表4　福祉用具売り上げの推移

	福祉用具(狭義)	家庭用治療器	義肢装具	パーソナルケア	移動	家具・建物	コミュニケーション	在宅等介護	その他	福祉施設用	社会参加
1993	7,735	1,021	1,419	1,416	304	400	2,697	414	30	18	16
1994	8,047	1,061	1,592	1,583	325	490	2,497	423	40	22	14
1995	8,655	1,113	1,757	1,758	380	608	2,489	428	50	27	45
1996	9,450	1,236	1,829	1,829	505	765	2,538	438	51	30	45
1997	10,495	1,327	1,958	1,958	594	857	2,826	441	20	31	122
1998	10,766	1,320	2,001	2,001	678	844	3,050	437	38	41	124
1999	11,647	1,279	2,161	2,161	1,004	931	2,900	488	43	44	259
2000	11,599	1,071	2,271	2,271	997	906	2,921	491	34	77	292
2001	11,787	1,062	2,320	2,310	1,104	864	2,988	482	29	63	427
2002	11,919	1,167	2,240	2,240	1,104	874	3,016	500	32	64	447

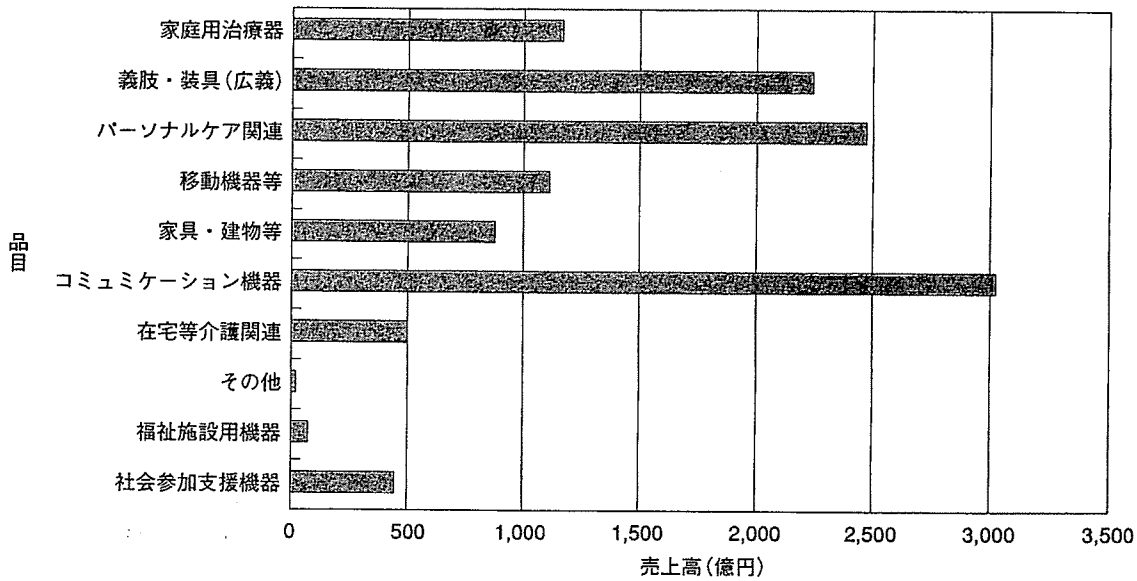

図13　福祉用具売り上げ規模(2002年)

(四)輪車や座席シフト型の乗用車を含めた福祉車両の増加が挙げられる．また，介護保険制度による住宅改修制度が普及したことにより，手すり・握りバーの市場が拡大している．さらに交通バリアフリー法の施行により，交通機関や公共施設におけるバリアフリー化が推奨されていることにより，社会参加支援機器システムが大幅な増加となっている．

一方，介護保険制度の対象品目については，レンタル対象品の「ベッド」や「手動車いす」とともに，「おむつ」や「入浴用品」などのパーソナルケア関連品や「杖・歩行器」などが減少しており，レンタル制度の普及・定着によるものと推測される．

共用品は，例えば温水洗浄便座，専用の福祉機器であったものが一般用途に普及，高齢者でも使いやすいように設計・デザインされた製品，点字を表示したビールなど一般製品をバリアフ

リー化した製品などをいうが，前年度とさほど変化はない．出荷額が増加した品目は「映像機器」，「住宅設備」となっている．情報通信機器は携帯電話に需要が移行し，固定電話機が減少している．

これらの調査の中で，安全性，品質などについての調査では，2001年の調査で「ISOやJIS，SGなどの基準・規格に準拠している」のが27.4%，「ISOやJIS，SGなどの基準・規格に準拠した自社基準・規格を作成している」のが11.2%，「自社独自の基準・規格を作成している」が25.1%で無回答を含む残りが，特に準拠していないという回答であった．基準準拠の方法については，自社で設置した試験施設や機関で行っているものが多く，第三者の評価機関に委託しているは1/4弱であった．基準準拠しない理由としては，必要性を感じていないが約3割，基準(規格)の存在を知らないが約3割，該当製品の基準・規格が公表されていないが2割を占め，機器開発の安全性については，PL法との関連もあり，経済産業省，厚生労働省で早期の対策が図られることを期待する．

おわりに

高度技術を背景とした高齢社会においては，可能な限り，身体的あるいは情報弱者としての高齢者・障害者を支援し，介護・自立・就労など前向きの人生を支えることが重要であり，さらに元気な高齢者を含むすべての年齢層の人たちが，積極的で健康な生活を享受し，幸福な人間関係を維持することができる活気ある社会を形成することが望まれる．看護・介護機器がこのような背景で開発されることが望まれる．第Ⅰ章以降，個別の看護・介護支援機器の現状と今後の展望について解説を加えていく．

