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Data modeling mobile augmented reality: integrated mind and body rehabilitation

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Abstract The rapid growth of elderly populations throughout the world necessitates inclusion of this sector in all active functions of communities. However, lack of physical and mental fitness threatens their effectiveness is making them to drain the community resources instead of positive and productive contributions. Our studies show the need for a massive large-scale boost in two main dimensions of physical and mental health enhancement. In order to solve this problem, in this paper we propose a new low-cost and innovative adoption of augmented reality (AR) functions through an agile deployment of mobile-based augmented reality (mAR) embedded in massively available intelligent smartphones. In our proposed method a set of downloadable AR-enabled embedded learning and exercising programs, designed upon users' historical and habitual improvement data would enable a collective sequence of required activities and individually optimized. At the system design level upon the individually recorded data in various databases select and configure the most suitable set of downloadable programs—a combination of mental and physical activities. From our experiment we provide some of our statistical results for two distinct application areas of mAR: 'exercising-rehab' and 'lifelong learning'. Three sets of results show the age related results for three user critical features of 'ease of use', 'usefulness' and 'user attitude'. Further analysis of data through modeling helps us to provide a systematic design procedure based on user's age in conjunction with other variables.

Keywords Mobile augmented reality · M-health · E-health · Elderly · Data modeling

1 Introduction

The rapid growth of elderly populations throughout the world makes the role of this sector in a community more effective and more critical than ever before. The change hangs on the key

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of inclusion factor where new generations and many governments tend to exclude the old generations from many proactive, sensitive and significant roles.

Deterioration of health conditions in elderly people mainly sourced from lack of interactions with others and reduced degrees of communication. Once very popular, nursing homes now have shown to be anti-productive for most old people who worked hard to enjoy their easy life after retirement. For example, McDonnell and Grimson [20] recognize that arranging care for older people, such as nursing homes, can inject low levels of social interaction, a crucial requirement to both the mental and physical well-being of older people. They claim social working for these people gets reduced in size placing them at a higher risk of social isolation affecting the condition of their health. Murphy claims major social change in a person's life has been linked to the onset of depression [24], at higher risk when initially moved around. Ronver et al. show that depression increases their death likelihood by 60 % in the first year of being moved to their new environment such as the nursing home [31]. Social contact also seems crucial to psychological wellbeing. Those in contact with existing friends and family can get bored due to lack of major life events and losses due to distance or widowhood.

The age and growth of the elderly population throughout the world combined with the cost of medication, hospitalization and care is recognized to be our biggest problem in the near future. For example, many reliable sources [6] express their concerns that the elderly growth ratio is a serious problem such that the worldwide elderly population with age 65 and over is expected to grow rapidly, double by 2020 and triple by 2050. China alone is expected to have two elderly for each workingman in 2020. Similar figures are coming from Europe and the rest of world supporting these claims [28].

This paper is structured as follows. After a literature search and classic investigation of the existing systems as well as comparative methods in Section 2 we analyze the pressing issues associated with elderly and senior citizens before devising our novel idea to address these problems in Section 3. Then, after exploring the idea we provide some of our supportive data in Section 4 with further analytical discussions of the results and following conclusions in Section 5.

2 Elderly health

Normally elderly people, due to sedentary habits do not get sufficient physical exercises as a result of which mostly suffer from inadequate blood circulation, weakened muscles and inactive critical parts of their body which cause serious deterioration in critical organs leading to serious chronic and mental disorders. The problem of health has been studied extensively with generic approaches resulting in many interesting solutions under electronic health (e-health), telehealth and mobile-enabled health applications (m-health) but as they are not specifically designed for the elderly they lack compatibility with such an experienced population and therefore cannot be used effectively due to their inadequacy for the old people.

It is hard to define the health and measure its limitations for old people, but broadly speaking we can classify them into two main groups of 'physical-rooted' and 'mental-rooted' problems. Elderly people's problem of health deterioration rapidly grows with age and varies widely based on physical and mental pressures and working environments. Some become handicap in various sensitive parts of the body and organs. For example, Seelman et al. [33] claim about 70 million individuals worldwide suffer from hearing loss, which makes hearing the most common sensory disorder in the world. The solution is, however, limited to well-established traditional improvement of the signal which can help mainly with the sensing nerves part of the problem whilst Mirzaei et al. [21] consider a text based solution, which can be regarded as one step towards the method proposed in this paper. That is, texts spoken by various people being displayed for them can bring both confidence and a joining-in possibility so that they can enjoy communicating with others and then psychologically benefit from being able to understand what is going on and provide intelligent and clever conversation to boost their confidence. Mozgovoy [23] proposed using specific computer technique, extensible dependency grammar, to build language assisted learning instruments. Though the latter solutions seems to be very clever and sophisticated again the problem of carrying a computer is a difficulty that we can solve with cost-effective and popular smart mobile technology.

