Towards an Ageless Computing Ecosystem

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Abstract

In the 21st Century, the world faces a unique challenge – global aging. The simultaneous manifestation of this challenge in so many countries is unprecedented and will have major social and economic ramifications. The impending tsunami of silver populations also presents unique opportunities for forward thinking nations and businesses. These elderly citizens command major purchasing power, and possess invaluable knowledge, wisdom and skills accumulated over many years. Countries and businesses which develop and adopt innovative technologies to allow elderly citizens to continue making important contributions to society will derive enormous benefits. In this paper, we analyze how computing technologies can be used to help us build an ageless society in the future. We identify six major challenges facing today's elderly populations and propose six corresponding research directions in computing technologies. A vision for forming an ageless computing ecosystem that serves the needs of the elderly and other stakeholders is proposed based on this analysis.

Keyword: population aging, ageless computing, age-friendly, ecosystem.

I. The Problem

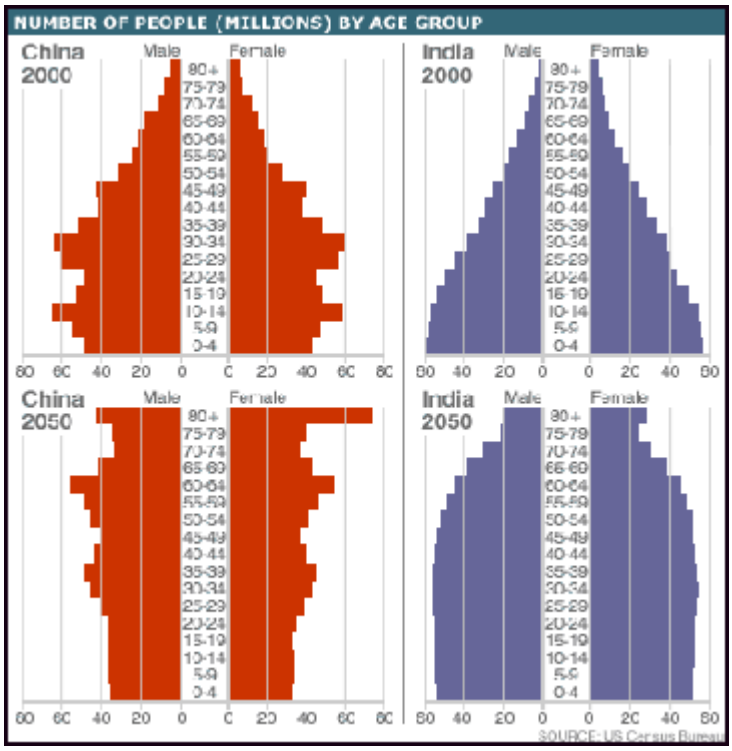

Figure 1. The Projected Demographic Transition of China and India [*Source: US Census Bureau*].

In the 20th Century, the world has witnessed an unprecedented period of rapid technological advancement and economic growth. Within 100 years, the world has moved from the industrial age into the information age. The rapid improvement in the general standard of living around the world has resulted in lower mortality rates, prolonged life span and huge increases in the total world population. As the birth rates around the world decreases due to a variety of reason, today, the world is faced with a unique problem – population aging. As can be seen from Figure 1, two of the world's most populace countries – China and India – have already started to feel the burden of increasing percentage of elders (people aged 55 years or older) in their populations. It is projected that by 2050, the elderly populations in China and India will be almost equal to the young age group (people aged 25 years or younger) [2].

This trend puts enormous strain on the existing healthcare structure around the world. Be it based on filial piety (which is mostly the case in Asian countries) or institutionalized elderly welfare and

healthcare (which is mostly the case in the developed countries), the existing framework for elderly care will not be able to meet the needs of the coming tsunami of aging populations. On the other hand, today's "silver" populations present unique opportunities for forward thinking nations and businesses. As a group, elderly citizens command major purchasing power, and possess invaluable knowledge, wisdom and skills accumulated over many years. Countries which embrace technologies to allow elderly citizens to continue making important contributions to society will reap huge benefits.

