The Design of Interactive Physical Game for Cognitive Ability Detecting for Elderly with Mild Cognitive Impairment

Y.T. Chen[1], C.J. Hou[1], M.W. Huang[2], J.H. Dong[1], J.Y. Zhou[3], and I.C. Hung[1]

[1] Department of Electrical Engineering, Southern Taiwan University of Science and Technology, Tainan, Taiwan
[2] Deputy Superintendent, Bali Psychiatric Center, Ministry of Health and Welfare, Bali, Taiwan
[3] Asia University, Taichung, Taiwan

Abstract—**The problem of population aging is getting worse in many countries. Taiwan will become an aged society in 2017. Alzheimer's disease is the most common form of dementia in the Elderly population. The pathogenesis of Alzheimer's disease at the early stage usually starts slowly and gets worse over time. The preclinical stage of the disease has also been termed mild cognitive impairment (MCI). Detailed neuropsychological testing reveal mild cognitive difficulties and questionnaires are popularly used in clinics. Those procedures are hard to use by the families and health caregiver. A way of ease using for cognitive ability detecting at home should be considered. Therefore, the interesting interactive physical game with body motion sensing device has been developing in this study. The body motion game not only promote the physical and mental health, but also supervise the behavior of player. The behavior information recorded by the body motion sensor device can be used to evaluate the cognitive status of the elderly who play the game. Three major works in this study have been performing: (a) the diverse easy-playing interactive physical game with body motion sensing device has been designing, the parameters for featuring the behavior of player are recorded, (b) the face recognition using computer vision techniques was implemented for identifying the player, (c) the management of the user authorities for accessing player's historical records and personal information. The performance of the proposed system has evaluated by seven psychiatrists, the statistical results showed that the player's cognition statuses can be revealed by the behavior features and game records. This system were used on the spot of some healthcare institute and residential communities. The statistical results showed that the system has good performance for detecting the cognitive abilities of elderly.**

Keywords—**Dementia, Cognition Ability, Body-motion Sensor**

I. Introduction

Population aging in developing countries become a very serious problem. Because of rising life expectancy and declining birth rates, the proportion of aged population rise acutely. The issues about population aging are getting important. Taiwan will become an aged society in 2017. The proportion of aged population will be higher than 20% by 2025 and Taiwan will be a super-aged society.

In Taiwan, the proportion of population with dementia in the aged population occupied 8.09% in 2013. Symptoms of dementia vary depending on the cause and the area of the brain that is affected. The progressive decline in cognitive function due to damage or disease in the brain beyond what might be expected from normal aging. Alzheimer's disease is the most common form of dementia in the elderly population. The pathogenesis of Alzheimer's disease at the early stage usually starts slowly and gets worse over time. The preclinical stage of the disease has also been termed mild cognitive impairment (MCI). The memory loss is usually the earliest and most noticeable symptom and always is associated with the decline of other cognitive abilities. The symptoms are not only the decline of memory, the affected cognitive abilities include attention, judgement, language and problem solving [1]. Trouble controlling moods and behaviors, personality changes, and having delusion are very possible occurred. To take care of the patient with dementia is a heavy burden to the family and healthgiver.

Detailed neuropsychological tests reveal mild cognitive difficulties and questionnaires are popularly used in clinics. The professional psychologist always apply the mini-mental status examination (MMSE) [2], cognitive ability screening instrument (CASI) [3], and clinical dementia rating (CDR). These tests are very important reference for the diagnosis of dementia. These procedures of using questionnaires and tests are hard to practice by the families and health caregiver in usually daily lives. A way of easy use for cognitive ability detecting at home should be considered.

There are novel techniques developed to detect the symptomatic appearance of dementia. B. Dubois [4] devised a short bedside cognitive and behavioral battery to assess frontal lobe functions. Che [5] extracted the featured qEEG variables from resting eyes-closed continuous EEGs. The results showed statistically significant difference between early dementia group and control subject group. Waragai [6] evaluated the diagnostic value of brain perfusion SPECT using eZIS in patients with various neurodegenerative diseases at a very early stage, within one year from onset. Huang [7] developed several systems including visual, audio, and memory tests. Those systems were designed on

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Tablet PC for elderly to self evaluate their health status. However, the above-mentioned systems were not easy use in family for homecare of elderly daily lives.

