Design and Development of a Mobile-based Caretaking System for the Elderly People in Thailand: A Design Thinking Approach

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***Abstract*—As the ageing population has become a global phenomenon in the past few decades, it has brought several issues to many countries (e.g., aged care). Thailand has one of the highest ageing populations in the region, which has challenged society to find a feasible solution for promoting the elderly's quality of life while considering the vital role of caregivers in the aged care context. Thanks to the advances in ubiquitous mobile computing, mobile-based applications have become promising for the aged care sector. However, a limited number of mobile-based applications can cater to the needs of the elderly and caregivers, particularly in Thailand. Using the design thinking approach, we developed an innovative elderly caretaking system called 'Aegis' to effectively manage aged care by caregivers. Using this system, the elderly can effectively communicate with their caregivers, while the latter can easily support what the elderly need. We conducted a usability evaluation of 'Aegis' with three elderly-caregiver pairs in Thailand. The findings show that the 'Aegis' is useful in promoting the quality of life for the elderly and caregivers while considering the importance of user-friendly interface design and experiences. The usability recommendations suggested by this study can help HCI researchers understand design guidelines for intergenerational digital technologies.**

***Index Terms*—user interface design; usability; user experience; ageing; caregivers; mobile applications; design thinking**

I. Introduction

As people's life expectancy has increased over the past decades, the ageing population has become a global issue. According to the United Nations, it is predicted that by 2050, 1 in 6 people in the world will age 65 years or above [1]. This global phenomenon might bring challenges for many countries, such as inadequate healthcare systems and in need for social policies for aged care and elderly-friendly environments. Thailand is not an exception in these countries, with one of the world's most rapidly increasing ageing populations [2]. In 2022, Thailand transformed from an aging society to a senior community. Furthermore, it is also predicted that Thailand will be one of the first developing countries to transition to a hyper-aged community by 2035 [3]. As the ageing population is rapidly increasing in Thailand, it has concerned not only the government but also the individuals and families to provide adequate care for the elderly people. In this study, the elderly in Thailand refer to those 60 years or above [4].

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With increasing age, the elderly face age-related health complications, including chronic diseases (e.g., diabetes and hypertension) and a decline in their physical and cognitive health [5]. Hence, the elderly, who are in need of healthcare commodities, amenities, and services, may require assistance from others to perform daily tasks (e.g., house chores) while taking care of themselves (e.g., taking medicine). In Thailand, caregivers, who closely take care of the elderly, are mostly the adult family members of a household or their close relatives. The potential issue caregivers encounter in aged care in Thailand is that they cannot devote their time to aged care due to their limited time (e.g., full-time jobs). The approaches and tools in aged care in Thailand include conventional and digital means such as face-to-face communication, instant messaging, and voice and/or video calls. Although having benefits, these approaches are highly limited in effectively keeping track of the elderly's condition throughout the day, as caregivers may be often responsible for other tasks as well [6]. At times, the elderly may even be entrusted to take care of themselves without a caregiver's presence. This situation gives rise to many risks from unexpected health problems or physical accidents.

Over the past few decades, researchers and developers have used up-to-date technologies to replace traditional methods for aged care. For instance, they have used assistive technologies (e.g., social robots) [7], game-based exercises [8], and wearable technologies [9]. Furthermore, the increase in smartphone ownership in Thailand [10] and advancements in internet and mobile technologies have suggested that a smartphone-based application may be an alternative and a feasible solution to aged care. Using such intelligent technologies, not only can caregivers easily communicate with the elderly, but also, they can provide adequate care for the elderly. According to [31], in the 2nd quarter of 2022, 70.1% of the age group (50+ years) used smartphones in Thailand, and this trend is expected to grow in the upcoming years. The literature also describes that elderly smartphone users are increasing in Thailand [11]. The use of smartphones for aged care has also been growing due to their accessibility, convenience, portability, and affordable prices [12].

Although mobile-based health management systems, in general, are promising for aged care, the existing tools are not explicitly designed for the elderly in Thailand. Furthermore, such devices do not address the cultural needs of the elderly in Thailand (e.g., language). Also, the existing tools in aged care mainly target elderly users. To the best of my knowledge, a limited number of applications cater to the elderly and

caregivers in Thailand. Hence, in this study, we aimed to innovate a mobile-based application that will help caregivers quickly and effectively monitor and manage the elderly's health and activities of daily living. Furthermore, it can help the elderly manage themselves (e.g., reminders or health data recording) and communicate effectively with their caregivers.

