加速度と角速度を用いた行動計測装置の開発

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The development of the motion recorder that used acceleration and angular velocity

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Abstract 　　We have developed the fall air bag in order to prevent injury, when elderly fall. It is necessary to reduce false detection other than a fall to put a fall air bag in practical use. It is necessary to analyze the motion of the subjects in daily life. In this research, the small motion recorder that used acceleration sensor and angular velocity sensor was developed. The developed recorder monitored a subject's behavior continuously for about two days. The monitor is50×56×18mm in size and 62 g in weight. The recorder consists of an accelerometer, an angular velocity sensor, an amplifier, a CPU, and a memory-card connector. By using this unit, the prolonged behavioral analysis which was difficult until now became possible.

1. まえがき

われわれはこれまで，高齢者の QOL の向上と健康支援を行う目的で，転倒エアバッグの開発を行ってきた[1]. 転倒エアバッグは転倒時に大腿部や頭部を保護するエアバッグをふくらませ，衝撃が直接加わらないようにすることで外傷を軽減するシステムである．これまで，加速度センサを用い，自由落下を検出することで，転倒の衝撃が発生する 0.1～0.2 秒前までに転倒を検出可能であることが明かとなった．しかしこれまでの研究により，自由落下のみの情報では，転倒以外の日常行動でもエアバッグが誤動作する可能性があるため，実用化するには加速度だけでなく角速度の情報を用いた誤動作を軽減するアルゴリズムを検討する必要があることがあきらかとなった[1]. これには，まず誤動作を起こす行動を特定する必要があるが，実験室で日常の行動を模擬して計測する実験などでは，限定された動きになるため，十分なデータを得ることが困難である．これらの問題を解決するには，対象となる被験者の加速度や角速度を長時間計測し，誤動作する波形が生じるか，また誤動作をキャンセルするにはどのようなアルゴリズムにするのが良いのかを検討するのが理想である．人間は一日のうちで様々な動作をするため，計測時間としては 24 時間以上計測可能であることが望まれる．

これまで，人間の加速度などの行動を計測する研究がいくつか行われている[2-5]. また，市販品も販売されており行動の計測などに応用されている[6]. しかしこれらの機器は一般に数時間程度の計測しか出来ず，行動を 24 時間以上計測することは困難であった．またわれわれはこれまで無線を使用したテレメータ型加速度モニタリングシステム[7]を開発したが，電波の範囲が限られるため，日常的に計測することは困難である．さらに，従来の機器は加速度の計測のみで，角速度を計測可能な記録機器は開発されていない．本研究では，24 時間以上の長時間，加速度と角速度を計測可能な行動計測装置の開発を行った．

2. 行動計測装置の開発

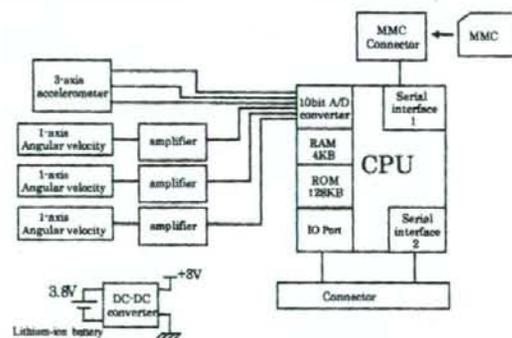Fig.1 に装置のブロック図を示す．装置は加速度センサ，角速度センサ，増幅部，CPU, メモリカードコネクタより構成されている．加速度センサには 3 軸加速度計(MMA7260Q,

Fig.1 A block diagram of recorder.

Freescale Semiconductor, Inc.)を採用した．センサ内に増幅回路を内蔵しているため，アナログ回路を少なくすることが可能である．角速度センサは 1 軸超小型振動ジャイロセンサ(VX-3500CB, エプソントヨコム(株))1 個と 1 軸圧電振動ジャイロ(ENC-03R, (株)ムラタ製作所)2 個を用い，3 軸方向の角速度を計測可能とした．CPU は 16bit マイコン(H8-3048, Renesas Technology Corp.)を用いた．CPU には A/D 変換器，ROM, RAM, シリアルポート(SIO), パラレルポート(PIO) 等が内蔵されており，加速度波形と角速度波形を 10[bit]で A/D 変換する．変換速度はプログラムにより最高 256[Hz]まで設定が可能である．データを保存するメモリカードには小型軽量なマルチメディアカード(MMC)を用いた．MMC は近年一般的に用いられている SD カードと同サイズで，フラッシュメモリであるため計測中に電源が切れてもデータを保存可能であるというメリットがある．また 512MB の容量まで記録できるため，長時間のデータ保存が可能である．電源部にはリチウムイオン電池(T56KAB, 三洋ジーエスソフトエナジー(株))を用いた．電池は装置内に内蔵し，USB ポートから充電可能とした．1 回の充電で最大約 2 日間の連続計測が可能である．Fig.2 に装置の外観を示す．被験者に装着する場合，小型軽量で突起部がなく装着に違和感を与えない構造とすることが重要である．このためケースには MX 型丸型モバイルケース(MX2-6-5, (株)タカチ電機工業)を用いた．外

形寸法は 50×56×18mm，重量は電池，メモリカードを含め 62g である．このため，装着の負担を軽減可能である．小型化と誤操作を防止するためスイッチは装着せず，メモリカードを装着することで自動的に計測を開始する構成となっている．

3. 動作実験の方法

本装置を自ら装着し，平地歩行と階段の上り下りの波形を計測した．装置は専用のベルトを用い，体の重心に近い腰部に装着した．サンプリング周波数は 32Hz に設定した．

4. 結果と考察

Fig.3 に歩行中の波形，fig.4 に階段の上り下りの波形を示す．各図の(a)に加速度，(b)に角速度を示す．加速度の上下方向は下方向に加速度が生じた場合にプラスが表示される．前後方向は前方に傾斜した場合をマイナス，後方に傾斜した場合をプラスとした．さらに左右方向は右に傾斜した場合をマイナス，左に傾斜した場合をプラスとした．計測で用いた加速度センサは重力加速度を計測可能である．このため，+9.8[m/s]の波形が生じている．また，歩行時には加速度の変化により加速度が生じている．一方角速度は体の前後方向の移動により波形が生じており，約 50[deg/s]程度である．また階段の上り下りの加速度波形は階段下りの振幅が大きくなっている．また角速度も下りの際大きくなっており，上りより下りの場合のほうが，身体の揺れが大きいことがわかる．

これまで加速度と角速度を同時計測可能な小型データロガーは存在しなかった．加速度だけでなく角速度を同時に計測することで身体の姿勢変化が詳細に把握可能である．転倒の検出を行う際には，加速度のみの情報だけでなく，角速度を用いることで身体の傾斜の速さを知ることができるため，誤動作を防止できると考えられる．たとえば，被験者がジャンプした場合，加速度の情報のみでは自由落下を検出してしまうが，角速度の情報は身体の回転がないため，転倒とは区別可能であると考えられる．しかし，判別の閾値をどのようにすればよいかは，実際に波形を計測する必要がある．本装置は小型軽量であるため，被験者に負担をかけることなく長時間の加速度と角速度波形を計測可能である．今後は本装置を用い，日常行動を長時間計測することで，誤動作防止のアルゴリズムを検討する必要がある．

5. まとめ

本研究では，メモリカードを用い加速度と角速度を長時間計測可能な行動計測装置を開発した．動作の確認を行い簡便に加速度と角速度を計測可能であった．今後は本装置を用い，計測した波形から転倒エアバッグの誤動作を防止するアル
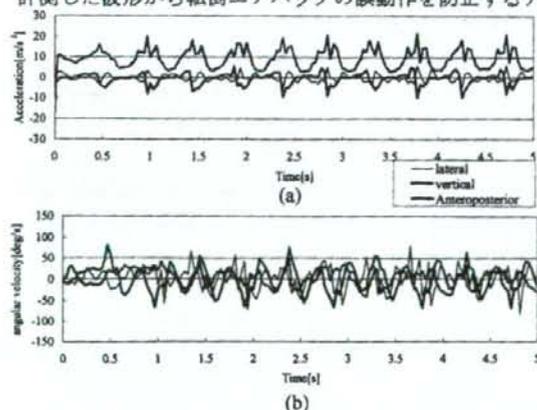

Fig.2 Externals of recorder.

ゴリズムを検討する．

6. 謝辞

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Fig.3 The acceleration and angular velocity waveform of walking.
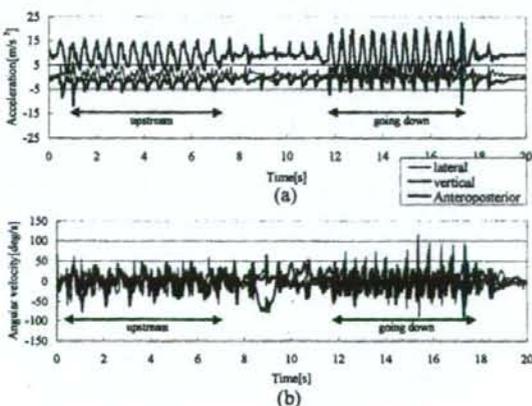
Fig.4 The acceleration and angular velocity waveform of upstream and going down of stairs.

