Vision: Requirements Engineering for Software Development in Aged Care

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***Abstract*—Technology can play a key role in enabling the aged care system to provide better care for the older adults. In the past few years we have collaborated with several industry partners working in the field of aged care. Some of these operate and maintain aged care facilities, and some provide technological solutions to aged care providers. These collaborations involved extensive requirements elicitation to identify the needs of aged care residents, carers, clinical staff and facility administrators, on projects including mobile apps, data analysis, workforce training, and smart homes. Our experiences have highlighted a number of opportunities, and exposed many significant challenges, for requirements engineering in the aged care software domain that must be addressed. We summarise some of these requirements engineering challenges and a proposed framework to help address them in next-generation aged care software projects.**

***Index Terms*—software for aged care, ageing users, adaptive user interfaces, machine learning, mobile apps, data analysis, predictive analytics, smart homes**

I. Introduction

The world population is ageing, placing huge burdens on health care systems [1], [2]. People above 60 years of age are impacted by a variety of challenging health conditions; many by reduced mobility, some by reduced cognition, and many have accessibility, language, culture, technical proficiency, education and other challenges when using software. The growth in ageing populations means there is great demand on aged care workers, care facilities, hospitals, and funding systems. Increasing demands to stay longer in ones own home and increased quality of life, while living longer and having increased likelihood of different chronic diseases, is very challenging worldwide.

In this paper, by 'aged care' we refer to all facilities that provide care for the older adults including *residential aged care*, *independent living units*, *short term/respite care* as well as *At home care*. A variety of software solutions have been developed to assist with managing aged care, both in home and in managed care settings [2], [3]. Fall detection, workforce management, predictive analytics in aged care and more general clinical record systems are widespread either currently being adopted or trialled [4], [5]. This includes various new technologies including sensors, wearables, robotics, VR/AR, and "smart" environments [6], [7]. Increasing deployment of software in homes e.g. booking care services, smart homes, wearables etc increases access to software by diverse end users. Aged care and health workforce in general are under increasing workload and mental health pressures, increasing need for productivity gains via technologies, including better software. However, not all ICT deployments for aged care and related services are successful [8]–[10], it is unclear what requirements for many of these software-based solutions should be and how to best gather them [1], [11], [12], and many emerging technologies exist with unclear implications for diverse ageing people and carers [3], [7], [13]

In the next sections of this paper we discuss our vision of some emerging opportunities for software in aged care, some key requirements we have identified in our work in the aged care sector, few key challenges that might be faced in addressing these software opportunities, and potential ways to address these challenges.

II. Opportunities for Software in Aged Care

A. *Software for Residents*

Smart homes: Smart homes for aged care have become a popular area of research and practice. These typically have a number of sensors – movement, appliance usage, temperature, lighting, various health measurements (weight, heart rate, etc) – and software to leverage this sensor data (fall detection, anomalous behaviour, automated reminders etc) [14], [15].

Preventive/Health Promotion apps: Personalised preventive/health promotion applications that help to maintain a healthy life style with support in diet, exercise and in other activities are not confined to ageing people. But improved diet, exercise, adherence to cognitive activities, adherence to drug therapies etc can all greatly benefit ageing people [15].

Addressing physical and mental health: Many ageing people have diverse physical health challenges. A growing issue for ageing people, their family and friends and aged carers is loneliness and mental health challenges. Partly this is due to changes in community activities and culture, partly mobility or other challenges of ageing for some, partly greatly increased diffusion of families, partly reduced family sizes and single ageing people in many countries, and combinations of all of these. Software to assist with some of these challenges that can help establish connections with others and connections with family is in increasing demand [15]–[17].