To achieve our goals, in this study, the '*design thinking*' approach was adopted in which we empathized, designed, and developed an innovative system in a human-centric way to address unmet users' needs [13]. Through the iterative process, we designed, developed, and conducted a pilot usability evaluation of '*Aegis,'* a customizable mobile-based caretaking system. The main objectives of the study include: 1) to understand users' needs in aged care in Thailand, 2) to design and develop a user-friendly and innovative mobile-based system for both stakeholders, and 3) to evaluate the usability, user experience, and usefulness of '*Aegis'* so that it can contribute to future design and development of caretaking systems in aged care.

II. Related studies

Regarding related studies to this project, in [40], the researchers used the commercial Nintendo Wii games and controllers as an entertainment and socialization tool for improving the mental and social health of the elderly in Singapore. The findings from their study reported that commercialized digital games (e.g., Wii and its controllers) are promising for helping the elderly improve their quality of life. According to [41], the researchers designed and developed a digital social activity space for the elderly in Singapore and investigated how elderly users socially interacted with peers on a virtual social platform. Their findings reported that digital-based social activities could enhance the elderly users' social interactions, particularly intergenerational ties (e.g., older and younger generations). Similarly, in [5], the researcher suggested that digital game-based physical exercises could enhance the Finnish elderly people's participation and engagement in exercise activities. Such intervention could help them feel motivated in exercise adherence. Also, in [32], the researchers advocated the use of exergaming for improving the elderly's social interaction, and their findings report that different types of social interaction and competitive information provided by exergames could affect the elderly players' motivation and attitude toward playing exergames. By using three different activity settings: exergames, conventional non-digital exercise, and non-exercise daily activities of the elderly, the researchers [33] measured the outcome from three various interventions and reported that exergames are promising for improving the physical functionality of the elderly, as well as their cognition in doing exercises (e.g., attention and memory). In terms of effective communication between the older and younger generations, interventions such as intergenerational digital games could help enhance the relationship between the two generations [34, 43]. Although the existing research shows promising results of using digital technology for the quality of life for the elderly, there is limited study in the context of Thailand and Thai elderly people and caregivers. Specifically, to the best of the authors' knowledge, no existing application can effectively solve the communication gap between the elderly and their caregivers regarding healthcare and management. Furthermore, there is no all-in-one system that can cater to aged care, such as reminder system, health management, emergency contact, emotion tracking, etc.

In recent years, as ubiquitous communication and related technologies have become advanced, the research area of cognitive infocommunications (CogInfoCom) has attracted many researchers in different research areas to study how users' cognition can co-evolve with infocommunications devices such as mobile, tablets, and wearable devices, and Internet of things (IoT) sensors [35]. As stated in [36], *CogInfoCom* is a relatively young research area; however, due to its agility, many research areas overlap with *CogInfoCom*, such as interaction design, human-computer interaction (HCI), artificial intelligence, human-centric computing, and data science. Over the past few years, researchers from different disciplines have studied *CogInfoCom* by combining it with specific research areas. For instance, in [38], the researchers designed and implemented a metaverse-like virtual space for organizations to conduct business events and functions (e.g., meetings and seminars). They studied how users interacted with each other, focusing on the cognitive aspects of users (e.g., attention and memory).

Similarly, in [37], the researchers developed a game-based exercise system to improve the elderly's mental well-being regarding their cognitions (e.g., attention, memory, and learning). In [39], the researchers studied the importance of users' cognition in using VR-based exercise systems for their physical health. The findings showed that VR-based games could help users engage in exercise activities. In [42], a virtual evaluation to assess users' driving acuity and spatial perceptual capacity was designed and developed. Then, the researchers discussed how this tool could be utilized mainly for training driving skills and various purposes in cognitive neuroscience.

