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Technical requirements of age-friendly smart home technologies in high-rise residential buildings: A system intelligence analytical approach

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ABSTRACT

Smart home technology (SHT) has been identified as a promising means of helping seniors to remain independent and maintain their quality of life (QoL) while containing spiralling care costs for older people. Despite official pilot schemes in many countries to promote SHT in seniors housing, there is limited understanding of the forms that such SHT interventions should take. This study builds on the analytical model of intelligent building control systems developed by the author; the aim is to provide a systematic approach to understanding the key intelligent attributes of smart-home devices. A qualitative participatory evaluation approach involving focus groups was adopted to investigate the needs of seniors and their SHT preferences. Fourteen features of the SHT technical requirements of four key intelligent attribute types were identified. This study's insights will help to shape the way SHT is designed and used.

1. Introduction

In recent years, Hong Kong, like many other places in the world, has encountered the challenges of a sharp increase in the proportion of older people in the overall population and an increasing number of older adults living independently. Residential living environments have a strong influence on to the physical and psychological well-being of older people [41,42]. Past research shows that older people are likely to spend more time (i.e. 80% of their time) at home than other age groups [43,44]. The person-environment (P-E) fit model [45] posits that older adults become increasingly reliant on their surroundings, such as their physical living environment, to offset functional decline as they age [46]. To accommodate the demographic shift towards an older population, it is suggested that home environments should be designed to accommodate losses in physical function, and thus enhance the independence of older adults in their daily activities and increase their autonomy (Lawton and Nahemow, 1973).

The significant advances in microprocessor-based technologies over the last decade have led to the emergence of home automation and intelligent control technologies that provide convenience, comfort, energy efficiency, security and better quality home environments [40,47]. Smart home technologies (SHT) have been proposed as a method for helping older people to maintain independent living and safety at home; they can perform some of the activities of daily living (ADLs), predict normal and abnormal behaviour and alert caregivers to potentially dangerous behaviour [48,49]. SHT include a range of emergency assistance systems, security and safety features, fall prevention features, sensors and timers that aim to monitor the daily functioning of the older adults at home and to reduce falls, disability, stress, fear and social isolation [50]. For example, real-time monitoring and detection of accidental falls or slips among older people [51] would ensure timely first-aid by caregivers, families or paramedics [52]. Detection of unattended cooking in kitchens, an unsafe behaviour when using a stove top, particularly by the frail older adults with intellectual disabilities, would reduce the risk of accidental and sometimes fatal fires [53]. Detection of unauthorised intrusion would maintain home security. Appropriate information and communication technology (ICT) enables social interaction monitoring and assistance for the older people; for example, health care data can be remotely transmitted to a monitoring site (i.e. hospital or clinic) from an older adult's home [54]. Arguably, a home setting equipped with SHT should reduce stress and optimise quality of life (QoL): for example, by improving functional capacity; monitoring health status; enhancing psychological wellbeing; increasing social support; improving morale; enhancing independence; and allowing for coping and adjustment. SHT also can help relieve the burden on caregivers and social support services [55,48]. However, it is also possible that SHT would create feelings of confusion and anxiety in the older adults [56].

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A number of overseas studies have indicated that there are extensive acceptance barriers, such as privacy/ethical issues, security and accessibility, to SHT – presenting serious obstacles to the ability of SHT to provide technical solutions [55,57,58,59,60]. To date, the influence of SHT on seniors is ill-defined and has received insufficient attention from researchers, as is the question of how future cohorts of people may benefit from SHT [61,62]. Hong Kong has one of the best ICT infrastructures in the world, and the percentage of households with a computer or other IT equipment connected to the Internet is almost 80% [8]. Statistics also show that over 80% of people aged 55–64, and 36% of people aged 65 and over had smartphones in 2015 [8]. Similarly, over 70% of citizens aged 55–64, and 30% of citizens aged 65 and over have rich computer experience [8]. This implies that IT components are common in the daily activities of the older people in Hong Kong, in particular the 'younger' older people. Hong Kong is also very congested and the urban area has the highest population density in the world, which makes the city an interesting setting to investigate the potential of SHT.

The development of SHT in Hong Kong, as well as in many other cities or countries, is limited by the lack of reliable information about the human component; the specific needs and requirements of older people need to be incorporated into technical design so that appropriate technological solutions can be developed to address these needs. SHT research in Hong Kong has no knowledge of the local older adults' use or non-use of SHT (including the level), user needs and fears, or how SHT can enhance aspects of ageing in place (AIP). Most homes in Hong Kong are smaller than homes in Western countries, so the concept and application of SHT could be different in Hong Kong than in other countries. Previous study maintains that the size of the house controls the number of devices and the functionality, which in turn will affect the cost of the system [10]. Possibly, the potential for SHT adoption among the older people is larger in Hong Kong since the home is smaller - less system (e.g. sensors) required and a lower cost. Understanding the issues that are faced by seniors interacting with SHT is a necessary step in developing appropriate smart technologies and design solutions that address seniors' physical conditions. Without a clear and accurate understanding of the needs of older adults, the use and implementation of appropriate SHT to support seniors in Hong Kong is not feasible. This knowledge gap severely limits the ability of the local building sector and policy makers to make informed decisions about the adoption of SHT devices as early care solutions in future senior residential blocks/housing designs.