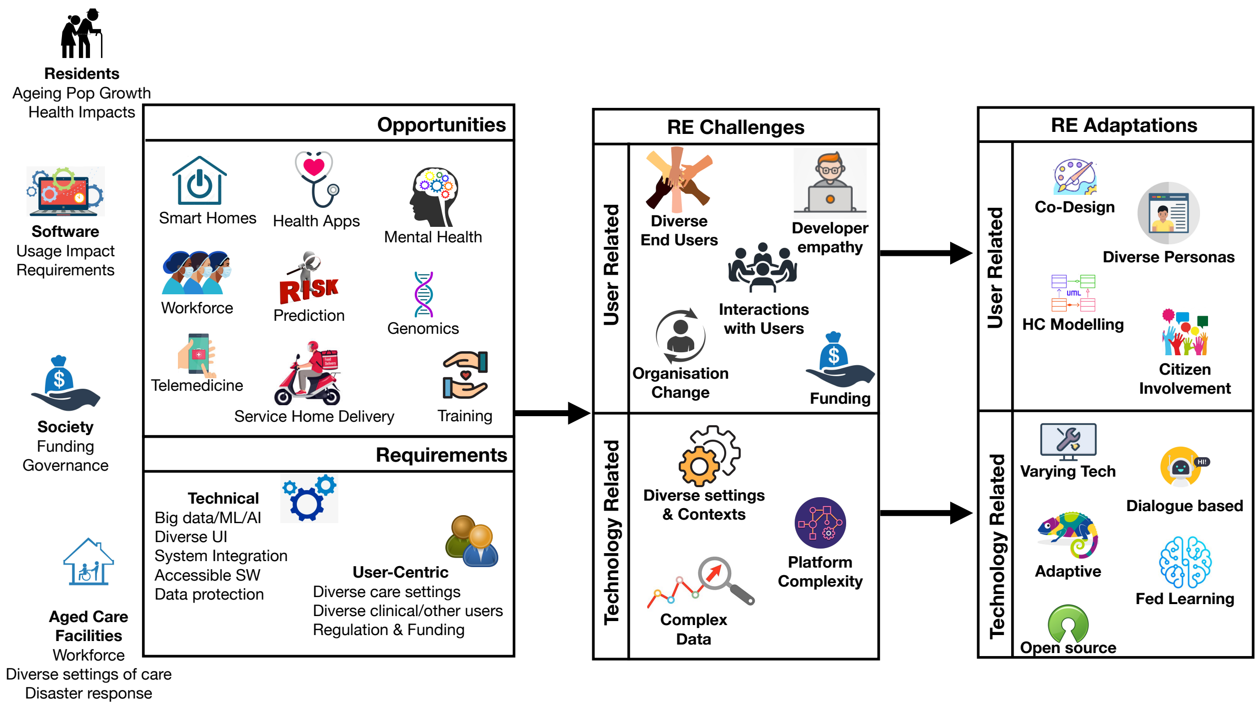

Fig. 1. Summary of RE for Aged Care

B. Software for Aged Care Facilities

Workforce management: As noted earlier, aged care around the world faces major challenges with its workforce. In some situations these are exacerbated due to the diversity of this workforce in age, culture, education and culture. Improving allocation and monitoring and training of the aged care workforce would lead to increased satisfaction of both staff and clients, and improved care outcomes.

Risk prediction: The increased availability of large data sets allows use of machine learning techniques to 'learn' patterns. These can include risk of injury, risk of dementia, risk of anxiety/loneliness, risk of failure to take medication or medication mismanagement, risk of admission to hospital etc. These can be use to improve personalised care plans and monitoring to enhance quality of life and safety [18], [19].

Training care workers, family carers: Finally, there is increasing demand for improved training of age care clinical staff but also 'informal' carers, such as family and volunteers. Use of AR/VR based training has become more popular to give carers insights into ageing person challenges e.g. cognitive decline, sight and mobility decline, etc [15].

C. Software for External Parties

Home delivery of services: As noted earlier, more ageing people want to stay in their own homes for longer, for mental and physical health benefits for themselves and family. Thus there is a growing demand for diverse in-home services and software to support it e.g. booking, delivering, tracking, evaluating services etc [17].