The existing literature highlights the importance of user cognition in using digital technologies and communication systems; hence, one of the objectives of our study is to investigate how the system's interface design can impact users' cognition in terms of their attention, memory, and learning. For instance, we aimed to understand if elderly users could quickly learn and use the system without having cognitive complexities. Similarly, we would like to study whether caregivers found the system user-friendly, usable, and useful. Furthermore, we applied existing HCI guidelines, UX laws, and principles to ensure the system is user-friendly and supports users' cognition regarding attention, memory, and learnability. To achieve these objectives, in this study, we adopted the *'design thinking* methodology to design and develop a user-centric mobile application that tackles the issues discussed earlier. During the process, we would gain the requirements and needs of users through empathy-based user research (e.g., interviews, questionnaire, and observation), followed by designing and developing the application that conforms to the user experience and interfaces design principles. Eventually, we conducted the usability evaluation of the system with users (both the elderly and caregivers) to understand their user experiences and how the interface design impacts users' cognitions. The findings from this study can help researchers and practitioners in HCI, *CogInfoCom*, and gerontechnology (technology for ageing) and create opportunities for future research.

III. Design Thinking

In this study, we employed '*design thinking*,' a principle that uses an iterative process to deliver user-oriented solutions to solve pre-existing problems. According to the Interaction-Design Foundation [28], using design thinking approach, designers and teams understand their target users, empathize with their needs and pain points, create assumptions, redefine the existing problems, and innovate human-centric solutions to prototype and test. This methodology is also effective in uncovering and tackling unknown or unclear user problems. Also, IDEOU [29], one of the pioneers in design thinking, also highlights that this methodology can help organizations and design teams understand the unmet needs of the target audience while encouraging the creative potential of designers and teams. Also, it allows designers deeply understand the existing and underlying problems and target users' goals [14]. In [30], the author also points out that design thinking can invoke designers' analytical and creative thoughts to solve problems that consider context, users' requirements and preferences, logistical issues, and cost.

Understanding the users allows us to tackle the problem at its root and help them create an effective user-oriented product. In this study, one of the objectives is to design and implement a user-friendly mobile application for the elderly and caregivers in health management. Hence, an in-depth understanding of our target users, the elderly and caregivers, is crucial in this study. While understanding their pain points, we aimed to develop practical solutions to address their unmet needs. Considering all these, we chose the 'design thinking' methodology due to its human-centric nature and creativity that contains five stages: Empathize, Define, Ideate, Prototype, and Test. First, in the '*Empathize*' phase, we conducted an empathy-based interview study in which we listened to, discussed, and empathized with our target users' existing problems and pain points. The interview study consisted of 20 sessions with ten elderly people and ten caregivers to understand our target users in-depth. The interview covered the existing methods in aged care, tools, and, more importantly, barriers they had. Afterward, we reviewed and analyzed the interview data. The findings from the user interviews highlighted that currently, there is no effective and unified method in healthcare management for elderly people and caregivers particularly in Thailand. As a result, the communication between the elderly and the caregivers are ineffective and delayed. Also, healthcare management (e.g., health records and reminders) is inefficient mainly due to the busy schedule of caregivers and the young family members of a household, particularly in Thailand. For instance, most caregivers use various methods to remind the elderly to take medicine on time (e.g., daily diabetes medication) and record their health data (e.g., blood pressure). More importantly, in emergencies, the elderly can only use traditional methods, including making a phone call or sending messages through chat communication systems (e.g., LINE). These findings from the user interviews clearly showed a need for an effective system for the elderly and caregivers in terms of communication, health management, and records.

In the '*Define*' stage, based on the findings from the interview data, we created a persona for each stakeholder: the elderly and the caregiver. According to [15], the persona is a fictional character that helps us understand our target users' needs, experiences, behaviors, and goals. In this study, the elderly persona (see Figure 1) depicts the frustrations of elderly people in terms of communication with their caregivers and the lack of practical solutions. It also illustrates their needs and goals. Similarly, the caregiver persona (see Figure 2) demonstrates the pain points of caregivers in managing the elderly's health and support while highlighting their needs and goals. In addition to the user personas, to effectively define our target users' needs, we employed the '*empathy map*' in which a visualization tool was used to show insights into users' emotions, needs clearly, and wants. Furthermore, it helped us articulate what we knew about our users and justified and empathized with the reasons behind each user's needs and wants.

