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Tatsuya ISODA
Kyushu Institute of Technology
1-1 Sensuicho, Tobata-ku,
Kitakyushu, 804-8550, Japan
is0tatsu.mail.25@gmail.com

Yasunobu NOHARA
Kyushu University Hospital
3-1-1, Maidashi, Higashi-ku,
Fukuoka, 812-8582, Japan
y-nohara@med.kyushu-u.ac.jp

Sozo INOUE
Kyushu Institute of Technology
1-1 Sensuicho, Tobata-ku,
Kitakyushu, 804-8550, Japan
sozo@mns.kyutech.ac.jp

Mako SHIROUZU
Prefecture Unviersity of Kumamoto
3-1-100, Tsukide, Higashi-ku,
Kumamoto, 862-8502, Japan
shirouzu@pu-kumamoto.ac.jp

Yasuhiko SUGIYAMA
CeFox Co. Ltd
bibi, Chitose-shi,
Hokkaido, 066-8655, Japan
sugiyama@cefox.co.jp

Mari HIRATA
Fukusei-kai hospital
1-2-36, Noke, Sawara-ku,
Fukuoka, 814-0171, Japan

Kyoko MACHIDA
Fukusei-kai hospital
1-2-36, Noke, Sawara-ku,
Fukuoka, 814-0171, Japan

Naoki NAKASHIMA
Kyushu University Hospital
3-1-1, Maidashi, Higashi-ku,
Fukuoka, 812-8582, Japan
nnaoki@med.kyushu-u.ac.jp

Abstract

In recent years, big data are utilized in many industries. In this study, in order to analyze duties of the nurses, we performed experiments to collect the duties activity data of the nurses for a long term. We set 38 nurses as subjects and asked them to carry out duties while attaching a wearable small sensor device, and collected the acceleration data, meeting information between nurses and the nurse duties information. In addition, we collected the location information of the nurses by using infrared information and communication equipment at the same time. From various data collected, we analyzed intensity and positional information of duties activity of the nurse, meeting information and the duties information between nurses and considered the influence that each factor affected to the nurse. As the result, we found that intensity of the activity increases in such nurses as who has many times of meeting with other nurses, visits the patient room many times, or who works on jobs concerning with the assistance of the patients such as rehabilitation assistance duties or the activity assistance duties.

1   Introduction

In late years, using large-scale medical data, development and introduction of new technologies such as the introduction of IT into electronic chart and nurse call system is actively pushed forward. Furthermore, in the medical front, by collecting and analyzing the activity data of doctors, nurses and patients, a trial to make use of these data for making duties more efficient or for offering more appropriate medical services is expected.

In this study, in order to analyze daily duties of the nurses, we performed experiments to collect the duties activity data of the nurse for a long term. We set 38 nurses as subjects and asked them to carry out their daily duties while attaching the name card type sensor in which an acceleration sensor is installed and an iPad touch for inputting the daily duties of the nurse, and collected the acceleration data, meeting information between nurses and the nurse duties information. In addition, we set up multiple infrared information and communication equipment at each block of hospital ward and collected also the positional information of the nurse by using infrared communications with the name card type sensors at the same time. We analyzed intensity and positional information of duties activity of the nurse, meeting information and the duties information between nurses that were collected from experiments of 33 days, and considered the influence that each factor affected to the nurse.

In the analysis, we set the other data such as the intensity of duties of the nurse, number of times of nursing duties, number of meeting times, number of places as explanation variables and, by grouping the factors using a decision tree (recurrence tree) we analyzed when and by what kind of conditions among the grouped factors were overlapped the duties are affected. As the result, we found that intensity of the activity increases in such nurses as who has many times of meeting with

other nurses, visits the patient room many times, or who works on jobs concerning with the assistance of the patients such as rehabilitation assistance duties or the activity assistance duties when compared with the nurses who do not work on such duties.

In the future, we will be able to expect that the result may help for distributing the nursing duties of nurses in such way as leaving the burdensome duty to one nurse in succession or making a duty plan so as not give a burdensome duty to the nurse per day.

