientation of the name tag attached to the nurse's shoulder, when the nurse might have been, for example, sitting near the corridor inside the NS and turned her body around to take a file behind her seat, even when the nurse who was wearing the tag did not leave the room at all. When observing the positioning data, it is obvious when there is a consecutive series of position changes within a few seconds. To rectify this kind of discrepancy, whenever there is position data showing less than 5 seconds duration of stay, the position change is ignored and the duration of stay is counted with the previous position.

(b) Proportion of duration of stay in all locations

The overall duty duration of all of the nurses within the complete survey period and the accumulation in each of the specified locations are summarized, and the proportion of duration of stay in each specified location is shown in figure 9. The one exception is the duration of stay recorded in "EV Hall," which includes the duration of time when the tagged nurse was leaving the ward floor for other duties outside the survey ward. The following findings were observed:

- 40.9% of the overall duty duration of all nurses was spent in the NS.
- 12.6% of the overall duty duration was spent in the corridor areas.
- 34.5% of the overall duty duration was spent in the patient rooms.
- Severely ill patients' rooms, namely 1103, 1121, and 1122, are all spatially close to the NS. The respective proportion of duration of stay in these rooms is relatively higher than for other patient rooms.

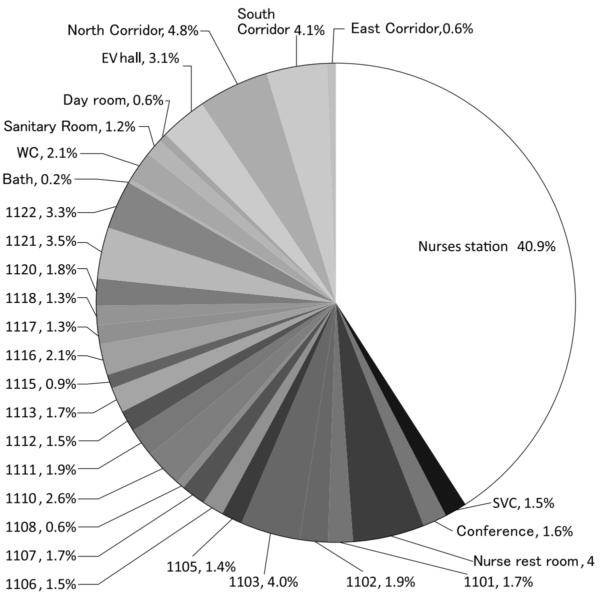

Fig. 9 The Proportion of the duration of stay in all locations where nursing activities were taken place.

(c) Duration of stay in patient rooms and travel distance of each nurse each survey day

The statistics of duration of stay in patient rooms [*5], durations of stay outside patient rooms, and the travel distances of every nurse each day of the survey is visualized in the following charts (figs. 10-16) for the purpose of clarifying the variation in workload of every type of nurse each survey day during the whole period of investigation.

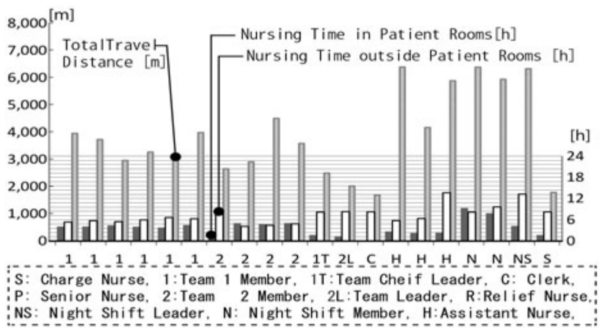

Fig. 10 The bar chart of duration of stay in patient rooms and travel distance of each nurse on Jan 19.