認知症対策に 住環境からアプローチ

中山茂樹・千葉大教授に聞く

原広

なかやま・しげき 千葉大学教授。工学博士。専門は医療・福祉施設設計論。論文に『認知症患者に対する回想的環境の治療的効果に関する研究』[日本建築学会技術報告集、審査論文][SDS4医療・福祉]、鳥取県琴浦町の西伯病院「思い出街道」などを監修した。

認知症と環境回想法

高齢化が進む日本で今後ますます問題になると懸念される認知症。臨床心理の分野では、数年前から認知症高齢者の治療法のひとつとして「回想療法」が試みられている。

高齢者が自分の過去を回想し、整理して、そこから未来に向き合うことを促す心理療法の一種だ。昔の出来事を思い出すことで、現在の自分の位置を見つめ直し、認知症の症状を緩和する効果を見出そうというのである。

この回想療法を住環境からアプローチしているのが「環境回想法」である。

昔を振り返る支援ツール

回想療法では、記憶をよみがえらせる手段として、過去の風景を描いた絵や写真、生活道具やおもちゃといった小物類が利用されることが多い。話のきっかけとして、患者の思考の組み立てに役立つかもしれないからだ。

医療・福祉施設などの建築計画に関する研究を専門とする中山教授は、患者・高齢者のための環境をつくる立場から「回想療法に関心をもっているという。回想療法で使われる写真や景色や道具などが、実際に高齢者の目の前に現れたり触れたり使ってみたりできたら、認知症高齢者の心により響くのではないだろうか。

「高齢者の住環境のなかに彼らが親しんできた時代の情景や道具をインストールして、環境を通して回想療法と同様の効果を得られないかと考えました。回想的な環境のなかにいることで、高齢者の五感に訴えかけ、認知症の症状を改善できないかということです」

認知症高齢者が過去を懐かしむ場合、その思い出に登場する過去というが懐かしいものと何かインタビューで聞き取る。その結果から、過去を振り返る支援ツールというべき道具や環境を選び、高齢者の住環境(具体的には老人病院や病院デイケアに組み込んだ。

ステレオタイプの懐かしさではダメ

かつて病院内に設置されたのは「童謡コーナー」や「回想ストリート」。前者は比較的どんな高齢者にも共通して懐古的な空間であり、後者はその地方に固有の記憶(ある時期まで多く見られた瓦屋根・商店街・昔の駅の看板など)を活かした要素を取り入れて設計されたものである。

「懐かしさを喚起するアイテムとして、昨今は『昭和30年代』などがクローズアップされていますが、懐かしさも年性別・地域・生まれ育った環境などの条件によって異なります。ステレオタイプの懐かしさでは

[回想ストリート]

ダメなのです。ただ、たとえばある地域のある世代が共有する固有の原風景があるのと同時に、そうした条件を超えたより一般的な『原風景』もあるのではないか。里・田園・渓谷などもそのひとつです。

中山教授によれば、そうした回想的環境に置かれたことで、認知症高齢者の周辺症状(徘徊などの問題行動)のある事例を客観的に確認することができたという。認知症でも、一定の症状の改善は、薬と同様、生活環境のあり方が影響を与えうるという仮説が立証されつつあるのだ。

土地固有の記憶をなくすとは

中山教授の試みに、都市再生機構の関係者も関心を示しているという。大規模集合住宅の建替え・再生のためのヒントとなると感じているようだ。

「団地のスラム化問題などを考える場合も、その土地がもつ固有の文脈のなかでの再生を志向するべきなのではない

しかと思います。造成から数十年を経た団地には、すでにそこに固有の文脈が存在するはず。それらを丹念に見つけ、活かしていくことが大切でしょう」

中山教授の試みからは多くの示唆を読み取ることができる。古くからつつあるニュータウンや集合住宅を抱える郊外におけるまちづくりに、その土地の記憶を活かす環境回想法的な手法を応用するというのものひとつだろう。

また、住環境の変化と認知症の進行となどの何らかの因果関係が、今後の研究によってさらに確認される可能性もある。もっとも認知症高齢者に限らず、生活環境がそこに暮らす人々に及ぼす影響は計りしれなく、環境回想法が認知症高齢者に対して一定の効果を上げているということを考えれば、その土地の来歴や記憶を無視しながら画一的な風景ばかりを生み出してゆくニュータウンや風土は、高齢化する日本社会にとって、もしかすると認知症を増やすことにつながるのかもしれない。

A Discussion on the Direction for the Study of Architectural Planning and Design

Towards Establishing the Healing Power of the Environment on a Scientific Basis

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Abstract — A Study on architectural planning and design was a new science system. It has been used for designing many public facilities, and has made their quality improve. In case of hospital architecture, many pioneer professors have accumulated important data, and they are the standard to design. However wider and deeper design qualification are required today. A hospital architecture seems to be not only the container but also the equipment in order to treat the patients by using environmental healing power. The study on architectural planning and design should focus this new academic province, and should start to research and investigate new purpose. This paper shows two researches based on new point of view, and discusses new direction of the study

Key Words — A study on architectural planning and design, Healing Environment, Healing power of the Environment

I. INTRODUCTION

A study on architectural planning and design was born as a new academic field just after 1950. It aimed to establish basic information concerning creating facilities by objective evaluation through scientific and statistical analysis and basis, and by imagination for user requirements, although facilities were build by empirical way until then. Among the academic system, studies on hospital architecture were developed precisely. A lot of prototypes were proposed through many approaches and solving problems required from society and the time. For examples, the subjects on nurses' traffic in the wards and on clean circulation and area in the operating theaters, from the special province in evaluation for separating clean from dirty area and/or rational and efficiently circulation planning.

Recently the role of studies on architectural planning and design seems to extend. That is introducing the concept of "Facility Design". Probably it is understood that is the planning and design which is used in longer phase from planning to design, wider territory as "Design Planning". As ever architectural planning and design has regarded the users' requirements as important, and located it as the same value as architectural design as a priori and conditions from building technology. However our daily living and consciousness has been changing after about 1900 when modern architecture started from the situation on which architectural space consists were not established. Public facilities must have been re-examined its existing with relationship with social system which involves much subjects. And not only architectural side but also common based group including architectural and civic sides have tried to change the public facilities. In cooperation with people and establishment of facilities by civil leading, the software, which operates public facilities, is planned. The design planning involves facility operating management. In the future, cooperation like this will be a useful method of design planning.

And not only from the response to people's requirement, in case of increasing interest in cost and performance in general architecture, an importance of facility management will be increasing, and at the same time, these movement will be a great subjects when we create the architecture, and innovates exiting building-types.

This paper introduces two theses which are investigated from new academic point of study on hospital architecture. They are focused to healing environment and tried to prove environmental healing power through scientific and statistical procedures.

II. CURRENT TYPES OF STUDY

Before discussing new type of study, the author would like to investigate developing of past studies and positioning of current studies. A study of space utilization, a discussion on plan-type of operating theatre and an analysis on nurses' traffic in the wards are taken up here. These researches can be separated to; 1) former meanings of the study are changed, its mission has finished, and the different discussion is requested to establish updated purpose. 2) the point and the view of study object have been changed, and the

signification and the purpose of the study have been changed. 3) being valuable as an architectural study, and the results contribute to the subjects of facility operating, beyond architectural province.

A. Study on the Space Utilization of Hospital

From 1960, investigation of the space utilization has begun in order to establish the data and information when the starting phase of the design of hospitals, the architects have decided the space proportion as zoning decision. The data of appropriate area ratio of each departments has been made by Prof. Yoshitake, Prof. Itoh and so on, and been made by every one decade.

This research investigated and discussed the area ratio by separating whole hospital into some departments from the view point of architectural planning and design, not operating view. Through 50years' research, departments were divided into five large classifications, "Wards", "Outpatient Dept.", "Diagnostic and Treatment Dept.", "Supply Dept." and "Administration" basically.

These data is aimed to use for zoning and area size decision in early design phase. But at present, each hospitals are required its own identity, and its own function, the meaning of appropriate proportion of area size and of standard department structures are not valuable. Not whole area proportion, absolute area size of each departments for the unit of patients, so to say number of beds or number of new admitting patients, are needed to discussed.

B. A Study on Plan Type of Operating Theatres

The most important purpose of designing of operating theatres is to achieve cleanness of operating room and the operating field. Especially the circulation of clean and dirty settle the environment. Informer days, the concept of circulation separation did not exist. Being affected by American administration sense, "Clean Hall Type", "Clean Supply Type", and "Withdraw Type" and so on have appeared. Dividing three traffics such as materials, staffs and patients into two circulation so to say before and after operation, after all six kinds of traffics was watched, then the combination of those six traffics was proceeded mathematically (6Cn), then they are regarded to concrete architectural planning or space.

The guidelines for operating theatres have published by CDC in US. It referred that traffic separation in operating theatres did not prove the decreasing of infection of operation. The purpose of traffic separation disappeared. At present, staffs and patients enter the operating rooms with general

shoos and wards beds go into there directly. Design subject for operating theaters is getting efficiency and rational work place.

Another subject is to create amenity environments in operating theatres for staffs and patients. For the patients, the number of day surgery is increasing. Then they can commit the environment in operating rooms. For the staffs, it is mentioned that the guarantee of comfortable, errorless and efficient work under the severe circumstance depend on the quality of space.

C. Nurses' Traffic in the Ward

Some examples of splitting the nurses' station has been appeared 20 years ago. Its purpose was to increase the time of direct nursing, and to decrease the time of traffic. At the same time, it was discussed that the balance of direct and indirect nursing depends on ward planning and design. From the beginning, the number of beds of one nursing unit is rather much comparative with Western countries. It has seemed to disturbed efficient nursing operation.

The example has been appeared that not only two nurses' station but some more bases are located in the ward. On the other hand, the standards, which provides the number of nurses for one unit nursing, has been changed slightly, High density nursing system, seven patients for one nurse including night time such as 1.4 patients for one nurse in day time, appeared, and it aims to shorten the length of stay. The results of the study on architectural planning and design affect the nursing operation.

