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Design of Case-based Intelligent Wheelchair Monitoring System

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Abstract

In this paper, it is aim to implement a wheelchair monitoring system that provides users with customized medical services easily in everyday life, together with mobility guarantee, which is the most basic requirement of the elderly and disabled persons with physical disabilities. The case-based intelligent wheelchair monitoring system proposed in this study is based on a case-based k-NN algorithm, which implements a system for constructing and inferring examples of various biometric and environmental information of wheelchair users as a knowledge database and a monitoring interface for wheelchair users. In order to confirm the usefulness of the case-based k-NN algorithm, the SVM algorithm showed an average accuracy of 84.2% and the average accuracy of the proposed case-based k-NN algorithm was 86.2% And showed higher performance in terms of accuracy. The system implemented in this paper has the advantage of measuring biometric information and data communication regardless of time and place and it can provide customized service of wheelchair user through user friendly interface.

Keywords: Case-based Reasoning, Wheelchair System, Biometrics Sensor, Monitoring System, SVM Algorithm, k-NN Algorithm

1. Introduction

In recent years, patients with spinal cord injury and brain infarction are increasing due to the rapidly advanced society and the progress of aging. It is anticipated that the population with potential disabilities may be at risk of physical disability and will continue to increase.

In general, retarded and brain-injured patients suffer from physical disabilities caused by paralysis, cutting, and deformation of the joints due to neurological problems of the brain. The elderly can easily be exposed to disability because of their poor physical function and having difficulty in coping with dangerous situations. The loss of independent physical ability also represents as the biggest obstacle to participation in the living environment that they experience[1]. In other words, rehabilitation and assistive devices are always required for the elderly and handicapped who are experiencing physical disabilities to participate in their valuable work. Therefore, rehabilitation and ancillary equipment are always required, and wheelchair is an essential auxiliary device for rehabilitation as well as independent movement.

In addition, since 90% of elderly and disabled people aged over 65 years prefers home-based long-term treatment, the importance of mobile devices like wheelchairs is increasing. It is expected continued growth in the future. Accordingly, the number of people using wheelchairs is increasing every year. The patient relies for at least one hour to resolve defecation and urination and to walk on the wheelchair. Users spend more than 5 hours in wheelchairs during the day and 77.3% of them are in wheelchairs for most of the day and time. In many cases wheelchairs allow participation in diverse lives in society, leisure, and the community but the important thing is that they can affect the quality and quantity of participation in these activities[2,3]. It means that the wheelchair should be designed to improve the quality of life of the individual with the functional benefits of the user.

The increase in the use of wheelchairs and the demand of users has greatly increased the demand for

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medical technology and services for wheelchair users. In addition, there is a growing demand for quality of medical services for personalized diagnoses as well as increased interest in health.

Studies on wheelchair-based systems have been actively carried out regarding manipulating electric wheelchairs[4], implementing obstacle avoidance and navigation functions using sensors in intelligent electric wheelchairs[5] and wheelchair driving through user intention using EEG[6,7].

However, most of the studies are wheelchair-based systems focuses on mobility rather than personalized medical service objectives, mostly in the context of user intent perception or autonomous driving of electric wheelchairs. The use of the wheelchair as a moving means may reduce the movement of the user, thereby it reduces the exercise function such as the reduction of the muscle strength. It may not meet the demands for reduced satisfaction and rehabilitation therapy. Then, opportunities which can improve the quality of life may be lost.

Therefore, it is necessary to research and develop a wheelchair-based monitoring system that provides users with customized medical service easily in everyday life, together with mobility which is the basic requirement of the elderly and disabled persons having physical disabilities. In addition, it is required to implement a system with an intelligent decision algorithm that not only monitors but also takes into consideration user characteristics.

This study measures environmental information such as blood pressure, heart rate, body temperature, basic biometric information and temperature in consideration of characteristics and mobility of elderly and disabled people. The measured data suggests the most similar past cases through the case database using the k-NN algorithm. If a new case arises, a case-based intelligent wheelchair monitoring system that monitors the risk situation based on the results stored and analyzed in the case database will be implemented.

The composition of this paper is as follows. In Section 2, the related research trends will be reviewed. In Chapter 3, the proposed system configuration and design will be examined. In Chapter 4, the system implementation results will be described. In Chapter 5, the performance evaluation of the implemented system will be verified. In Chapter 6, research directions will be suggested.