Below we will explain the data collection experiments on Chapter 2 and data analysis in Chapter 3, and describe about the related studies in Chapter 4, and finally we will sum up this study in Chapter 5.

2 Data collection experiments

In this chapter we describe about the method of collecting the activity data of nurses. We will show the finally collected data and propose the analysis method of such data.

2.1 Experiments to collect nurse's activity data

In this section we describe about the data collection experiments in the hospital. We carried out an experiment to collect the nurse's activity data in cooperation with a medical corporation Fukusei-kai's " Fukusei-kai hospital ". This time, we collected various data including the acceleration data, location information, and duties information of the nurse from the experiments utilizing whole one floor in orthopedic surgery hospital ward.

We divide one floor of the hospital ward into 83 blocks and installed multiple information and communication equipment using infrared (hereafter, infrared beacon) in each block. Total 223 infrared beacons were installed. This infrared beacon is used for obtaining the location information of nurses. Figure 1 shows an installation example of the infrared beacon. Infrared beacon is installed in red circled three places of Figure 1.

We set 38 nurses as the subjects of test, and asked them to carry a name card type sensor equipped with infrared rays and acceleration sensor. The name card type sensor was attached to each subject by hanging from neck. We collected also the duties information of nurses by inputting the duties information of the subject using iPod touch device. The duties information of the nurse was set up in advance, and the subject selected the duty that he executed from among the duties of nurses set up in advance by using an application " aTimeLogger" on iPod touch device. 115 items of the duties of nurses have been set up, and, among these, similar duties were grouped into 25 groups. Table 1 shows the details of data collection experiments.

This time, we used Hitachi High Technology's Business Microscope as infrared beacon and name card type

Fig. 1: Example of setting up infrared beacon (patient room)

Table 1: Details of data collection experiments

Experimental environment	Orthopedic surgery ward
Period of experiment	2015/02/16　2015/03/20
Number of days of experiment	33 days
Experiment hours per day	24 hours
Subjects	38 nurses
Quantity of infrared beacons (Total)	83　223
Number of duties of nurse (Groups)	115　25

sensor. location information of the subject is collected by the communication between the infrared beacon installed in the hospital ward and the name card type sensor that is attached to the subject. Figure 1 shows how to install the infrared beacon. In Figure 1, the infrared beacons are installed at three places enclosed by red circle.

In the experiments of this time, we carried out the data collection experiments for 33 days, from February 16 to March 20, 2015, 24hours per day. And we collected the acceleration information and the meeting information with other subjects from each name card type sensor and the location information of subjects from each name card type sensor and the infrared beacon. Data information collected from each sensor device is shown in Table 2.

2.2 Result of data collection

We executed data collection experiment for 33 days, 24 hours per day and collected the acceleration data, location information and the nurse duties information. Using these collected data, we were able to extract such information as *activity rhythm*, which is the momentum of movement, position, nurse duty and meeting information with other subjects. From collected data, we extracted such data as activity record and location information of the nurse, meeting information of each nurse,

Table 2: Each sensor device and the collected data

Sensor device	Collected data	Frequency
Infrared beacon, Name card type sensor	location information	1Hz
Name card type sensor	Acceleration	20Hz
	Meeting information	20Hz
iPod touch	Nurse duties information	By each activity

Table 3: Details of edited data of various sensors

Edited data	Data interval	Number of data
activity rhythm	1 minute	1805760
location information	1 minute	462418
Meeting information	1 minute	459139
Nurse duties information	Every duty	12406

Table 4: Orthopedics ward specific duties

Group name	Number of duties
Body cleaning	6
Help with eating	6
Observation	7
Transportation of patient	3
Toilet support	7
Ensure safety	2
Ensure comforts	5
Self-reliance support	3
Measurement	7
Total	46

nurse duties information, etc. The collected acceleration data was converted to value that indicates the intensity of activity called as activity rhythm through an algorithm installed into each name card type sensor. Unit of activity rhythm is Hz. Data of activity rhythm, location information, and the meeting information of each nurse was edited in every 1 minute interval. Table 3 shows the details of each edited data. Table 4 shows the details of orthopedics ward specific duties (9 groups, 46 duties) that were extracted from nurse duties. Table 5 shows the post and head-count of nurses who participated in the experiment. Among the nurses working in the ward, there were one chief nurse, two senior staffs, and 35 nurses having not title. Next, we

Table 5: Post and head-count of nurses

Post	Head-count
Chief nurse	1
Senior staff	2
Nurse	35
Total	38

categorized the rooms in which the infrared beacons were installed by kind. Table 6 shows the relation of kind of room and the infrared beacon.