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2．情報機器

はじめに

わが国では，高齢社会と情報社会がほぼ同時に到来し，社会システムが大きく変革しようとしている．日常生活，在宅医療など様々な場面で，高齢者および看護・介護者は何らかの支援を必要としており，その充実は急務である．

一方，社会の情報化により，大量の情報が高速に伝達されることが可能になり，公共サービスなどを在宅で受けることが可能となるとされている．このような状況下で，情報通信技術(IT)を積極的に利用し，高齢者の生活支援を行う試みがなされている(図1)[1]．しかしながら，必ずしもすべての高齢者が情報通信機器を使いこなすことができるわけではない．そのため，情報通信機器を使える人と使えない人の間に格差(情報格差)が生じ，すべての人が均一なサービスを受けられない危険性が指摘されている．現在，情報格差を埋めるべく様々な取り組みがなされている．

本稿では，情報通信を支える基盤技術，利用者の便宜を図るインターフェース技術，在宅生活を支援する遠隔医療技術の3つの話題について述べる．

基盤技術

情報社会を支える基盤として，情報通信そのものを行う具体的な施設・設備を「情報通信インフラ」と呼ぶ．ほんの10年ほど前まで，情報通信インフラは電話と一部の企業や官庁が有する専用回線しかなかった．当時は，情報通信といってもファックスか，パソコン通信と呼ばれる電話回線を利用した通信が可能なだけであり，伝達が可能な情報の量にも限界があった．

ところが，最近，インターネットの爆発的な普及により技術革新が大幅に進み，光ファイバーなどを用いた高速な通信網(ブロードバンド)により大量の情報が容易に伝達可能となった．わが国では，これまでブロードバンドの普及が遅れていたが，電話回線を利用した新しい通信技術であるADSLと呼ばれる仕組みにより，急激に利用者が増加している．さらに，IT基本法と呼ばれる法律に基づく国の基本政策「e-Japan戦略」[2]により，医療・生活・行政サービスなど7つの分野における先導的情報化と情報インフラの整備が進んでいる．同時に携帯電話の加入者数は2004年3月の時点で約8,000万件[3]と少なくとも国民の2人に1人は携帯電話を持っていることになり，こちらも急激に利用者を増やしている．

このように，ほぼ社会全体に行きわたった感のある情報通信インフラであるが，必ずしもすべての人々が有効に利用しているとはいいがたい．また，その利用料は10年前の半額から10分の1と極端に安価になっているが，機器の購入や設定などを考えると初期投資には数万円を要するため，収入の少ない高齢者には負担となることも少なくない．もちろん，インターネットに興味のある高齢者も少なくなく，電子メールの普及率もかなりの水準に達していると推測されるが，電話やテレビ・ラジオほどには普及していないし，利用のために積極的な意志を必要としていることには変わりがない．このよう

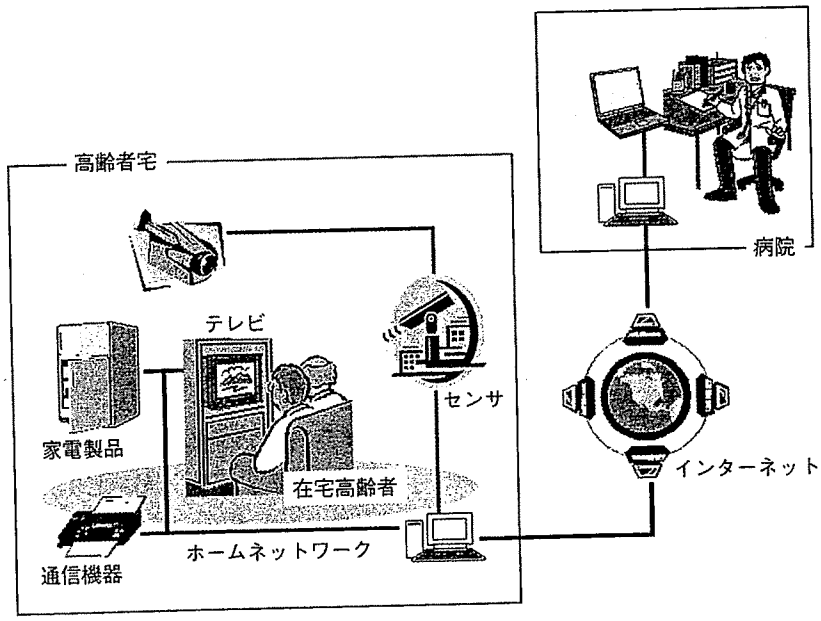

図1　情報ネットワークを用いた高齢者生活支援システム

に，ほぼ基本的な整備が完了した情報通信インフラをいかに利用し，高齢者の生活支援に寄与させるかが今後の課題である．

さらに最近，ユビキタスコンピューティング(ユビキタス：普遍的な，どこにでもある)[4]という新しい概念が登場し，話題となっている．これは，パソコンなどのコンピュータのみならず，家電製品，腕時計などの携行品，ひいては食料品や人間そのものにまで通信機能を付与し，いつでもどこでも情報通信ネットワークへのアクセスを可能とする技術である．

このように，情報通信インフラの充実という点では，いつでもどこでも情報通信技術の利用が可能な状況が実現しつつある．ところが行政サービスの効率化などにより，情報通信機器の利用ができないと重要な情報を得られない可能性も存在する．すなわち，情報通信インフラの整備が完了しても，すべての利用者がその恩恵を直ちに受けられるというわけではない．この問題を解決しない限り，情報通信技術を利用した高齢者支援システムは完成しない．

