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Sensor-Based Detection of Invisible Changes in Activities towards Visualizing Disuse Syndrome

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Abstract

Disuse syndrome is a condition in which mental and physical functions are declining, which is caused by continuation of the resting state for a long time. There is no clear diagnostic criteria and severity classification of disuse syndrome, and most of the doctors are diagnosed with ADL as a reference after surgery. On the other hand, ADL is often not measured in nursing homes, and it is not noticed that symptoms are getting worse in many cases. In this paper, we aim to detect disuse syndrome by observing long-term changes of activities that are carried out in daily life using sensors. Particularly, disuse syndrome is a disease consisting of multiple symptoms, so the system integrating multiple sensors is required. This paper conducts the subject experiment in nursing home using RFID to detect disuse syndrome and its experimental result are evaluated.

1.Introduction

Disuse syndrome is a general term for diseases and symptoms that appear in secondary physical and mental deterioration that occurs when medical care is continued without using the body's function for a long time. The primary cause of disuse syndrome is the bedridden life in bed. Even a young healthy person who is bedridden will lose 20% muscle strength if it lasts for one week, and muscle strength drops by 50% in 3 weeks. It takes more time to return the muscular strength once it has fallen, and disuse syndrome gets worse in a vicious circle. In addition, weakening of physical function appears not only in the muscle but also in the whole body such as bones and joints, skin, heart, respiratory organs, gastrointestinal tract, urinary tract and so on. There is no clear diagnostic criteria or severity classification in the diagnosis of disuse syndrome, and it is judged by activities of daily living (ADL): how active the patient can move by using two indicators. FIM (Functional Independence Measure) and BI（Barthel index）. The diagnosis of disuse syndrome is made mainly when one of the two indices satisfies the condition after a surgical operation in a hospital or a treatment such as pneumonia. Rehabilitation for recovery after surgery makes it possible to improve physical and mental functions up to preoperative ADL.

On the other hand, the problem is the diagnosis of disuse syndrome in a nursing home. Patients who move into nursing homes are already so weak that their recovery is difficult, and short-term rehabilitation alone has only the effect of maintaining ADL. Also, the number of people performing rehabilitation is not also sufficient, and it is difficult to recover the disuse syndrome. In order to improve disuse syndrome, self-help activities are required, such as periodic posture transformation and turning over during sleep to prevent muscle and joint contracture.

Sensors that are actually used in nursing homes are mat sensors that lay under the bed. This mainly identifies only whether the object has left the floor, it can not identify motion outside the bed. Sensors to be placed on the floor are also detected by nursing staff and other things, and there is hygienic problem. In home care, monitoring using a camera may be performed, but there is a problem with respect to privacy. There is also a wearable sensor for the care giver himself, but there are many problems such as putting off at bedtime and needing a battery.

We propose disuse syndrome detection system using RFID sensors in order to solve these problem. The UHF band's RFID is internationally standardized, and it is possible to read thousands of tags per second. There are various types of tags, including linen type RFID that can be attached in clothes and washable. Since RFID tag is very inexpensive and non-power source, once installing the environment, it is possible to monitor the position and posture of physicians, nurses, medical instruments as well as the care giver. Previous studies have been able to detect people's position and posture in real time using RFID tags and online machine learning (Numao 2016). In this method, classification accuracy was improved by re-learning to the classification model by changing subjects and experiment dates. However, in the case of detection of disuse syndrome, it is necessary not only to classify the posture but also to observe long-term changes.

In this paper, we proposed a change detection of posture using RFID and a long term change observation. Also, in order to detect disuse syndrome, it is necessary to simultaneously detect other symptoms, and to use a system integrating multiple sensors.

The remaining of this paper is organized as follows: Firstly, we describe diagnostic indicators currently used for disuse syndrome and indices of each case and describe the case detection using sensors. The next section shows the proposed method using RFID. Then the subject experiment is conducted and its result is shown. Finally, the conclusion of this paper is given in the final section.