III. PLANNING CONDTION OF PATIENTS' ROOMS IN AN ACUTE PSYCHIATRIC HOSPITAL

A. A Purpose of the Study

This study was held as a premise that recuperation environment relates to treatment in an acute mental hospitals. There exists a treatment and recovery model from seclusion room to multi-bed room, via single room, and then returning to society. But most of the facility in present situation, a ward is consisted with quite few seclusion room and many multi-bed rooms. The ratio of single bed rooms which can contribute to treat the patients is very low, and the variation of the rooms is very poor.

The purpose of this study is to discuss the type of patients' room on the point of medical & nursing, and its performance & equipments.

TABLE 1. PRESENT AND IDEAL ROOM

	n	%
Present room : all ward (n=599)		
Single room	119	19.8
Seclusion room	37	6.2
Multi-beds room	480	80.1
Ideal room : all ward(n=597)		
Single room	143	24.0
Multi-beds room	368	60.2
Either will do	86	14.4
Ideal room: less than 3month stay (n=299)		
single room	89	29.8
Multi-beds room	180	60.2
Either will do	30	10.0

TABLE 2. RATIO OF CHOICE OF ROOMS

		Ideal room					
		single		Multi-bed		either	
		n	%	n	%	n	%
present	single rm.	97	16.2	7	1.2	15	2.5
	seclusion	37	6.2	0	0.0	0	0.0
	multi-beds	46	7.7	361	60.5	71	11.9

TABLE 3. REASONS OF CHOICE OF ROOMS

	n	%
Reasons of choice for single rm. (n=136)		
Stress of other patients' communication	93	68.4
Troublesome for other patients	57	41.9
Evaluation of situation	53	39.0
Adequate rest without relationship of patients	49	36.0
Necessity for physical treatment	28	20.6
Violence to other patients	21	15.4
Violence to articles	21	15.4
Possibility of hurting himself	17	12.5
Keeping privacy	13	9.6
Avoidance of suicide	11	8.1
Reasons of choice for multi-beds rm. (n=360)		
Rehabilitation for social living	339	94.2
Evaluation of rehabilitation	281	78.1
Observation by mutual	259	71.9
Economical reason	62	17.2

TABELE 4. COMPARISON OF PERFOMANCE

	present	ideal
	%	%
Resistance performance to violence	40.5	53.6
Security for patients	23.3	73.2
Avoidance of suicide	24.1	52.2
Sound insulation	20.7	61.6
Isolation (from outside)	71.6	67.4
Isolation (from inside)	21.6	23.2
Medical gas piping	18.1	37.7
Observation camera	24.1	49.3
Observation microphone	40.5	56.5
Observation window	62.9	78.3
Toilet	65.5	46.1
Toilet door	48.3	62.3
Wash basin	62.9	69.6
Shower	15.5	40.6
Storage furniture	62.9	71.0
Desk	47.4	58.0
Common space	60.3	78.3
Number of patients	116	138

Then the variation and size of patients' room, which the modern hospital has to prepare, will be discussed.

B. Method

Following items are investigated in 18 hospitals for each patient; 1)present room type (seclusion, single or multi bed room), 2) ideal room type 3) a reason 4) architectural performance and equipment of ideal room. And a property of each patients like 1) gender, 2) age, 3) length of stay, 4)main disorder (ICD-10), 5) GAF (scale of functional level). This study deals with 7 hospitals, 13 wards, 599 patients, who stayed less than one year.

C. Conclusion

1. Using room and reason of choice

The patients in single bed rooms (including seclusion room) is 19.8%. The ratio of patients who admitted in multi-bed room but ideal room is single is 7.7% After all, single room is shortage. The patients who prefer to be admitted in single bed room is 24%, multi-beds room is 61.6%, either will do is 14.4% (Table 1 & 2). The reason for single room are "communication to others and stimulus is mental stress", "troublesome behavior to others", "evaluation of medical condition", "rest without consideration to others" and so on. The reason for multi-bed room are "rehabilitation training in society", "evaluation for social adaptation", "mutual observation", and so on (Table 3).

2. Performance and equipment of the single room

Existing single room has equipments showed Table 4. On the other hand, ideal single room request more equipments showed on the same Table. Many types of equipment, which are requested into the ideal single room essentially, can not be found at present. On the patients who need single room originally, a cluster analysis were done with "required performance and equipment in single room" as a variable. As a result, we can get 5 types.

Table 5. and Table 6 shows performance and equipment for more than 80% of the patients. Classifying single room type, Organic Psychosis and Drug Intoxication belongs to type IV, Schizophrenia belongs to type I or III, Psychopath belongs to type I, II or III. And from the point of GAF, low level such as GAF is less than 30 belong to type I, III or IV, intermediate level like 31-60 belongs to type I, III or IV, and high level like 61-80 is type II or III.

TABLE 5. TYPES OF RM. AND PERFOMANCE

	I	II	III	IV	V
	%	%	%	%	%
Resist. prfrm. violence	97.7	6.3	78.6	25.9	7.7
Security for patients	100.0	21.9	100.0	37.0	100.0
Avoidance of suicide	100.0	6.3	32.1	18.5	100.0
Sound insulation	100.0	15.6	75.0	11.1	100.0
Isolation (from outside)	100.0	43.8	96.4	29.6	7.7
Isolation (from inside)	32.6	12.5	3.6	0.0	100.0
Medical gas piping	83.7	21.9	10.7	22.2	0.0
Observation camera	100.0	18.8	39.3	25.9	7.7
Observation	97.7	6.3	67.9	7.4	100.0
microphone.	100.0	37.5	100.0	40.7	100.0
Observation window	100.0	100.0	92.9	14.8	0.0
Toilet	67.4	100.0	89.3	0.0	0.0
Toilet door	69.8	100.0	100.0	22.2	0.0
Wash basin	69.8	96.9	32.1	55.6	92.3
Storage furniture Desk	76.7	93.8	35.7	25.9	0.0
No. of patients	43	32	28	27	13

TABLE 6. TYPES OF RMS. AND DISEASE

	I	II	III	IV	V	Total
	%	%	%	%	%	
Main disease						
Organic psychosis	19.0	19.0	9.5	47.6	4.8	21
Drug intoxication	18.2	9.1	9.1	63.6	0.0	11
Schizophrenia	37.0	21.9	21.9	9.6	9.6	73
psychopath	40.0	30.0	20.0	5.0	5.0	20
GAF level						
71-80	0.0	50.0	0.0	0.0	50.0	4
61-70	0.0	50.0	0.0	12.5	37.5	8
51-60	6.7	26.7	6.7	33.3	26.7	15
41-50	11.1	22.2	22.2	44.4	0.0	9
31-40	39.4	28.6	27.3	9.1	3.0	33
21-30	35.7	0.0	19.0	11.9	4.8	42
11-20	47.8	0.0	26.1	21.7	4.3	23
1-10	40.0	0.0	20.0	40.0	0.0	5

D. Discussion

1. Necessary ratio of single rooms

Most of psychiatric hospitals ran short of single rooms. A shortage of single rooms occurs troublesome to other patients, lack of privacy and adequate rest. 30% from the patients who stays hospitals less than 3 months needs single rooms. In acute hospital, there requests more number of single rooms.

2. Performance and equipments of ideal single room

Present single room is designed to isolation and observation. For instance, it has a toilet, but without door. It focuses to the most serious patients. But ideal room requests the equipment to improve the daily living such as shower, toilet, desk and so on, to make sure safety such as the function preventing suicide, observation camera, and so on, to provide rest such as sound insulation performance.

Consideration of needed image by types, we get some distinctive feature as follows,

Type I requests the performance against violence behavior and suicide such as locking from outside and isolation.

Type II is comfortable patient's room with adequate rest with toilet, wash basin, furniture, desk and so on.

Type III request the equipments that can lock and be observed from outside, but basic daily living is done in the room. Then it has toilet with door and basin.

Type IV is focuses to Organic Psychosis and Drug Intoxication patients. But they reveal so multi feature that the definition of the room can not be decided.

Type V is the room where the patient locks the door by himself and stays alone with arranging the relationship to other patients. But consideration for suicide and observation is needed.

IV. A STUDY ON ENVIRONMENTAL REMINISCENCE THERAPY FOR MODERATING PERPHERAL SYMPTOMS OF THE DEMENTIA PEOPLE

A. A study of purpose and the proposal of environmental reminiscence therapy

At present, a reminiscence therapy is watched as one of non-drug treatments. When providing this psychological treatment, pictures and small goods are used for this therapy among the patients. Instead of conventional therapy, the authors proposed an ancient tools and architectural space as which or where the dementia people can use and can their own experience directly. The daily living and behavior of dementia people are affected from memorial scene and fondly-remembered architectural space. The authors attention that the concept of "Life Review" will be useful for the therapy.

In present clinical psychological therapy, the evaluation of reminiscence therapy is estimated by the quality and quantity of conversation, and the record and observation of emotion. Our study will propose the therapy, which can promote another efficient from former therapy, and which reminds past days by each other as a one's pace, in the architectural reminiscence space that is introduced into the day care dept. for dementia people. The authors call this therapy as Environmental Reminiscence Therapy.

FIGURE 1. THE MEMORIAL STREET IN SAIHAKU HOSPITAL IN TOTTORI PREF.

FIGURE 2. ENVIRONMETAL REMINISCENCE
THRAPY IN THE MEMORIAL STREET

B. Interview Investigation for the People in Nambucho-Tottori Pref.

In order to get some evidences to create design concept of the memorial street, we investigated 48 aged people in that village as interview. Average age of the people is 75 years old. Old houses with a straw-thatched roof and old fire place were talked by everybody as a memorial tools and scene. It depends on each region. •

C. Design of the Memorial Street

Referring the results of interview, we decided the design of the memorial street. Whole hospital was designed for warm environment with wood and paper which occurs Japanese taste. A lattice door of patients' room, Tatami-mat bench, lamps

with traditional paper, a ceiling with bamboo was introduced into the hospital interior. We aimed to make a neighbor become intimate, and the memorial street melt into the hospital design.