The key to adapting to an aging world is to identify ways to turn the aging population problem into new opportunities for innovation and business development. In this paper, we attempt to look into the field of computing technologies to analyze how to reshape this field in the face of population aging. We discuss innovative research directions that focus on providing *insight*, *involvement*, *encouragement*, *engagement* and *empowerment* to (I^2E^3) various stakeholders related to the aging population, and provide a vision towards building an ageless computing ecosystem.

II. The Research Challenges

Aging can be a challenging process for most people. In this section, we discuss six types of major challenges facing an elderly person.

A. Emotional Challenge

The main emotional challenge facing the elderly is the feeling of loneliness. The onset of such emotion can be caused by a variety of aging related reasons including children leaving their homes to pursue their own life, relocation to previously unfamiliar locations with no friends around, the passing away of their spouses or friends, inability to join social activities due to the loss of mobility through aging, etc. Such a negative emotion can lead to deterioration in physical wellbeing if left unaddressed. Past research works have shown that there is a high correlation between prolonged loneliness and heart diseases among the elderly [57].

To alleviate the elderly people's loneliness with computing technologies, many innovative attempts have been made. These research attempts are focused on the use of virtual or robotic companions to help the elderly users. Some were mainly concerned with assisting physically impaired elderly users with daily chores [25] and monitoring their health [13]; some were trying to help the elderly with remembering their schedules; other assistants were designed to display social sensitivity with interacting with the elderly user [36] albeit with limited success. Nevertheless, there are certain ethical concerns about using digital assistants to help the elderly. The elderly may increasingly have a feeling of objectification, their privacy might be invaded, they may feel infantilized and there may be circumstances in which it is difficult to determine at design time whether the elderly user or the assistant should have control [55].

We believe that the key to alleviating the emotional challenge facing the elderly lies in designing emotional companion agents catered for them. Such agents can reside in the cyber world or have a physical representation in the real world. A silver personal digital assistant should be able to deduce the elderly user's likely mood and emotions from a variety of sources such as the user's current context, ambient information from overhearing the user's utterances, the user's personal propensity toward displaying different types of emotions, etc; and take mediating measures such as helping the elderly develop interests and hobbies, acting as partners to interact with the elderly, display empathy and engage in emotional exchanges with the user. These research works require interdisciplinary efforts in order to be successful.

B. Physio-cognitive Challenge

Another aspect of aging that often takes a heavy toll on the elderly is the decline in physical and cognitive abilities. Such declines can sometimes be accelerated by injuries or degenerative cognitive conditions like Parkinson's and Alzheimer's diseases. To improve the elderly's physical and cognitive wellbeing so that they can live independently for longer, many researchers resort to the use of digital games. Currently, physical exertion games that let the elderly carry out simple exercises in

their homes [27], [45], [52] and cognitive training games [46] make up the mainstream of games designed for the elderly.

While these approaches are valuable attempts in building silver games, they are still mostly standalone games with very simple interactions, and usually designed for a single player. Such a design may be enough for clinical rehabilitation purposes. However, in order for silver games to serve a larger number of elderly users who live alone at home, they must be engaging enough with an emphasis on sports safety.

From past research, virtual world has demonstrated its appeal as an ideal candidate platform for silver game development [3], [33]. Such an environment can be customized to serve diverse needs of the elderly while exercising their bodies or minds. The elderly player can travel to unfamiliar places, meet new people, exercise together with their friends, and even engage in activities that are too costly or dangerous to do in real life. Moreover, a virtual world based silver game can be designed to be interesting for not just the elderly users but other age groups as well. Since they are popular among the young, it is possible to design silver game features that promote intergenerational interaction during game play which has been found to be highly beneficial for both the elderly and the young [19], [22], [41], [48], [53], [54]. Integrated together with age-friendly exercising equipment, virtual world based silver games can be a useful addition promoting an active lifestyle among the elderly.