Telemedicine for diverse users: Telemedicine is an area of growth driven by a combination of mobility challenges, highly distributed living, and need for productivity gains. It plays a crucial role in helping to combat issues in aged care such as limited workforce availability. Post COVID-19 there has been a considerable uptake on telemedicine services in the general health care area, particularly in the aged care space. However, these services rely on a suitable network connections, accessible and usable software for ageing people, availability of specialists and security and privacy requirements [16]. We envision future solutions that focus on telemedicine services paying attention to these limitations to improve usability.

Genomics: Use of genomics data – in isolation or combined with other data – offers further potential for personalised, precision care, including risk prediction, optimising care plans, improving pharmacology, exercise, dietary and other therapies, and adapting care support during ageing [20]. It also offers risks for mis-use [19].

III. Some Key Aged Care Software Requirements

We have identified a range of key requirements for aged care software, along with key challenges in RE for aged software and several approaches that can be used to address these challenges. We outline these in Figure 1. We formulated this model from analysis of our own aged care software RE experiences, related literature, and trialling some of these approaches to try and address the challenges.

A. User Related

Rising ageing population and health challenges: The world's population is rapidly ageing. While a lot of people wish to stay in their homes longer, many require varying degrees of residential or hospital care [21]. With age, most people have more health problems [1], [22]. These range from cognitive decline, one or multiple chronic diseases, reduced mobility, hearing, sight and motor control reductions. These can get exacerbated in the face of unprecedented disasters such as the COVID-19 pandemic and its lasting health impacts. Future solutions in aged care can address these requirements.

Range of care settings: The aged care services vary from self-managed care to aged-care residences, and to more intensive dementia care and chronic disease care in hospitals relating to aging. Each of these different types of services have quite differing users and diverse contexts of use [2], [3]. With the increasing demand for people to remain at home longer with more care services delivered at home, the self-managed or family-provided care are becoming increasingly popular. But there is also a significant growth in managed care places and request of short term hospital care especially during the COVID-19 pandemic. To meet these needs, the aged care workforce and the funding has to be stretched and this leads to issues. These include recruitment, retention, maximising productivity and satisfaction, mental and physical demands of the work, work related injury and illness and insufficient workers and skills [23].

Diverse Users: Many stakeholder use aged care-related systems. These include 1) hospital specialists such as gerontologists, 2) nurses and occupational therapists, 3) hospital and in-home care workers, 4) volunteers, 5)family members, and even 6) ageing people themselves. These groups have varying levels of skills, experience, training and clinical knowledge. These can be led by challenges such as low literacy, low educational attainment, diverse languages, lack of medical knowledge, and even mobility and cognitive challenges. Therefore aged care tech providers need to take into account these limitations when designing the new systems.

Regulatory and funding frameworks: Aged care services, in-home, in-residential care and in-hospital care are all expensive, some very expensive. Combined with increased frailty and health issues, growth in number of ageing people worldwide, and increasing costs of many treatments and services, this places increasing burden on funding systems [21]. The growing number – proportionally and total numbers – of ageing people, increasing demand for higher quality of life and longer life care, and increasing technology-based solution in aged care settings all bring challenges to future aged care-related software development. This includes who uses aged care related software, who funds it, data protection and privacy, complex systems integration, and ethical issues in using – especially AI-enabled - aged care software [19], [24].

Governance: Aged care sector has a large number of stakeholders and interest groups and are usually heavily regulated by governments e.g. UK and Australia. Our conversations with aged care providers show that at times, managing the competing interests of these multiple parties and navigating the increasingly demanding regulations placed by government, place a significant administrative burden on care providers.

B. Technology Related

Leveraging big data and ML/AI: More and more datasets relating to ageing are becoming available. These include but are not limited to E-health records, genomics, in-home and in-care behaviour models, diverse sensing systems, large scale population datasets, and others. AI-based solutions include fall detection, risk prediction, cognitive decline assessment, optimising the provision of different care services, streamlining admissions, semi-automated support during telemedicine, personalised educational programmes, and many others [18].