インターフェース技術

人が情報通信機器を利用するためには，パソコン・携帯電話やそれらに付属する端末と呼ばれる何らかの入出力装置を使用する必要がある．これは，人・コンピュータ双方が互いの利用する言語を解さないためであり，人とコンピュータの間を取り持つ仕組み，すなわちインターフェースが必要とされるためである．現在このインターフェースとして，一般的に利用されているのは入力側がキーボード，出力側がパソコンのモニタや携帯電話の液晶画面のような画像提示装置である．日本ではタイプライターが一般に普及することがなかったため，キーボードに対する抵抗感が強く，アレルギーなどにたとえられることさえある．若年者にあっては，携帯電話の普及により，携帯電話の12個のキーにより文字を入力する方法に親近感をもつ場合があるようではあるが，キーの大きさなどを考えると決して高齢者が利用しやすいものではない．

われわれの調査によれば，高齢者の一部には銀行などの現金預払機(ATM)や切符自動販売機などの利用も忌避する傾向があり[5]，現在一

般化しているインターフェースが必ずしも良いものであるとは限らない．そのため，音声・身振り・視線など様々な方法によりコンピュータに情報を入力する仕組みが研究されている[6]．これらは，実用的なレベルに到達しつつあり，音声入力システムは，パソコンのシステムの一部として，視線による入力装置は障害者用の入力装置などに組み込まれて市販されている．

とはいえ，これらは特殊な入力装置の使用や，一定の条件下での使用を前提としており，日常生活中に環境を問わずに利用するためには改良の余地がある．例えば，音声入力は，どのような話し方をしても言葉を認識するというわけではなく，雑音が多い環境下では誤認識される可能性が高い．一方，表示装置としては，現在利用されている画像提示装置は十分有効であるが，色遣いや文字の大きさなど，高齢者の視覚機能に関わる部分が情報を提供する側に任されているため，場合によっては高齢者には見づらいものとなることがある．このため，視覚機能に障害を有する利用者にも利用可能なように，一定の規範が存在するが[7]，すべての情報でこれが守られているとはいいがたい．また，携帯電話などの携帯端末の画像提示装置はもともと画面や文字が小さく高齢者の利用には適していない場合がある．今後，高齢者の利用を前提とした機器の開発が期待されている．

高齢者の生活支援のために，日常生活中で情報機器が活用されるためには，高齢者の身体機能を考慮した利用の容易なシステムとすることのみならず，利用者のモチベーションを向上するような仕組みが必要になると考える．現在提案されているシステムとして，愛玩用のぬいぐるみや人形などに音声入出力機能を組み込むことによりこれを端末とするシステムや，留守番などの機能を実装したロボットに同様の機能を組み込んだシステムがある[8]．これらのシステムは単に情報端末ではなく，独居の高齢者には話し相手としての役目もあり，積極的に利用されることが期待される．

遠隔医療技術

従来遠隔医療技術は，病院と病院を連携し，高度な医療を均一に提供する目的で開発され発展してきた．特に遠隔地の専門医による診断や地域医療機関の連携，電子カルテシステムは現在の医療では必要不可欠である．さらに，遠隔手術支援や手術ロボットを用いた遠隔手術なども，実用化されつつある．このように遠隔医療技術は医療の高度化・均一化に大きく貢献している．高齢者医療の臨床では，慢性疾患に対する日常的な病態管理，通院の手間の軽減，健康の維持管理など，様々な目的で実施される在宅医療の基幹システムとして必要不可欠なものとなっている．特に高齢者の疾患は，慢性疾患であることが多く，在宅での療養が求められることも多い．また，通院にかかる体力的な負担も少なくない．さらに，高齢化率の高い山間部などにあっては，往診に要する時間も長くかかるため，問診や相談程度の診断の場合は，電話による聞き取りが双方の負担を軽減するために有効な手段である．一部の医療機関では，テレビ電話を利用した遠隔医療システムの実証実験なども実施されている[9]．

在宅高齢者向けの遠隔医療システムでは，治療行為は困難であるため診断が主たる目的となる．これらのシステムでは，日常的に身体機能に関わる情報，例えば体温，心拍，血圧などの生理量から，起床，摂食，排泄，就寝など，日常生活行動の情報など様々な情報を獲得し伝送する必要がある．また対面診断のためには顔画像の伝送なども必要である．

これらの情報を獲得するためには，患者宅にセンサやカメラなどを実装する必要がある．この際，最も問題となるのは，プライバシーであり，情報獲得および伝送の際に，患者が望まない情報が外部に漏洩しないよう最大限の努力が払われなければならない．そのため，通信の際には伝送データを暗号化し，悪意の第三者による盗聴が非常に不可能なようにしている．また，これらの装置は，日常生活に積極的に介入する機能を有するがゆえに，患者の日常生活を妨げ

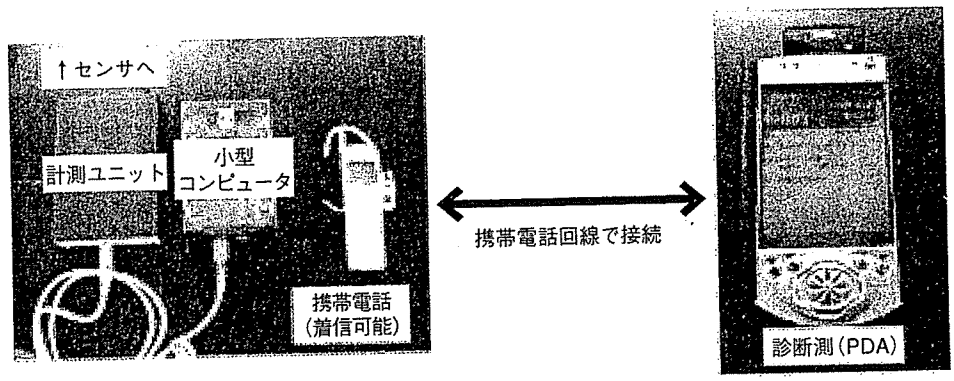

図2　高齢者生活支援システムのプロトタイプ

るものであってはならない．したがって，患者がその存在を意識せず利用可能でかつ患者を拘束しないものであることが理想である．この条件を踏まえ，在宅患者の日常生活中のデータを連続して獲得可能なシステムが開発され一部は実用化されている．特に最新のシステムではパソコンを利用しないシステムも開発されている(図2)[10]．