Relational rooms for the demented day care are located on the memorial street. A resting room, cooking room, bath and staff rooms except day care room as the reminiscence room are located, and each room are designed what occur the interior. The wall of the street was made with wood wall. We installed the equipments, which stimulate five senses. One of them is the equipment lighting system which direct morning and evening sky by the changing the color of light.

We provided many elements into the many points of the memorial street, and aimed to introduce their own scene that appear their distance childhood memory. At present, red tile roofs, a sign of Hossho-ji station, a poster of kabuki-play at Hossho-ji district and the pictures of Hossho-ji train were installed; in near future we will install some other elements, for instance fireplace into the therapy room, immediately.

D. Evaluation of Environmental Reminiscence Therapy

Dementia disease is consisted with core disease occurred by disorder of brain directly and peripheral disease with psychological, situational and physical factors. This study watches that peripheral disease is affected with environment strongly, tries to verify environment reminiscence therapy through architectural space and circumstances.

As one of therapies of day care program, it was observed that a certain demented patient revealed following change through a tea party with other patients and staffs in the memorial street for one hour. 1) Stability of emotion (conversation with staffs and complete conversation), 2) Easing of mental stress (reducing the stress with long time injection), 3) Lasting concentration (long time conversation), 4) Becoming five senses actively.

TABLE 7. SCORE BY MOSES SCALE

period	Female, 89 year old		Female 74 years old		Male 84 years old	
	before	after	before	after	before	after
Depressed mood	15	8	15	9	11	9
	Recognition for 2 items		Recognition for 3items			
Irritation			15	9	11	12
	No disease		Recognition for 1 item			
confination	17	14	21	20 ~	19	19

In order to get objective evaluation of the change for the demented in reminiscence environment, psychological test was held with dementia scale in the field of clinical psychology. MOSES Scale was adopted to this study. It is the one of the best scale for the demented and used in general field in clinical psychology and evaluated its reliance. This scale is multilateral, and can measure ADL, emotion and the change of peripheral disease of dementia. Observation subjects person are three dementia people. Before test, the occupational therapist measured the degree of dementia by MOSES based on the medical chart. Concrete environmental reminiscence therapy was a kind of tea party with talking about old memories of this district in the memorial street. After one hour therapy, the Occupational Therapist and the nurses evaluated the people by MOSES scale during tea party. Reducing the point from before observation to after one, the items recognized as improvement.

We could get the same result that the past clinical psychological study mentioned that reminiscence therapy is effective for stability of emotion, especially improvement for stress of the demented.

E. Conclusion

A reminiscence therapy is recognized to improve the peripheral disease of the dementia, and environment reminiscence therapy is cleared to verify for many demented people through installing the memorial street into the hospital. It is confirmed by not only observation but also clinical psychological scale.

It is easy to conclude that installing memorial scene like these studies is fake or theme park. However for demented who forgot everything in a few minutes, what is the real? What is the environment the demented recognize? We have to reconsider them.

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Quantitative Evaluation of Movement Using the Timed Up-and-Go Test

Detection of Task Phase and Clinical Application to the Rehabilitation of Hemiplegic Patients

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Many hemiplegic patients who have suffered strokes need rehabilitation. The expected outcome of rehabilitation is the patient's independence and freedom from the aid of a nurse and a consequent improvement in the quality of life. Thus, occupational and physical therapy should be carried out efficiently, and the development of support technology for therapy is important. Developing independence in basic activities is essential in the early stage of rehabilitation as it influences the subsequent recovery of the patient's normal way of life. The timed up-and-go test (TUG-T) is a simple technique for evaluating competence in the following basic activities: standing up from a chair, walking forward, turning around, walking back to the chair, turning one's back to the chair, and sitting down. The total time taken to complete the TUG-T is used to predict the risk of falling [1]–[4]. However, no objective criteria exist for demarcating each activity phase of the TUG-T. At present, these are evaluated subjectively based on the experience of the therapist, and thus it is difficult to obtain objective data for clinical rehabilitation. Conventionally, the therapist evaluates how well the patient performs the TUG-T, at a detailed motion level, and confirms the patient's problems with particular activities. The therapist then determines ways to resolve the problems. Although the TUG-T measurements are easy to perform and accurately predict the risk of falling, it is necessary to perform an evaluation applying appropriate objective data. Acquiring quantitative data would be of great benefit in a rehabilitation program.

Measurements during clinical rehabilitation have been attempted using a triaxial accelerometer to measure the activity objectively, which allows a quantitative evaluation. The triaxial accelerometer enables motion evaluation in the frontal, sagittal, and horizontal planes by measuring the motion in the antero-posterior, vertical, and lateral directions, respectively. The acceleration signals can also be used to evaluate muscle power, joint function, and postural reflexes. Consequently, this assessment provides key information for evaluating the walking activity phase and the other basic activity phases of the TUG-T.

Previously, the activity was examined to evaluate quantitatively using only the signal from an accelerometer attached at the waist because it was believed that it would facilitate

measurement during clinical rehabilitation [5]. The literature on evaluating posture using commercial, low-priced, accurate accelerometers is extensive [6], [7].

During clinical rehabilitation, the measurement method should not restrain the subject with too many sensors. Angular measurements can be derived using Kalman filtering of the direct current (dc) element of the acceleration signal. However, this method has a reported error margin of $\pm 2°$ [6]. During clinical rehabilitation, it was difficult to identify hemiplegic walking from the angular displacement signal. It was also difficult to identify the activity phase clearly, which was our objective, using the acceleration signal alone.

A waist gyrosensor is useful for measuring the postural displacement with high accuracy. The posture can be determined by measuring the acceleration and angular velocities, although this method has never been used to evaluate and verify continuous activity from static sitting to walking [8]–[10]. Therefore, an accelerometer and rate gyrosensor was attached to the subject's waist and lower limbs to evaluate postural displacement. A further objective was to identify the activity phases of the TUG-T. Trained therapists measured the time for each activity phase from a videotape recording (VTR) of the TUG-T for reference [11]. This combined accelerometer or gyro method was used during clinical rehabilitation sessions during which the subject performed the TUG-T independently or while being supervised. Under both conditions, the walking phase activities extracted from the TUG-T data were compared qualitatively.

Method

The Measurement System

The measurement system used for the TUG-T consisted of two sensor units (Gyrocube), a multitelemeter system (WEB-5000), and a personal computer with a built-in analog-to-digital converter.

Each sensor unit can measure the three axes of acceleration (the waist accelerometer measures ± 3 g with a sensitivity of 1.33 V/g, whereas the lower limb sensor measures ± 5 g and 0.80 V/g, respectively, with a frequency response dc of 60 Hz) and the three axes of angular velocities (angular velocity ratings $\pm 400°$/s, sensitivity 10.0 mV/°/s, and frequency response

dc of 40 Hz). The sensor measured $30 \times 40 \times 20$ mm^3 and weighed 7 g.

The signal from the sensor unit was recorded on a personal computer at a sampling frequency of 128 Hz via the multitelemeter system (the high cutoff frequency was 30 Hz).

The transmitter of the multitelemeter system measured $128 \times 80 \times 28$ mm^3 and weighed about 300 g.

Measurement Method

The measurement task was based on the TUG-T introduced by Podsiadlo and Richardson [11], and the procedure is as follows:

1) The subject sits with his or her back in contact with the back of the chair (the seat is 460 mm high and lacks armrests)
2) The TUG-T begins with the therapist's go sign and the subject stands up (standing up)
3) The subject begins walking (walk 1)
4) The subject turns around a post placed 3 m away from the chair (turn 1)
5) The subject walks back toward the chair (walk 2)
6) The subject turns away from the chair to sit down (turn 2)
7) The subject sits on the chair (sitting down).

The acceleration measurement points are at the waist dorsally (near the second lumbar vertebra) and at the lower limb on the side that takes the first step. Figure 1 indicates the positions of the accelerometer and gyroscope. The activity was captured with a CCD camera (EVI-D30) and recorded with a VTR (GV-D900NTSC). The therapist recorded the duration of each activity phase using a stopwatch while watching the video. Ten young, healthy subjects and 20 hemiplegic patients from Fujimoto Hayasuzu Hospital, Japan, were studied (Table 1). Twelve experienced therapists from the clinical rehabilitation center measured the durations of the activity phases. For safety, a therapist stood beside the hemiplegic patients during the activity.

The Method of Detecting and Evaluating the Activity Phase of the TUG-T

The data gathered from the healthy subjects were used to identify the data from the sensor signals corresponding to each activity phase. The features of these corresponding points were examined, and a method of detecting each activity phase was proposed. Figure 2 shows a typical example of the TUG-T in a normal young healthy subject (mean age, 21.0 ± 2), and Figure 3 shows the flowchart used to detect the phase changes. First, each activity phase was identified from the video images using a stopwatch.

From the perspective of rehabilitation training, the ability to stand up and walk is the most important task leading to the activity. Therefore, these two phases must be identified.