Using the various edited data, we plotted the positional information and the meeting information of each nurse and showed the number of people with whom the nurse confronted each other per day. These data are shown in Figure 2.

Vertical axis shows the number of people with whom nurse confronted each other per day, and horizontal axis shows time of day. The plots are colored by nurse. From

Table 6: Kind of room and number of infrared beacons installed

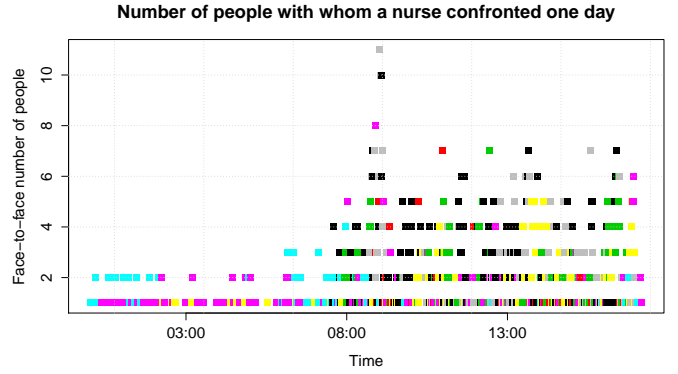| Kind of room	Number of beacons	Number of rooms in which infrared beacons were installed
Patient room	17	50
Nurse station	8	2
Toilet	4	4
Bath room	1	1
Dining room	1	1
Others	19	18

Fig. 2: Number of people with whom a nurse confronted one day.

Figure 2, it is seen that there is a difference in number of confronted people between night-work nurses and the day-work nurses. Because number of night-work nurses is fewer than day-work nurses, also the number of confronting people becomes few. In addition, it was found that there are many nurses who have the most number of confronting people around 9:00 in the morning. It is thought that meeting of nurses is held around 9:00 in the morning. Such result was common characteristic seen in all days of experiment.

Then, we expressed the daily location information of nurses with graph. Figure 3 shows the positional information of each nurse on one day.
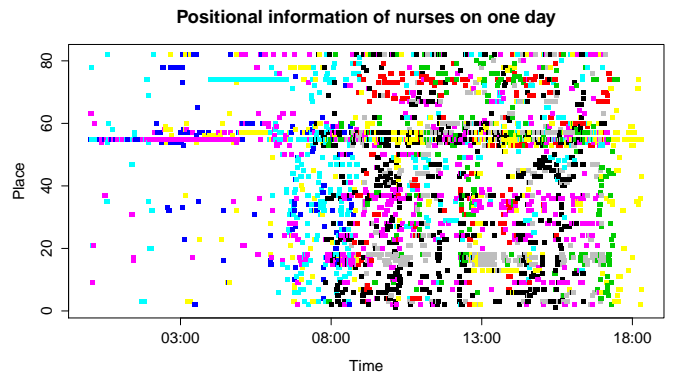

Fig. 3: location information of nurses on one day.

Vertical axis shows the position of nurses and horizontal axis shows time of day, and plots are colored by nurse. Also from Figure 3, it is seen that there is a difference of number and position of nurses between day-work nurses and nigh-work nurses. Infrared beacon No.54, 55, 56, 57, 58, 60, 62, and 83were installed in the nurse station. It can be seen that, in almost all time zones of day, nurses mostly stay in the nurse station. Especially in night-work, it may be said that a possibility that nurses stay in the nurse station is high. Also such a result was characteristic feature that was seen commonly in all experiment days.

