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A Preliminary Study of Biofeedback System based on "Snoezelen: -Stimulation of Senses-" Devices and Robots

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ABSTRACT

It is sometimes stressful for human beings to live in Today's society. There are more demand to be relaxed and feel safe, comfortable by use of some devices and equipments, currently controlled by electronics and even by robot technologies in near future possibly.

The new role of "Robot Technology" in the 21st century, is to develop the robots in new category, supporting people directly. The concept of a bio-feedback system by use of "Snoezelen (Feel good and enjoy relaxed, mild time in the comfortable space)" devices and robots, is derived from the market analysis in the working group of Advanced Research Institute for Science and Engineering, Waseda University, to make business plan, and several contacts to potential users and related officers of cooperating municipalities/institutes in a few countries.

The basic system of robot and "Snoezelen" devices, main functions of robots as Interface for users, an example of business style with related possibility of business expansion, the method to measure a stress level of users (Off-line measurement as preliminary study), a preliminary measurement result, are described. The further step of this bio-feedback system, to measure more vital data of users by specific sensors and integrate with robots and Snoezelen devices - stimulating tool, is also mentioned.

This study is a united research of multiple group, consist of Architecture Engineering, Robot Engineering, and Medicine, supported by ASMeW (Consolidated Research Institute for Advanced Science and Medical Care, Waseda University) and and has possibilities to explore the new combined area of Human Environment Control, Medicine and Robotics.

Key word: Biofeedback, Healthcare, Service Robot, Stimulation Device, Snoezelen
論文
シンポジウム（1）「先端科学と医療」
“スヌーズベン：五感の刺激”デバイスとロボットを用いたバイオフィードバックシステムの予備検討

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抄録
現代社会で生活する中で、人は様々なストレスを感じることがある。そのためリラックスして安心・快適に感じるための装置やツールがさらに求められ、現在はエレクトロニクスで制御されているものが、近い将来はロボット技術によって制御されるかもしれない。

21世紀における“ロボット技術”の新しい役割とは、人間を直接サポートする新しいタイプのロボットを開発することである。

“スヌーズベン（気持ちよく心地よい空間で、リラックスし穏やかな時を過ごす）”デバイス、及びロボットを用いて、バイオフィードバックを行う考え方は、早稲田大学理工学総合研究センターの研究会で提案されたものである。

本稿では、“スヌーズベン”デバイスとロボットからなる基本的なシステム、ユーザのインタフェースとなるロボットの主要な機能、事業化の事例と事業拡大の可能性、ユーザのストレスレベルの計測方法（予備検討のレベルのオンライン計測）、予備計測の結果などにつき報告する。また、このバイオフィードバックシステムの次のステップとしては、提示のシステムを導入して生体計測をさらに行い、ロボットやスヌーズベンデバイス（刺激ツール）との統合を進めることも考えている。

本研究は、建築学、ロボット工学、医学などの各研究グループが融合した形で行われ、ASMoW（早稲田大学先端科学・健康医療融合研究機構）の中で活動しており、人間の環境制御、医学、ロボット工学が融合した新しい分野を切り開く可能性もある。

キーワード：バイオフィードバック、ヘルスケア、サービスロボット、刺激デバイス、スヌーズベン

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1. INTRODUCTION

The new role of "Robot Technology" in the 21st century is one of the main technology to support people directly by the intelligent machine and system with sensor, information technology, network, and devices to take care of people. Many prototypes of robots for welfare application, have been developed. But less number of those robots is introduced as final product to home care and rehabilitation market as shown in the International Home Care and Rehabilitation Exhibition, one of the most important exhibition of welfare equipments [1]. If we focus not only on technical issues but also on business issues, it will be easier to find an appropriate application as final product for these prototypes of robots, as we found many applications for industrial robots in the 20th century.

We propose to focus on the specific application area for these robots based on both technical and business analysis, and to integrate as "Healthcare Partner Robot System", contributing to the healthcare of elderly people.

This paper provides the basic analysis of the healthcare service market of elderly people care, and proposes "Snoezelen (Feel good and enjoy relaxed, mild time in the comfortable space)" application in welfare area, as the specific target to integrate with prototypes of robots. The basic system of robot and "Snoezelen" devices, main functions of robots as Interface to users, an example of business style with related possibility of business expansion, are described respectively. The further important step of the development of "Snoezelen" applications, is to measure vital data of users to evaluate how "Snoezelen" devices influence on user conditions, and integrate robots and Snoezelen devices - stimulating tool, as vital feedback system. This vital feedback system has possibility to be used as stress reduction tool in future.