しかしながら，このようなシステムの運用において，初期投資の費用と運用に付随する通信費などの経費を誰が負担するかという問題が生ずる．特に，疾患を有する患者ではなく，在宅高齢者の健康管理システムでは，健康な時点での投資が必要であり，現在の健康保険の枠組みでは対応不可能である．ゆくゆくはこのような予防医学的なシステムの運用にも，社会保障の枠組みが適用されることが望まれる．またこのような予防医学的システムは重篤な疾患の予防に有効であり，社会保障費全体の低減に寄与することが期待される．

おわりに

さて，このような在宅高齢者生活支援を目的とした情報システムは日常的に患者の生体情報を計測・蓄積し，長期的なデータの変動を検知して疾病の兆候を検出し，利用者に病院での検査を促す機能と，転倒や急性の疾患を検出し，緊急通報を行う機能が必要である．現在実用化されているシステムでは，このような異常検出については，医師や看護師による主観的な評価に頼らざるを得ない．しかしながら評価可能な利用者の人数には限界があり，評価者として業務に従事可能な医療従事者の人数にも限界がある．

いずれにしても，医療従事者による対応には費用の面での負担が大きい．この問題を解決するには，人工知能などの情報技術を導入し，自動的に健康状態の異常を検出するシステムの確立が必要不可欠である．現在いくつかの試みが行われており，近い将来実用化されることが期待されている．

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From Smart Homes to Smart Care
S. Giroux and H. Pigot (Eds.)
IOS Press, 2005

An Easily Installable Wireless Monitoring System for Ordinary Houses

Sosuke Tsukamoto [a,1], Hiroshi Hoshino [a] and Toshiyo Tamura [b]
[a] *School of Science and Engineering, Tokyo Denki University, Japan*
[b] *Faculty of Engineering, Chiba University, Japan*

Abstract. This paper describes a behavioural monitoring system for ordinary houses. The system employs a device that uses weak radio waves for transmitting obtained data and was designed to be installable without any technical knowledge on part of the user or extra constructions. An ad-hoc network in the house is important in case of an emergency or a sudden illness. The ease of installability of the system is also important. Therefore, a simple experiment was performed to assess the installability, and the system was determined to be easily installable by clients.

Keywords. Behavioural monitoring, weak radio wave, simple installation and removal

Introduction

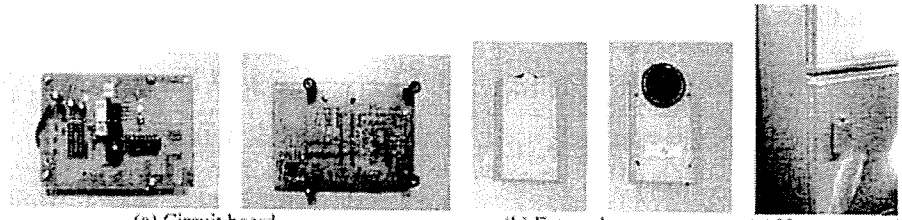
Preventive medicine is one of the types of health care for the aged. Obtaining and utilizing biomedical or behavioural information appear to be effective for maintaining and improving the quality of life [1–4]. However, most behavioural monitoring systems are installed when a house is newly built or is reconstructed. For the aged society, we sometimes need to install such systems in case of an illness or emergency. Therefore, we need an ad-hoc home network, i.e. the system should be easy to install and remove [5, 6].

In this study, we built an ad-hoc wireless behavioural monitoring system that is technically similar to the Mote [7]. The measuring unit was designed to be usable after merely installing it or attaching it to appliances. The installability of the system by clients was evaluated by means of a simple experiment.

1. System Structure and Apparatus

The system has at least one data storage terminal (master server) and many measuring units. The units automatically sample sensors' outputs and transmit the obtained data to the server by radio. The radio network, i.e. data relay path, is automatically constructed and is modified when a relay failure occurs. Another storage terminal (slave server) can be added to the system; if a unit has no path to the master

[1] Corresponding Author: Department of Electronic and Computer Engineering, Tokyo Denki University, Ishizaka, Hatoyama, Hikigun, Saitama, Japan; E-mail: tsuka@f.dendai.ac.jp.



(a) Circuit board (b) External appearance (c) Usage example

Figure 1. Measuring unit (attachable type)

Table 1. Specifications of the measuring unit.

Item	Specification
Microprocessor/Controller	PIC16F876 (Microchip Technology, Inc.)
Processor Clock	10 MHz
Radio Module	CDC-TR02B (Design Circuit, Inc.)
Radio Frequency	315 MHz
Modulation	Amplitude Shift Keying (Manchester Coding)
Maximum Transfer Rate	115.2 kbps
Unit Weight	~200 g
Size (H × W × D)	100 × 65 × 35 mm

server, it can attempt to send the obtained data to the slave server. The slave server can also be used as a portable data recorder for biomedical monitoring. When there is a relaying path from the slave server to the master server, the former transmits stored data to the latter.

Figure 1 shows the circuit board, the external appearance, and a usage example of the measuring unit developed in this study. Table 1 shows the specifications of the unit. The unit employs a pattern antenna. The maximum transfer rate of 115.2 kbps enables us to handle biomedical information. Two types of units were developed—standard and attachable. The former type is set adjacent to some object and can be used as a proximity sensor, TV sensor, etc. The attachable type can be attached to a specific device such as a microwave oven, refrigerator or washing machine. The size of the measuring unit is almost the same as that of a human hand, and therefore, it is not very small; however, we considered that there is a possibility that the unit may be dropped into a crevice.

2. Experiments

We carried out two types of experiments: an evaluation of the installability by clients and a data transmission test.