1) *Standing-up phase*: During the sitting phase, the waist pitch angular velocity, which is integrated in the angular velocity per unit time, is determined uniquely. In fact, the angular velocity in the sitting phase should be zero. In the healthy volunteers, the waist pitch angular velocity is almost zero, although a maximum waist pitch angular velocity of 10°/s was observed in a healthy subject. Therefore, the standing-up phase occurs when the output of the waist gyrosensor in the pitch direction exceeds a threshold of 10°/s.
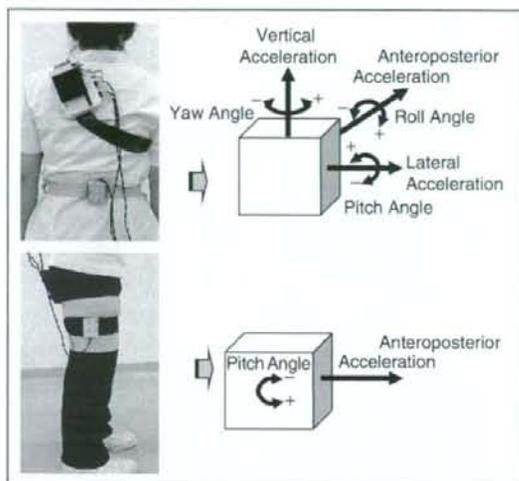

Fig. 1. Sensor unit positions.

Table 1. Subject profiles.

Case	Sex	Age (years)	Paralyzed Side	L/E Br. Stage	Gait Level
1.	Female	66	Right	III	Supervised
2.	Female	51	Right	III	Supervised
3.	Female	82	Right	IV	Supervised
4.	Male	74	Left	IV	Supervised
5.	Male	83	Left	IV	Supervised
6.	Male	65	Right	IV	Supervised
7.	Male	39	Right	III	Supervised
8.	Female	66	Left	IV	Supervised
9.	Female	65	Left	IV	Supervised
10.	Female	62	Right	IV	Supervised
	(Mean age, 65.3 ± 13)				
1.	Female	63	Left	IV	Independent
2.	Female	75	Left	IV	Independent
3.	Male	75	Right	IV	Independent
4.	Female	78	Right	IV	Independent
5.	Male	74	Right	III	Independent
6.	Female	70	Left	V	Independent
7.	Male	57	Right	IV	Independent
8.	Male	70	Right	IV	Independent
9.	Male	74	Left	IV	Independent
10.	Female	76	Left	IV	Independent
	(Mean age, 71.2 ± 6)				

Similarly, the start of the sit-down phase is when the pitch angle is below 10°/s.

2) *Walking phase*: This phase is defined as the first instance when the output of the lower limb gyrosensor in the pitch direction exceeds the threshold Th_w, which equals 10°/s. In fact, the zero-crossing time (the time when the readout is no longer zero) is sufficient to indicate the start of walking. However, to eliminate the effects of the subject swaying and swinging, the value of 10°/s instead of the zero-crossing time was used.

3) *Turning phases*: For turning, the turns while walking (turn 1, t_1) and for sitting down (turn 2, t_2) were identified by a large angular velocity signal in the yaw direction from the waist sensor. To obtain t_1 and t_2, the yaw direction angular velocity signal was processed by applying low-pass filtering using second-order Butterworth filters with a cutoff frequency equal to the walking cadence.

To obtain T_{max}, the time when the yaw direction at the waist is the maximum, and ω_{max}, the maximum value of the yaw direction, β as 35% of ω_{max} was first determined empirically. When the angular velocity exceeded $\omega_{max} \times \beta$, this gave the duration of t_1 (the blue line in Figure 2). Furthermore, the value of $\omega_{max} \times \beta$, which is one step before and after the time of $\omega_{max}(T_{max})$, was considered. When the angular velocity exceeded $\omega_{max} \times \beta$ within $T_{max} \pm \alpha$, these periods (the green line in Figure 2) was added to the duration of t_1 (red line).

The duration of turn 2 (t_2) was obtained in a similar manner. Both made use of the necessary assumptions that turn 1 occurs not long after the start of the walking phase, and turn 2 takes place before the sitting-down phase.

4) *Sitting-down phase*: The sitting-down phase begins at the end of turn 2 and ends when the output of the waist gyrosensor in the pitch direction falls below the threshold Th_s.

When the proposed method was applied to hemiplegic patients, it was taken into account that the movement of both legs during walking is not symmetrical. Therefore, the value of α was set to double the period of one step by a healthy volunteer.

These parameters were uniquely determined from the healthy subjects. The maximum error was included in the proposed assumptions.

Clinical Application of the Proposed Method

The subjects were 20 hemiplegic patients. Ten subjects were able to walk independently, whereas the other ten could only walk under supervision. Table 1 shows the details of the subjects. The various activity phases were
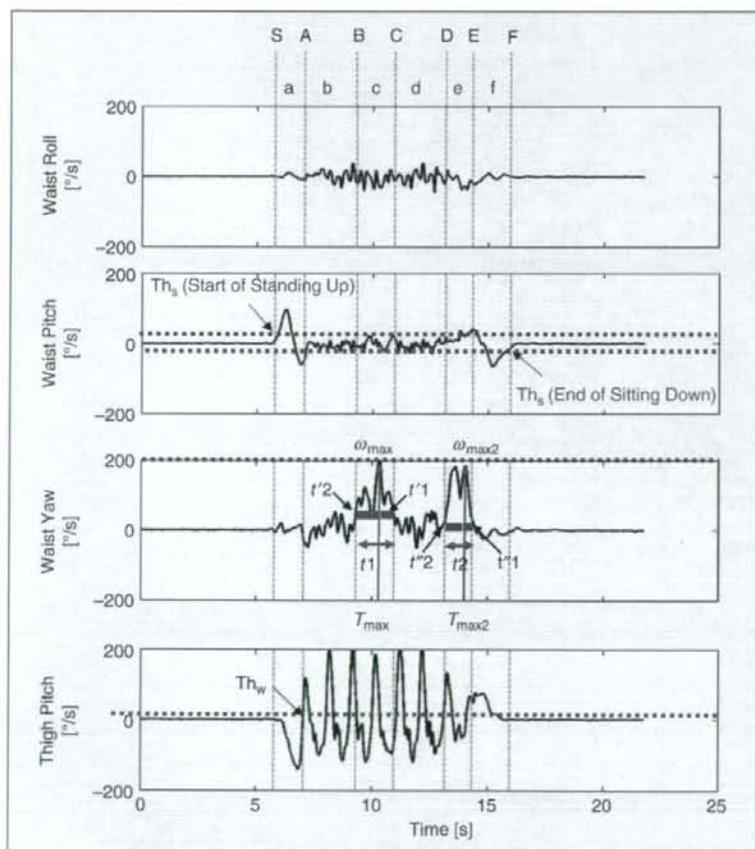

Fig. 2. Typical angular velocities and the points at which the phase changed in a young subject during the TUG-T: (section a) standing up, (section b) walking 1, (section c) turn 1, (section d) walking 2, (section e) turn 2, and (section f) sitting down.

identified, and their durations were obtained from the angular velocities signals during the TUG-T. The data were examined for qualitative differences in walking among subjects, and the independent and supervised walking subjects were compared. The cadence was calculated from the signals for walk 1, turn 1, and walk 2. The root mean square (RMS) value of the acceleration signal, and hence the coefficient of variation (CV), was calculated from the walking cycle. The acceleration signals were compared using these values and the direction of movement. The t-test was used for statistical comparisons, and Bland-Altman plots were used to evaluate the accuracy of our

method. Using this method, the data were compared to the measurements made with a stopwatch while the therapist was watching the VTR.

Results

Correlation Between the Proposed Method and Therapists' Measurements

Figure 4 shows that the activity phases of a typical hemiplegic patient identified using the proposed method was similar to the results with a healthy volunteer. The results using the

Fig. 3. Flowchart used to detect the changes in phase.
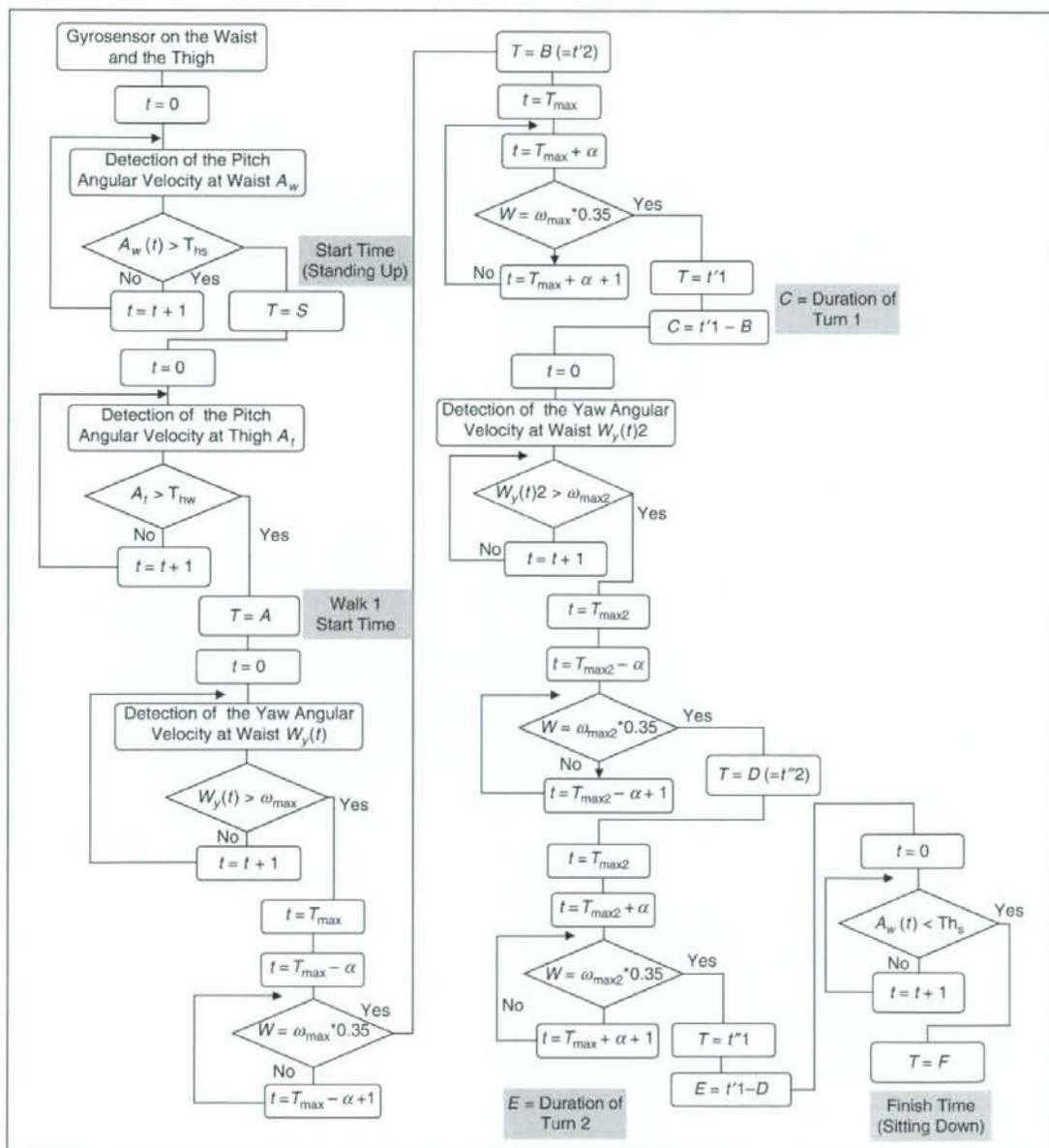
proposed method were strongly correlated with those based on the therapists' observations (Figure 5). Furthermore, most values were included in the Bland-Altman plot within ± 1.96 SD (Figure 6).