2. MARKET ANALYSIS

2.1 Healthcare, Homecare Market in Japan

The percentage of the population of Japanese society over 65 years old, will be 25% range in 2014 (about 17% in 2000), and reach to about 35% in 2050. The population of the working-age group, 15 - 64 years old, is expected as 62% in 2014 (about 68% in 2000), and about 54% in 2050 [2]. This shows that 1 elderly person is currently supported by 4 working-age persons in 2000, but will be supported only by 2.5 persons in 2014, and by 1.4 persons in 2050.

When we focus on the actual number of elderly people, who really needs care from other persons in meal/ toilet/ bath, more than 70 min per day, ranked as "Demand Level 3 or more (Heavy Users)", are 1,254 thousands in 2003, increasing 100 thousands per year from 2000 as shown in Table 1 [3]. If we assume that it increase by same number for 10 years, it will increase by 1 Million people as heavy user. As we have a look on "Demand Level 2 or less (Light Users)" people, who needs care partly for about 30 min up to 60 min per day, are 2,191 thousands in 2003, increasing 310 thousands per year, and will increase by 3.1 Million people after 10 years.

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<td>Level 4 (very he.)</td>
<td>339</td>
<td>365</td>
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<td>Level 5 (super)</td>
<td>290</td>
<td>341</td>
<td>381</td>
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Table 1 The trend of certified number of Need-care persons

Consequently, there will be demand for caring power from 1 Million "Heavy Users", and 3.1 Million "Light Users". The demand from "Heavy Users" are described as follow, such as

1) Needs care partly in meal, toilet, bath/ clothes
2) Needs care fully in meal, toilet, bath/ clothes due to dementia/alzheimer disease
3) Needs intensive care for all movement
The development cost to realize the expected functions to support applications for "Heavy Users", can be higher than the cost for "Light Users"-related applications in general. On the other hand, most of welfare equipments are categorized as "Consumer Products", like TV, furniture, others.
The condition of product development to deal with "Heavy Users" demand, is severe as
1) Less number of potential users comparing with general consumer products.
2) High development cost to utilize robot technologies to realize the complicated tasks.

2.2 Focus on the Demand from "Light Users"

The other target users, "Light Users", can take care of themselves mostly, including early stage of dementia, and tend to do by themselves as far as possible. Therefore, functions to be implemented can be simple, which they use frequently or according to condition.

2.2.1 Hardware-related Tasks Requested from Users

Reviewing the tasks of Service Dogs as good reference, which are already working to support handicapped people with wheelchair, the examples of hardware-related tasks are as follows; [4]
1) Pick up something ordered by voice command
2) Pass to user or bring to trash box
3) Pull/push door by pulling towel (as shown in Fig.1)
4) Touch on some switches of wall,
5) Power Assist to keep body balance of master for transfer or walking in stairs
6) Prepare communication equipment, telephone, if Master is in dangerous condition
7) Support to change clothes by pulling
8) Other features as customized

Currently, 38 service dogs are working in Japan, certified by the specific test including the scene of taking a train with Master. The cost for the training of service dog is around 3 Million yen, and the duration is about two years, making the potential users to wait for long time.
The basic part of Service Dog's features, can be

Typical features of the robot for "Light Users", working for daily care, because of this market acceptance.

Fig. 1 A Service Dog to Open Door

2.2.2 Other Tasks Requested from Users and Care Persons to Motivate, Feel Safe and Relaxed

Hearing from managers of welfare facilities for elderly people care, it is requested frequently to develop robots or tools to talk with or play with, for elderly people. Those who stay in the caring facilities in long term, usually do not have specific items after meal time, and sometimes just sit on a chair and look like to wait time goes by. Even though caring persons are working so hard, it is still difficult to take care of elderly people to talk with, to play with for long time.

It is much more severe condition to take care of dementia elderly people, because the dementia users need care more frequently and much more time, for same or similar issues, as if they are confused about location, condition, time and others.

One of the possible reasons to be confused for dementia elderly people is considered that the stimulating signals of living space do not fit to the current available sensory, when we imagine to walk without information from eyes. If we regulate the stimulating signals to the basic level easier to accept, and prepare the extended part or type of signals as selectable by user's demand, it is considered that there is possibility for dementia elderly people to be less confused.
The basic method of regulating, using multiple stimulation, to feel good and enjoy relaxed, mild time in the comfortable space, is called as "Snoezelen". The integrated applications with "Snoezelen", will have typical functions of the robot for "Light Users", who needs to feel good and enjoy relaxed, mild time.

2.3 Healthcare Partner Robot for Hardware-related Tasks and other Tasks to Motivate, Feel Safe and Relaxed

As reviewed in the tasks for hardware-related requests and requests to motivate, feel safe and relaxed, a category of robot is proposed with the following key points to support "Light Users", as shown in Fig. 2, and Fig. 3.