C. Social Challenge

In modern societies, more and more elderly people are able to enjoy good health after the normal retirement age. They are not only attracted to leisure activities but also want to live with dignity and honor. Many find personal fulfillment by continuously contributing to the society. And indeed, governments around the world are starting to realize that the elderly population is a pool of great wisdom, experience and skills that have been traditionally overlooked. Some studies have quantified the potential loss to the economy by not tapping into the elderly talent pool, e.g. in Australia, this figure is estimated at $10.8 billion per annum [24].

The concept of *productive aging* has been recognized as a possible way to address this challenge by researchers and governments around the world. Participating in social activities has been found to help preserve cognitive functions among the elderly [29]. Some earlier studies even suggested that social and productive activities can enhance the quality of life in the elderly and prolong their lifespan [28] apart from their obvious benefit of contributing to social welfare. Currently, the discussions of productive aging measures mainly revolve around what government institutions and policies should do to encourage productive aging [40], and the form of productive aging activities envisioned for the elderly are mainly volunteer work [32]. However, it is often difficult for the elderly to put their knowledge, skills and experience to work in areas where such qualities are in high demand. This contributes to the generally low level of participation in volunteer activities by the elderly.

In our view, the mismatch between the skills acquired by the elderly over years of experience and the demand for such skills in the society can be efficiently resolved by ageless computing technologies, specifically, using a crowdsourcing [23] based approach. A silver crowdsourcing platform, designed to alleviate the elderly of the task of search which they tend to find challenging, to find work that can fit into small slices of time periods so as not to over burden the elderly users, and to match available work to individual elderly user's interest, skills and schedules can be a useful potential way for computing technologies to help bring about more ubiquitous productive aging in the form of easily accessible services to the elderly.

D. Challenge for the Elderly to enjoy Modern E-commerce

According to data published by the Federal Reserve [1], currently, household wealth tend to concentrate with the elderly. As shown in Figure 2, in both U.S. and Australia which are typical developed western societies, the median household net worth of people at various stages of aging (55 years old and above) combined is more than twice that of all other age groups combined. Thus, the current cohort of elders commands considerable purchasing power. In order for world economy to keep growing, it is vital to adapt the existing consumer market to be inclusive to the elderly.

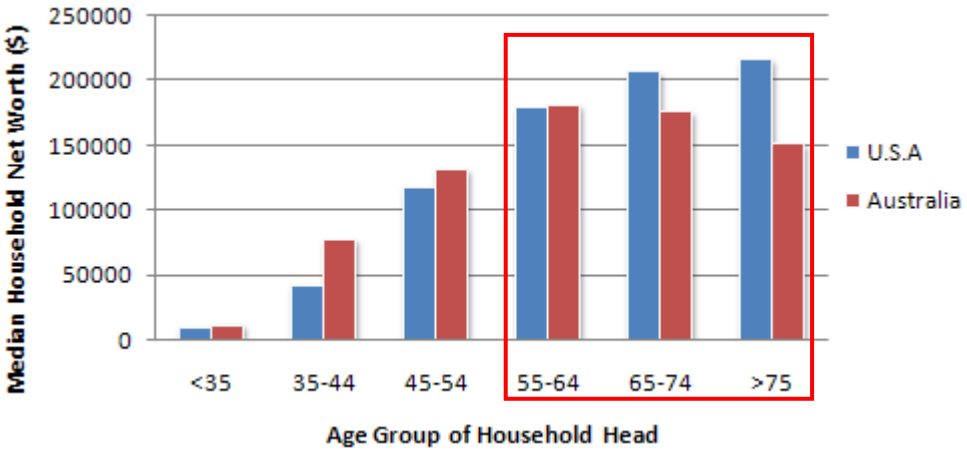

Figure 2. Median Household Net Worth by Age Group in 2010 [*Source: Federal Reserve*].