2.Disuse Syndrome

Activities of Daily Living(ADL)

ADL is everyday activity necessary for living such as diet, movement, bathing, getting up. In order to evaluate elderly nursing care independence degree that the elderly can live on themselves, using the ADL score at nursing care facilities and medical facilities. FIM and BI are often used as evaluation index of ADL. If the value of FIM or BI is below a certain level after surgery, it is diagnosed as disuse syndrome, and patient will be received rehabilitation until the value recovers. There are several detailed items in the two indices, and the doctor scores one for each item.

Barthel Index(BI)

In BI, nursing care degree is evaluated based on 10 evaluation items(Table 1). The highest score is 100 points, and if the BI score at the time of diagnosis is less than 85 points, it is diagnosed as disuse syndrome. It is evaluated in BI by actions that can be done only at the time of diagnosis, so FIM is more often used for diagnosis of waste syndrome than BI.

Table 1: BI

Task	With help	Independence
Feeding	5	10
Moving from wheelchair to bed	5-10	15
Personal toilet	0	5
Getting on/off	5	10
Bathing	0	5
Walking	10	15
Ascend, Descend stairs	5	10
Dressing	5	10
Controlling bowels	5	10
Controlling bladders	5	10
		Total BI Score 100/10

Functional independence Measure(FIM)

In FIM, based on the 18 evaluation items, the degree of nursing care care is classified and evaluated in seven stages from completely independent to total aid (Table 2). The highest score is 126 points, and if the BI score at the time of diagnosis is less than 115 points, it is diagnosed as disuse syndrome. Since FIM puts emphasis on behavior in everyday life, FIM is often used to measure degree of nursing care. The relationship between FIM and disuse syndrome has been studied, and it is known that severity of pneumonia correlates with FIM as one of the symptoms (Chigira 2015) (Gotou 2014).

Table 2: FIM

Motor	Self-Care	Eating
		Grooming
		Bathing
		Dressing Upper Body
		Dressing Lower Body
		Toileting
		Subtotal Score 42/6
	Sphincter Control	Bladder
		Bowel
		Subtotal Score 14/2
	Transfers	Bed, Chair, Wheelchair
		Toilet
		Tub, Shower
		Subtotal Score 21/3
	Mobility	Walk, Wheelchair
		Stairs
		Subtotal Score 14/2
	Motor Subtotal Score 91/13	
Cognitive	Communication	Comprehension
		Expression
		Subtotal Score 14/2
	Social Cognition	Social Interaction
		Problem Solving
		Memory
		Subtotal Score 21/3
	Cognitive Subtotal Score 35/5	
Total FIM Score 126/18		

Bedsore

Bedsore is a skin ulcer caused by poor blood flow. This is because you can not turn over and move with your own power, which results in long-term bedridden. Depending on the posture, such as supine, prone, and sitting position, the part where bedsores are likely to occur is different. The common thing is that bedsores are more likely to occur in parts that are pressured for a long time in the same posture. It is said that at least every 2 hours' posture change is effective for prevention. For diagnosis, it is the major to measure the depth and size of the wound by doctor's diagnosis, and classify it into Stage 1 to 4 according to the severity of damage. Bedsore can be easily treated by early detection, but delayed discovery makes it difficult to treat because of infections concurrently.

3.Related work

Sensor-based detection system

There are several researches on ADL using sensors. RFID Tracking for ADL Recognition system can detect the location of people among 6 different rooms (Frederic 2016). Object-based ADL(OADL) recognition system has also been proposed (Tanabe 2012). OADL system recognizes the ADL by monitoring "what thing is done how". What things is associated with RFID, and How done is associated with the acceleration sensor. This study implements a medication support system using OADL. There is a research to identify the position and posture of a person with attached RFID in real time by using Online machine learning (Numao 2016). The effectiveness of online machine learning is shown by evaluating by selecting test data and teacher data on another day.

For detection of bedsore, there are many cases where a body pressure measurement sensor is installed to a mattress (Misaki 2014). The air pressure control targets of individual air cells of the mattress are set by using the body pressure information, and the air pressure is adjusted so that the mattress surface matches the shape of the bedded person.