2. Related Research

2.1. Case-based Reasoning

Case-based reasoning can be effectively applied to both classification and prediction problems as a way of solving a given new problem based on experience that has been used to solve a problem in the past. Case-based reasoning is based on two basic ideas. One similar problem has similar solutions and the other one can happen frequently. So if you realize a problem similar to the current problem in the past and you know how it was resolved, you can infer the solution to the current problem based on your past experience.

The problem-solving method of case-based reasoning is similar to that of human problem solving method, so it is easy to understand the result and advantageous that learning is carried out without additional work by simply storing new case. Case-based reasoning resolves new problems through case search, case reuse, case modification, and case maintenance as shown in Fig. 1[8].

In the case of retrieve, the past cases that are most similar to the new problems to be solved will be extracted. In the case of case reuse, the solutions of similar cases found through retrieval for current problem solving will be used. In the revise phase, the derived solution is evaluated and the case is re-calibrated based on the evaluation result. In the case of retain phase, the new case that occurred in the previous three steps is stored in the existing case library.

Case-based reasoning can be applied even when there is no prior knowledge about the application field because it can be learned without modeling the system to be applied. If the output class is discrete or continu-

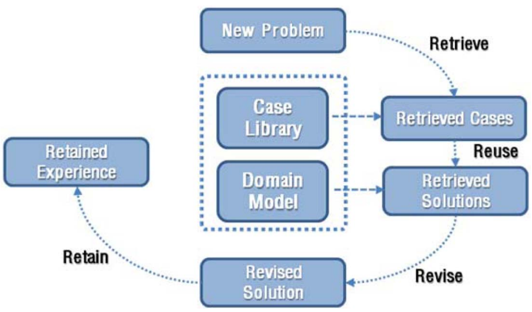

Fig. 1. Case based reasoning process.

ous, it has the advantage of being able to handle it all. As the use of case-based reasoning models increases in various fields, the demand for performance improvement is also increasing. The case-based reasoning model is a key performance indicator of how quickly the most similar cases are extracted.

Therefore, in order to improve the performance, it is very important to decide how to perform case indexing and case retrieving of two important algorithm elements of case-based reasoning.

2.2. k-NN Algorithm

Representative search methods for measuring the similarity from the case database include inductive search and nearest neighbor search. Inductive search is a method of finding attributes that best identify a case and then searching for similar cases using these attributes. Inductive search uses a structure of decision trees in order to search and organize cases.

The nearest neighbors search is a method to find the similar cases by searching for a certain number of cases with high similarity after measuring the similarity between the cases expressing the current problem and all the cases in the case base for retrieving the similar cases of the current problem. The most commonly used method in the nearest neighbors search is the k-NN algorithm which searches k cases that are closest to the current case. In this paper, similar cases were searched using k-NN algorithm.

The k-NN algorithm does not rely solely on the closest one case in classifying and predicting new cases but uses the method of taking votes from the nearest K cases, so that the accuracy of prediction becomes higher.

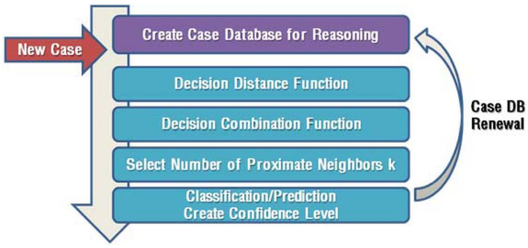

Fig. 2. k-NN Algorithm execute process.

In addition, the similarity is calculated for all cases from the input data and the case with the highest similarity is selected. Fig. 2 shows the implementation process of the k-NN algorithm.

2.3. SVM Algorithm

In this paper, the performance of the case-based k-NN algorithm with that of the SVM model, which is a popular technique for classification problems was compared. The SVM algorithm is a method to find a classification hyperplane that separates two groups well[9,10]. The basic principle of SVM starts from the problem of linear separation. Consider the problem that when the input data is given in the dimension, the output of the training data is divided into binary values such as -1 and +1.

A hyperplane, a linear discriminant function, it can be defined to define a model for classifying two sets. Here, Support Vector is a sample closely related to the boundary that determines the classification rule. The SVM maximizes the classification margins rather than simply searching the classification plane or minimizing sample errors.