Such an initiative has already been set in motion in the field of e-commerce research. Many e-commerce systems are looking into the direction of improving user experience by incorporating virtual assistants in their websites to help the elderly users navigate their existing user interfaces which are still primarily designed for the young. However, researchers have found some important disconnections between what these virtual assistants offer and what the elderly users prefer [18]. Moreover, an important hindrance to the elderly when it comes to transacting in online e-commerce systems is their general lack of trust in the systems. Studies have shown that many elders perceive e-commerce systems are highly useful but very risky places to conduct purchases [43]. Lack of perceived social support in existing e-commerce systems is also an important hurdle for the elderly to shop there [17].

In order to bridge the digital divide that excludes most of the elderly from existing e-commerce marketplaces, we envision a new ubiquitous commerce (u-commerce) platform by enabling existing e-commerce systems to offer “experience economy” [16] to the elderly. This consists of allowing e-commerce to have a presence in the physical world where they elderly can easily see and learn about them through mobile technologies [50], [59]; building sophisticated trust management systems that can counteract a wide range of misbehaviors towards the elderly users [35]; and suggesting what the elderly users may want and need based on their contexts, interests, and online and offline behavior patterns to minimize the effort of searching; etc. Most importantly, u-commerce should involve more

family based decision-making where the elderly can interact with the family members or others in their social network to collaboratively customize their purchasing plans and decide on what items to select so as to turn the commoditized goods and services sold on e-commerce websites into fun experience products to encourage the elderly to spend on such platforms.

E. Where should Ageless Computing Technologies Converge?

When it comes to promoting aging-in-place among the elderly, the natural question that first comes to people's mind is "how to turn the elderly persons' homes into an intelligent and caring environment for them?" To address this problem, many research works in the field of smart homes have been carried out. The major areas of focus include monitoring the health of and providing telemedicine for elders with chronic diseases or disabilities [37], [42], [51]; creating intelligent assistive environments to help the elderly with their daily chores [14], [20]; providing easy access to information and services through smart home user interfaces [11], [12], [60]; integration of cognitive and physical training into smart homes [38]; and simulated studies of interactions between the users and smart home functions [30], [31], [47]. While these technological solutions provide valuable insight into how to make the homes *intelligent*, they are still not able to answer the question how to make the homes *caring*.

To advance the state of the art in smart home research and better serve the elderly, we believe silver lifestyle based services and technologies need to be designed. Being the environment an elderly user spends most of his time in, a silver smart home is a natural platform where a diverse range of ageless computing technologies catering to the emotional, social, and physio-cognitive needs of the elderly can converge. Smart homes provide an excellent environment for the continuous collection and monitoring of a wide range of data concerning the elderly user's lifestyle and behavior patterns [49], [8], [39]. However, apart from designing intelligent sensing technologies, the aspect of unobtrusive data collection is also vital to the success of such devices. The reason is that many elders have been found to be desiring a dignified lifestyle. They may become annoyed by the fact that they are being monitored constantly and intrusively which cause them feel infantilized. In addition, the social

signals [58] sent out by the elderly in their living environment may be a valuable source of information for predicting changes in their mood or physical conditions and, therefore, need to be integrated into the decision making process while caring for them. In addition, the elderly users should be able to control and alter the intelligent behaviors of the technologies embedded into the smart homes. This provides them with a sense of control and may help the system earn their trust. Nevertheless, as many intelligent behaviors may influence each other in a non-linear way, end-user modifications should be carefully evaluated by the system before being included. Researches in this area are currently limited. To consolidate a diverse range of silver services into smart home platforms, it is necessary for future smart homes to leverage on the openness and flexible framework of Cloud Computing [10], [26]. The key challenge to incorporating Cloud Computing into smart homes for the elderly is one concerning the cost. How to design affordable and functional Cloud Computing technologies for silver services and devices to be used in an elderly household is an important research problem worth pursuing.