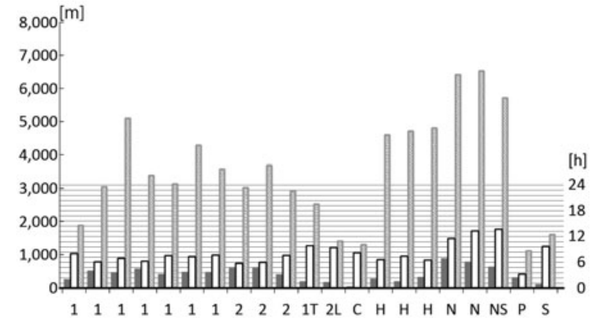

Fig. 11 Bar chart of each nurses on Jan 20

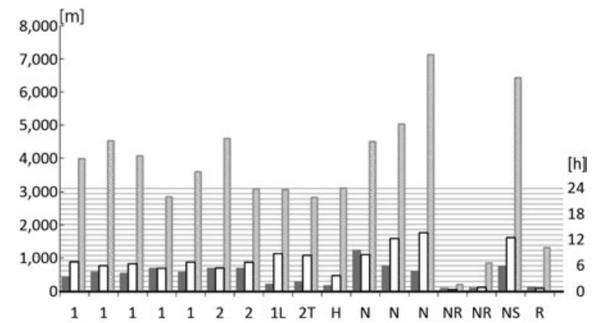

Fig. 12 Bar chart of each nurse on Jan 21

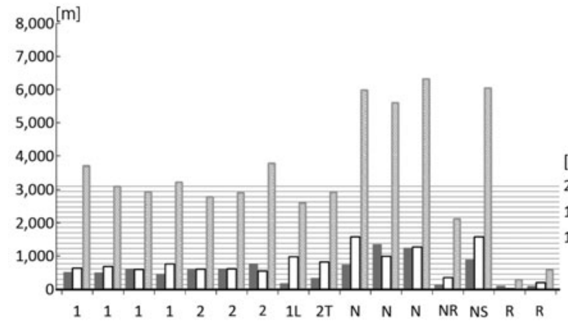

Fig. 13　Bar Chart of each nurses on Jan 22

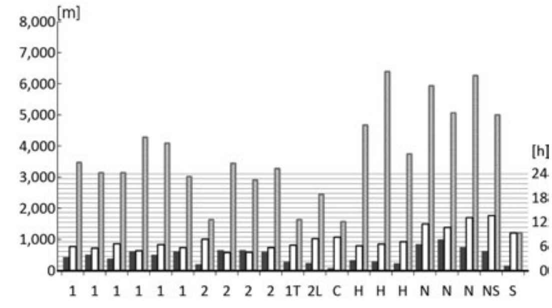

Fig. 15　Bar Chart of each nurses on Jan 24

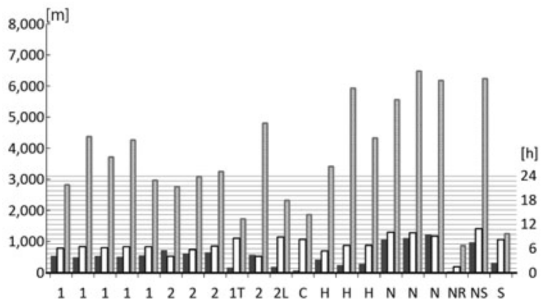

Fig. 14　Bar Chart of each nurse on Jan 23

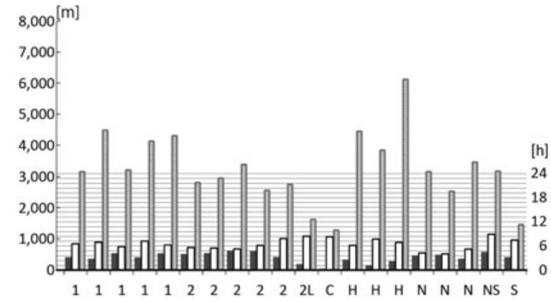

Fig. 16　Bar Chart of each nurse on Jan 25

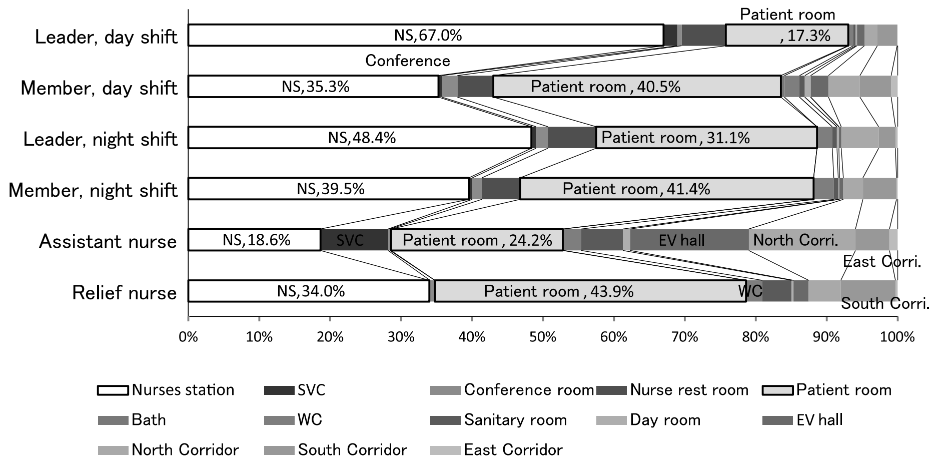

Fig. 17　Comparison of the characteristics of the durations of stay in each specified locations among each nurse types