We conserved the output power of the radio module in order to (1) keep in accordance with the radio regulation law that strictly restricts the output power of a device that employs weak radio waves and (2) ensure that the output is within the weak radio wave range. The communication distance was checked by the data transmission test.

Table 2. Characteristics of the subjects and experimental results.

Case	*Sex*	*Age*	*T*	N_{TB}	N_A	E_P	E_D
1	F	46	20	10	10	1	0
2	F	47	40	10	10	2	0
3	M	49	20	10	10	3	0
4	M	55	17	10	10	2	0
5	F	51	7	13	13	0	0
6	F	76	11	13	11	1	10

T: time consumed for finishing a task [min], N_{TB}: number of units to be set, N_A: number of units actually set, E_P: positional error, E_D: directional error.

We examined the installability of the system by clients. Six healthy volunteers (two male and four female; average age 54.2 ± 11.2) participated in this study. Their characteristics and the corresponding experimental results are shown in Table 2. A descriptive instruction manual was prepared for describing the types of units (sensors) used for obtaining different types of data as well as the installation procedures of the units; several helpful illustrations were also provided. Prior to the experiment, written informed consents were obtained from all the subjects. We also obtained the arrangement of their rooms and programmed the positioning of the units based on the arrangements. The subjects were requested to install the units at the designated positions (indicated on a map in the manual). The subjects in cases 5 and 6 live together (mother and daughter). In these two cases, the differences in the installation positions were examined on the basis of the difference between the subjects.

3. Results and Discussions

The result of the data transmission test revealed that the maximum range of the wireless network is about 1.5m. This distance is insufficient for practical use. However, it is adequate to test the multi-hop network system. For a practical system, the antenna type and output power should be adjusted so that the transmission range is at least six meters.

Table 2 shows the results of the installability evaluation. T denotes the time consumed for finishing a task; N_{TB}, the number of units to be installed; N_A, the number of units actually installed (including E_P and E_D); E_P, the number of units that were installed at wrong locations (counted only when the intended data was not obtained; the installation position and direction are left to the subjects' discretion) and E_D, the number of units that were placed in wrong directions (equal to E_P, counted only when the intended data was not obtained). The averages are as follows: N_A = 97.4% and E_P = 15%. In cases 1 to 4, the subjects installed almost all units properly. In case 6, two units were not installed and the rest were installed in wrong directions.

In most cases, the installation positioning error (E_P) appears to have been caused by mistakes in the instruction manual. In particular, the TV sensor unit was required to be placed adjacent to the TV screen, but most subjects placed the unit on the floor. In this situation, the unit cannot detect the period for which the TV is used. The descriptions in the manual were written as briefly as possible to reduce the time spent on tasks. In case 6, the position at which a unit was placed was completely different from what was specified in the manual. This type of error may cause data confusion.

The slave server cannot be realized with the Mote because the routing method of XMesh (Crossbow's multi-hop networking protocol) only has *any-to-base* and *base-to-any*.

4. Conclusions

In this study, we designed a wireless behavioural monitoring system with the objective of simple installation and removal. Two types of evaluations—data transmission range and installability—were performed. The data transmission range was determined to be about 1.5 m; therefore, the antenna shape and output power should be optimized for practical use. The result of the installability evaluation revealed that the subjects installed units properly in most cases. Since a particular subject installed all units in wrong directions, the unit (sensor) should not be sensitive to direction. An error in the installation position may cause data confusion; therefore, a method should be developed for inspecting the unit position.

Acknowledgements

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A Smart House for Emergencies in the Elderly

Toshiyo TAMURA[1]
Faculty of Engineering, Chiba University, Japan

Abstract. An automated monitoring system characterised as a smart house and called the Welfare Techno House (WTH) has been designed for home health care to prevent disease and improve the quality of life in the elderly. In this paper, we describe the smart house project in Japan and evaluate its effectiveness. The WTH concept involves a monitoring system for the continuous measurement of physiological parameters. Using this system, we collected physiological data and then analysed the key features of the data with regard to health monitoring. We review the previous 10-year trial of the WTH experimental project and discuss future developments.

Keywords. Smart house, wireless LAN, automatic health care system, ad hoc network

Introduction

Given the increase in elderly people in our society, a need exists for the promotion of new methods of disease prevention using information and communication technology. Consequently, several "smart houses" have been developed worldwide that use applied information technology to measure daily health activity at home. Epidemiological research is also needed to assist in the prevention and identification of diseases such as diabetes and hypertension, but this research requires long-term monitoring [1]. Our proposal is to use a smart house to monitor physiological parameters noninvasively. The ability to monitor physiological and vital signs without attaching sensors and transducers to the body is preferable especially in emergency cases. Thus, fully automated measurements are needed to acquire data in a noninvasive manner and minimise procedures for subjects. An experimental project on noninvasive automatic monitoring of a patient's daily physiological status during bathing, elimination, and sleep was conducted at the Welfare Techno Houses (WTH) in Japan.

In this paper, we present the current home health care technology at the WTH and propose new, simple technology for installation at this facility.

[1] Corresponding Author: Faculty of Engineering, Chiba University, 1-33 Yayoi, Inage, Chiba, Japan; E-mail: tamurat@faculty.chiba-u.jp.