3 Analysis

We analyzed the influence that such factors as positional information, number of meeting times with other nurses, basic duties of nurses, and orthopedic surgery ward specific duties give to the activity rhythm of the nurse. We investigated the affecting factors and, based on this result, we considered the cause of burden to nurses and improvement of efficiency of duties.

Fig. 4: Factors of activity, meeting, and place that affect to activity rhythm.

3.1 Method of analysis

We assumed a mean value of activity rhythm per one minute of the day of the nurse as a purpose variable, and grouped these purpose variables by explanation variables such as the number of times of every nurse duty, the number of meeting times, and the number of places. For grouping, a decision tree (recurrence tree) was used. We analyzed by what kind of conditions among the grouped factors were overlapped the duties are affected. Depth of decision tree was set so as to repeat branching until a change of more than 0.5% became never seen. We set up two methods and executed analysis while changing the explanation variables in each method.

In method 1, we took average value of activity rhythm of the nurse as an objective variable, and number of duties, number of meeting times, and number of places as the explanation variables and execute grouping. In method 2, we took average of activity rhythm as an objective variable, and extracted only the duties relating to the orthopedic surgery ward specific duties from among the nurse duties and the set the number of times of these duties as an explanation variable. Data of meeting and place information were excluded from explanation variables.

3.2 Results

The result of analysis by decision tree in Method 1 is shown in Figure 4. In Figure 4, we made branching the factors that affect to activity rhythm from the viewpoint of number of times of duties per day, number of meeting times with other nurses, and number of places visited. There are three lines of description in each node. In the first line, either of number of times of duties, number of meeting times with other nurses, or number of places is shown. In the second line, average value of activity rhythm is shown. And n in the third line shows the sum of work days when data of number of times of duties, number of meeting times and number of places were combined.

The average value of overall activity rhythm is 211.2 Hz, and we take this value as a reference. From Figure 4, we obtained the result that number of meeting times with nurse who has a title of " Nurse " has the biggest influence to activity rhythm. When looking the tree from the top, it is known that, at first, there exist many part where branching occurred by number of meeting times and number of places. The result showed that the more the number of meeting times of nurse who visited to patient room many times, the higher the value of activity rhythm becomes in comparison with the average value. In addition, the activity rhythm in case the nurse visited patient room many times and executed " Improvement of patient room environment " more than 3.5 times was the highest. After that, as the node approaches to the end periphery, influence by number of duties became to be seen.

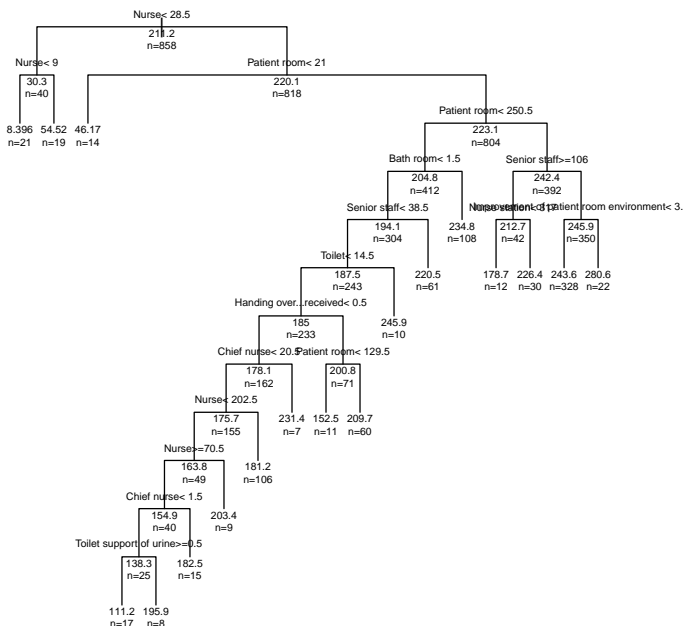In Table 7, the factors of explanation variables that

became significant with significance level of 5% by recurrence analysis against the same data are shown.