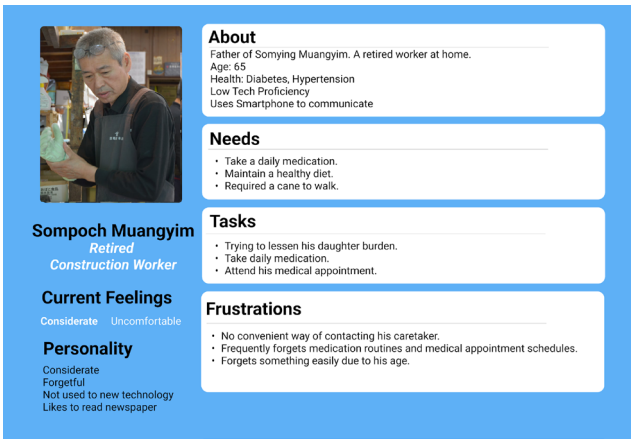

Fig. 1. The elderly persona [44]

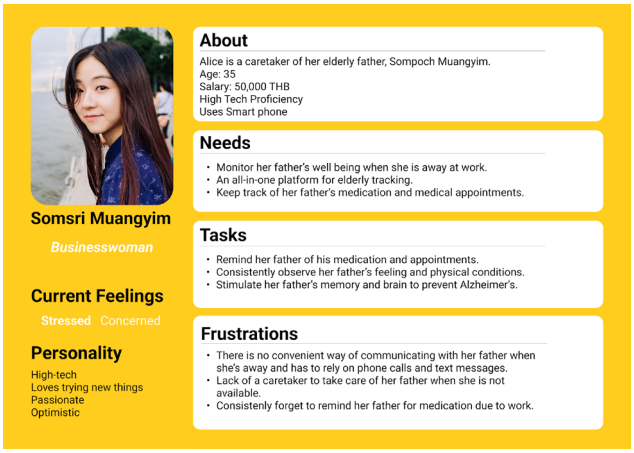

Fig. 2. The caregiver persona [44]

Afterward, we created a customer journey map (CJM) for each person to understand what users experienced when interacting with a particular service, product, and system [16]. In this study, we created a CJM for each persona: the elderly and the caregiver. The CJM for the elderly describes how they interact with various touch points in their journey in terms of performing a user's tasks, such as communication, healthcare management, and records. It also depicts their emotions along the trip (e.g., positive and negative). It clearly shows the gaps to be addressed and what to improve regarding user experiences and their feelings.

Before moving to the '*Ideate*' phase, we revisited and identified the important user needs and pain points based on the *'Define'* phase findings. Then, using the features matrix technique, in the '*Ideate'* phase, we determined the system's features with respect to our target user's needs derived from the empathy map, user persona, and user journey map. For instance, in this study, based on the users' needs, we created a module called *'reminder'* for both the elderly and caregivers to communicate with each other in terms of healthcare and communication management effectively. Similarly, we also created the '*health record'* module in which both the elderly and caregiver users can effectively and efficiently keep track of the health-related data of the elderly. The *'emergency alert*' module is designed for elderly users to immediately and easily notify their caregivers and immediate family members when they are in an emergency. The *'memory recall*' module is designed for the elderly and caregivers to support the former's cognitive abilities through well-designed game-like questionnaires. Lastly, the *'emotion tracking*' module,

After the '*Ideation'* phase, we continued to the '*Prototyping'* phase, in which we designed and developed the '*Aegis'* system. First, we developed a low-fidelity prototype, followed by a quick evaluation with our target users. Based on the early feedback from the users, we then prototyped the high-fidelity functional system of '*Aegis,'* which consists of five modules for both the elderly people and caregivers, namely '*reminder,' 'health record*,' '*emergency alert,' 'memory recall*,' and '*emotion tracking'*. Figure 3 shows the conceptual diagram of '*Aegis'*.