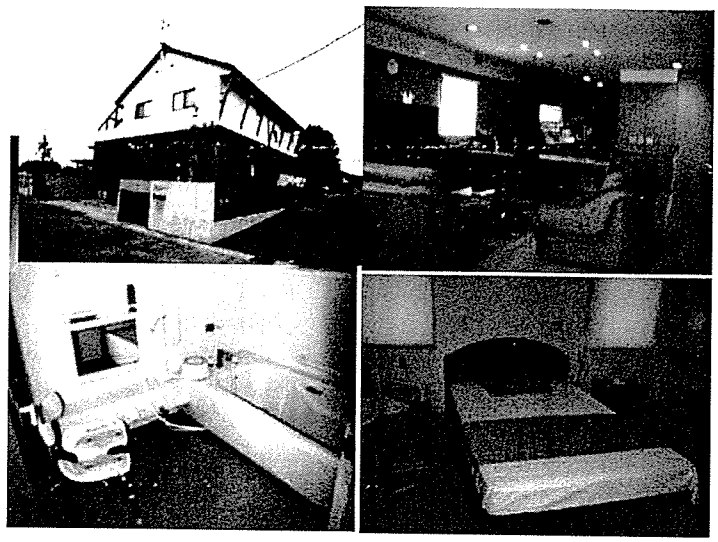

Figure 1. Welfare Techno House in Mizusawa. Overview (top left) of a barrier-free living room with an infrared sensor on the ceiling (top right), bathroom with an electrocardiogram (bottom left), and bed with an electroconductive sheet.

1. Welfare Techno House

1.1. Health monitoring

In 1995, the Japanese Agency of Industrial Science and Technology, under the auspices of the Ministry of International Trade and Industry (MITI), and the New Energy and Technology Development Organizations (NEDO) collaborated to support the construction of 13 demonstration and research houses across Japan, known as WTHs. After a few years, three more houses were built for a total of 16 WTHs. The concept of these experimental houses is to promote independence for elderly and disabled persons and to improve their quality of life. The houses provide the opportunity for clients and caregivers to explore issues concerning accessible design and to participate in trials that enable them to meet their own specific needs; the WTHs are therefore used for testing and exhibiting new products and design concepts. Elderly and disabled people may stay in the houses for several days to try out the facilities. In addition, manufacturers are able to test their equipment, although no accreditation is given based on this use.

The Ministry of Health, Labor, and Welfare supports the integration of information technology with health care. Consequently, we have developed an electronic healthcare system for the WTH.

Three of the 16 houses were built as smart homes. The Mizusawa Techno House (Fig. 1) was designed to accommodate two generations of people as a two-story building with an

area of 400 m^2, which is greater than the average Japanese house. This facility incorporates a range of features that relate to the approach to the house, orientation and movement within the house, and building management. These features are integrated to provide flexibility of use and to meet a variety of individual needs, particularly for elderly who require care. The floor has a cushioning effect and under-floor heating, and a home network system was installed as part of the smart house control and communication network to provide for the control of lighting, curtains, and windows. Furthermore, the security system has a video phone connected to the front door. The future of the Mizusawa Techno house involves the introduction of automatic health care facilities as shown in Fig. 1.

The concept of an automatic health care monitoring system has been published elsewhere [1–5]. For example, automated electrocardiogram (ECG) measurements can be taken while a subject is in the bed or the bathtub without the subject's awareness and without using body surface electrodes. Furthermore, body weight can be monitored by the toilet. To evaluate these automated health monitoring systems, overnight measurements have been performed to monitor the daily health status of both young and elderly subjects [6].

Simple physical sensors, such as pyroelectric sensors and magnetic sensors, have been installed inside rooms, and the number of activations or switches are counted to monitor the movement of subjects [7].

1.2. Data analysis

Several attempts for long-term monitoring and epidemiological study have been performed to evaluate the health effects of the monitoring, and simple histograms have been produced to present the data based on the average activation per unit time [8].

We applied imaging technology to monitor the well-being of occupants. We focused on the use of the television, and the on/off switching time was plotted as shown in Fig. 2. A regular signal output is shown in Fig. 2(a), while an irregular signal output is shown in Fig 2(b). We can evaluate the well-being of a subject with this simple monitor [9]. We were able to detect an irregular condition at an early stage before hospitalisation was required.

2. Further development of smart house projects

Over the last 10 years, our group and colleagues have attempted to create several sensors, such as temperature and optical flow monitors located in the bed, as well as software.

The WTH concept is a valuable contribution to the development of accessible domestic dwellings and the integration of these structures with the information technology infrastructure and daily living products. The WTH technology will facilitate independence and improve the quality of life for elderly and disabled people in Japan. Although few reports have been published on the Japanese smart house project, we have proposed innovative new projects and products; however, only two have been made commercially available (Sekisui and Panasonic, Japan), and the system was not implemented in private homes.

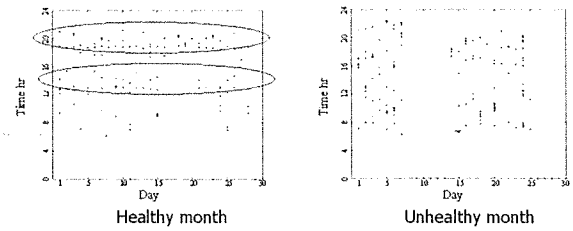

Figure 2. The time course of the TV on/off switch use. The left panel shows data from normal daily life, and the right panel shows an irregular pattern before hospitalisation.[9]

In terms of a business model and integration, the proposed system is very useful for elderly subjects. The clients typically only require this type of monitoring once a week or during an emergency. The questionnaire given to these subjects indicated that continuous monitoring was not required [10]. The proposed system, however, must be refined to meet their needs better.

Issues of privacy and ethics are also critical in this system. The elderly were not comfortable with the idea of continuous monitoring, which seemed to rob them of their privacy.

The main disadvantage of this system is that it must be installed when a house is being built, and the installation is expensive and time-consuming. For emergency cases, such as sudden illness, we will sometimes need to install this type of system in an existing house; therefore, a monitoring system should be easy to install and remove. Furthermore, the system must be evaluated through evidence-based health care (EBHC).

3. Wireless network and wearable sensor

The integration of wireless data communication technologies such as wireless LANs, Bluetooth, ZigBee, MOTE, and other radio frequency systems with a sensor unit for data collection is effective for introducing health monitoring systems into ordinary houses in a short time.