2.1 Problem of non-moving, rehab

The physically rooted problems are associated with lack of minor movements and weaknesses in some muscles due to some historical or forgotten injuries and disease, which reappear as age increases.

The problem of the elderly, being in their normal condition or under medication, is putting incredible pressure on national resources throughout the world. The use of automation and robotics in many cases may become useful but what exactly these advanced mechanical devices can do is quite limited and also they come with a rather hefty running cost of maintenance to keep them in good and reliable order which often require storage areas and associated resources with significant cost that not many people and few nations can afford. That is, it would help considerably if the patients themselves could stay active and contribute to the rehab and medication throughout their lifetime and get engaged proactively by being kept moving and get engaged with most or even part of rehab they need to overcome certain fatigue and physical rigidity as they get older. For example, Ferrigno et al. [11] shows a typical solution where an adaptive autonomous- assistive robot can help elderly and physically disabled people using an autonomous wheelchair control system. Here, the assistive robot, separated from the wheelchair, can learn preprogramed rehab training movements. Though it can help with a better quality of life but this, similar robotic solutions come with many practical bottlenecks for decades to come due to:

(a) Understanding of the use of the advanced robots is too limited for solving the emerging problems of the elderly
(b) Very limited use of mechatronics and intelligence augmentation make these robots too naïve for fast growing demands
(c) Limited to very few with serious physical mobility and severely disabled patients
(d) Given the saturation and marginal cost reduction for a potential share of the global market they require potential investment risks.

One common approach is to encourage the elderly to take regular physical movement and exercises very seriously. For example, Fasola and Mataric [10] see this as the way ahead for helping a happier life for the elderly and reducing a hefty national budget for looking after pensioners. The fivefold increase in the number of people over the age of 85 by 2050 [30], with the serious problem of nursing shortages [25]. They see regular physical exercises can help with health [2], and any physical fitness processes can correlate lesser atrophy of frontal cortex regions [8] and improve the reaction time [34], which in turn could help with social interaction with a positive impact on general mental and physical wellbeing [22]. Their proposal of a socially assistive robot (SAR) is a system that can help but it can be limited due to the use of a complex and rather rigid robot.

Problem with specific movements and muscles often causes serious problems with the older people. For example, Zhang et al. [40] work on exercising the hand using augmented reality. This solution is both interesting and effective but the complexity of the use of a complicated hardware system reduces its effectiveness and use for older generations. A similar case applies to use of augmented reality in games for post-stroke rehabilitation by Burke et al. [4]. That is, though they identify a serious problem the solution covers very limited cases and is rather too complex for the elderly to accept.

2.2 Isolation, mental & psychological problems

The mentally rooted problems in old people stem from psychological weaknesses and loss of strong willingness, joy and excitements, which could be caused by loss of loved ones, poor communications, poor care or a feeling of being abandoned. Boredom is one of the biggest enemies in old age. It often can get extended to more serious cases of Alzheimer's disease or cases of dementia as reported by The International Federation of Alzheimer's Disease and Related Disorders Societies, Inc. [35]. Dementia originally means madness but in milder format means mindlessness due to a serious loss of global cognitive ability often in a previously unimpaired person as normal ageing takes place [9]. It can be recognized by changes in receptive and expressive language or lack of ability to plan and problem solve that cause some agitated behavior and deterioration with incidents that may arise if the person's needs are misunderstood. No clinically proven medication methods are available because of the difficulty of access to the underlying pathophysiology. However, it is logical to consider biological level problems of irregular blood circulation throughout the brain that often causes brain cell loss and that could be also a source of Parkinson's disease.

2.3 Existing solutions

To understand the persisting underlying common problems of old people let us look further at some of the existing solutions. In order to overcome the problem of blood circulation any motivation should help these people to extend normal movements enhanced with lightly loaded brain activities to extend healthy life and overall better quality of life. In many situations people feel their time is being wasted, especially for those who depression and the problem of boredom dominates their life. One significant solution is to facilitate some self-initiated interesting interactions such as life-long learning, strategic gaming or challenging programs that can (a) motivate them to use their brain more actively, (b) build some extra interest in life and (c) interact with others for grouping, discussing and socializing.

Although both classic e-health and m-health are helping many populations with medical care harnessing the fast growing sensor technologies incorporated with mobile phone devices. However, their impact on imminent elderly problems is quite limited and slow. The following classification show typical solutions:

(1) Medical care associated with physical health status tracking and monitoring (heart rate, blood pressure) of special needs (disability, impairment) [18]
(2) Personal care systems including personalized interactive care and pet-like companions [10]
(3) Entertainment and exercise activities also called exergaming and elderly motivation management exercise activities [13]

Most of above classic care solutions, 1 and 2 in particular are in effect difficult, complex and usually costly to implement on an individual basis. Large organizations such as healthcare industries and care systems are too slow and too expensive to adopt fast turnaround solutions. For example, there are very few social computing applications designed for older users and none specifically designed for older people living in nursing homes [37].