- Simple functions like consumer products
- Easy to use only by simple commands
- Use inexpensive, high reliability hardware proven in the Factory Automation market
- Prepare Healthcare menus as standard software on the platform of Human-Machine Interface (HMI) and controller, through network protocol

These partner robots are controlled by the scenario of Middleware, located in HMI or controller, through network. Some examples of partner robots are shown in Fig. 4, Fig. 5 respectively.

![Fig. 4 An Example of Partner Robot, MARON-1 developed by PFU (Fujitsu group)](image)

This robot is originally called as "Mobile Agent Robot", shown in Fig. 4, controlled by handy phone or PC remotely, and moves around according to instructions, detects the human-size object by CCD camera, generates pre-recorded voice accordingly, then call to pre-registered phone number to indicate these events. There are other functions to turn ON/OFF TV or any devices by infra-red signal, which can be used to control "Snoezelen" devices as well.

![Fig. 5 An Example of Partner Robot, MAPLE, developed by Mitsubishi Electric Corporation](image)
This robot is called as "MAPLE", Mechanical Ape for Living Environment, the external view is shown in Fig.5 and the configuration is shown in Fig.6, and developed as partner robot to support people, by moving around inside home, by using hand for simple tasks. The basic concept is to realize stable walk by 4 legs, which waling style is popular in Ape, to give safe and a little bit lower image than human being, but more capable image than pet animals like dogs and cats. It also has idling stop mode realized by mechanical lock to reduce power consumption while monitoring for targets or watching for elderly people in mid-night at the same position. [5]

![Fig.6 The Configuration of MAPLE](image)

### 3. "SNOEZELEN" IN WELFARE

#### 3.1 What is "Snoezelen"?

"Snoezelen" is started in the Netherlands in the middle of 1970's, and overall concept for multiple stimulating space, its theory and method to use. This basic idea is to feel good and enjoy relaxed, mild time in the comfortable space, and was originally developed to improve the QOL of heavily handicapped people. It has been widely accepted in Europe for many different applications, like care of dementia elderly people, reduction of stress in Children's hospital for long term clients, kinder garden, public space. It has been also gradually installed, more than 700 in Japan, for the application of intellectually handicapped people, cares of dementia people. As increase of the number of installations, there are several possibilities of effect as follows;

1. "Snoezelen" space provides the calm down effect by regulating stimulations.

2. The "Comfortable" feeling, difficult to teach how to control, can be experienced in "Snoezelen" space

3. Handicapped People feel "Accepted" to play and relaxed in "Snoezelen", and improve performance.

---shown in [6] and mostly translated to English---

![Fig.7 An Example Demo Room of "Snoezelen" (provided by Japan Snoezelen Association, 2005)](image)

#### 3.2 "Snoezelen" Application

The bottom line of "Snoezelen" is to reduce the "chaos". For example, " those who have handicapped people, their world seems like a "chaos" in which everything seems to be complicated and puzzling and that they are incapable of influencing these stimulation, and to understand. Because of this feeling, every day life will be scary for those people. - short summary of a part in page4- [7]."

Therefore, it is considered to regulate the stimulation as basic level first, and to provide "additional, selectable, various" stimulations in the space for users. The users can choose if they like...
and when they needs, but not requested by others.

3.2.1 Examples of "Snoezelen" Devices in Demo. Room

As shown in Fig. 7, several devices are installed in Demo. Room, as follows;

(1) Bubble units (Electrically Controlled)
"Perspex tubes filled with water, underneath an air pump is installed to generate bubble, and lighting tool is also installed, which color changes gradually. With the incoming air, air bubbles rise constantly and are illuminated by a light. - shown in page 15- [7]

(2) Mirror balls (Electrically Controlled)
"two balls of different sizes, covered in little mirror tiles and rotate. Spotlights illuminate them. - shown in page 15- [7]

(3) Side Glow (Electrically Controlled)
Numbers of optical fibers are illuminated by light with multi color.

(4) Mirrors
Reflect the scene of multi colored bubble units and side glow inside of demo room.

(5) Water Bed
A water bed is installed under the bubble units and side glow where users can play with units and devices on the water bed.

(6) Projectors (Electrically Controlled)
A few different colored-oil liquid are mixed in the narrow gap of 2 glass disks and heated by projection light. As the disc is rotated, the liquids are mixed together in many different ways. This scene is projected to screen or wall.

(7) Music (Electrically Controlled)
" Significan part of Snoezelen rooms and can be heard as background music everywhere. The purpose of the music is to support the calming effect of Snoezelen and to "fill" the rooms with a warm atmosphere. Not very active, But not passive either. A sort of "swinging along". Light classical music, vocal or instrumental pieces with preferably only one voice or one instrument or one instrument in the foreground as well as light entertaining music are very suitable as Snoezelen music. - as shown in page 19, 20- [7]

It is also reported that dementia elderly people usually like sweet cakes, taste stimulation [8]. Additionally, aroma of forest or others are also used in some applications.