In addition, SHT adoption also raises questions about the nature and attributes of appropriate smart home devices [63]. Although enhancing the QoL of the older adults at home is considered to be a primary goal of SHT adoption, we have only a limited understanding of what smart home devices must be able to do to meet the specific requirements of older adults. Existing research lacks a systematic approach to determining which 'intelligence' performance elements should be incorporated, and how these elements can accommodate the needs of seniors' AIP requirements. These knowledge gaps and practical deficiencies have forced the industry to continuously rely on existing designs or personal caring experiences, 'gut-feeling', rudimentary judgments or a combination of these, to justify the appropriateness of smart home devices for the older people. As a result, many new but not entirely beneficial home-based technologies tools have been installed. Thus, an inadequate understanding of the needs and expectations of seniors has led to poor knowledge of which devices should be designed and provided to the market. This study builds on the existing analytical model of intelligent building control systems by the author ([40]). The analytical model of system intelligence posited that any intelligent device holding identified intelligent attributes, including autonomy, controllability for complicated dynamics, human–machine interaction, and bio-inspired behaviour, which can help improved operational effectiveness and energy efficiency, enhanced cost effectiveness, increased user comfort and productivity, and improved safety and reliability, in buildings ([40]). This model helps explore the functionalities and attributes of SHT devices that promote the AIP of seniors living independently in HK. The research objective is to identify the key intelligent attributes of smart-home devices that would benefit senior citizens in their daily lives.

2. Development of relationships between SHT and intelligent attributes

How smart are smart home technologies? How do we determine a system's degree of smartness? These questions demonstrate the difficulties in standardising 'smartness'. This problem extends to the technical definition of SHT. Although SHT always involves the concept of home automation, it should be much more then home automation and should make use of modern information technologies. The idea of a smart home is to make living in a home more enjoyable and convenient through the application of intelligent design [17]. Functionally, a smart home consists of a group of intelligent attributes that control the features of home appliances within a domestic residence [21]. However, the technical developments needed to evaluate intelligent building systems is mainly theoretical, although there are studies evaluating environmental intelligent building performance and physical parameters [39,40], for example, a recent study conducted by Arditi, Mangano and Marco [1].

Studies of machine intelligence in the engineering literature can provide insights into the evaluation of intelligent buildings and their subsets – SHT. Studies of machine intelligence aim to make systems and machines more intelligent by evaluating existing systems and then improving them with new designs. In a review, Bien et al. [6] identified four key attributes of intelligent systems: autonomy, controllability of complicated dynamics, man-machine interaction and bio-inspired behaviour [6]. The framework developed from these categories can be used to measure a machine intelligence quotient and the system intelligence of building control systems [40,64]; this framework is adopted in this study. Two notions of common intelligent attributes, i.e. autonomy and controllability of complicated dynamics, and two notions of specific intelligent attributes, i.e. man-machine interaction and bio-inspired behaviour of intelligent control devices in building, are examined in our research [40] (Fig. 1).

Details of the four attributes of system intelligence (i.e., autonomy, controllability of complicated dynamics, man-machine interaction and bio-inspired behaviour) are discussed in Wong et al. [40]. In brief, 'autonomy' relates to the ability to perform self-operative functions, which is a characteristic of a system that minimises human intervention during the execution of tasks. This includes the ability to perform self-calibration, self-diagnostics, fault tolerance and self-tuning. In complicated dynamic systems, controllability refers to the features of a system that allow it to perform in a manner that is based on non-conventional models, adaptation, non-linearity and motion planning under uncertainty. Man-machine interaction refers to the ability of the system to embrace human-like understanding or communication, the emergence of artificial emotion and ergonomic design. A system with bio-inspired behavioural-based technology has the ability to interact with the built environment and to provide services based on biologically motivated behaviour, cognitive-based behaviour and neuro-scientific data. Table 1 summaries the scope

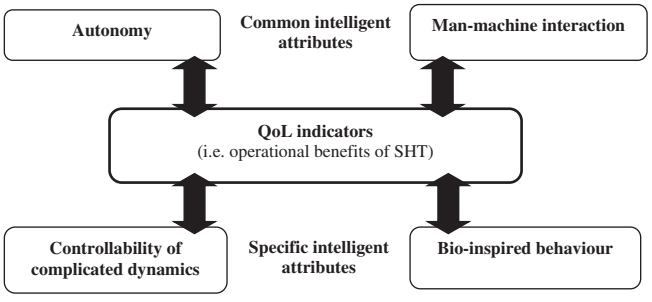

Fig. 1. Proposed taxonomy of key intelligent attributes of smart-home technologies (SHT) for older adults.