Table 7: Factors of duties, meeting and place that affects to activity rhythm

	Estimate	Std. Error	Pr(>|t|)
Others	-12.01	2.91	0.00
Conference	8.65	3.97	0.03
Injury part exchange	16.27	8.16	0.05
Auscultation	17.88	8.36	0.03
Eating	10.70	4.28	0.01
Vital reactivity	-21.80	9.80	0.03
Postural change	7.92	3.45	0.02
Improvement of patient room environment	8.14	2.00	0.00
Restraining	-74.68	28.41	0.01
Compensation report including overtime work	83.50	29.85	0.01
Employee interview	-90.04	43.32	0.04
Patient room work	0.19	0.02	0.00

From Table 7, we can find out that activity rhythm correlates positively with such activitys as " Conference"," Injury part exchange"," Auscultation"," Eating " , " Postural change " , " Improvement of patient room environment "," Compensation report including overtime work", and" Patient room work", and correlates negatively with such activitys as" Others"," Vital reactivity"," Restraining", and" Employee interview". Result of analysis by decision tree in Method 2 is shown in Figure 5.
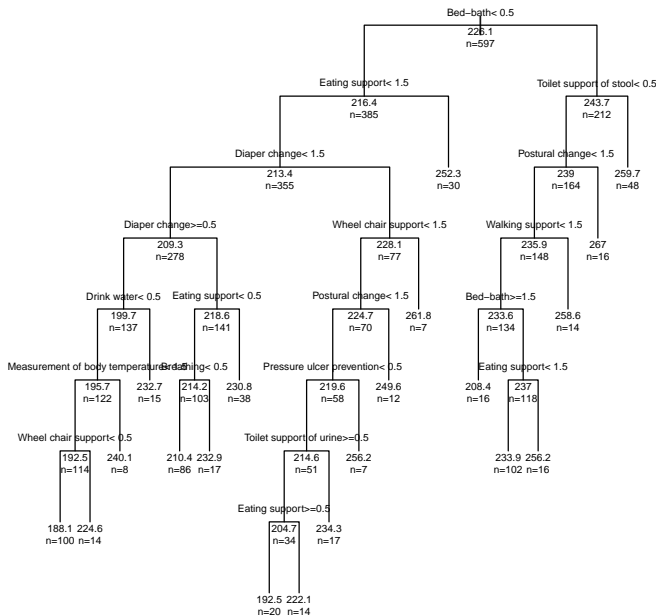

Fig. 5: Orthopedic surgery ward specific duties affecting to activity rhythm

The average value of overall activity rhythm is 226.1

Hz, and we take this value as a reference. From Figure 5, we also obtained the result that " Bed-bath " is a duty of the most affective among the orthopedic surgery ward specific duties. And it was also found that when executing such duties as " Toilet support of stool "," Postural change "," Walking support ", " Eating support "," Wheel chair support " and" Pressure ulcer prevention " several times a day, the activity rhythm becomes higher than average value of all duties. Table 8 shows the factors of explanation variables that became significant at significance level of 5% by recurrence analysis against the same data as Figure5. From Table 8, it is known that the activity rhythm has positively correlates with such duties as" Toilet support of stool "," Bed-bath "," Eating support "," Water drinking support "," Postural change " and" Urinary support ".

Table 8: Orthopedic surgery ward specific duties affecting to activity rhythm

	Estimate	Std. Error	Pr(>|t|)
Toilet support of stool	8.22	3.56	0.02
Bed-bath	10.03	3.11	0.00
Eating support	6.70	2.92	0.02
Water drinking support	9.45	4.25	0.03
Postural change	9.83	3.62	0.01
Urinary support	29.76	15.08	0.05

3.3 Discussions

From the result of Figure 4, it was known that the more the number of meeting times of nurse who visited to patient room many times, the higher the value of activity rhythm becomes in comparison with the average value. It may be said that amount of activity per day of such nurse who has many meeting times and visits patient room many times a day by making a round trip between a nurse station and a patient room many times a day becomes great. In addition, most nurses are executing their duties while being associated with many other nurses every day, and their amount of activity is clearly greater than such nurses who is associated with only few other nurses.

As a background of such tendency, it can be considered that the nurse who works midnight meets with a few other nurses and that they do not move many places in comparison with day-work nurses.