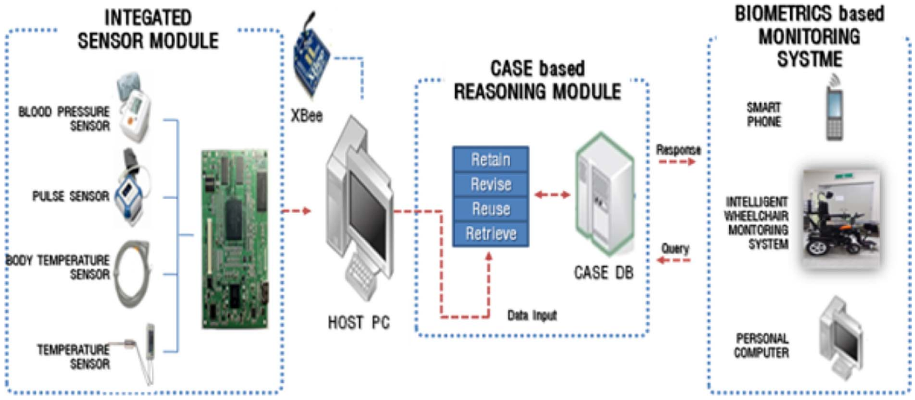

Fig. 3. Configuration of system.

3. System Configuration and Design

3.1. Bio Sensor Module

Case-based intelligent wheelchair monitoring systems use each measurement sensor to acquire stream data (Systolic Blood Pressure, Diastolic Blood Pressure, Heart Rate, Body Temperature, Temperature). The data used in the analysis are the data in the same environment, so they are bundled and transmitted in one packet. As additional traffic and energy consumption occur when they are transmitted in each packet, they are processed as a single packet, processed as queries, and bundled as one packet for energy efficiency.

3.2. XBee Wireless Communication

The XBee system is a 2.4 OEM RF module developed by Max Stream that provides a ZigBee/IEEE 802.15.4 compliant solution that meets the needs of low-power wireless networks.

The XBee module uses the XBee PRO DigiMesh Type which forms a network and serves as a relay between the magnetic values and other nodes. The communication configuration between the XBee modules is configured as shown in Fig. 4.

The XBee Pro DigiMesh module provides two to three times the transmission distance of existing ZigBee modules, providing easy to use, low power requirements and reliable transfer of critical data between devices. In addition, it is difficult to implement sleep mode or multi-hop when wireless communication using ZigBee is performed. However, various functions can be easily set through a firmware program that sets up the XBee communication environment, It is easier to implement the system because only the operating part of the program needs to be designed[11,12].

3.3. Case Database Design

In this paper, k-Nearest Neighbor (k-NN) algorithm which recommends k cases that are most similar to the current case was used. The k-NN algorithm is a classification algorithm that stores already known entities in memory in the form of a training set, then selects a similar entity among them, and predicts the value of the new entity according to the value of the selected entity[13]. In addition, case-based reasoning is appropriate for areas where similar problems are solved through past experiences that occur continuously. If a complex problem is the same as a past experience, you can get the solution right away without any special reasoning. Since similarity function is used to find the most similar cases, it is effective for problems that require a lot of time to solve[14,15].

In this paper, biometric data is composed of relational database and consists of three tables : biometric information, basic information of a living body, and information of a living environment. The object-relationship diagram of the data is shown in Fig. 5.

In the table configuration, the biometric information table is composed of the date and time of the biometric data, the measurement site, and the measurement values. The basic information table is composed of systolic blood pressure, diastolic blood pressure, heart rate, and body temperature. The bio-environmental information table is composed of environmental attributes that can affect the occurrence of user risk, and consists of date and time of measurement, measurement place, weather condition, and temperature.

3.4. Data Modeling

In this paper, 172 data from 287 data were used as training data sets, and 114 data were used as validation data sets for selecting the optimal model, and the

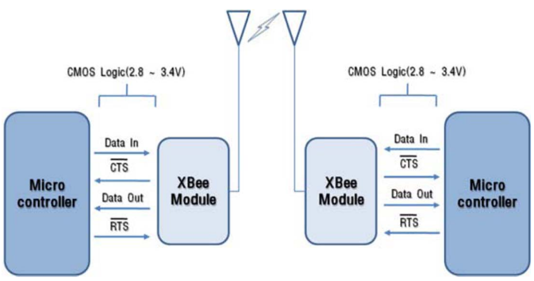

Fig. 4. Configuration of XBee Module Communication.