F. Knowing what the Elderly Want

The abovementioned aspects which are important to the development of ageless computing technologies need to rely on an in-depth and real-time understanding of the characteristics, needs, and preferences of the target groups of elderly people as well as related stakeholders. Such a need has been well recognized by many government organizations and researchers. In the past, many studies concerning various aspects of the elderly have been conducted. Among them, the Survey of Health, Aging and Retirement in Europe (SHARE) [6] is one of the most long-lasting and large scale data collection efforts. More recent studies about aging and economic development [5], elderly housing issues in America [56], elderly healthcare expenditure [44], and lifestyle and longevity [15] have also been reported.

These studies are often conducted in waves with sample size ranging from a few hundred to tens of thousands of respondents. The most commonly used form of data collection is through survey questionnaires and face-to-face interviews. Such an approach, while able to provide a personal touch

to the respondents, puts heavy burden on the manpower and cost of conducting elderly studies. In addition, the collected data often take a long time to process and analyze, which makes the results less timely.

In order to alleviate these problems and build the foundation for a dynamic ageless computing ecosystem, we believe that a silver study test-bed designed based on the principles of participatory simulation [4] is a useful research direction. Data collection will be separated into two aspects: 1) self-reported data, and 2) observed behavior data. Apart from designing automated survey questionnaire management and delivery systems, appropriate incentive structures need to be set up to persuade the elderly and other stakeholders to participate in these studies. We believe personalized analysis reports derived from each individual participant's data can be a valuable source of longitudinal information for the elderly themselves as well as their loved ones. The data collection process can be made more fun if presented through a popular social network or in the form of social games. In addition, automated behavior data collection applications should be developed for various technological platforms that elderly may come into contact in their daily lives so as to turn their normal activities into data inputs for the silver study test-bed. Through integrated data analysis systems, knowledge discovered can be translated into new behaviors for intelligent agents used in the test-bed to simulate the actions of the elderly individuals. By enabling the modification of environment conditions such as urban facility layout, new policies, and social mood changes, etc, such a test-bed can provide valuable insight into the effect of new silver products/services or policies regarding the elderly for various stakeholders in an ageless economy. Through such a platform that fosters understanding, builds up a shared view about the elderly population, and supports collective decision-making among stakeholders, the drivers of the new ageless economy can have access to more intimate and up to date insight into their key target demographics.

III. The Vision

The vision towards an ageless computing ecosystem can be illustrated in Figure 3. It is one that consists of an infrastructure primarily made up by platforms addressing the six research challenges mentioned in Section II. By involving the elderly in productive aging, engaging them through intergenerational silver games, encouraging them to adopt an active lifestyle with their personal silver agents, empowering them by allowing them to reflect their opinions and needs through silver life technologies in their homes, enabling them to contribute to the development of world economy by spending through u-commerce, and deriving insights into their collective psyche through the silver study test-bed, an ageless computing ecosystem can be built up around the daily life of the elderly. Using the silver agent as a gateway connecting the elderly with silver technologies, it is easier to ensure that technologies will appear transparent to these end-users and be seamlessly integrated into their lives. By gaining insight into the elderly population, the results produced by the silver test-bed can help the design of silver products, services and policies to evolve with the changes in the aging populations and thus, enable continuous adaptation of the ageless computing ecosystem. The six platforms presented in this vision form the essential backbone of the ageless computing ecosystem to serve the duel purposes of serving the elderly and providing a framework for various stakeholders, demand drivers and policy makers to participate in a technology enabled silver economy. Based on this backbone, a wider range of silver services and products may be designed and infused into the elderly's life.