From the result that we confirmed this using all the data, it was known that the number of people with whom day-work nurse confronted each other was 5.41 in average, that of nigh-work nurse was 3.77 in average, and that both were significant in t-test at significance level of 5% and in Wilcoxon rank sum test. From this fact, it was found that there is a difference in number of people with whom day-work nurse confronted each other and the number of responses of infrared beacon between day-work and night-work.

In addition, from the result of Figure 5, we found that when executing such duties as " Toilet support

of stool ", " Postural change ", " Walking support ", " Eating support"," Wheel chair support" and" Pressure ulcer prevention" several times a day, the activity rhythm becomes higher than average value of all duties. It may be said that amount of activity becomes larger in duties to assist the activity of the patient who is difficult to work by himself among the orthopedic surgery ward specific duties. According to the opinion from the expert of the nursing, these real assistances are high duties of the fatigue degree to use all whole body, and are the things causing the low back pain that is easy to occur in nurse duties.

This time, it was known that, among the nurse duties, performing duties that relate to assistance of patients lead to the burden of the nurses. It was also known that, when there are many duties to need to visit to patient room many times, amount of activity of the nurse may be increased. This will become useful information in considering the load distribution of the nurse duties.

We succeeded in find out the duties that give a big burden to nurses. So, it can be expected in the future that we can make use these results for load distribution of nurse duties in such way as by leaving the big duties of the burden to a single nurse in succession, or by making the duties plan that doesn't give a big burden to nurses a day.

4   Related work

In this chapter we introduce the main studies using the big data of large scale medical treatment information.

Recently, in medical front, many experiments to collect the activity data of doctors, nurses, and patients and many studies to make use of these collected big data for improving efficiency of duties or for offering the appropriate medical services are conducted [1-5].

As an example of long term activity data collection experiment in medical front, there is an experiment conducted for one year and 7 months at circulatory disease center of Saisei-kai Kumamoto Hospital [6, 7].

In this experiment, they collected many data from both of nurses and patients. They recorded sensor data from patients indirectly using a monitoring electrocardiogram, wrist sensor as 3D acceleration sensor, a bed sensor to measure heart rate, breathing and acceleration, and an electronic clinical path. From the nurses they collected the acceleration data and the in-and-out information into/from patient room. In this experiment, there are many similar parts to our data collection experiment that we have conducted this time. But, in our experiment, we focused mainly on nurse activity and collected the positional information and activity label as well as the acceleration data at the same time. In addition, such study as behavior recognition of nurses or development of labeling automation system using the data containing the activity label information such as

nurse's behavior, meeting information, audio and video data collected through the sensor network comprised of wearing type acceleration sensors or environmental setting type sensors are conducted [3]. In these studies, it is intended to reduce vagueness of the duties labeling by hands and the burden of duties measurement by automating the measurement of nurse duties.

Daby Sow, et al. collected the physiology data of newborn babies having such problems as prematurity or abnormal chromosome, and found out many patterns by analyzing the flow of these data. They established a system that performs early prospective analysis of problems that newborn infants have in the intensive care unit [8]. Like this study, the physiology data of the patients are saved as large scale medical data and are connected for the early detection of an effective cure by analyzing these data. Although the data collected in this study was different from our nurse activity data, there is a similarity in part to find out the pattern to lead to improvement of hospital duties from many medical treatment data.

Furthermore, a study relating to a method to make use of the medical treatment data obtained from multiple hospitals in other hospital is conducted [9]. This study utilizes the medical data acquired from multiple hospitals using metastasis learning at a hospital to make the model about many diseases and duties from many data.

Our experiment of this time was executed at one hospital, but we are planning to execute experiment at other hospital at present to compare the collected data obtained from multiple hospitals in the future.