The third class of solution, exergaming, though the approach is an interesting solution but mostly hard-to-use and infeasible for old people. They also do not use their mobiles merely for trivial intentions such as status and they also refuse to allow any attachment devices and some resist accepting own poor-health. One interesting solution is a Bayesian network based model proposed by Choi et al. for interactive edutainment applications that exposes to construct a set of parametric rules and propositions pertaining games and problem solving activities [7].

Another critically important problem associated with researching human behavior modeling problem is the volume of data and processing time. The statistical data are always hard to collect and some can be unreliable or affected by natural human behavior against systems and systematic measurements, as sometimes referred to as big data [17, 27]. For our case, the care systems for the patients with higher age require longer processing for in-depth analysis of their long history for various critical aspects of medical history, health conditions, and up to certain degrees their family and social activities, an accurate analysis for optimum design to devise best treatments/solutions require use of big data analytical systems. Here we have somehow simplifies these to show how such systems work. In one our earlier research works [14–16] we made use of body language by integrating learners' interactions with the computer in their learning based set of physical activities in a way that the effectiveness of the method/technique increases their academic performance. Ahn et al. proposed the RescueMe system which leverages the sensors on a smartphone and utilizes AR, cloud information, daily-based user walking patterns, and an adaptive GPS connection method, to deliver critical evacuation information to mobile phone users in indoor emergency situations [1]. Further, an adaptive neuro/fuzzy system which can be trained to detect the current human emotions from a set of measured responses [19].

Also, in many cases we need to consider using complex analytical systems such as the new mapping approach based on the Boolean modeling of critical domain knowledge and on the use of large masses of heterogeneous data and hyper-documents relating to healthcare and psychological information via the data mining technique in order to improve the process of acquiring knowledge explicitly [3]. A similar research work demonstrates the need and feasibility of using massive processing through different distributed infrastructures. Then, it reveals the analysis of the navigation patterns of users' activity within the Virtual Campus. This work shows a real example of the convergence of different technologies and paradigms such as massive processing, data mining and online learning to study user behavior and modeling in online sites [38].

3 Our augmented reality approach

Use of augmented reality (AR) in human interactions with computers and communication systems has a long history but due to its complex nature it is vastly under-developed. Scanning some of innovative ideas we come across some relevant examples. Use of game-based AR solutions for mentally retarded people and elderly with mental problems such amnesia and forgetfulness have been proven effective. For example, Zapirain et al. [39] show effectiveness of AR based a game known as 'Board of Wisdom' or 'Board of Astuteness', the Chinese game of Tangram. However, existing solutions are designed for computers and therefore has limited uses (for our case) due to the fact that (a) old people prefer to be socialized so do not use computers and (b) the cost of running a computer whilst the mobile phones are already accepted and carried by most is an extra burden that may not help with such difficult users.

A more sophisticated suggestion to combat boredom tiredness and drowsiness is from Sakurai et al. to make extensive use of the Web and Internet resources [32]. They use an augmented cyberspace system for a wide variety of applications such as light e-learning. This system assesses the situation of remote users through use of information collected from multiple remote sensors and associated contexts. For psychologically enhanced interactive learning the system transmits and uses required information of such users' situations, the system remotely augments the cyberspace by stressing signals and providing warnings through multimedia channels achieved upon member's physical and mental status. The drawback of this system is its complexity and it is too difficult for the elderly to use. It also requires the user to work in isolation and may have an anti-productive effect on those with lower mental status.

Another interesting learning mechanism is proposed by Oh and Byun [26] where learning an art can be achieved through an AR learning system. This system enables users to experience a practical learning such as flower garden arrangement using an interactive agent. Though the idea is very interesting its use could be very limited with insufficient interested users due to the complexity of the system.

The demographical distribution of users supports a general tendency towards a better use of the mobile technology as it is becoming smarter and easier to use away from the hype of being children's expensive toys. For example, a survey from Nielsen's report shows positive tendency from the market as to how the number of smartphone users is moving up with the age group [36]. This and many similar data sources support our approach of deploying AR into smart mobile phones (mAR). That is, the most progressive technology of the decade, smart mobile, is moving in the right direction with two distinct features:

a. Ubiquitous access as all smartphone industry makes maximum use of wireless technology and for the 3G now adopting the Internet capabilities under the 4G. That is, access to all Internet resources making mobile users of the old aged who become keen to carry one for all information and communication requirements.

b. Adoption of many lightweight smart functions make all affordable smartphones capable of integrating lightweight AR into these devices at a considerably low additional cost when the volume of production becomes very high.