One feature of the signal for a hemiplegic patient was that the angular velocities in the roll and pitch directions were large, whereas those in the yaw and lower limb pitch directions were small. The results suggested a good correspondence between the times measured by the therapists and the times estimated using our method.

Clinical Application of the Proposed Method

1) Comparing the total TUG-T time, the supervised group took longer than the independent group ($P < 0.05$; Figure 7).
2) Comparing the duration of each activity phase, the supervised group took longer than the independent group for walks 1 and 2 (walk 1: $P < 0.05$, walk 2: $P < 0.01$), while no significant differences were observed for the other activity phases (Figure 8).
3) Comparing the RMS values of acceleration, the supervised group had lower values than the independent group. Specifically, the RMS value in the lateral and vertical directions was smaller ($P < 0.01$; Figure 9).
4) Comparing the CVs, the supervised group had a higher value than the independent group in the lateral direction ($P < 0.01$; Figure 10).

Fig. 4. Typical angular velocities and the points at which the phase changed in a hemiplegic patient during the TUG-T. (a) Standing up. (b) Walking forward. (c) Turn 1. (d) Walking backward. (e) Turn 2. (f) Sitting down.
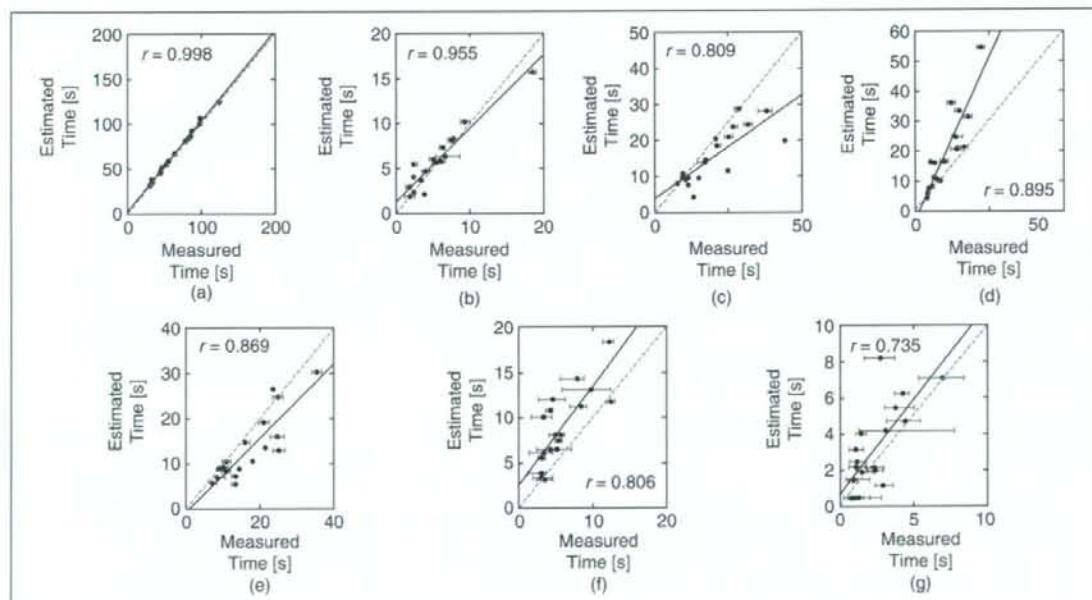
Fig. 5. Comparison of the time measured to hemiplegics by the therapists and that estimated using our method. (a) Total time. (b) Standing up. (c) Walking forward. (d) Turn 1. (e) Walking backward. (f) Turn 2. (g) Sitting down. (The error bar indicates the minimum and maximum values. The solid and broken lines show the regression and identity lines, respectively.)
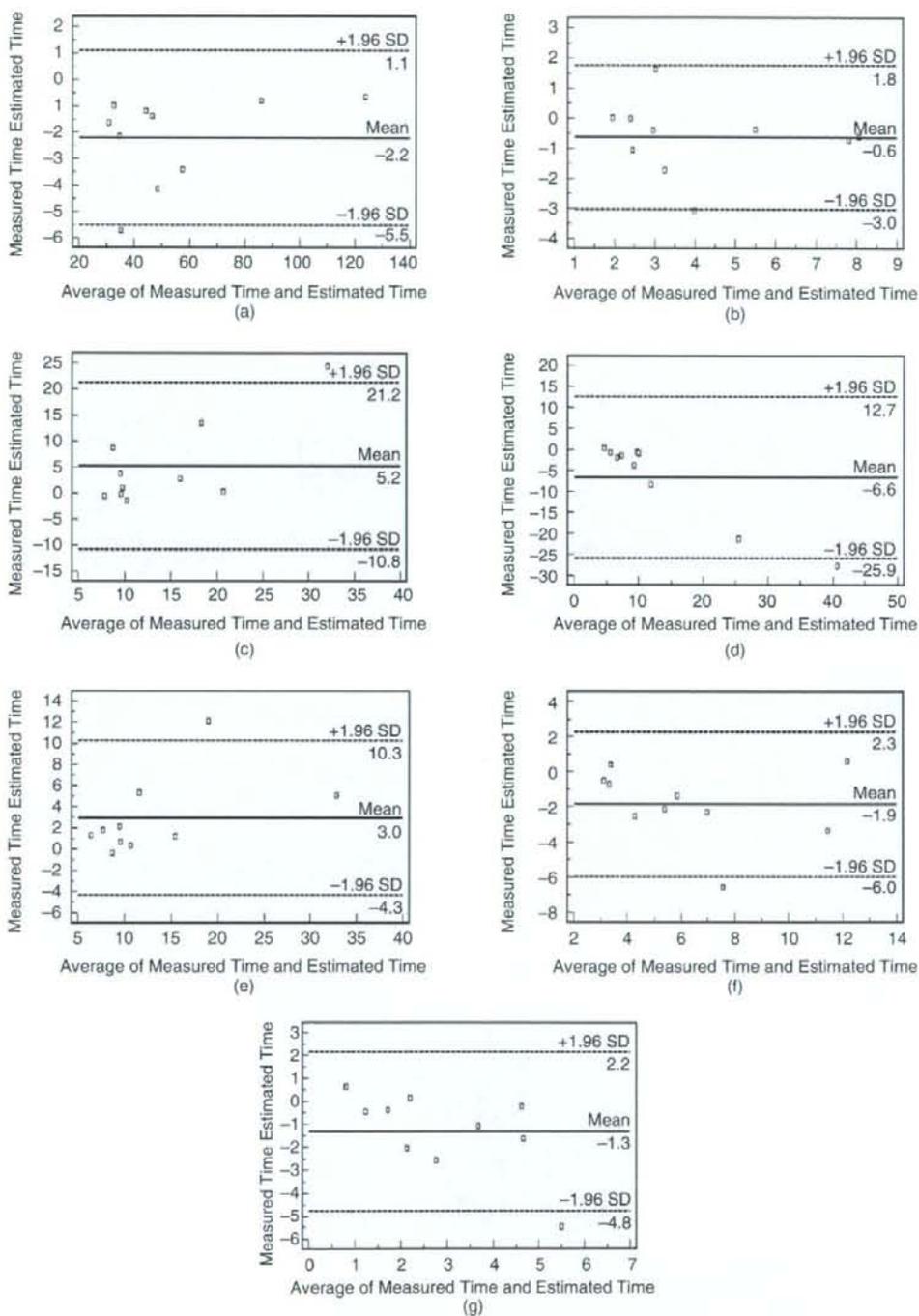
Fig. 6. Comparison of the time measured to hemiplegics by the therapists and that estimated using our method with the Bland-Altman plot. (a) Total time. (b) Standing up. (c) Walking forward. (d) Turn 1. (e) Walking backward. (f) Turn 2. (g) Sitting down.
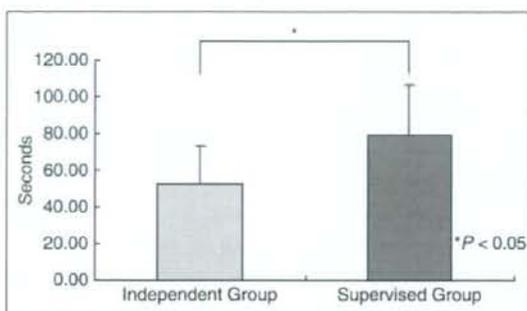
Fig. 7. Comparison of the total times between the independent and supervised groups.
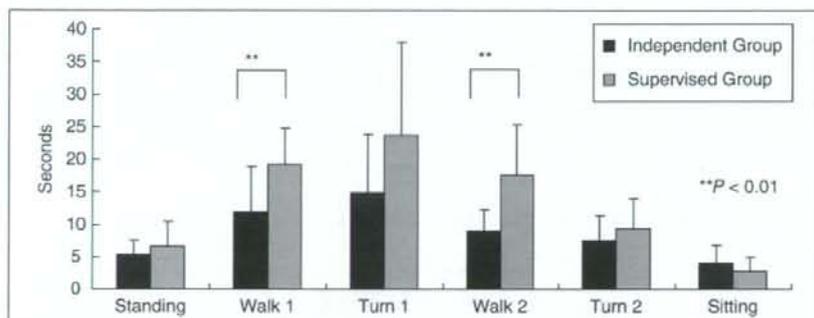