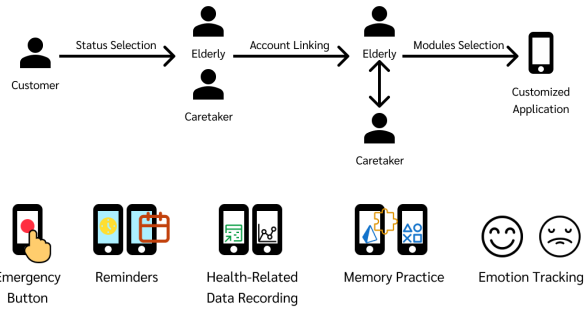

Fig. 3. The conceptual diagram of '*Aegis.'*

In the '*reminder'* module, both the elderly people and caregivers can mutually set up a reminder for various purposes (e.g., medical appointments). In the '*health record*' module, the elderly and caregivers can record health-related inputs such as daily blood pressure. In the '*emergency'* module, when the elderly person needs immediate help, they can alert the caregiver by pressing the '*emergency'* button (see Figure 4-left). In the '*memory recall'* module, the caregiver can set up a simple cognitive assessment for the elderly. For instance, the caregiver can create simple questions such as '*When is the name of the temple we visited last week?*' so that the elderly can choose a relevant answer from the given options.

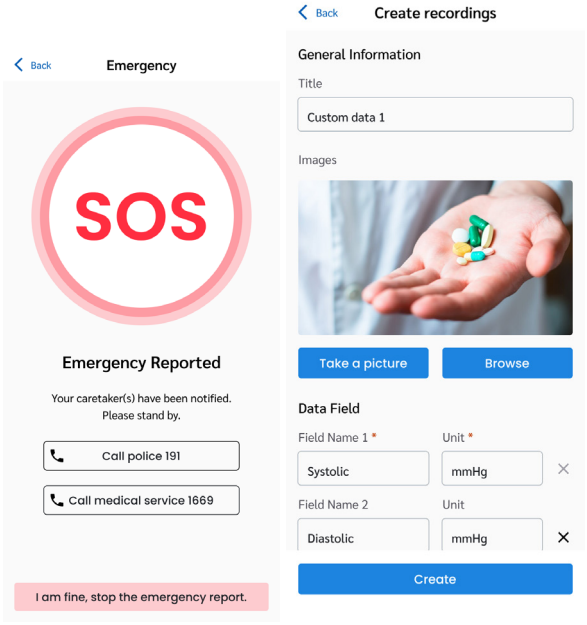

Fig. 4. Aegis' emergency (left) and health record modules (right)

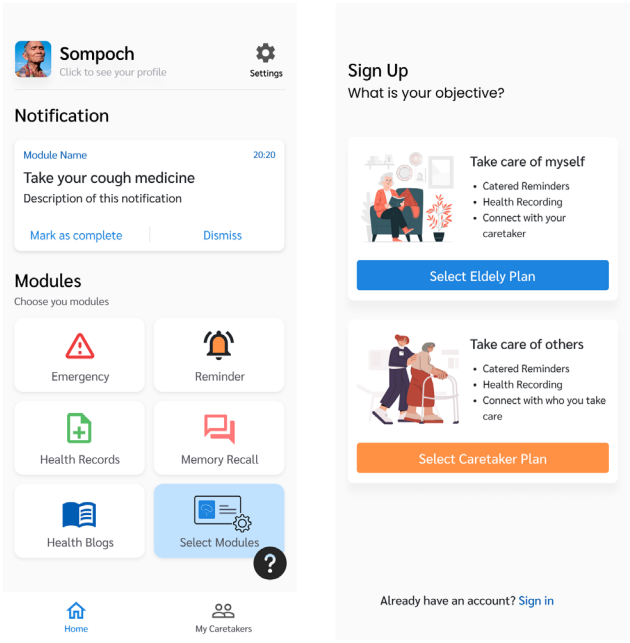

Fig. 5. Aegis' elderly module

Lastly, in the *'emotion tracking*' module, the system will encourage the elderly to respond to their current emotion by choosing an emoticon, and the caregiver will be able to track

the elderly user's present emotions. The system also supports authentication and profile management for both the elderly and caregiver users, as well as a linkage system to synchronize and communicate with each other effectively. Furthermore, it supports an *'analytical module*' that helps the elderly and the caregiver gain insights into the physical and mental status of the elderly. Figure 5 shows the elderly module of *'Aegis'*.