3.1 Generic design approach

In order to maximize the deployment market for new agile technology one can consider adopting the multicore processing technology similar to that proposed for the sensors as in Chapter 1 of [29]. The final optimization of the design is normally adopted at the manufacturing phase so it is beyond this paper's scope but the approach can be used at a higher level, i.e., the programming level where the functions can be managed better by separating the smartphone operation into three parts:

(1) Lightweight core processing part—this part is enlightened software of the existing smartphones where many extra bits and excessive selling and marketing functions which harm acceptability of the device by the elderly, are often the main cause of rejection by intelligent users. This would enhance the smartphone to last longer running on the batteries and include some very basic functions such as housekeeping, common functions used for AR and basic but ubiquitous communication parts of the device.

(2) AR specific I/O device control functions enhanced to function beyond the existing common smartphone functionality. The design of this part is application-dependent and therefore its capability and share of processor's time varies extensively from one application to another [5, 12].
(3) Application front-end controlling and optimizing the inputs and the outputs of the user interface. In this part certain devices could be disabled to increase the speed and reduce power consumption of application.

The general approach mentioned here indicates an infrastructure for futuristic products therefore in order for this to be adopted for this experiment we had to start with the two most viable groups of applications. Group 1 is for applications built around exercising and rehab. The cameras, microphone and other mechanical, e.g., gyro devices play the main role and some usual calibration process may be required for accuracy and gathering user confidence. Group 2 is for game-oriented applications aimed at mental exercises and learning enabled psychological applications.

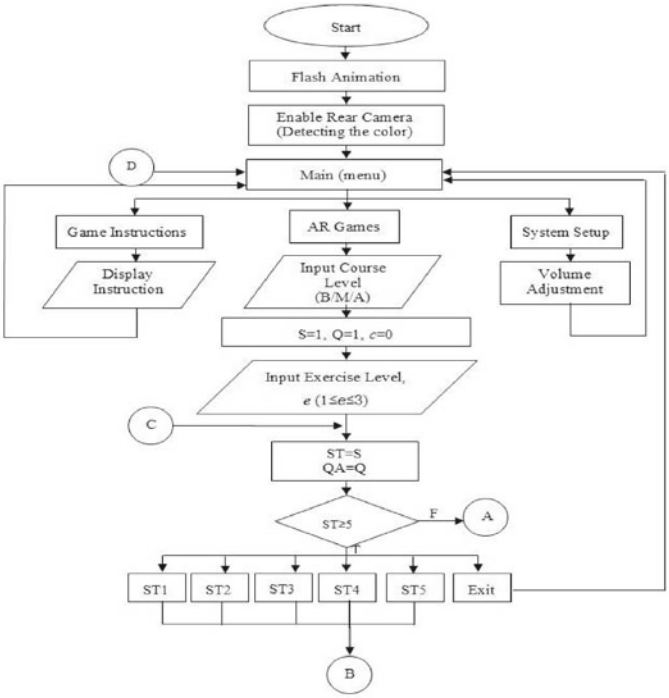
In general, to save memory space and energy most of these two Groups of applications may not be stored in the smartphone at the same time. Therefore if a user would like to use one application from Group 1 and one application from Group 2 then after finishing with one he can trigger a download of the second application and a default setting in the smartphone will clear the previous application from the memory before installing the next one. The potential of using mobile phones for health (m-health), which lies on their recent fast growth in both number and increasing popularity amongst senior citizens. There are, however, problems of usability and effectiveness of the systems being offered to this age group as they are neither children to play silly games nor ambitious business users.

3.2 Core process

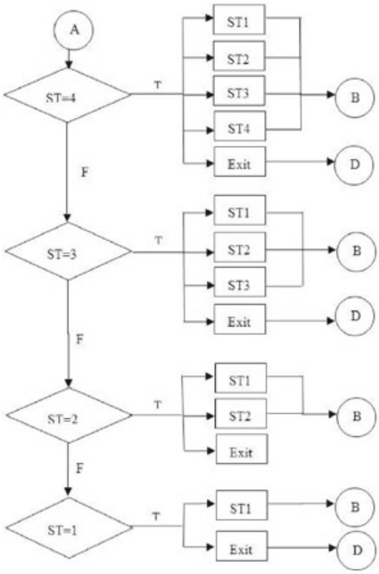
In order to make use of smart mobile phones as a sustainable solution for the elderly health problem we integrate AR in the user interfacing functions of the device where the application process combines some user-selectable physical activities such as a lightweight exercise with some entertaining functions such as a light-hearted gaming or non-intensive lifetime learning to keep the user both interested and rewarded with noticeable feelings of improvement in their health, removing some pains or extensive rehabilitation processes.

For example, the game application case, user interacts with the mAR system by initiating the rear camera to detect the color of a specified object, i.e. shoes, for labeling requirement before actually executing the mAR learning game (Fig. 1a). System then starts Flash animation to welcome the user. The main menu provides options for detail game instructions, system setup, and the mAR game itself. To accommodate different level users, the system retrieves three difficulty quiz levels, beginner, medium, and advanced, from the same cloud database.