New technology will provide advanced computational capabilities and reliable healthcare monitoring at locations where the number of caregivers and their time are limited and where biomedical analysis-and-decision-making computing devices are urgently needed to assist the medical staff.

The network chip that we are now developing will be deployed as a medical sensor-network for home health care. In this scenario, a patient would have biomedical transducers attached to their body that measure an ECG 1 lead and oxygen saturation in the blood (SpO_2) noninvasively for several days. Different sensors in turn would be connected wirelessly to a wearable network chip that collects different parameters and performs filtering, complex calculations, and analysis of received information to identify the state of the patient. The collected and analysed data will then be transmitted wirelessly (GPRS, 3G) to a hospital where physicians and nurses can follow-up on the patient's condition. The

medical parameters are sent in real time from home appliances and/or medical equipment to the network chip for processing and real-time analysis of large amounts of data. For example, an ECG for heart monitoring may produce megabytes of data by monitoring for only half an hour. Thus, a real-time analysis solution becomes crucial, and the network chip would be used, i.e., for fast complex computations to deliver results within an acceptable period of time, especially in an emergency. In normal monitoring situations (i.e., nonemergencies), the processed and analysed data would be sent from the network chip to the hospital three or four times per day or at a rate based on the individual case.

4. Conclusions

We developed a fully automatic health care monitoring system for use in a WTH that effectively collects physiological data. However, the problem of implementing this system in the real world is difficult to resolve. We are now developing a simple and highly specific health monitoring device to use in the home for evaluating the personal health status and daily activity level without the use of invasive measurements.

Acknowledgements

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Easily Installable Sensor Unit Based on Measuring Radio Wave Leakage from Home Appliances for Behavioural Monitoring

Sosuke TSUKAMOTO [a,1], Yoshinori AKABANE [a], Noriyuki KAMEDA [b], Hiroshi HOSHINO [b] and Toshiyo TAMURA [c]
[a] *School of Science and Engineering, Tokyo Denki University, Japan*
[b] *Graduate School of Science and Engineering, Tokyo Denki University, Japan*
[c] *Faculty of Engineering, Chiba University, Japan*

Abstract. This paper describes a sensor unit used in a behavioural monitoring system for ordinary houses. This unit has been developed to obtain information on the usage of home appliances by measuring the radio waves leaking from these appliances. Since the unit employs a device that uses weak radio waves for transmitting the obtained data, the unit is ready for use by simply attaching it to an appliance. A simple evaluation test revealed the applicability of the sensor unit.

Keywords. Sensor, behavioural monitoring, home appliance, radio wave leakage

Introduction

Preventive medicine is one of the types of health care for the elderly. Obtaining continuous physiological information will be useful for health care since quantitative information is very important for physicians in order to make a diagnosis and suggest treatments. Furthermore, due to an increase in the elderly population, the investigation of preventive and epidemiological medicine is important to reduce the costs incurred in medical insurance and health care. Because of the large medical costs incurred due to a large number of patients, the reduction in medical costs is a crucial issue.

Recently, behavioural information has been shown to be effective for maintaining and improving the quality of life [1–8]. It is known that both the physical and mental conditions of elderly people are reflected in their behaviour. The elderly are somewhat conservative and their day-to-day activities do not differ significantly; these activities may include preparing food and watching TV regularly. This pattern will be different when they are not healthy [8]. Many behavioural monitoring systems have been developed thus far. However, these systems consist of many physical sensors such as drawer sensors and movement sensors, and wiring is required to connect these sensors with a computer that stores their status. Therefore, most of these systems are installed when a house is being newly built or reconstructed. In reality, the installation is

[1]Corresponding Author: Department of Electronic and Computer Engineering, School of Science and Engineering, Tokyo Denki University, Ishizaka, Hatoyama, Hikigun, Saitama, Japan; E-mail: tsuka@ieee.org.

expensive and time-consuming. For the elderly who live alone, we sometimes need to install such systems in their houses in case of sudden illnesses or emergencies. Therefore, such a system should be easy to install and remove [6, 7]. Recently, a behavioural monitoring system based on radio-frequency identification (RFID) was proposed as one of the low-cost and easily installable monitoring systems. The generality and the applicability of the system are remarkable; however, it is difficult to analyse the obtained data since the target and number of the attached RFID tags are different for each subject and a generalized analysis method has not yet been designed.

Recent studies have revealed that the usage statistics of home appliances, which fall under behavioural information, are useful for estimating the health conditions of the elderly by evaluating their daily activities [5, 8]. For the detection of the usage of home appliances, an electric current detector is used; this monitors the total amount of electric power in the power plug. Ideally, the integration of wireless data communication technologies such as wireless LANs, Bluetooth, ZigBee and other RF systems with the sensor unit for data collection is effective for introducing such systems in ordinary houses in a short time. Unfortunately, no studies have been performed thus far to monitor and transmit physiological parameters. Furthermore, since the electric current detector requires access to a power plug, some of the advantages of a wireless system will be lost. The design of both the monitoring system and the sensor needs to be improved for facilitating their easy installation and removal.

In this study, we built an ad hoc wireless behavioural monitoring system that was technically similar to that built by Mote [9]. A wireless system is very important for the temporal construction of a monitoring system in ordinary houses since it does not require any wiring. In addition, we developed a sensor that detects the usage of home appliances. The sensor was designed to be usable by simply attaching it to an appliance. The unit employs a device that uses weak radio waves for transmitting the obtained data, and it detects whether an appliance is in use by measuring the radio waves leaking from it. Therefore, engineering expertise is not necessary to install the unit.