(d) Characteristics of proportion of duration of stay and travel distance for each type of nurse

After clarification of the daily characteristics of nursing activities for each nurse, the characteristics of working modes of each type of nurse have been analyzed through the respective summation of their duration of stay in each specified location and their average travel distance for comparisons (see table 7 and figs. 17-19).

- Lead nurses of the day-shift teams and night-shift team have similarly longer working hours as the team members within the NS, but shorter duration of stay in the patient rooms (see table 7 and fig. 17).
- The night-shift team (including the lead nurse and member nurses) shows a longer duration of stay in the patient rooms than those of the day-shift teams.
- The relief nurses, who work in the ward on demand, have the longest duration of stay in the patient rooms.
- The nurses' assistants move around the most, working

mostly in the corridor areas or function rooms other than the patient rooms.

- Among the day-shift teams, the members have a longer the average travel distance per day and per hour than the lead nurse (figs. 18 and 19).
- The average travel distance per day and per hour of lead nurses of the night-shift team are both much longer than the night-shift member nurses. The lead nurse's working time is longer than that of the member nurses.
- From the travel distance statistics, it is found that the night-shift lead nurse travels 1.4 times more per hour and 2.5 times more per day compared to the day-shift lead nurse. It is evident that the night-shift lead nurse is busier on that shift.
- The members of both the day-shift and night-shift teams have similar travel distance per hour. However, considering the longer working hours per day for the night-shift member nurses, on average the night-shift member nurses travel 1.5 times more in one day's work than that of the day-shift member nurses.
- The nurses' assistants and the relief nurses both have the relatively longer distance of travel per hour. Considering the short shift hours, it is evident that they move around relatively more for various tasks during their working hours.

(e) The Frequency of visits of each type of nurse

It has been clarified that for nurses in different work positions, there are different patterns of duration of stay in

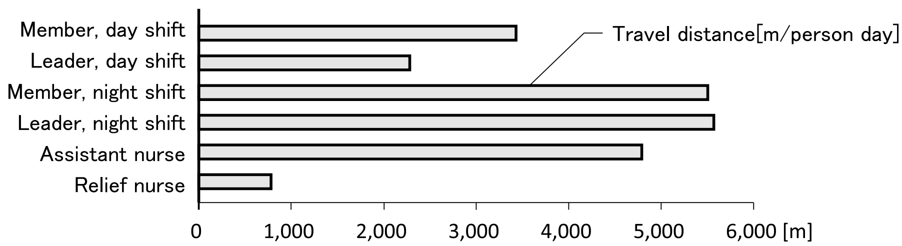

Fig. 18 Average travel distance per man day

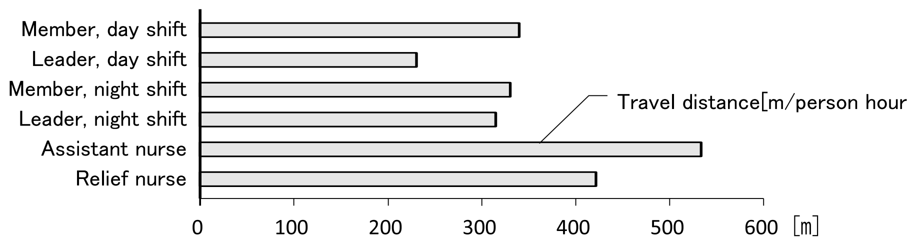

Fig. 19 The average travel distance per man hour

Table 7 The proportions of the durations of stay in each location characterized by each nurse types