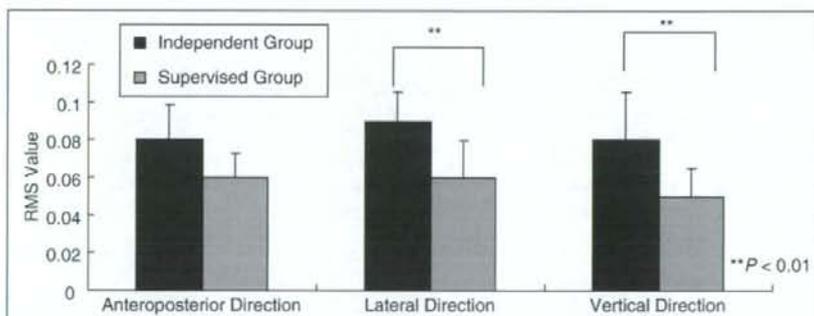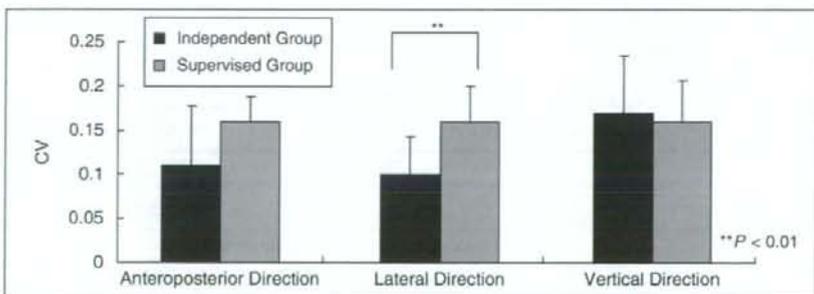**Fig. 8.** Comparison of the time for each activity between the independent and supervised groups.

Fig. 9. Comparison of the RMS value for each direction between the independent and supervised groups.

Fig. 10. Comparison of the CV for each direction between the independent and supervised groups.

5) Looking at typical data for supervised and independent subjects, the RMS value for the supervised subjects varied widely at the beginning of walking after standing up (Figures 11 and 12). Similarly, the RMS value varied widely just before sitting.

Discussion

Activity Identification and the Use of Acceleration and Angular Velocity Measurements

The TUG-T is a convenient first test used in teaching fall prevention. The general practice in current research is to measure the activity time in the TUG-T with a stopwatch. However, the TUG-T consists of several activity phases (i.e., standing up, walking 3 m, turning, and sitting down). To better understand the complete performance, it is necessary to evaluate the consecutive sequence of activities. However, because it is difficult to isolate individual problems within each activity phase in the clinical environment, it becomes necessary to identify each activity phase and evaluate each individually.

The Method Used to Detect the Activity Phases in the TUG-T

The start of the standing-up phase could be detected using the waist gyrosensor signal in the pitch direction. Generally, at the time of standing up, a hemiplegic patient shifts his or her trunk by inclining forward markedly, shifting the center of gravity forward to counter the weakness of the lower limbs. The measurement of the pitch angular velocity of the waist was excellent for detecting this forward inclination. The activity of sitting down is similar to, but opposite, that of standing up.

The start of the walking phase immediately after the standing-up phase could be detected from the pitch direction signal of the lower limb angular velocity sensor. Several methods for evaluating walking quantitatively have been used; e.g., electric goniometers, force plates, and impact acceleration [12]–[14]. However, to identify walking as one of a consecutive series of activities, we obtained

excellent results from the pitch angular velocity signal of the lower limb.

The identification of the turning phase from the waist yaw direction angular velocity using the proposed method was correlated with the judgment of the therapist. Some features of walking were then considered when hemiplegic patients made turns. For example, hemiplegic patients turn slowly because the radius of gyration is widened to prevent falls. Another feature of walking in hemiplegic patients is the reduced step length to confer stability. This is evident from the small signal of the lower limb pitch direction angular velocities. A small signal for the yaw direction angular velocity showed rotation of the waist, and the signal for the waist roll direction angular velocity had a large amplitude, reflecting the compensational reaction of the waist in the lateral direction while drawing in the lower extremity.

In addition, the signal of the waist pitch direction angular velocity had a large amplitude. This reflects the left-right asymmetry in walking because of the paralysis. Our results showed

Fig. 11. Typical RMS value in a supervised case.

Fig. 12. Typical RMS value in an independent case.

that the signal information from the gyrosensors worn during the TUG-T can be used to identify the individual activity phases. Our results from the accelerometer can also be used to analyze the activity effectively. In the near future, we should be able to analyze the consecutive activity phases.

Correlation Between the Proposed Method and Therapists' Measurements

In this study, the length of each activity phase identified using the proposed method was compared with the times measured by the therapist. A high positive correlation was observed between the two, but the error margin for the turn was large among the therapists. Usually, it is easy to identify the activity from a video recording of the frontal and sagittal planes, but to identify the beginning and end of a turn, a video recording of the horizontal plane is necessary. However, it was difficult to cover all angles in the video recording. This explained the comparatively large error margin in the durations of walks 1 and 2, which occur immediately before and after the turn, respectively. The durations of walks 1 and 2 determined using our method tended to be shorter than those determined by the therapists, whereas the duration of the turn between walks 1 and 2 tended to be longer. Therefore, the error margin of both the sensor-derived results and human perception should be considered.

Clinical Application of the Proposed Method

1) Comparing the total TUG-T time, the supervised group took longer than the independent group in walks 1 and 2, but not for the other phases.
2) Comparing the RMS values, the supervised group had lower values than the independent group because the walking velocities of the independent group were greater.
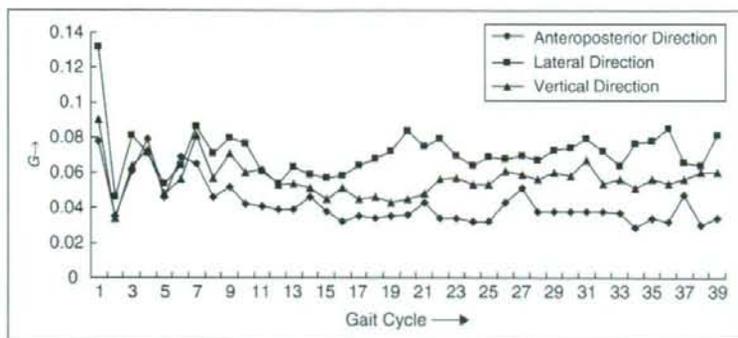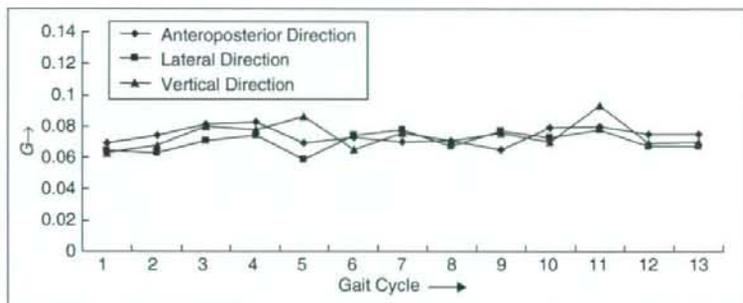
3) The RMS of the acceleration for the supervised group in the lateral direction was smaller because during steady walking, their step length decreases, reducing the vertical movement. Their stride width also decreases, reducing lateral movement. The combination of these two factors prolongs the walking phase.
4) Comparing the CV, the supervised group had a higher value than the independent group in the lateral direction because of less constancy in the stride width.
5) Comparing the data from different subjects, the RMS value varied widely at the beginning of walking after standing up. Similarly, the RMS value varied widely just before sitting because the subject is not steady while walking.

Conclusions

In this study, the combined use of an accelerometer and rate gyrosensor to identify the activity phases of the TUG-T was proposed. For the comparison, trained therapists measured the duration of each activity phase from a video recording. As a result, the proposed identification of the activity phases was well correlated with the therapists' observations. By using both the accelerometer and gyrosensor signals, it was possible to detect the activity phases, which were similar to those observed by the therapists. In addition, the walking activity was extracted from the TUG-T, and the RMS value and CV from the acceleration were calculated in every walking cycle. A qualitative difference between the subjects who could walk independently and those requiring supervision was revealed.