Developing a game system with the body-motion sensor and applying the function of cognitive ability detection in the system may be a useful way for elderly to detect the MCI in the preclinical stage. It can be like an execise or entertainment to use in the daily life. Instead of the boring process of questionnaires and tests, the game can be performed every day to trace the variations of cognitive ability. The Dual-Task Tai Chi designed by Kayama [8] and the KiMentia recognition system proposed by Breton[9] could be the representative systems which combined the functions of exercise/mutimedia and cognitive ability detecting.

Therefore, the interesting interactive physical game with body motion sensing device was developed in this study. The body motion game not only promote the physical and mental health, but also supervise the behavior of player. The behavior information recorded by the body motion sensor device can be used to evaluate the cognitive status of the elderly who play the game.

II. Materials and Matheds

Three major works in this study have been developed: (A) The design of interactive physical games. Five diverse easy-playing interactive physical games with Kinect, the body motion sensing device, has been designed. The parameters for featuring the behavior of the player were recorded. (B) The player identification implemented the face recognition techniques for identifying who the player is. This procedure can ease the operation steps of the system for elderly and facilitate the access of personal information. (C) The management of the user authorities was designed for accessing player's historical records and personal information (Fig. 1).

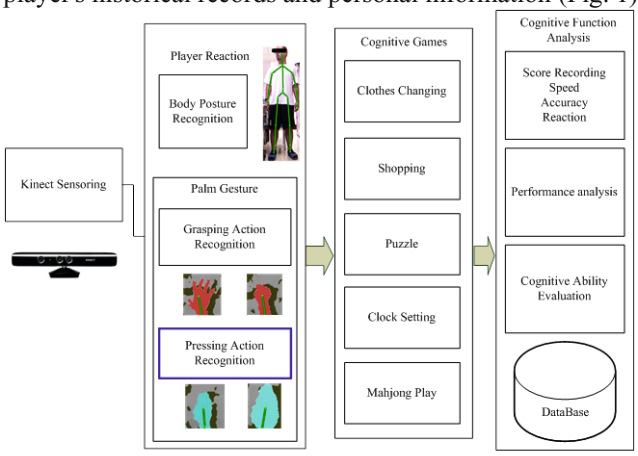

Fig. 1 System block diagram

A. Interactive physical game design

This study adopted Kinect, the motion-sensing device, to develop an interactive motion-sensing game for cognitive ability detecting. The player controlled and interacted with the game through a natural way using hand gestures. These games were designed referring to the specific cognitive functions. The performance in the playing history of the player would be recorded and analyzed for cognitive ability evaluation.

Cognition function can be divided into domains of ability including attention, memory, orientation, calculation, construction ability, and language and other higher cognitive functions [10]. Five games were designed in the proposed system to evaluate the cognitive abilities. The parameters, including the accuracy ratio, the time taken to complete the game, and the number of right answer, for every game need to be recorded for the subsequent cognitive ability evaluation. These five games are briefly explained as follows and the main operation screens are shown in Fig. 2.

a) Cloths changing:

The hat, coat, and pants of three kinds of clothes including a uniform, casual dress, and athletic suit can be selected individually from the figure items on the screen. The taken time, the accuracy are recorded.

b) Shopping:

The subject is requested to answer the hypothetical questions about shopping to subtract 7 dollars from 100 dollars, and to keep subtracting 7 dollars from the result. The taken time and the accuracy ratio are recorded.

c) Puzzle:

The subject is required to put pieces of a picture together to compose the picture. Various pictures with different pieces can be selected. The recorded parameters include selected pictures, the taken time, and the accuracy ratio.

d) Clock Setting:

The subject is required to recognize what time the clock is and then select the correct time from the lists in the bottom of screen. The figure of the clock might be pointer-type or numeric-type. The recorded parameters include the mode of clock, taken time, and the accuracy ratio.

e) Mahjong Play:

The player selects the tile of mahjong game from four tiles listed at the below of the screen to complete the order of rules. The accuracy ratio and taken time are saved.

Fig. 2 The five games of the proposed system (a) Cloths changing, (b)Shopping, (c) Puzzle, (d) Clock Setting, and (e) Mahjong Play.

B. Player identification

The Kinect could estimate the body posture and transfer the matched skeleton model to the system. It is very easy to segment the region of face from the synchronous video image. This user identification procedure in the proposed system applied the Scale-invariant feature transform (SIFT) proposed by Lowe [11] to identify the player.