% of duration of stay	Nurse Station (NS)	NS (ICU1)	Conference	Day room	Patient rooms	Bath	WC	Sanitary	Day room	E V Hall	North corridor	South corridor	East corridor
Day Shift Leader	67.0	1.9	0.6	6.2	17.3	0.1	0.6	0.3	0.2	1.0	1.8	2.8	0.1
Day Shift Member	35.3	0.5	2.2	5.1	40.5	0.5	2.1	0.7	0.8	2.5	4.4	4.4	0.9
Night Shift Leader	48.4	0.6	1.7	6.8	31.1	0.0	2.1	0.6	0.3	0.3	5.3	2.4	0.3
Night Shift Member	39.5	0.5	1.4	5.4	41.4	0.0	2.8	0.6	0.2	0.5	2.8	4.7	0.2
Assistant nurses	18.6	9.5	0.3	0.1	24.2	0.1	2.5	5.9	1.0	16.7	15.0	4.8	1.2
Relief Nurse	34.0	0.1	0.7	0.0	43.9	0.0	2.3	4.1	0.3	2.1	4.5	7.7	0.3

various specified locations (fig. 17). So it is worthwhile to further clarify the characteristics of their place-visiting pattern in the respective locations. For each type of nurse, the pattern of the frequency of visiting the various locations in the ward is visualized in a separate network graph (figs. 20-24). Each node represents each location of a visit. The radius, and therefore the size of each node in the graph, is proportional to the average numbers of visits per each nurse in one day (per person-day). The thickness of the link between each pair of nodes represents the number of direct trips between the two locations. Bigger nodes show that the location is more visited on average. The thicker links show that it is more usual that that type of nurse tends to travel back and forth between the two locations. Other observations are summarized below:

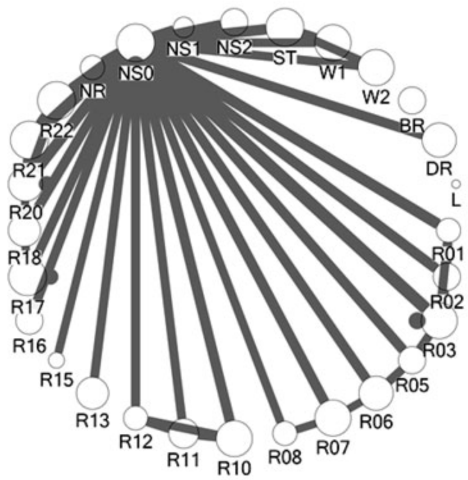

Fig. 20 The average times of visit to every room of the day shift nurse members

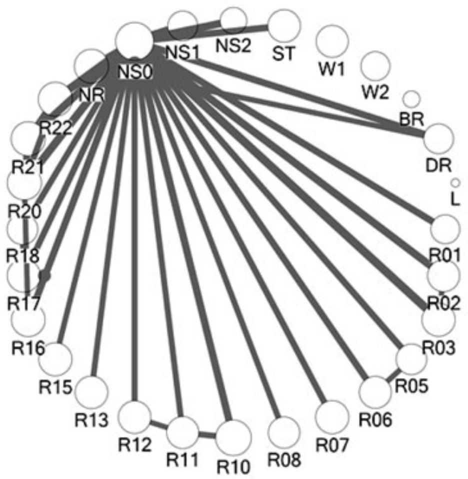

Fig. 21 The average times of visit to every room of the day shift nurse leaders.

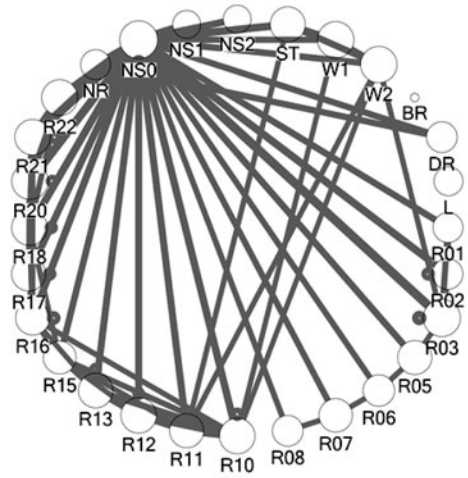

Fig. 22 Network graph of all night shift nurse members.