Increasingly diverse interfaces to aged care systems and apps: Conventional aged care-related clinical systems use desktop and to a limited extent tablet interfaces. But most of current health systems have moved beyond these. Some examples include 1) most e-Health solutions have some form of mobile app support, 2) smart homes and care wards employ a diverse range of sensing technologies, 3) voice and gesture-activated devices have become popular in home care settings though are still challenged in multi-person environments, 4) VR and AR interfaces have been trialled for e.g. cognitive decline assessment and carer training, and some limited big data analytics dashboard support, 5) Chatbots have become popular for some care services [15]. The future software developments in the aged care sector, would benefit from exploring these diverse interfaces to address the diverse user needs that we described earlier.

Integration of diverse systems: Large numbers of systems are common in many healthcare settings, and aged care is no exception [25]. Hospitals, large scale aged care providers, and general practitioners all run related but different clinical systems capturing some aged care-related data (but usually not all). An increasing number of in-home care service providers have systems to book services including cleaning, medication, physical therapy, monitoring, transport, food, and other services. Many e-Health app providers have niche solutions for particular services. Smart homes and smart care environments capture diverse behavioural data. Integration of many such systems can support more seamless aged care support, including leveraging heterogeneous data for AI-based solutions.

Accessible software: Many ageing people who book care services, track medication and diet, follow exercise and monitoring programmes have accessibility challenges due to age e.g. sight, hearing, tremor issues. These make using software solutions very difficult if not impossible when these issues are not adequately addressed [26].

Data protection and privacy: Aged care systems store a lot of very sensitive data. Those that are accessible to clinical staff, care providers, residents as well as their family members need to have appropriate levels of data protection. This is especially important when the users such as residents and family members have varying levels of digital literacy. Certain individuals and certain scenarios may also require different levels of data protection e.g. should the family members be allowed to view residents' end of life care plans? should a resident with dementia have equal access to their data as a person without dementia? [19].

IV. Key Challenges for RE in Aged Care

A. User Related

Diverse end users: Aged care residents are rapidly increasing in number as well as in diversity. We found this to be a particular challenge in designing smart homes where different ageing people want very different solutions. Some want very basic support e.g. simple reminders, video conferencing. Others want sophisticated monitoring of their diet, medication, toileting, fall detection, and other activities. Self-configuring their smart home software becomes a challenging problem itself. While some aged users find the smart home very reassuring, others find it quite intimidating, fostering negative emotions and reactions.

Another example of diversity of end users is in clinical system interfaces. Typically these are one-size-fits-all with very limited personalisation per user. This makes them very difficult for many users as they contain far too much complexity, difficult or impossible to understand and irrelevant content, and increase chances of data entry and usage errors.

Developers not understanding diverse users: We have encountered this issue on many projects where most developers are male, relatively young, highly educated, and many have limited experience in interacting with ageing users, let alone designing for them. As developers have little understanding of both clinical users and ageing people's requirements for the software, they often make inappropriate design decisions. We found this to be a challenge on several ageing-related app development projects, smart home projects, and clinical user interface design projects.

Interaction with end users and workforce: As outlined above, software-intensive systems for "aged care" range from traditional clinical systems to smart homes, robots, e-health apps, sensors, VR/AR, carer support, tele-health, connectivity, etc. How to elicit diverse requirements – including handling emergent ones when new diverse users, contexts, data sets and technologies unexpectedly occur – makes RE for ageing a major challenge [1], [11]. When developing solutions for aged care it is important to constantly be in the loop with aged care stakeholders specially to extract and validate requirements. However, recently with the extra burden placed on aged care by the COVID-19, this has proven to be significantly challenging. Some aged care facilities went in to lock downs and some still have visitor limitations to protect its residents. The workforce is already stretched beyond capacity and find it difficult to contribute to new initiatives. We have tried to overcome these issues by building on their pre-established connections e.g. organisations/teams they have already worked with, conducting studies when they are off-duty such as at lunch time, by keeping our studies short, and whenever possible shifting to remote interactions instead of face to face.