3.2.2 Examples of Additional User Demand derived from Solution Engineers of "Snoezelen"

Here is an example to integrate "Snoezelen" application and robot as future version of "Snoezelen" products. The toy sheep, shown in Fig.8, is a typical "Snoezelen" device which is widely used in Europe, and by hugging this, elderly people feel comfortable. As additional request, it is better to have moving functions by touching or reacting to voice.

Fig. 8 An Request from "Snoezelen" Solution Engineers

for hug toy sheep, hoping to move by voice or touch sensors (provided by Barry Emons, Netherlands, 2005)
4. BIO-FEEDBACK SYSTEM FOR "SNOEZELLEN"

4.1 Basic System

The basic robot system for "Snoezelen" in 2005, exhibited in the International Robot Exhibition 2005, is implemented as follows, shown in Fig.9:

1) Voice Recognition of key word from users to show the basic condition of users, for example, "Feel Bad", "Very Well", and others.

2) Middleware executes the pre-registered Scenario of Robot movement, and related actions, finally controlling "Snoezelen" devices and others.

3) The input timing of keyword from users, and execution are stored in database for analysis, to extract user specific behavior in further extended system.

4) The middleware sends command to partner robots and other equipments, if available, through network.

5) Partner robots control "Snoezelen" devices by infra-red, for example, and also replay the recorded voice of family, relatives, friends of users, for example, as interactive voice stimulation.

6) "Snoezelen" devices and other devices provides stimulations according to the pre-registered scenario in the middleware.

4.2 Extended System with Bio-feedback

In the extended robot system as further step, the vital data, such as alpha wave from brain, blood pressure, heart beat, are measured, for example. According to the status of these data and trend of the personal behavior of that person, an appropriate scenario will be chosen from group of scenarios.

For example, if someone feels good for the last one month, and the number of times increases to say some negative keywords in last a few days, or some vital data tends a little bit worse, this system starts to stimulate a little bit more to improve the condition.

Fig.9 Basic Configuration of Robot System for "Snoezelen"

Fig.10 Extended Configuration of Robot System for "Snoezelen" with Bio-feedback
4.3 The Preliminary Measurement (Offline) of Vital Data to check the possibility of Bio-feedback

Fig. 11 The actual installation of Snoezelen room with robot to be extended to Bio-feedback

Fig. 12 The Top View of the actual Snoezelen Room

As shown in Fig. 11 and Fig. 12, the actual system of "Snoezelen" devices and robots are installed as one system, connected by voice recognition and middleware in the PC, network and infra-red control in the robot.

Then, we made preliminary measurement of stress level of Object Testee by use of measurement equipment as off-line.

Mainly University Students in 20's

(3) Measurement Item: Alpha-Amylase in saliva

(4) Equipment to measure: "COCORO METER" produced by NIPRO, as stress measurement tool

(5) Measurement Procedure:
a) Gargle by water
b) Take a rest on the chair for 3 minutes with open eyes just out side of "Snoezelen" room
c) Measure Alpha-Amylase by COCORO METER directly after that
d) Enter Snoezelen room, and take a rest on the chair for 3 minutes with open eyes.
Snoezelen room has stimulations of
1) Bubble Unit (Visual)
2) Healing Video (Visual)
3) Side Glow (Visual)
4) Star Carpet (Visual)
5) CD Player (Music)
by the exact same pattern controlled by Robot and PC.
e) Measure Alpha-Amylase by COCORO METER directly after that

(6) Measurement Result
--- Before Taking a rest in Snoezelen room---
c) The average of Object Testee, 
Amylase → 33 (ku/l)

--- After Taking a rest in Snoezelen room---
e) The average of Object Testee, 
Amylase → 27 (ku/l)

Note: When figure is smaller, Object testee is more relaxed.

More than 70 % of Object Testee had reduced amount of Amylase, after taking a rest in Snoezelen room, as defined in Fig. 11 and Fig. 12.

<Measurement of Biological Reaction>
(1) Place: In-, and Out- side of Snoezelen Room (as defined in Fig. 11, and Fig. 12)
(2) Object Testee: 35 members,
5. CONCLUSION

The healthcare partner robots, available prototype robot, and existing, already accepted application, "Snoezelen", are integrated as robot systems for "Snoezelen" applications, which can be extended as Bio-feedback system. This integration has just started by the cooperation of welfare, medical people and robot engineering people in this year, as far as we investigated. However, the basic scheme to integrate is normal method, which can be implemented on the standardized equipments. Therefore, the variety of this integration will result in large size of business, as we extend our functions requested from users, solution engineers [9].

After introducing the various sensors to measure vital value of human and developing real-time signal processing functions, this system will be a new type of training tool for users to control to be relaxed.

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