The SIFT algorithm can be applied to the topics of object recognition, video tracking, image matching, etc. SIFT consists of four key stages including 1) *scale-invariant feature detection*: the image is trasformed into a large collection of feature vectors which is invariant to image traslation, scaling, and rotation, 2) *feature matching and indexing*: the consists of storing SIFT keys is indexed and then identify the matching keys from the new image, 3) *cluster identification*: Hough Transform is used to cluster reliable model hypotheses to search for keys that agree upon a particular model pose, and 4) *model verification*: the identified cluster is then subject to a verification procedure in which the solution of linear least squares is evaluated for the parameters of the affine transformation relating the model to the image.

C. Data management

The performance and playing historical records of player would be recorded. The authority management of this proposed system included the administrator (highest), the clinical staff, and personal user and his/her family. The clinical staff can trace and access the information and historical game-play records of players. These records are used to evaluate cognitive ability of the player.

D. Experiments and Statistical analysis

Seven psychiatrists participated in evaluating the correlation between the games and cognitive function which includes attention, memory, orientation, calculation, construction ability, and language and other higher cognitive functions. Totally 168 questionnaire items were designed for surveying these correlations. The correlation scale ranked by psychiatrists was low, moderate or high. The cronbach's alpha [12] is used as an estimate of the reliability or internal consistency of the games. The rule for describing internal consistency using cronbach's alpha, α, is: $\alpha \geqq 0.9$ represented 'excellent', $0.7 \leqq \alpha < 0.9$ represented 'good', $0.6 \leqq \alpha < 0.7$ represented 'acceptable', $0.5 \leqq \alpha < 0.6$ represented 'poor', and $\alpha < 0.5$ represented 'unacceptable'. The α value is represented as

$$\alpha = \frac{n}{n-1}\left(1 - \frac{\sum s_i^2}{s_H^2}\right)$$

where s_i^2 is the variance of the *i*th items, s_H^2 is the variance of the sum of all items, and n is the number of items. Fleiss' kappa [13] is used for accessing the reliability of agreement of the games among seven psychiatrists. The degree of agreement interpreted by the kappa value, κ, includes poor ($\kappa < 0$), slight ($\kappa = 0.01$~0.20), fair ($\kappa = 0.21$~0.40), moderate ($\kappa = 0.41$~0.60), substantial ($\kappa = 0.61$~0.80), and almost perfect agreement ($\kappa = 0.81$~1.00).

Twenty subjects participated in the game. They accepted an evaluation of MMSE before playing the game. Eleven subjects showed normal in cognitive function and nine subjects had mild cognitive impairment. Each subject had completed the test of playing five games. The parameters such as the accuracy ratio, the time taken to complete the game, and the number of right answer of playing each game were recorded in data management and used for statistically analyzing the correlation between the game and cognitive function. The relationship between the parameters of the game (independent variables) and the MMSE score (dependent variable) was investigated by a stepwise regression analysis method. The multiple regression equation is assumed

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k$$

where y is the dependent variable, x_k is the kth independent variables, and β_k is the coefficient of the kth independent variables. The statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) statistical software for Windows. The study had the approval of Institutional Review Board in Taiwan.

III. Results and discussion

The results of cronbach's alpha analysis showed that α value was 0.961. It revealed the reliability of the games was excellent. The Fleiss' kappa value was 0.50, which meant the reliability of agreement of the games among seven psychiatrists was moderate. The result of the regression analysis obtained the following equation ($R^2 = 0.87$ and F=34.52 (p<0.05) for checking the goodness of fit of regression equation model)

$$y = 10.183 + 0.166x_1 - 0.15x_2 + 0.47x_3$$

where three game parameters, 'x_1, x_2 and x_3' were the number of right answer, the time taken to complete the game and the accuracy ratio. The results showed that the cognitive ability detection in our games was highly correlated with the MMSE.

IV. Conclusions

Five body-sensing game using Kinect for cognitive ability detecting were developed in this study. The performance of the proposed system has evaluated by seven psychiatrists, the statistical results showed that the player's cognition statuses can be revealed by the behavior features and game records. This system were used on the spot of some healthcare institute and residential communities. The statistical results showed that the system has good performance for detecting the cognitive abilities of elderly.

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Author: Chun Ju Hou
Institute: Department of Electrical engineering, Southern Taiwan University of Science and Technology
Street: No. 1, Nan-Tai Street, Yungkang Dist.
City: Tainan City
Country: Taiwan
Email: cjhou@mail.stust.edu.tw