Funding solutions: Once the software solutions are developed, a main issue is who pays for the implementation and maintenance of infrastructure, devices and services. When there is a technology service provider this is mostly handled by them. But when the initiatives are requested by aged care providers it is difficult to decide who would pay for the ongoing costs e.g. care residence, telecommunications company, government, ageing people and their families, or some combination. Many solutions are not cost-effective, including many smart home solutions and e-Health apps.

Organisational change: We worked in more than one project where due to role changes, organisational hierarchy changes, company sellouts, the organisations' priorities changed over time. This meant that we had to adjust our work to match the new priorities while trying to ensure minimal impact is placed on the work that was already completed. When ageing people or their families want to continue using a prototype, but this is no longer supported by the original sponsor, managing disappointed expectations is challenging.

B. Technology Related

Diverse settings and contexts of software usage: Aged care related software was once confined to hospitals and care residences and was limited to clinical use or administration. Now software usage includes in-home care services, smart homes and wards, a wide range of e-Health apps, and complex workforce rostering, funding claim processing, insurance, and population analysis. The need to combine complex datasets and to provide end users with access to complex data in diverse situations makes understanding end users, their needs, and software requirements challenging. In a cardiac treatment software requirements gathering exercise, we had to identify requirements for hospital, residential aged care and home monitoring services, all with vastly different users, usage context, and collected data.

When developing solutions it is also imperative to ensure that the provided technologies are accessible from diverse geographical areas (rural, urban), low bandwith connections and are affordable to people with various income levels. The users may also be from varying digital literacy levels and maintaining increasingly technical solutions, especially in home, may be difficult to them. Therefore it is imperative to establish proper support frameworks to support high-tech solutions. We have found these issues particularly challenging in remote telemedicine, smart home and in-home service delivery software projects.

Access to and understanding of complex data: Aged care software and data sets work with data that are sensitive and personal in nature. Therefore privacy, security, transparency etc are critical in health software more than in other fields. In working with aged care software solutions it is important to respect and follow these values. In our aged care software projects, we obtained data from a range of sources; including large clinical data sets; by conducting surveys, interviews with residents, carers and clinical staff; and from previously collected study data. In all these cases, it was imperative to obtain ethical approvals during the design stage of the projects.

In working with previously collected data, we faced challenges when the companies did not posses metadata or data dictionaries. We dealt with this by conducting meetings with database experts and building a meta model of the database based on these meetings. Then we used these meta-models to determine which data features we intend to work with and shared this information with ethics committees. However there have been situations when such meetings were not sufficient to understand databases with 10K+ tables. When this was combined with insufficient information to justify that researchers could explore the data with enough protection of the data, we abandoned such projects.

Increasing technical platform complexity and diversity: We have worked on several projects employing AR/VR, a variety of sensors, complex device connectivity and data management on edge/cloud platforms, many machine learning tools and techniques, and a variety of clinical system platforms and e-Health app platforms. The increasing range of technologies that can be deployed to develop aged care related software, places heavy technical demands on development teams, and can lead to unrealistic requirements about platforms.

V. Addressing RE Challenges

We outline key approaches we have been using to address these aged care software Requirements Engineering challenges in various projects, and highlight areas for key future solutions.

A. User Related

Co-design: Ideally RE teams will draw from a range of representative stakeholders and development teams include them throughout software engineering, not just during RE. We have been trialling the Living Lab approach to this [16], [27]. However, access to suitable stakeholders is challenging with many hospital and aged care residence staff under high work pressure, pandemic induced and due to an increasingly limited workforce. Ideally such a living lab would be in situ in hospital, aged care facility or even selected ageing user homes.