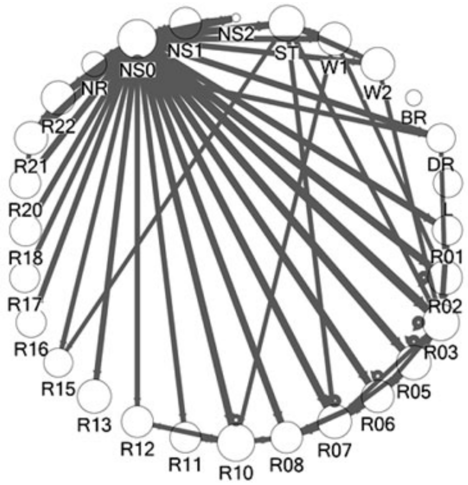

Fig. 23 Network graph of all night shift nurse leaders.

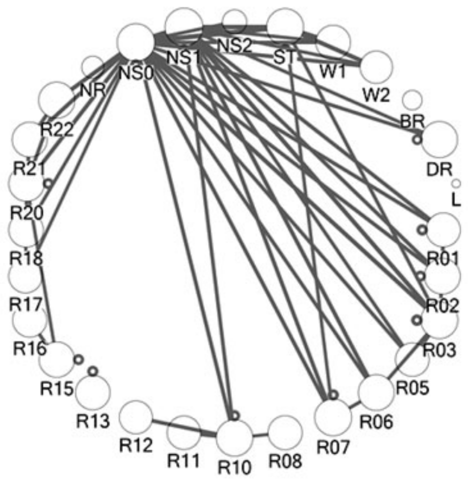

Fig. 24 Average by all nurse assistants (H).

- The nurse members make a greater number of visits to every location than the lead nurses.
- It is evident that there are more trips between the patient rooms accommodating severely ill patients and the NS, probably because these patients need more frequent nursing care than others.
- The night-shift nurses visit every location more frequently than those of the day-shift nurses on average.
- The day-shift members, having the NS as their base, tend to travel directly between the NS and the patient rooms.
- As compared to the night-shift members, other than traveling more between respective patient rooms, they also tend to travel between patient rooms more frequently, thus resulting in a more interwoven network graph.
- Similarly, the assistant nurses, who are not necessary based at the NS, travel over places in the ward to deliver nursing services. Their network graph is the most interwoven among the types of nurse.

V. Summary

1. The Validity of the ultrasound positioning method

With less than 5% system error, it can be concluded that the ultrasound positioning method is feasible for the measurement of trips for nursing activities in a busy hospital ward for proper analysis.

For achieving higher accuracy of measurement, it is suggested to: (1) increase the number of receivers in black spots where discrepancy frequently occurs, or (2) relocate the receivers into a strategic location for better signal reception.

2. The reality of nursing activities reviewed in the Analysis

(a) The proportion of duration of stay in locations where nursing activities took place

Through simple analysis, the statistics of where nursing activities took place, for how long activities took place in total, how far the nurse traveled, and therefore the characteristics of the activities can be visualized.

The working hours in the nurses' station (NS) are the longest among all the locations. It is believed that improving accessibility of the NS, where miscellaneous tasks like recording, preparation, meetings, and discussions take place, would be strategically beneficial for increasing the efficiency of daily nursing activities.

In this project, patients in severe condition are allocated to rooms located near the NS. The duration of stay and the frequency of visits to these rooms are proportionally higher. This planning of special rooms to be adjacent to hubs such as the NS has been proved in preceding studies to be beneficial in saving staff resources.

(b) The working characteristics of different types of nurse

(i) Proportion of working hours in various locations

The lead nurses of both day and night shifts have a large portion of working hours in the NS than the team members, but have a shorter duration in visiting patient rooms. For both lead nurses and other team members, the night-shift teams have a higher proportion of duration of stay in the patient rooms. The relief nurses have the largest proportion of working hours in the patient rooms. The assistant nurses travel and stay more along the corridors, go outside the wards through the EV Hall, and travel among function rooms other than the patient rooms for carrying out nursing activities. The relief nurses and the night-shift teams have the longest working hours, and it is evident that they are particularly busier in direct nursing.

(ii) Travel distance

Regarding the day shift, the team members have a longer daily and hourly travel distance than the lead nurses do. Regarding the night shift, the lead nurses travel a longer distance daily, while the member nurses travel a longer distance hourly. On the night shift, the lead nurses have longer working hours than the member nurses. The night-shift lead nurses, as compare to the day-shift lead nurses, travel 1.4 times more in an hour, and 2.5 times more in a day. It is evident to conclude that the workload of the night-shift lead nurses is extremely heavy. The night-shift member nurses have similar hourly travel distances as the day-shift member nurses do. However, considering that the night shift requires longer working hours, the night-shift team members travel 1.5 times more daily than the day-shift team members. The assistant nurses and the relief nurses have a relatively long hourly travel distance. They work for a shorter time, but they travel intensively within their working hours in order to share the ward' s workload in the peak hours.