4.Method

There is no diagnostic index of disuse syndrome in nursing home, and quantitative diagnosis can not be performed unlike recovery rehabilitation after surgery. Also, ADL is often not measured, so residents in care facilities can not realize that they are becoming immovable. This paper proposes disuse syndrome detection system by using sensors suitable for symptoms.

This paper aims at discovering disuse syndrome such as bedsore and joint contracture by observing posture changes point with RFID sensor. Figure 1 depicts an illustration of the proposed method. In the proposed method, the change point of the RFID tag (right of Figure 1) is extracted by the change point extraction program from the RSSI waveform (left in Figure 1) when RFID tag is pasted on human clothes. Although it is said that it is in the same position as attitude change point decreases, it also leads to early detection of bedsore and joint contracture. This system is implemented the following steps.

1. Attach RFID tags to clothes of residents in nursing home and collect logs
2. Downsampling and normalizing collected logs
3. Extract tag change point with changefinder algorithm
4. Count multiple tags change point as posture changes (Figure 1)
5. Visualize posture change point every week, month, year

When the patient is a disuse syndrome, the number of posture changes decreases gradually. Therefore, in order to detect disuse syndrome, it is necessary to observe the number of posture change points over a long period of time. Also, if posture changes occur, the RSSI of multiple tags changes. Consequently, multiple tags change points can be paraphrased as posture change points.

RFID

The amount of calculation and the number of dimensions depend on the position where the RFID tag is put on clothes and how to put the antenna. The dimension of RFID log at once is as follows from the number of antennas and the number of tags.

$$D = Antenna \times Tag$$

D : Dimension of feature vector

It is difficult to decide where to put the RFID tag, and it is necessary to change it depending on the experiment object and environment. We perform principal component analysis on RFID tags attached to clothes, observe the factor loading for each tag, and extract variables expressing bedridden posture.

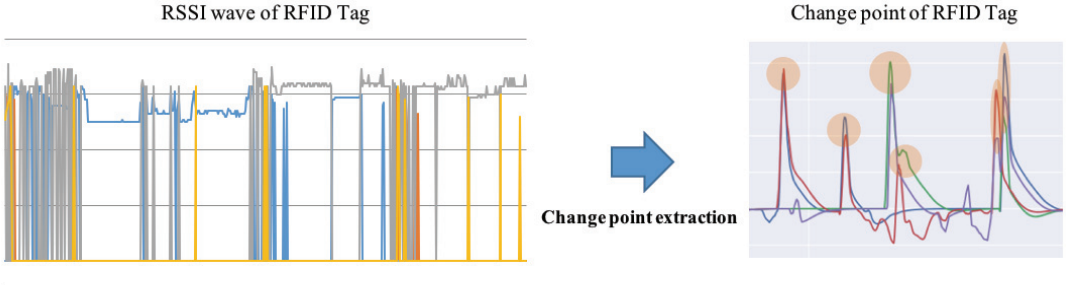

Figure 1: Proposed change point extraction method

ChangeFinder

ChangeFinder is an algorithm that can detect change points of time series data in real time (Yamamoto 2005). The conventional change point extraction algorithm was a method of inputting time series data and detecting a point where a large change occurred between the predicted value and the observed value. This algorithm has a large amount of calculation and can not cope with unsteady data. ChangeFinder adopts Online learning algorithm with forgetting type learning algorithm, it can reduce the influence of past data and can cope with unsteady data. This algorithm learns the time series model according to the following procedure.

1. Learn the probability density function of time series data by SDAR algorithm as the first stage learning.
2. Smooth outlier score of probability density function learned with respect to data in window with width T.
3. Slide the window and obtain a new moving average score.
4. Learn the probability density function again using the obtained new time series data using the SDAR algorithm as the second stage learning.