It is currently believed that the TUG-T performance is correlated with the risk of falling. By identifying each activity phase in detail, it is possible to evaluate both the activity from beginning to end (standing up → sitting) and the switches

between activity phases (walking → turn → walking). Detailed information was obtained for each activity phase so that the evaluation of the consecutive sequence of activity phases could be realized.

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研究速報

高齢者に対応した歩数カウントアルゴリズムの開発

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Development of a Step Count Algorithm for the Elderly

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Toshiro FUJIMOTO,[**] Yoshitake OSHIMA,[***] Toshikazu SHIGA[***]

Abstract　　Step counters are popular for quantifying walking. However, they may not measure the number of steps taken by elderly persons. In this study, we proposed a step count algorithm based on a filter bank and threshold processing to improve the accuracy of an accelerometer-type step counter for elderly persons. The accuracy of the proposed algorithm was compared with the observed steps taken during walking. The waist acceleration signals during self-paced walking were recorded for 74 attendees (age 82.7 ± 8.6 yr, height 148.1 ± 7.6 cm, weight 52.3 ± 7.8 kg) participating in gait training at a rehabilitation services center using a triaxial accelerometer. The participants walked approximately 20 m (10 m in each direction and a turning arc). After seven different band-pass filters were applied to the magnitude of the acceleration vector, a signal related to the step cycle was selected from the outputs of those filters. Then, the number of steps was estimated from this signal using a predetermined threshold. The percent error was calculated as (estimated steps − observed steps)/observed steps × 100. On verifying the algorithm using the data for the 74 elderly subjects, the steps taken by 57 (77.0%) were estimated with less than 10% error. We suggest that our step count algorithm is suitable for estimating the number of steps taken by elderly persons.

Keywords: step counter, acceleration, step count algorithm.

1. は じ め に

今日, 日々の身体活動量の低下が血栓症や糖尿病, 高血圧症, 肥満等のような生活習慣病の危険要因となることはよく知られている. また, 身体活動量の増加に伴う効果として, 虚血性心疾患のリスクの減少, 降圧, 糖代謝改善, 骨粗しょう症の予防などが報告されている[1-3]. 脳卒中片麻痺患者などの身体障害者においても活動量の低下による体力低下が指摘されており, 獲得した機能を維持・増進する上で日々の身体活動が重要であるとの報告もある[4].

歩行は, 特別な用具や場所を必要とせず, また身体への無理な負担がなく, 安全性にも優れているため身体活動量を増加させる運動として注目されている. 厚生労働省は 1 日の歩数と血圧, HDL コレステロール (善玉コレステロール)との関係を調査している[5]. この国民栄養調査によれば, よく歩いている人ほど血圧は低く, 善玉コレステロールが多いという結果が得られている.

歩数を客観的かつ手軽に把握する機器として, 歩数計が広く用いられている. 近年では, Micro Electro Mechanical Systems (MEMS) 技術の向上とともに多軸の感度をもつ加速度センサを内蔵した歩数計も市販されている. しかし, このような歩数計をもってしても, 筋力の低下にともない歩行速度が減少した高齢者や, 片麻痺などの運動障害をもち歩行リズムの不規則な高齢者の歩数をカウントすると, 正しい値が得られないことが見受けられる[6-8]. Cyarto らの研究結果によれば, Yamax 歩数計を用い老人福祉センターを利用する高齢者を対象に通常歩行時の歩数をカウントしたところ, 55%の誤差が観測されている[6]. この問題に対して, これまでの先行研究では得られた加速度を 4 秒間ごとにフーリエ変換し, パワーが最大となる周

波数からその区間の歩数を推定する歩数カウントアルゴリズムを提案し，49名中40名（81.6％）の高齢者に対して誤差±10％未満で歩数をカウントしている[9]．しかしながら，この手法は加速度信号を窓（4秒間）ごとにフーリエ変換する必要があり，窓内で周期が変化した場合に歩数カウントの誤差の原因となる．

　そこで，本研究では先行研究の経験をもとに，フィルタバンクと閾値処理を用いて加速度波形の変化を考慮した歩数カウントアルゴリズムを提案し，本アルゴリズムの高齢者への対応についてオフラインによりコンピュータ上で検証した．

2. 実 験 方 法

2・1 歩数カウントアルゴリズム

　提案する歩数カウントアルゴリズムは，3軸加速度信号の合成，7つの周波数帯域にフィルタリング，適切なフィルタ出力の選択，閾値処理による歩数のカウントという要素を含む．本アルゴリズムでは，まず測定により得られた3軸方向の加速度から加速度ベクトルの大きさを算出する．これはベクトルの大きさは取り付け角度に依存しないため，歩数計の向きにある程度の自由度をもたせることができると期待したためである．次に，加速度ベクトルの大きさをフィルタバンクにより7つの周波数帯域に分離する．各バンドパスフィルタの周波数帯域は $0.5 \sim 1.0$ Hz，$1.0 \sim 1.5$ Hz，$1.5 \sim 2.0$ Hz，$2.0 \sim 2.5$ Hz，さらに各周波数帯域の間の $0.75 \sim 1.25$ Hz，$1.25 \sim 1.75$ Hz，$1.75 \sim 2.25$ Hz に設定し，各フィルタからの出力は概ね単一の周波数成分のみをもつ波形となるようにした．なお，各バンドパスフィルタは1次のバターワースフィルタとした．これら7つのフィルタ出力を時刻毎に比較し，歩数カウントに最適なものを随時選択する．フィルタ出力の比較は，それぞれのフィルタ出力を全波整流し，カットオフ周波数 0.1 Hz の1次のバターワース型ローパスフィルタを通した波形で行い，振幅が最大となるものを選択した．この選択された歩数カウント用波形が閾値以上となる点を1歩としてカウントした．なお，歩数カウントの際の閾値は予備実験の結果を踏まえ 0.01 g とした．図1に，模擬波形に対するフィルタ出力とフィルタ出力の選択，歩数カウント用波形を示す．ただし，図1は3つのバンドパスフィルタ（フィルタ帯域 $1.0 \sim 2.0$ Hz，$2.0 \sim 3.0$ Hz，$3.0 \sim 4.0$ Hz）を用いた場合の例である．まず，加速度ベクトルの大きさを模擬した波形を図1(a)に示す．この模擬波形に対するフィルタ出力はそれぞれ図1(b)のようになる．フィルタ出力の大きさを比較するためそれぞれの信号を全波整流し，ローパスフィルタを適用し平滑化した結果，図1(c)のような波形が得られ，振幅が最大となるバンドパスフィルタを選択すると図1(d)となる．図1(c)では，模擬波形の周期にあわせて，$0 \sim 2$ 秒までは $1.0 \sim 2.0$ Hz，$2 \sim 4$ 秒までは $2.0 \sim 3.0$ Hz，
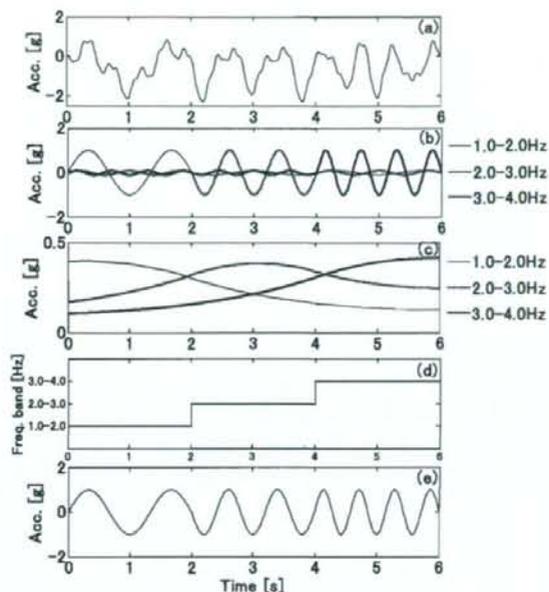
図1 フィルタリング課程：模擬信号（a），バンドパスフィルタリング後の信号（b），ローパスフィルタ後の信号（c），選択した周波数帯域（d），歩数カウントに用いる波形（e）

Fig. 1 Filtering process: a dummy signal (a), the band-pass filtered signals (b), the low-pass filtered signals (c), the frequency band of selected filter (d), the synthesized signal from the filtering signals for step count (e).
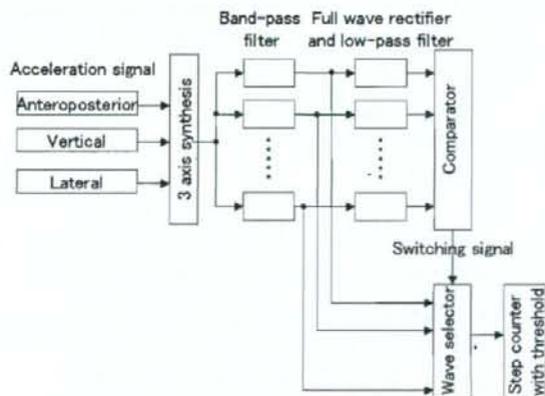

図2 歩数カウントアルゴリズムのブロックダイアグラム
Fig. 2 Block diagram of the step count algorithm.

$4 \sim 6$ 秒までは $3.0 \sim 4.0$ Hz の周波数帯域を選択している．最終的に，各時刻において選択されたバンドパスフィルタの出力波形をつなぎ合わせた歩数カウント用波形は図1(e)のようになる．この歩数カウントアルゴリズムのブロックダイアグラムを図2に示す．今回の実験では実際には回路は作成せず，MATLAB（version7.0，Math Works，MA）によりシミュレーションおよび解析を行った．