(iii) Frequency of visits to patient rooms and other locations

In relation to the duration of stay and travel distance summarized above, it is evident that the lead nurses work in the NS as a base, while the member nurses work more closely with the patients, who stay in the patient rooms to receive nursing care. The night-shift teams have a higher frequency of visits than the day-shift teams. The lead nurses of the night shift have more visits to the patient rooms and other locations than the day-shift member nurses. Meanwhile, the assistant nurses do not necessarily make the NS their base for providing nursing services. Instead, they move around from room to room, place to place to relieve the heavy workload carried by the regular team members.

VI. Afterword

Our group has succeeded in carrying out a comprehensive survey in a very busy acute respiratory ward. The nursing activities of all the nurse members on the ward floor were recorded in the form of positioning data in corresponding time for a 7 consecutive days, and an acceptable level of accuracy was achieved.

As the first group to attempt this, we have successfully revisualized the reality of nursing activities and quantitatively ascertained the characteristics of the nursing activities of each type of nurse, namely the day-shift and night-shift nurses, lead nurses and member nurses, regular team members and helpers.

For comparison of the characteristics among each type of nurse, a certain quantity of data, obtained through a certain period of time and obtained from a certain number of samples, is needed for analysis. In this project, we have attempted to introduce a new data-acquiring method?an ultrasound positioning system and we displayed evidentially the variations in the characteristics of nursing activities carried out by different roles of nurses on the same ward.

To review the feasibility of applying the on-demand nurse-staffing model adopted in Western countries in the context of Japan, it is necessary to develop a close-to-reality model of the present nursing services environment to create a cost and services simulation. However, the provision of proper nursing services to fit the demands of the ever-changing conditions of the patients is a complicated issue, not to mention other substantial support for daily living or mental health care. Drawing conclusions on the characteristics of travel distances or duration of nursing care alone would not be sufficient to provide optimal adjustment for easy access to direct patient nursing.

From now, further efforts are needed to refine our skill and equipment for conducting quantitative surveys in hospital wards, for the purpose of accumulating data on nursing activities for further clarification of the characteristics of nursing services in the field. We are aiming at the development of a nursing service model for simulation and adjustment of nurse staffing for better cost and services performance.

Acknowledgements

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Note

[*1] The content of this research project is approved by the Showa Hospital Ethics Committee.
[*2] ZPS-3D ultrasound positioning system setup by the Furukawa Sangyo Kaisha, Ltd. is used in this project.
[*3] The Table of Codes of Nursing Activities specified by the Showa University Hospital.
[*4] A Java-based development language specialized for CG production, called "Processing", is used.
[*5] The "duration of stay in the patient rooms" is considered almost equivalent to the "direct care duration". In this paper, for analysis purpose the nursing activities are not categorized according to its contents which can be finely defined into direct care, indirect care and others. Therefore, in this paper, the term "duration of stay in patient rooms" is used to represent the direct nursing duration.
[*6] This report is revised from result presented in the precedent technical paper [14].

センシング技術を活用した医療スタッフのマネジメント

抄録

高齢化，疾病構造の変化，受療者の意識変化，医療技術の進歩などに伴い，急性期病棟の看護業務は繁忙で複雑化しており，患者の安全確保が困難な状況にある．このような状況は今後一層顕著となるとされており，限られた医療資源を適正に配分するために，病棟計画や看護配置計画の改善を続けることが求められている．看護業務量を把握して適正化を目指す研究は様々に行われてきた．筆者らはセンシング技術の一つである超音波測位により昭和大学病院呼吸器センターにおいて７日間継続的に全看護スタッフの動線を計測した．142人日，1,464人時間の看護動線が計測された．看護スタッフの移動経路を把握するためにネットワークモデルを作成した．看護動線は病院平面上に動画により可視化された．看護行為のパターンがグラフやネットワークモデルにより表された．得られたデータの集計により，看護スタッフの各場所での滞在時間，室訪問回数，動線距離などが把握され，看護スタッフのシフトや職能の属性による特徴が明らかになった．

キーワード：人間行動，看護動線，看護配置，センシング技術，人工物連環

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