5.Experiment in nursing home

Setting

To investigate the effectiveness of the proposed disuse syndrome detection using RFID method, we conduct the human subject experiment. A female subject participate in this experiment. The subject degree of care is 1, and the subject ADL is not routinely measured. Two RFID antennas were installed beside the subject's bed (Figure 1), and 4 tags were attached to right shoulder, left shoulder, front and back on subject's pajama (Figure 2). In order to obtain correct answer data on posture change point in bed, a mat sensor was installed under the bed separately from RFID. The experimental conducted for 5 days, and using time from get in bed to get up (from 19 to 4 o'clock).

RFID and mat sensor

UHF RFID gen2 compliant reader was used for experiment. RFID antenna can obtain the received signal strength indication (RSSI) when each tag is read. The RSSI varies based on the distance and direction between the tag and the antenna.

The sampling terms is 100m sec for RFID and 10ms for Mat sensor. The date is logged. Since these data differ in missing values and units, normalization was performed after down-sampling with the RFID maximum read RSSI and the variance value of the mat sensor every minute. As for the missing value, processing to take the average before and after was performed.

Principal Component Analysis

Principal component analysis(PCA) was performed on 4 tags attached to clothes in order to extract variables expressing posture during sleep. Table 3 shows factor loading. The first principal component shows that the tags of Left and Back are high numbers, which indicates that the frequency of prone position is low. The second principal component shows that the tags of Right and Back are high numbers, which indicates that the frequency of left-side position is low.

Table 3: Factor loading of each RFID Tag

	PC1	PC2	PC3	PC4
Right	-0.01	0.84	-0.15	0.52
Left	0.72	-0.34	0.13	0.60
Front	-0.31	-0.37	-0.80	0.34
Back	0.62	0.22	-0.55	-0.51

Change Point Detection

Figure 4 shows the change points of RFID and mat sensor. The blue, green, red, and purple lines are scores for extracting change points of tags attached to the right shoulder, left shoulder, front, and back of RFID, while the skin color is the score of the mat sensor. We set the forgetting function to 0.05, the degree to 1, and the smooth window to 5 for the arguments of Changefinder. Experimental results were plotted for sleeping time for 4 pieces. As you can see from the figure, the mountains of most change point overlap with RFID and mat sensor.

Figure 2 Installed 2 RFID Antennas

Figure 3: Attached 4 RFID Tags

The number of peaks at the changing point was visually counted (Figure 5). We want not to measure the number of points which changed simply but to observe the point that the attitude continues for a certain period of time in the experiment, so we count as one that the pluralities are changing in a short period. The blue line is the number of change points of the RFID, the orange line is the number of change points of the mat sensor, and the gray line is the point where the RFID and the mat sensor change at the same time. Among the changing points, only the RFID changes in many cases, and this is considered to be a change of the reading of the RSSI tag by multiplying or removing the comforter. Also, the only point where the mat sensor is changing is considered to be reasons such as coughing and turning over with comforter multiplied.

6.Sensor integration for syndrome detection

There are multiple symptoms in the disuse syndrome, and it is difficult to detect with only one type of sensor. Therefore, it is necessary to create a system integrating a multiple of sensors, but as the number of sensors increases, the number of data to be acquired increases and it becomes difficult to operate in a nursing home. In order to solve this, it is necessary not to use all the life logs, but to count the number of turns over, coughs, swallowing according to the symptoms, and to use it in dimension reduction. Considering the actual operation at the facility, it is troublesome to change the value used for the feature quantity each time a new sensor is installed, so it may be necessary to determine in advance the model of the sensor to be used for each symptom. Then, data can be obtained according to the model created in advance, care and watching according to the patient can be done, and a practical watching system can be constructed.