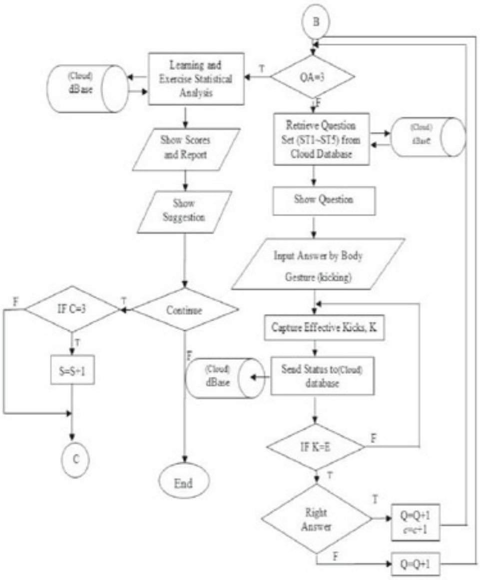
Each level has five sets of game (Fig. 1b), while three quizzes are included in a set (Fig. 2a–c). Up to this stage, all the above functions operate via a touch panel. However, when moving to the phase of answering the questions, AR technology plays an essential role. A critical point of our mAR system is the user has to use body gesture, leg kicking in this case, to activate the sensor area until achieve a certain numbers predefined in exercise levels (Fig. 2d). Fail to reach the required effective exercise will not be able to go to the next question. A verification step is applied to check if the answer is correct or not (Fig. 1c). The feedback of the result is acting as a gating parameter for granting a new set of game. Meanwhile, the learning and exercise status are sent to cloud database on the fly for in-situ



a Flowchart of the mAR, Part a

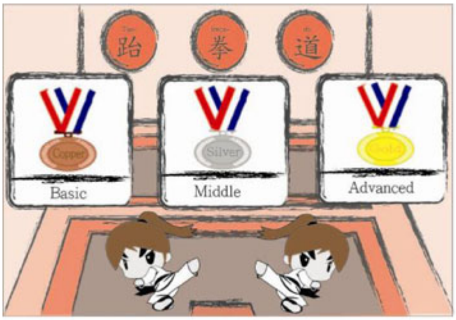


b Flowchart of the mAR, Part b

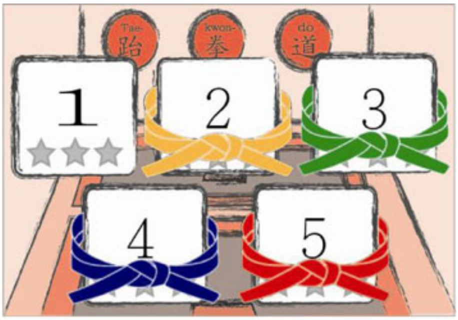


c Flowchart of the mAR, Part c

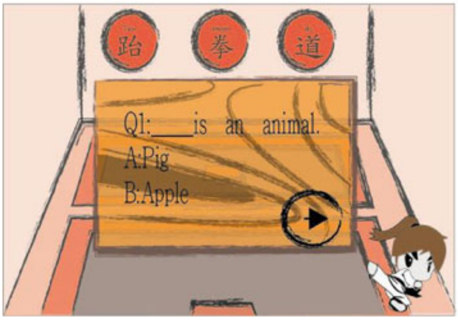
Fig. 1 Flowchart of the mAR operating system



a Each course topic offers three different levels, including “Basic”, “Middle”, and “Advanced”.



b A sequential five sections are available, but the user needs to unlock one after another by completing each course section.



c The screen shows the question for the user.

d The board will break into pieces If the use’s foot kick the ‘sense areas’ of A or B.

Fig. 2 Screenshots of the essential key phases in the system

statistical analysis. Successfully go through the five sets of game will win the ticket to challenge the higher difficulty level of course, i.e. game level. A comprehensive statistical analysis report of learning strength, weakness, and in conjunction with exercise status will be displayed when user accomplishes each set of question. Suggestions are also available following with the report for user’s reference. Some screenshots of the essential key phases are provided above (Fig. 2) to be corresponding to the main steps in the Fig. 1 of the system flowcharts.

Further, Fig. 3 shows a block-diagram of the solution where the input and output functions integrate AR functions for the central processing machine whilst the other parts vary extensively upon the application software. For example some applications require movements of certain parts of the body using images provided from some cameras, rear and/or front. The camera is an input device for, e.g., a color detection to perform the labeling task such as user’s shoes with a pointing device to interact with mAR system. If the application is to combine learning e.g., English as a foreign language then a smart and intelligent process control system is required to estimate or collect the challenging levels of process such as starting a learning level of difficulty from basic to advanced and physical strengths level from 1 to 5 for an optimized operation. All the executing logs, results, and settings are stored in a data bank for follow-up operations as well as experiment statistical