One of the goals of this study is to provide an effective and user-friendly or age-friendly system for our target users. Hence, in designing '*Aegis,'* we applied the existing and widely-accepted human-computer interaction (HCI) and usability guidelines to the high-fidelity user interface based on three principles: easy-to-use, modular, and non-disruptive, on top of the low-fidelity design. Examples of the application of the design principles include good color contrast, appropriate text size, minimum steps to complete a task, customizable functionality modules, and non-intrusive advertisements. Moreover, user experience design laws were extensively considered as the target user groups, the elderly and caregivers, were not very familiar. Hence, they needed the most comfortable user journey to use the application. For instance, we applied *Fitts's law* by creating touch targets that are large enough for our target users to select them quickly and accurately [17]. Also, we used *Jakob's law*; for instance, the log-in page of the system was based on the standard log-in page design that can be familiar to our target users [18]. In addition, we applied other laws, including *Hick's law* (minimize choices for user's decision), *Miller's law* (smaller chunks to help target users process the task), and *Gestalt principles* of UX design (e.g., laws of proximity) [18].

We also used the heuristics guidelines by Nielsen [19] as follows. First is the visibility of system status; for example, on the onboarding page, the number of pages is displayed. Second, for '*user control and freedom*', users can freely include or exclude functional modules and customize reminders, health records, and profiles. Third, for '*consistency and standards*', the whole application is designed in a single-color theme. Moreover, many user interface components are reused throughout the application. Fourth, for '*error prevention*', feedback and information are displayed with understandable and clear messages for general users using easy-to-understand descriptions. Fifth, for '*recognition rather than recall'*, for example, every text input has an intuitive hint so that users can easily recognize it rather than recall it when they revisit the system. Sixth, for '*help and documentation*', for example, there are tour guide pages in every functional module that will automatically introduce the users to the module's capabilities and usage on their first visit, and the users can revisit them. Lastly, for '*reduce cognitive load*', for example, components unrelated to the current functional module and components that add additional complexities to the primary usage are kept hidden by default.

As displayed in Figure 6, in the '*Aegis'* system, we applied the 3-tier architecture. The servers are dedicated to processing and data storage, which would be deployed via Google Cloud Run and Google Cloud Platform's compute engine, respectively. For the technologies we used in this system, React Native framework was the primary technology used for this application development. At the same time, Nest.js was the leading software package for the dedicated service, operated in the background. MySQL database system was chosen as the database in this application. The application would run on Android 10.0 or above for the operational software requirements, which is one of the most popular mobile operating systems among elderly users in Thailand, according to our user research. The applicable device would be equipped with sufficient RAM and storage, and it would be connected to Wi-Fi or a cellular network with a standard data rate or above. The system would always have a stable network connection to enable real-time database updates.

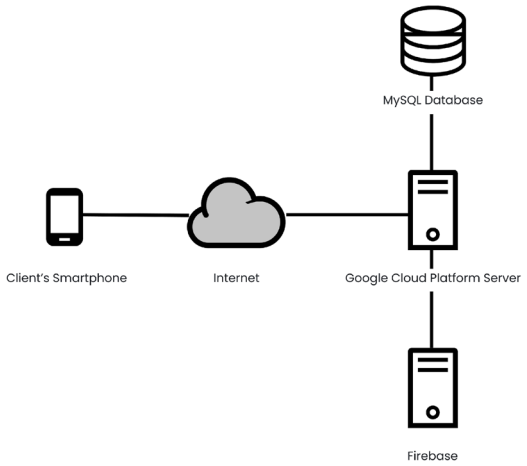

Fig. 6. Technical diagram of 'Aegis.'

IV. Pilot usability testing

After designing and implementing the functional system of '*Aegis,'* we conducted a pilot usability testing to investigate whether our target users could perform the designated tasks. Also, we aimed to understand the usability and user experiences in using it and to explore whether the chosen UI principles are suitable for elderly users and caregivers. According to [20], '*usability testing*' refers to evaluating a system or product by testing it with target users in which participants will perform and accomplish typical tasks. At the same time, UX researchers watch, listen, and take notes on the interaction between users and the system. The ultimate goal of the usability test is to identify any usability problems encountered by users, gather qualitative and quantitative data, and investigate if participants are satisfied with the product. Generally, usability testing constitutes learnability, efficiency, memorability, errors, and satisfaction [21]. This study conducted a pilot usability test with three elderly people and three caregivers who voluntarily participated in the trial. The number of participants was three per group of users, as suggested in [22]. The participants were recruited based on the user personas defined in the '*Define'* phase. For the inclusion criteria of the participants, the elderly must be between 60 and 80 years old, and they must be taken care of by family members. The caregiver participants must be less than 60 years old and have at least one elderly-in-care member.