1. System Structure and Apparatus

1.1. Behavioural Monitoring System

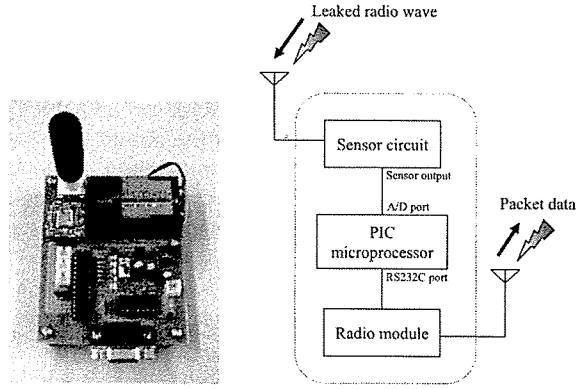
The system developed in this study comprises a data storage terminal and many measuring units. The units automatically sample the outputs of the sensor circuit and transmit the obtained data to a server via a radio module. The radio network, i.e. data relay path, is automatically constructed and modified when a relay failure occurs.

Figure 1 shows the circuit board and the schematic diagram of the sensor unit. The unit shown in Figure 1(a) has an RS232C-type communication port in order to directly connect it to a personal computer (i.e. the unit can also act as a radio interface for the server). A 1/4-λ antenna (Diamond RH-3) makes the radio communication more reliable than the previously developed pattern antenna [9].

1.2. Sensor Circuit

1.2.1. Television Sensor

For developing a sensor that detects the usage of home appliances, we first focused on



(a) Circuit board (b) Schematic diagram

Figure 1. Sensor unit for behavioural monitoring

Table 1. Definitions of conventional colour television formats

Format	Scanning line N (lines/frame)	Frame rate f_V (Hz)	Horizontal scanning frequency f_H (kHz)
NTSC	525	29.97	15.734
PAL (PAL-M, PAL60)	625 (525)	25 (29.97)	15.625 (15.734)
SECAM	625	25	15.625

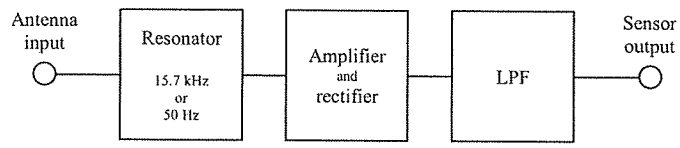


Figure 2. Schematic diagram of the sensor circuit

the television set. This is because the habit of watching television is always associated with the type of programme, and this habit is strongly influenced by the physical and mental conditions of the subject [8]. The image on a television screen is composed of a number of horizontal lines (scanning lines). By displaying different images at a certain frame rate, the television displays a moving picture. The number of scanning lines N and the frame rate f_V of conventional television formats are shown in Table 1. The horizontal scanning frequency f_H can be calculated as the product of N and f_V. The scanning in a conventional television set comprising a cathode ray tube (CRT) is performed by driving an electromagnet near the electron gun in the CRT. The electromagnetic activity near the CRT during the operation of the television can be detected by obtaining the leaked radio (electromagnetic) waves from the electromagnet. In this manner, information on the usage of a television set may be gathered.

Figure 2 shows the schematic diagram of a television sensor. The leaked radio waves from the television set are extracted by the resonator. Since f_H is almost the same

among the television formats, the resonance frequency was set as 15.7 kHz, which is also the intermediate frequency. The amplified and rectified signals are then low-pass filtered (LPF) in order to determine whether the television set is on or off by very low frequency sampling. Generally, a comparator circuit is necessary for the on/off distinction. However, because the output voltage of the circuit may be affected by the placement of the unit, a comparator circuit, which requires a constant threshold, was not introduced in this study. The distinguishing of the on/off status can be performed following the raw sampling of the sensor unit output by using the software in a PIC microprocessor unit that employs the variable threshold technique.

1.2.2. General-purpose Sensor for Home Appliances

A television sensor uses a special resonance frequency at which it does not respond to waves from other appliances such as video tape recorders or AV amplifiers. In other words, depending on the type of electromagnetic waves radiated by an appliance, the sensor unit can be adapted to receive waves from almost all appliances; this can be done by tuning the resonance frequency of the resonator and the gain of the amplifier.

In this study, we also developed a general-purpose sensor that responds to a resonance frequency of 50 Hz, which is the power-line frequency of commercial electric power systems in Eastern Japan. The frequency of leaked radio waves can be observed in almost all appliances since most of the appliances have power transducers, i.e. a (electromagnetically) coupled transformer.

2. Experiments

To assess the applicability of the sensor developed in this study, we conducted simple experiments. The sensor unit was placed on the target appliance, and the data storage server was placed at a distance of ~2 m. The sensor output was automatically sampled by the PIC microprocessor installed in the sensor unit at a sampling frequency of 10 Hz and a sampling resolution of 8 bits. A reference voltage of 5.0 V was used for the A/D converter. The data obtained was then transmitted to the server. A simple handshake protocol was employed in this experiment. In the case of a transmission error (when the sensor unit was unable to receive an acknowledge (ACK) packet from the server), the unit retransmitted the data without any limitation on the number of retransmissions.

During the first evaluation, based on the output of the sensor, we confirmed that no appliances were in use (i.e. the sensor circuit measured the environmental noise).

To confirm the behaviour of the proposed sensor circuit, we observed the obtained raw signal (leaked radio waves from the television set), processed signal (resonance, amplification and rectification) and filtered sensor outputs. These signals were recorded using Tektronix TDS210. The A/D converter in the PIC microprocessor was not used in this experiment. The applicability of the television sensor was then evaluated by a simple television on/off test. Further, we confirmed the dependency of the sensor output on the screen size; several conventional television sets that comprised CRTs were evaluated in this study.

For the evaluation of the general-purpose sensor, we selected a microwave oven as one of the home appliances; this is because the magnetron used in a microwave oven is driven by a voltage-doubled half-wave-rectified power generated by a high-voltage transformer.