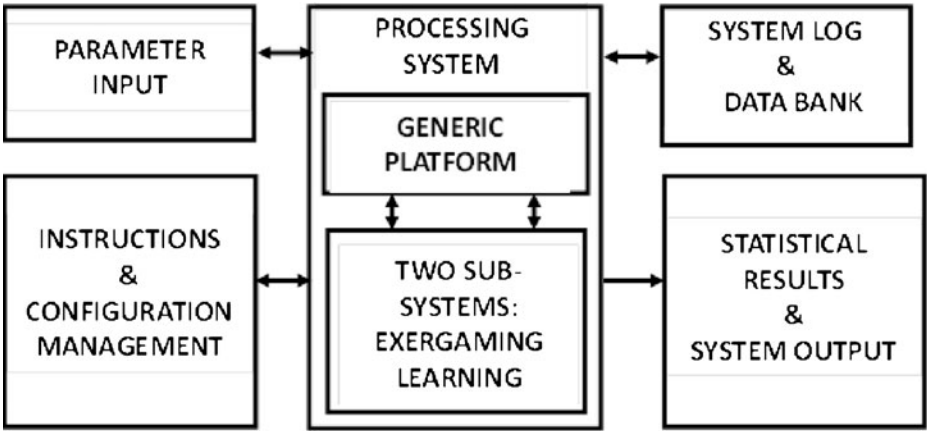


Fig. 3 Generic block diagram of the mAR system with dual core processing system

analysis. A system's suggestions for the user's learning progress, levels, and physical indicators are made available at the completion of each session.

3.3 The experiment

In order to understand the elderly people's habits of the use of the mobile phone and their attitude towards the use of our mAR system, we have taken on a case study. There are 60 senior citizens involved in our experiment who are from two elder learning centers in English learning classes in the North of Taiwan for its popularity and go through three phases, in order of implementation: 'induction', 'experimentation' and 'questionnaire'. In this section, we look at the participants and experimental details.

3.3.1 Participants

The initial number of elderly participants is 60. However, after removing the invalid samples, a total of 51 valid data samples are left for our statistical analyses. In terms of the gender distribution ratios, male versus female are 15 (29 %) versus 36 (71 %). With regarding to the age distribution ratios, 3 are within 46 to 55 (5.88 %), 56 to 65 years old are 20 (39.22 %), 66 to 75 years old are 22 (43.14 %) and 76 to 85 years old are 6 (11.76 %).

Among 51 elders, 33 (64.71 %) always carry mobile phone with them in contrast to 17 (33.33 %) who do not carry mobile phone with one missing value. Though not all elderly people always carry mobile phone with them, during our experiment we provide them the smart phones with our system to practice English learning.

3.3.2 Collecting data

Several evaluation techniques were applied in conjunction with the recordings, questionnaires and interviews. In order to explore older people's preferences towards learning a foreign language (e.g., English) and preferred exercises in conjunction with the habits of using mobile phones, two specific parts are included in our questionnaire. One is personal information including age, gender, portability of the mobile phone, willingness to the use of mobile phones to learn and to increase their body movements, and the top three parts of body movement the elderly would like to enhance. The other contains the questions relating to the usage of the system, for instance, Ease of Use (EOU), Usefulness (UFN) and Attitude (ATT) towards our system.

In the latter part of the questionnaire, the items scored based on Likert's five-point scales: “strongly disagree”, “disagree”, “normal”, “agree”, and “strongly agree”. That is, a “strongly agree” scores 5 whilst “strongly disagree” response is 1. Therefore, when a participant obtained a higher score for a given scale, it represented that the student showed stronger preference towards to that feature. Further, both parts of the questions are paper-&-pencil based and only answer the questionnaire after the use of our system but the using time is flexible and various by individuals.

3.3.3 Processing phases

This experiment includes three phases in order of ‘induction’, ‘experimentation’ and ‘questionnaire’. In the first phase, our research team provided the required introductory initiations and demonstrated how to operate the system for about 15 min (Fig. 4a). Then they move to the second phase; that is to provide our elderly participants the smartphones pre-installed with the mAR system to operate the system (Fig. 4b–c). As soon as the users passed these two levels, they need to answer three questions for each level for which they should fill in

a Initiation **b** User experimenting-1

c User experimenting-2 **d** The questionnaire

Fig. 4 The experimental measurement process in three phases: **a** initiation, **b**–**c** experimenting, and **d** the questionnaire our structured questionnaire that includes the experiment and attitude towards the use of mAR system in the final phase (Fig. 4d).

4 Results and discussions

In this section, some statistics of the use of mobile phones for elderly in our experiments are presented including general personal information, three questionnaire scales of the use of our mAR system as well as the models of elderly ages versus three scales within the use of the mAR system. In our questionnaire, three scales consist of Ease of Use (EOU), Usefulness (UFN) and Attitude (ATT) towards our mAR system.