In this case, we conducted the test in a natural setting at the elderly participants' homes. Each participant performed the usability testing individually at their home in the most comfortable settings, in a quiet environment, and used their Android smartphone. The duration of each usability test was approximately 60 minutes. At the beginning of the usability testing, an introduction to the project and instructions about the usability testing were given to the participant. The participant was also informed about the voice recording and use of data for the analysis. Then, with the help of a UX researcher, each participant was required to fill in the pre-study questionnaire, which asks for age, gender, health conditions, occupation, and the number of caregivers and elderly care. Next, the participant was asked to perform a list of tasks that covered the main functionalities of the '*Aegis'* application. While performing the tasks, we adopted the '*Think-aloud'* technique, which requires the user to verbally express their thoughts or planning, with their voice recorded. At the same time, the UX researcher filled in the feedback capture grid for each task the participant was performing. The feedback capture grid is a grid that collects information about the things the participants liked, constructive criticism, questions that arose, and additional ideas from the test [18]. After completing the tasks, the participants were asked to fill in the post-study questionnaire. The team used the *System Usability Scale* (SUS) to gain a quantitative measurement of the application's usability. According to Sauro [22], *SUS* is the most used questionnaire-based instrument for measuring the usability of a system or product, consisting of 10 questions and five response options (5-point Likert scale) that measure from *strongly agre*e to *disagree strongly*'' SUS is an easy tool due to its simple scaling system. It can be used in small sample sizes [23]. Table I shows the design and procedures of the pilot usability testing.

TABLE I
USABILITY TESTING DESIGN AND PROCEDURES

No.	Step-by-Step Testing Procedures			
	Task Description	*The Elderly*	*Caregiver*	*Duration*
1	Introduction to the usability testing and Informed consent	Yes	Yes	5-mins
2	Pre-study questionnaire	Yes	Yes	10-mins
3	User testing Task 1: Sign up	Yes	Yes	10-mins
3.1	Feedback Capture Grid for Task 1	Yes	Yes	10-mins
4	User testing Task 2: Navigate to the personal QR code screen to link with the elderly or caregiver	Yes	Yes	10-mins
4.1	Feedback Capture Grid for Task 2	Yes	Yes	10-mins
5a	User testing Task 3: Add Health Record Module and Memory Recall to the module list	Yes	No	10-mins
5b	User testing Task 3: Create a health record table to keep track of blood pressure and add one record (filling in the upper value with 120 and the lower value of blood pressure with 80)	Yes	Yes	10-mins
5.1	Feedback Capture Grid for Task 3	Yes	Yes	5-mins
6a	Using testing Task 4: Press the emergency button to report the emergency	Yes	No	10-mins
6b	User testing Task 4: Check the emergency notification and view the elderly's location	No	Yes	5-mins
6.1	Feedback Capture Grid for Task 4	Yes	Yes	5-mins
7	Post-study Questionnaires SUS	Yes	Yes	10-mins
8	Post-study Interview	Yes	Yes	10-mins

V. RESULTS AND FINDINGS

In this study, the responses from the pre-study questionnaire, SUS, feedback capture grid, and notes from post-study interviews were analyzed to understand if '*Aegis'* is usable and user-friendly for our target users: the elderly and caregivers. More importantly, based on the results, we researched and discussed if the participants could successfully execute all the tasks in the pilot usability testing. Afterward, we also analyzed and discussed if the '*Aegis'* was well-accepted by both stakeholders. Lastly, we explored the user's satisfaction with using this system and their intention to adopt it in future aged care. According to the findings, the average age of the elderly participants is 65 years, ranging from 62 to 72 years old. The average age of caregivers is 53, and the range is from 51 to 57. There were two male and one female elderly participant, while one female and two caregivers participated in this study. All elderly participants have chronic health conditions (e.g., diabetes), while the caregivers are generally healthy. The elderly participants had prior experiences in using mobile phones and apps, while the caregivers were also familiar with such technologies. Table II shows the user profiles of the individual participants. Participants' profile