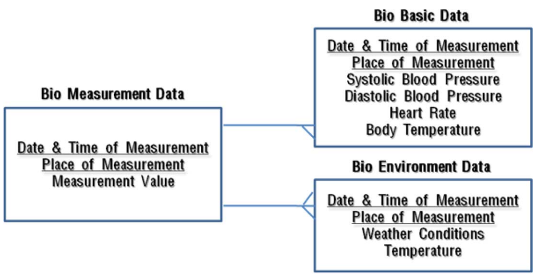

Fig. 5. Diagram of data entity relationship.

Table 1. Data input attribute

Input Date	Attribute Type
Systolic Blood Pressure	Numerical Type
Diastolic Blood Pressure	Numerical Type
Heart Rate	Numerical Type
Body Temperature	Numerical Type
Temperature	Numerical Type
Weather Condition	Categorical Type

remaining one data (Actually measured and input data) was used as an input case data set (Test Data Set). The training data set was used to build the model for the SVM and the case database for the case-based k-NN algorithm. Table 1 shows the input attributes used to construct the model of the system.

The prediction performance of the case-based k-NN algorithm is affected by the number of nearest neighbors referenced to generate the solution and the weights of the attributes used in calculating the similarity. In this experiment, systolic blood pressure, diastolic blood pressure, heart rate, body temperature, and temperature were numerical data, and each attribute had similar effects on risk occurrence, and the weight of the property was given as '1'. In the case of weather, the property type is categorical, so 1 is assigned if the property value is the same, and 0 otherwise.

3.5. Similarity Measurement

To calculate the similarity of all cases from the input data and select the case with the highest similarity, the method of calculating the similarity between cases is as follows. The total similarity $S(N, O)$ between the new input cases N and the cases with O in the case database is calculated by summing the similarity score $f(N_i, O_i)$ of each attribute i as shown in equation (1), multiplying the weights of each attribute, and summing them.

$$S(N,O) = \frac{\sum_{i=1}^{n} f(N_i, O_i) \times W_i}{\sum_{i=1}^{n} W_i} \quad (1)$$

Here, n is the number of attributes, N and O is the score of similarity between the attributes of i and W_i is the weight of the attribute i. The similarity between cases is expressed as a real value between 0 and 1 according to equation (1). The closer to 0, the lower the similarity of the two cases. The closer to 1, the higher the similarity. In other words, when searching for a case, the closest case of similarity is recommended. The similarity score $f(N_i, O_i)$ between attributes varies depending on the type of attribute (Numerical Type, Categorical Type). In this paper, since the input data are all numeric, the similarity score is calculated as shown in equation (2).

$$f(N_i, O_i) = 1 - \frac{a_i - b_i}{max_i} \quad (2)$$

In this case, a_i is the value of N_i and b_i is the value of O_i, max_i is the maximum value of case database in attributes i. In general, the performance of the case based reasoning system is affected by the number k of nearest neighbors referenced to generate the solution and the weights of the attributes used to calculate the similarity. In this paper, the system by experimenting with increasing the number k of nearest neighbors will be optimized. After calculating the total similarity for all the cases in the case database, the order is sorted from descending order to the case-based intelligent wheelchair monitoring system.

3.6. User Interface

To implement the user interface of the case-based intelligent wheelchair monitoring system proposed in this paper, a tablet PC was attached to the front of the wheelchair and used as a touch screen interface. Sensor information processing and motor control, which acquire the information of the surrounding environment, are performed in real time, and the tablet PC is designed to be linked to the case based wheelchair monitoring sys-

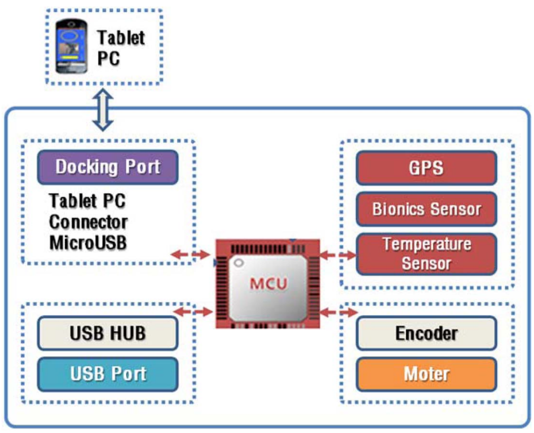

Fig. 6. Configuration of tablet PC docking system.

tem and designed to be performed with an auxiliary control board and a user interface.