4.1 Personalized information

In this study, we collected the general personal information of our elderly participants by the paper-&-pencil based questionnaires. We investigated the willingness of learning English and taking exercise by the use of mobile phones, the habit of the portability of mobile phones and the top three parts of body movement exercise. Table 1 (a) reveals 64 % of the participants always carry their mobile phones. After the use of our mAR system, a very high ratio (88.89 %) of females is willing to use mobile phone to learn English whilst over half, 60 %, of male have the same intention (Table 1, b). Table 1 (c) shows 88.89 % of female participants have willingness to use mobile phone to increase their body movement comparing to 80 % of male have the same willingness after using the system. Finally we investigated the top three parts of body movement by the use of mobile phones for elderly people and Table 1 (d) indicated 32.79 % of female prefer to exercise ‘Wrist & Arm’ and 31.35 % of female prefer to exercise ‘Neck’ whilst 45.83 % of male prefer to exercise ‘Wrist & Arm’ and 33.33 % of male prefer to excise ‘Knee’. Overall 36.47 % of all elderly participants prefer to excise ‘Wrist & Arm’ comparing to ‘Knee’ (28.24 %), ‘Neck’ (25.88 %), and other parts of the body (9.41 %).

4.2 Scales of the usage of the system

In this research, a series of statistical test analyses were conducted to examine the questions relating to the usage of our system including three scales: Ease of Use (EOU), Usefulness (UFN) and Attitude (ATT) towards our mAR system. The statistical software applied for analyzing is SPSS 18. Table 2 reveals the elders shows the positive response (all means>3) to the use of our system in all three scales, EOU (mean=3.53, SD=0.922), UFN (mean=3.95, SD=0.9938) and ATT (mean=4.03, SD=0.848).

4.3 Analysis for tendencies

Based on the data being collected in the experiment, we build up the models for the relationships between the elderlies’ ages and the level of scores: EOU, UFN and ATT within our system. In this system, we first test the accuracy of our evaluation against a trend line with a proximity denoted by *the coefficient of determination*, R^2. The R^2 varies between 0 and 1, indicating how close the measurements to the estimated trend line. A trend line is most reliable when its R^2 value is close to 1 and very poor when approaches 0. Therefore, by selecting the bigger values of R^2, three formulas for our modeling system are formed as shown below, as plotted against the measurement data in Figs. 5, 6 and 7, respectively:

Table 1 Participants general personal information

Gender	Male	Female	All
a. Always carry mobile phones (unit: person)			
Yes	10(66.67 %)	23(63.89 %)	33(64.71 %)
No	5(33.33 %)	12(33.33 %)	17(33.33 %)
Missing	0(0 %)	1(2.78 %)	1(1.96 %)
Total	15(100 %)	36(100 %)	51(100 %)
b. Want to use mobile phones to learning English			
Yes	9(60 %)	32(88.89 %)	41(80.39 %)
No	6(40 %)	2(5.56 %)	8(15.69 %)
Missing	0(0 %)	2(5.56 %)	2(3.92 %)
Total	15(100 %)	36(100 %)	51(100 %)
c. Want to use mobile phones to increase body movement			
Yes	12(80 %)	32(88.89 %)	44(86.27 %)
No	3(20 %)	3(8.33 %)	6(11.76 %)
Missing	0(0 %)	1(2.78 %)	1(1.96 %)
Total	15(100 %)	36(100 %)	51(100 %)
d. Top three parts of body movement needed			
Neck	3(12.5 %)	19(31.35 %)	22(25.88 %)
Wrist & arm	11(45.83 %)	20(32.79 %)	31(36.47 %)
Knee	8(33.33 %)	16(26.23 %)	24(28.24 %)
Others	2(8.33 %)	6(9.84 %)	8(9.41 %)
Total	24(100 %)	61(100 %)	85(100 %)

EOU (Y) vs. *age* (X), quadratic polynomial

$$EOU = 0.004 \times age + 3.908 \tag{1}$$

UFN (Y) vs. *age* (X), cubic equation

$$UFN = 0.0000008284 \times age^3 - 0.016 \times age + 4.744 \tag{2}$$

ATT (Y) vs. *age* (X), quadratic polynomial

$$ATT = -0.001 \times age^2 + 0.079 \times age + 1.670 \tag{3}$$

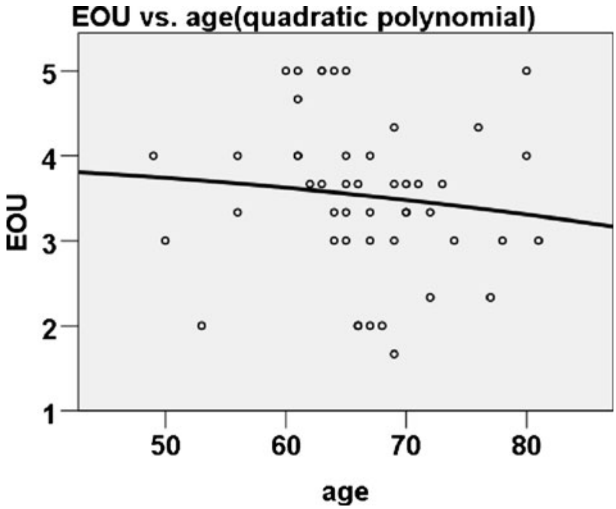
4.3.1 Ease of use

With regards to 'Ease of Use' of the system the second order trend provides best statistical match and the tendency with age is negative. Figure 5 reveals older people show lesser