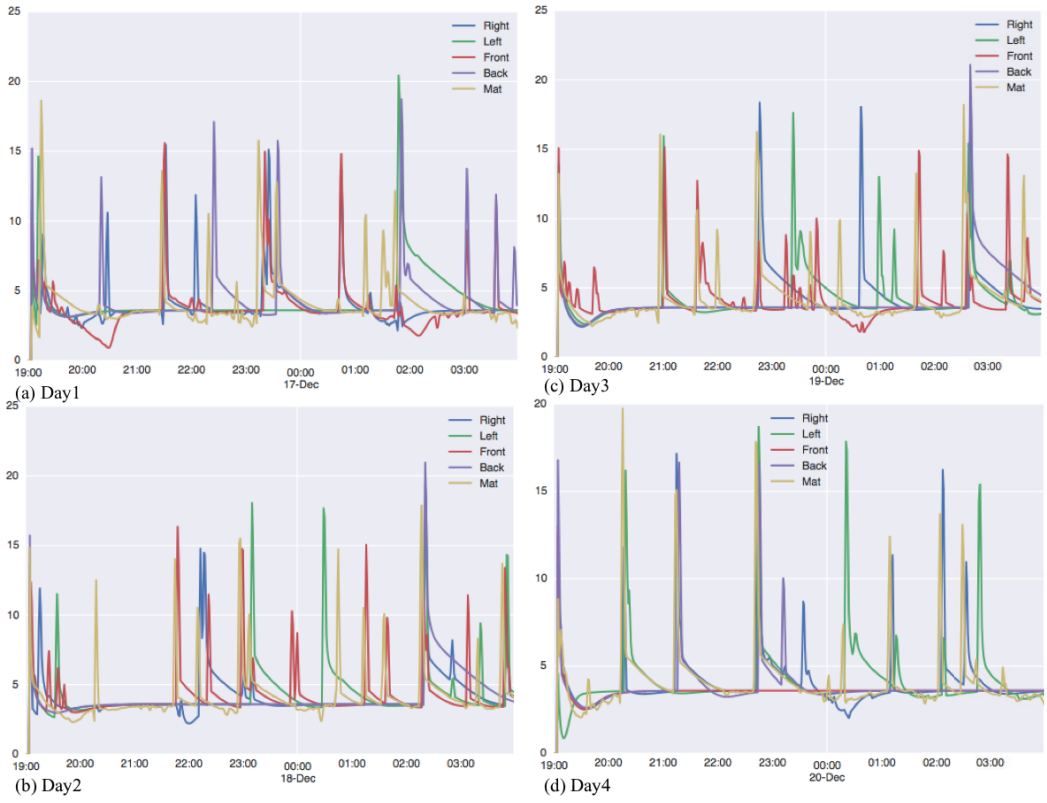

Figure 4: Change point extraction using RFID and mat sensor

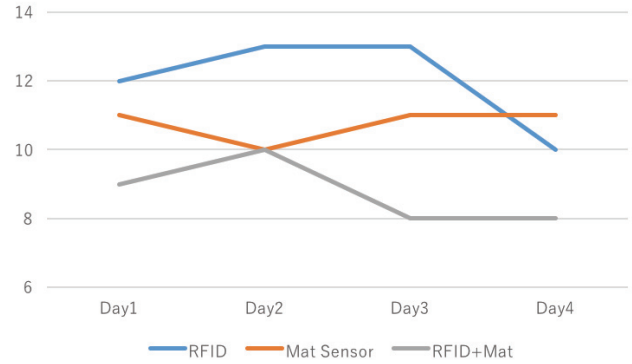

Figure 5: Count of change points during sleep

7. Conclusion

In this paper, to detect disuse syndrome, we attached RFID tags to clothes of resident of nursing home, extracted of point of change in sleeping posture, and compared with change point of mat sensor. In the change point extraction using RFID, although the number of change points is larger than that of the mat sensor, it can be observed that it is changing at about the same time point. We experimented the antenna from one direction to the target in this experiment, but it is necessary to extract the change point by placing the antenna from the bottom or side of the bed.

There are multiple symptoms in the disuse syndrome, and it is difficult to detect with only one type of sensor. Therefore, it is necessary to create a system integrating a plurality of sensors. We proposed an indicator to replace FIM and BI using a single sensor, but we will model more concrete case indicators, and will conduct more verification tests repeatedly in the future.

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