The user interface is designed to detect the remaining battery level and travel distance of the case-based intelligent wheelchair monitoring system. In addition, the GPS location program is installed to allow the user to know the current location, and the GPS location is utilized by Google Maps. Fig. 6 shows the configuration of the tablet PC docking system.

4. Implementation Result of System

The case-based intelligent wheelchair monitoring system implemented in this paper uses the tablet PC to configure the interface to utilize the touch screen and smart phone interworking. The tablet PC uses Intel ATOM Z3740, Windows 8 operating system, and Bluetooth 4.0 communication method.

The implemented user interface measures the user's biometric information (Systolic Blood Pressure, Diastolic Blood Pressure, Heart Rate, Body Temperature) and environmental information (Weather Conditions, Temperature) so that it can be linked with smart-phone.

Fig. 7. Wheelchair of case-based intelligent wheelchair monitoring system.(Front/Side/Rear)

Fig. 8. DB and Module of Case-based intelligent wheelchair monitoring system.

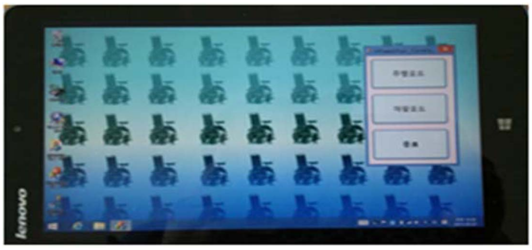

Fig. 9. Implementation result of user interface.

Fig. 10. Results of running the user interface driving mode.

Fig. 7 shows the wheelchair implementation results of the case-based intelligent wheelchair monitoring system.

Fig. 8 shows DB and module of case-based intelligent wheelchair monitoring system. As shown in Fig. 9, the driving mode and the monitoring mode are configured in the user interface.

In the driving mode, it is possible to check the user's position and driving speed with the GPS position recognition program, and it is possible to check the remaining battery level and the driving distance with time. Fig. 10 shows the results of running the user interface driving mode.

In case of monitoring mode, it is designed to monitor user's risk situation according to biometric information and environmental information. The measured data (body temperature, blood pressure, heart rate, temperature) are stored in the case database with XBee wireless communication and can be confirmed immediately by the implemented case-based intelligent wheelchair monitoring system. The interface is divided into items that can be used to monitor data classification results and numerical data by time and date, and graph items that show changes in systolic blood pressure, diastolic blood pressure, heart rate, and body temperature respectively.

Fig. 11 shows the results of user's biometric measurement and execution, and Fig. 12 shows the results of smart-phone integration of case-based wheelchair monitoring system.

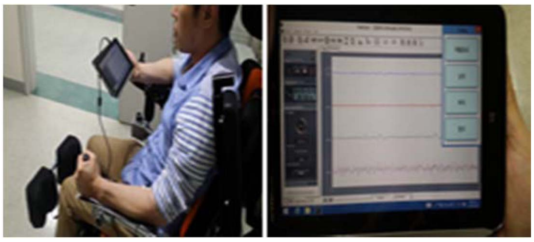

Fig. 11. Measurement and Execution result of biometric data.

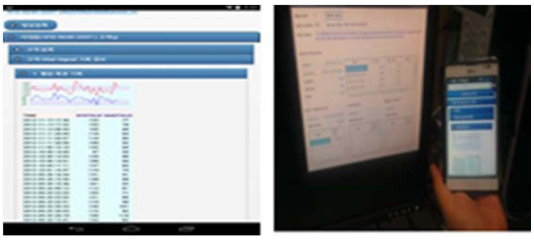

Fig. 12. Result of smart-phone integration after biometric data measurement.

Table 2. Performance evaluation of data

Fold Number	SVM	Case-based k-NN
1	83.1	82.3
2	84.3	89.4
3	86.5	88.9
4	79.5	86.7
5	82.4	85.6
6	83.3	86.8
7	87.8	86.4
8	86.1	85.5
9	83.3	857.
10	85.7	84.2

Table 3. Accuracy by number of k

Number of k	Average Accuracy(%)
1	76.1
3	81.3
5	84.5
7	85.6
9	82.5

5. Performance Evaluation

In this paper, a total of 287 data sets were used to construct a case database and generate input data. In order to verify the effectiveness of the case-based intelligent wheelchair monitoring system proposed in this paper, the performance of the SVM algorithm, which is a typical technique used for classification problems was compared and evaluated.10-fold crossover verification was performed to minimize the influence of the learning data on the experimental results and ensure reliability.