Table 2 The descriptive data of academic achievements for the three AR groups

	Mean	SD	n
Ease of Use (EOU)	3.53	0.922	48
Usefulness (UFN)	3.95	0.938	49
Attitude (ATT)	4.03	0.848	48

Fig. 5 The age trend for 'Ease of Use'

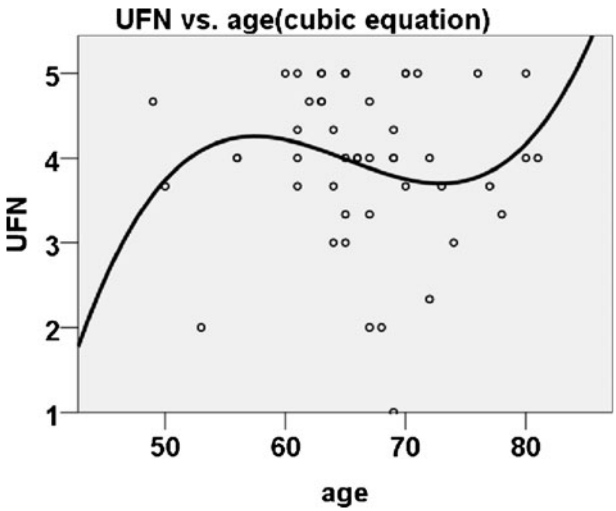


sensitivity to EOU which can be justified as higher aged elderly people have higher needs for such a solution as they see EOU cannot be an obstacle. On contrary, the younger ones in the group tend to be more agreeable with the fact that our system is easy to operate. The overview of whole sample data shows the average of EOU (3.51) is well above 3.0, which means all users show positive response to new system's EOU.

4.3.2 Usefulness

In terms of 'Usefulness', we consider a third order tendency fits this parameter best and provides a logical explanation. As shown in Fig. 6 the middle range old people find the system useful with a rapid rise after a kink in the middle. That is, as the age goes up they feel a need for it much higher than the younger ones. An overall view of the whole sample data

Fig. 6 The age trend for 'Usefulness'



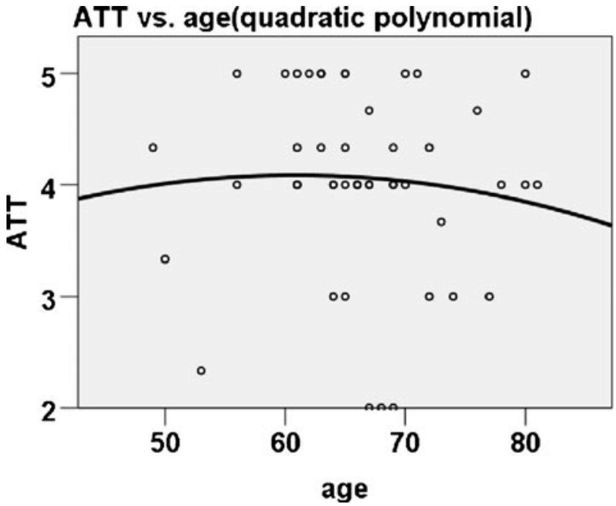


Fig. 7 The age trend for 'Attitude'

shows an average of UFN (3.95) that is well above 3.0 meaning all users tend to have positive response using the system.

4.3.3 User attitudes

With respect to 'Attitude' towards the new system the second order trend provides best statistical match and shows a logical explanation. As shown in Fig. 7 the user attitude increases with age but after a peak in the middle it slowly reduces as the older ones have lesser confidence and understanding of mAR technology. The overall users' view, average ATT (4.03), well above 3, shows a strong positive support of mAR technology as a good solution for their need.

5 Conclusions

Following an overview of the overwhelming problems associated with elderly health issues in the near future we have devised a mass-market low-cost innovative integration of augmented reality within smartphones. Following detailed description of our experimental trial we have used our results to demonstrate how our results for EOU, UFN, and ATT can be modeled for individual activity design procedure for a dynamic deployment of AR enabled smartphones. Upon the new approach we have shown that the two proven application areas of physical rehabilitation and lifelong learning for improved health and rehabilitation exercises due to superior performance over classic e-health and m-health. They are dynamically optimized to motivate the intended user new learning methods superior to the classic games, puzzles and other general computer-based solutions. We envisage this concept would initiate a whole new family of AR-enabled tailored interactive processes to promote a new brand of sustainable mAR solutions for the rapidly growing old generation people.

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