5   Summary

In this article, we carried out experiments to collect the activity data of nurse duties for a long term in order to analyze every day duties of nurses. We extracted the activity rhythm and location information of nurses, meeting information between nurses and duties information and analyzed the influence to activity rhythm of nurses that is given by the positional information, number of meeting times, fundamental duties of nurses, and orthopedics ward specific duties. First, we set the average value of activity rhythm as an objective variable, and number of duties, number of meeting times, and number of places as the explanation variables and execute grouping by decision tree. As the result, we found that activity rhythm becomes high in such nurses as who has many times of meeting with other nurses, or who visits the patient room many times. It was also found that a duty of " Improvement of patient room environment " affects strongly to the activity rhythm. Then, we took out only the duties that relate to the orthopedic surgery ward specific duties among the nurse duties, and set the number of times of these duties as explanation variables. As the result, we found that when

executing such duties as " Toilet support of stool ", " Postural change "," Walking support "," Eating support "," Wheel chair support " and " Pressure ulcer prevention " several times a day, the activity rhythm becomes higher than average value of all duties. From analysis result, we found that fatigue degree increases in such nurses as who has many times of meeting with other nurses, visits the patient room many times, or who works on jobs in patient room because amount of activity per day is high. And it is thought that amount of activity becomes large in duties to assist the activity of the patient who is difficult to work by himself.

We were able to consider the factors that affect to the amount of activity of the nurse by this experiment to collect the nurse duties activity data and the nurse duties analysis. However, since we will be able to extract more information from the data that we collected by experiment to collect the duties activity data, we will push forward analysis further in the future. For example, we will find out the characteristic features by nurse, by place, or by meeting, by visualizing the activity of the nurse during working time from the every time, every day positional information of the nurse. In addition, we will execute analysis about not only the activity rhythm but also the factors that affect the nurse duties or the positional information. Furthermore, we will investigate the characteristic features to be connected for duties or efficiency improvement by visualizing the communication between in-hospital nurses from a post and the years of experience of the nurse, the meeting information between nurses.

6 Acknowledgements

References

[1] Katharina Morik, Peter Brockhausen, Thorsten Joachims, " Combining statistical learning with a knowledge-based approach: A case study in intensive care monitoring ", Technical Report, SFB 475: Komplexitatsreduktion in Multivariaten Datenstrukturen, Universitat Dortmund, No. 1999, 24.

[2] J. Wiens, J. Guttag, E. Horvitz, " Patient Risk Stratification for Hospital-ssociated C. diff as a Time-Series Classification Task ", NIPS 2012, Lake Tahole, CA, December 2012.

[3] F. Naya, R. Ohmura, F. Takayanagi, H. Noma, and K, Kogure, " Workers' Routine Activity Recognition using Body Movements and Location Information ", 2006 10th IEEE International Symposium on Wearable Computers, pp. 105-108, 2006.

[4] M. Tentori and J. Favela, " Monitoring activity patterns in hospitals through activity-aware computing ", in 2008 Second International Conference on Pervasive Computing Technologies for Healthcare. IEEE, Jan, 2008, pp. 173-176.

[5] V. Osmani, S. Balasubramaniam, and D. Botvich, " Human activity recognition in pervasive healthcare: Supporting efficient remote collaboration ", Journal of Network and Computer Applications, vol. 31, no. 4, pp. 628-655, Nov. 2008.

[6] Yasunobu Nohara, Sozo Inoue, Naoki Nakashima, Naonori Ueda, Masaru Kitsuregawa, " A Large-scale Sensor Dataset in a Hospital ", International Workshop on Pattern Recognition for Healthcare Analytics, 4pages, November 11, 2012, Tsukuba.

[7] Sozo Inoue, Kosuke Hayashida, Masato Nakamura, Yasunobu Nohara, Naoki Nakashima, "Capturing Nursing Interactions from Mobile Sensor Data and In-room Sensors", International Conference on Human-Computer Interaction (HCI International), Springer LNCS, Vol. 8014, pp. 280-289, 2013-07-21, Las Vegas, USA.

[8] Daby Sow, Alain Biem, Marion Blount, Maria Ebling, Olivier Verscheure, " Body sensor data processing using stream computing ", International Conference on Multimedia Information Retrieval (MIR), March 2010.

[9] J. Wiens, J. Guttag, and E. Horvitz, " A study in transfer learning: leveraging data from multiple hospitals to enhance hospital-specific predictions ", Journal of the American Medical Informatics Association: 0:18, January 2014. Informatio Processing Society of Japan,(2009)