Diverse personas: It is impossible to meet with, elicit and validate and test out solutions with all possible stakeholders and all possible ageing people, carers, clinicians and administrators. As noted above, diversity means requirements for solutions need to incorporate a very wide range of diverse user characteristics. On several projects we have successfully used diverse personas to complement co-design approaches [15]. However, building diverse personas is itself a challenge, and we have begun working on a corpus of ageing user personas to assist developers. Following this, tools that generate diverse ageing user, carer and clinical worker personas is envisaged [28]. We have also experimented with the use of augmented reality and virtual reality tools to assist developers and carers gain appreciation of ageing user needs [15], [29]. These require further refinement and support for more diverse ageing user challenges.

Human-centric models for requirements: Human centric modelling languages can help to record captured requirements in a format that is more understandable for non-technical stakeholders [27]. This can help to ensure that all the requirements presented by the diverse aged care stakeholders can be properly elicited and validated. We have developed several human-centric model, including iStar extensions, for aged care and eHealth requirements and design modelling [30].

Citizen development: Allowing end user development – users of aged care systems to have very controlled ability to change how the system looks, feels, presents information etc – is an interesting requirement for some future aged care software. Not all systems suit this model, but like adaptive software, they allow for limited tailoring of solutions to unanticipated users, usage contexts and emergent requirements. One area is managing complexity of clinical systems where users are provided a range of support to manage information presentation, filtering, alerts etc. Another is care plan models tailored to individual health history, living arrangements, exercise and dietary needs etc [31].

B. Technology Related

Range of tech solutions (low to high): Not all aged care software needs to leverage sensors, edges servers, 5G networks, VR/AR, voice input, etc. In fact, leading edge technologies introduce various risks including cost, reliability, need for highly expert installers and maintainers, and having end users unfamiliar and uncomfortable with the solution. Sometimes very basic interfaces and features can provide a high degree of service and satisfaction for most end users. So saying, our AR-based solution for dementia carer training proved to be very well received by users [15].

Dialogue-based systems: Avatars, chatbots, voice-controlled systems and autonomous robots can all provide useful interactions in some contexts. We have successfully used dialogue systems in smart homes, dietary advice apps, and very specific care plan guidance apps [15]. However, again high diversity of end users, over-reliance on expensive and unreliable technologies, and need to avoid unhelpful or harmful automated responses all require caution in systems incorporating such approaches. The emergence of Large Language Models (LMMs) gives rise to powerful chatbots, code generation, and dialogue-based controllers, which may potentially help in common tasks: planning, reminder of medications, entertainment, communication with family, etc. LLMs can call tools (other software or even robots), serving as a new kind of Operating System.

Adaptive/adaptable software: A key requirement we identified for many aged care software is providing support by tailoring to end user needs via adaptivity. This typically takes the form of accessibility support, which is surprisingly poor in much software targeted to aged care domains, or that at least may have significant ageing user base. More sophisticated adaptation can be to usage context, taking into account changing user needs, and learned behaviour. Software for smart homes and smart care situations can greatly benefit from the latter.In one of our project when we presented resident's risk of hospital admission, we explored presenting this information adaptively. However, these adaptations need to happen at a pace that is comfortable for the user, as constant adaptations may lead to severe cognitive overload [32].

Federated learning for data privacy: Federated learning (often referred to as collaborative learning) is a decentralized approach to training machine learning models [33]. This will not involve an exchange of data from client devices to researchers computers. Instead, the raw data on edge devices is used to train the model locally, increasing data privacy. This enables the data to never leave the client site but instead only the trained model will be extracted.

Open source solutions: Most aged care software adopt proprietary solutions. Moving to more community driven solutions where multiple organisations contribute to shared software platform provides potentially range of benefits. However, as aged care, data privacy, use of AI, and funding regulations all differ across countries and sometimes within countries, tailorable solutions or bespoke solutions will still be required.

VI. Summary

Increasing numbers of elderly, expectations for quality and longevity of life, cost of care, and workforce and funding issues all make software requirements for aged care domain very challenging. We have worked on a range of aged care-related software projects and have summarised some key challenges and approaches for RE in these domains.

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