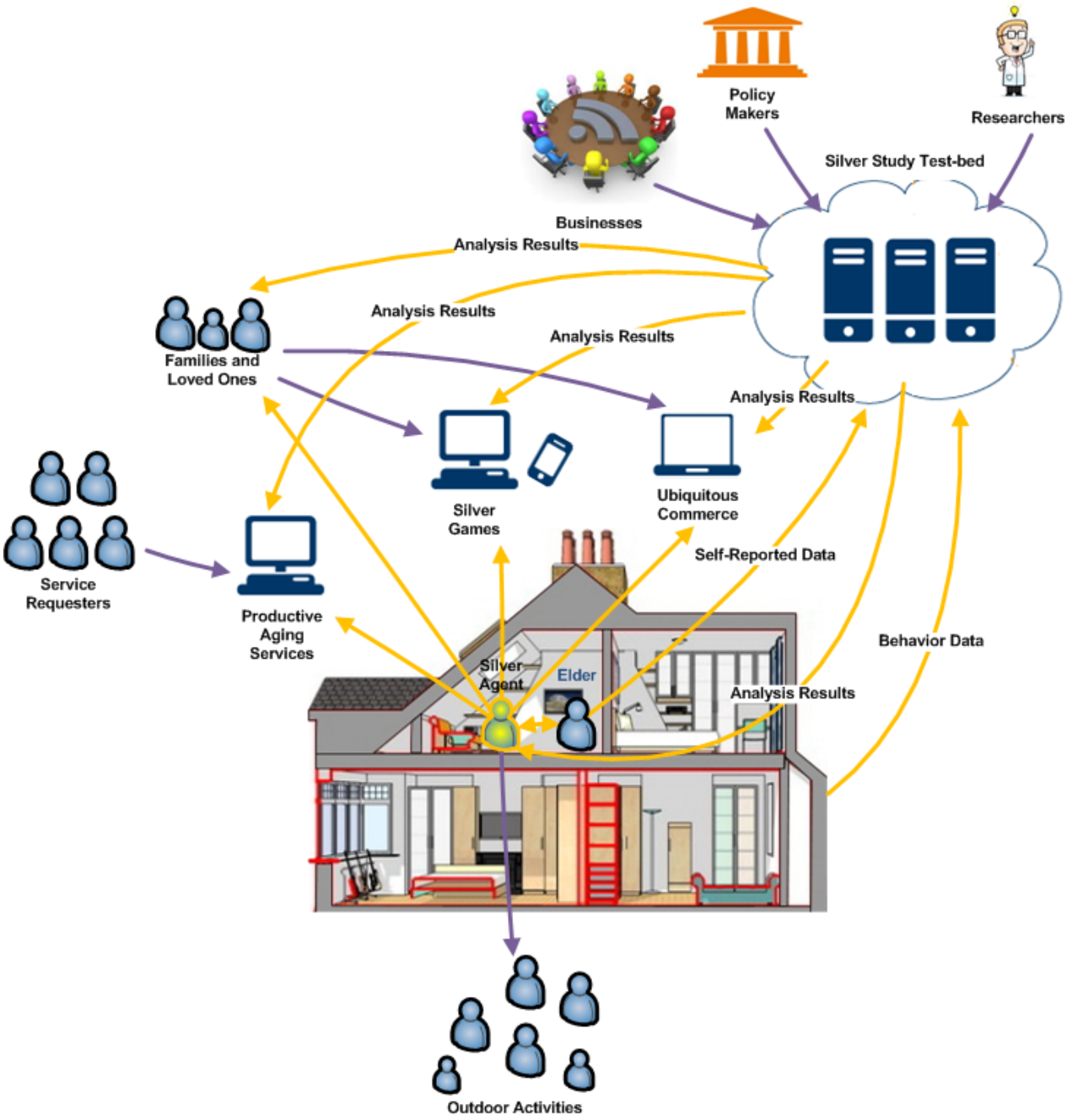

Figure 3. The Vision for an Ageless Computing Ecosystem.

IV. The Way Forward

To build the backbone for an ageless computing ecosystem is not purely a research endeavor. Apart from involving scientists and engineers from multiple disciplines, it is vital for government agencies to play an active facilitating role right from the start. Moreover, it is necessary to incorporate the concept of aging societies into our educational programs to prepare the population for the inevitable

transition to an aging world. Fortunately, a confluence of such developments around the world, albeit in different stages, can be observed today. This makes us confident that the proposed vision is closer to being realized than previously imagined.

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