Experimental data were divided into case database construction data and verification data and they were used at a ratio of 6:4. In this experiment, systolic blood pressure, diastolic blood pressure, heart rate, body temperature, and temperature were numerical data, and each attribute had similar effects on risk occurrence, and the weight of the property was given as '1'. In case of the weather condition, since the property type is categorical, the case database is created by assigning 1 if the property values are the same and 0 when the property values are different and then the system is optimized by the leave-one-out method.

Table 2 shows the data accuracy of the SVM algorithm and the case-based k-NN algorithm of the verification data obtained through the experiment. The average accuracy of the SVM algorithm is about 84.2% and the average accuracy of the case-based k-NN algorithm is about 86.2%. Therefore, the case-based k-NN algorithm presented in this study has higher performance.

Also, in order to construct an optimal case-based intelligent wheelchair monitoring system, experiments were conducted while adjusting the number of similarity classification k. Table 3 shows the results of the average accuracy (unit:%) according to the number of

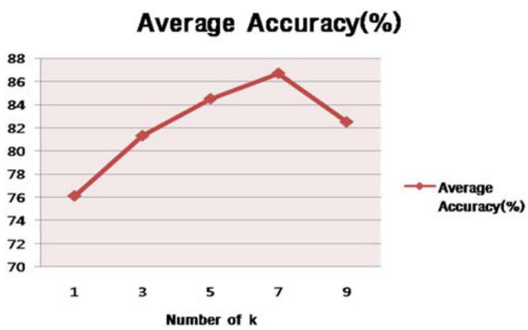

Fig. 13. Accuracy change by number of k.

k. Experimental results show that the accuracy is relatively decreased when the number of k is very low or high.

Fig. 13 shows the variation of accuracy according to the number of k, and the average accuracy is the highest when the number of k is 7.

6. Conclusions

Recently, the increase of the elderly population and the disabled population is emerging as a new social problem. Most of these elderly and disabled people want to live the life equivalent to normal people in various aspects of their life and hopes for active daily life and social activities.

As the use of wheelchairs increases and health becomes a core value of society, personalized medical services such as specialization and diversification of medical services are required and the development of various types of wheelchair based systems is accelerating. However, most research focuses on mobility, rather than personalized medical services, in the study of intentional perception of the user or autonomous driving of electric wheelchairs. The use of wheelchairs as a means of transportation may result in a loss of satisfaction with wheelchair use and an opportunity to improve an individual's quality of life by failing to meet their needs.

In this paper, it is aim to implement a wheelchair monitoring system that provides users with customized medical services easily in everyday life, together with mobility guarantee, which is the most basic requirement of the elderly and disabled persons with physical disabilities.

The case-based intelligent wheelchair monitoring system proposed in this paper is based on a case-based k-NN algorithm, which implements a system for constructing and inferring examples of various biometric and environmental information of wheelchair users as a knowledge database and a monitoring interface for wheelchair users. To construct the case database, 287 data were input and 10-fold cross validation was performed.

Also, in order to confirm the usefulness of the case-based k-NN algorithm, the SVM algorithm showed an average accuracy of 84.2% and the average accuracy of the proposed case-based k-NN algorithm was 86.2% And showed higher performance in terms of accuracy. In order to construct an optimal case-based intelligent wheelchair monitoring system, it is experimented with adjusting the number of similarity classifications k and found that the accuracy decreases when the number of k is very low or high.

The system implemented in this study has the advantage of measuring biometric information and data communication regardless of time and place and it can provide customized service of wheelchair user through user friendly interface. In addition, it is possible to cope with the dangerous condition of the user appropriately by continuously monitoring the status of the user.

It is expected that the proposed system will assure the user's mobility, provide sustained monitoring in daily life and user-tailored information using the user's biometric information and environmental information, and help improve the user's will to quality of life.

In the future, it is expected to develop an algorithm that can predict various histories based on the diagnosis results. In addition, it will improve the system if statistical algorithms is added.

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