TABLE II
PARTICIPANTS' PROFIL

	Elderly Participants			*Caregivers*		
	E1	*E2*	*E3*	*C1*	*C2*	*C3*
Age	72	62	62	51	57	51
Gender	M	M	F	F	M	M
Occupation	Retired Business Owner	Public Officer	Public Officer	Hous ewife	Business man	Business man
Health Conditions	High blood pressure, overweight	Heart condition	Hypertension Pre-diabetes	-	Physical Pain	-

The overall usability of the application could be deduced mainly from the SUS scores (see Table III). The SUS scores were calculated using the SUS scoring formula provided in [24]. For each response, the scores of all odd items were summed together before being subtracted by 5. Then, 25 was subtracted from the sum of all actual items. Finally, the two values were summed together before multiplying them by 2.5 to give the SUS score. The average score of the '*Aegis'* mobile application is 72.1 points, which corresponds to the adjective rating of '*Good*' and falls into the acceptable range [25]. The sample standard deviation was calculated to be 19.5 points. The 80% confidence interval of the '*Aegis'* SUS score is from 60.4 to 83.8 points. The 60.4 and 83.8 falls in marginal and acceptable acceptability ranges, respectively. The result from the SUS questionnaire indicates that the usability of the current prototype of the '*Aegis'* application is acceptable. However, further improvements could still be made to the design to enhance the user experience and make the application more attractive and usable to the users. Table III displays the SUS scores of the individual participants and overall scores.

TABLE III
SUS SCORES

	Elderly Participants			*Caregivers*		
	E1	*E2*	*E3*	*C1*	*C2*	*C3*
I want to use this application frequently.	5	5	5	5	3	5
I found the application unnecessarily complex.	2	2	4	2	3	1
I thought the application was easy to use.	4	4	3	4	2	5
I think that I would need the support of a technical person to be able to use this application.	5	1	4	3	1	1
I found the various functions in this application were well integrated.	3	5	4	4	1	4
I thought there was too much inconsistency in this application.	1	1	2	2	2	1
I imagine that most people would learn to use this application very quickly.	4	4	3	5	3	5
I think that I would need the support of a technical person to be able to use this application.	5	1	4	3	1	1
I found the various functions in this application were well integrated.	3	5	4	4	1	4
I thought there was too much inconsistency in this application.	1	1	2	2	2	1
Overall SUS Scores	65	87.5	55	80	47.5	97.5

Qualitative data from the feedback capture grids and post-study interviews were analyzed by grouping feedback with related topics into the same categories. The frequency that each topic occurred among each group also signified the importance of the topic towards the system's usability and user satisfaction. Based on the findings, we discussed the following issues. Both the elderly participants and caregivers agreed that '*Aegis'* is a promising application that could improve the overall communication between the elderly and caregivers in terms of elderly care both social, mental, and physical care. For instance, the elderly and caregiver participants recommended that the reminder be one of the most valuable features of the '*Aegis' application*. Not only does it help the elderly participants perform their tasks effectively, but also it helps the caregivers manage the elderly care effectively and efficiently.

Furthermore, both user groups mentioned that '*health data record'* is an essential and useful module in which the elderly and caregivers could easily monitor and keep track of their previous health status. Furthermore, the emergency module is useful for the elderly and caregivers in an emergency, for instance, if the elderly falls at home while no one is around, they can quickly press the button to notify their caregivers. The '*memory recall'* functionality could improve the elderly's cognitive health and maintain social communication between two user groups. Lastly, they both recommended that the *emotion tracking* feature is simple but helpful in expressing the elderly's current emotions, which their caregivers can easily track and provide emotional and physical support to the elderly.

The qualitative feedback on the usability and user interface design by the elderly and caregiver participants suggests that '*Aegis'* has offered a simple, age-friendly user interface suitable for both user groups. They all agreed that although they used the system for the first time, they could easily learn and perform the tasks without difficulty. Both participant groups highlighted the simplicity and familiarity of the interface design of '*Aegis', which* led to the easy execution of the functions. Specifically, they emphasized that the information architecture (e.g., the grouping of related items) is straightforward to learn. Furthermore, the instruction and feedback provided by the system are primarily free-of-jargon and easy to understand. Especially the design and layout of the application are suitable for the elderly who may have limited vision and memory. Lastly, they mentioned that they were satisfied with the user interface design and the features and functionalities of '*Aegis.'* Most elderly participants said that they would use this application in daily life because the modules available in '*Aegis'* are helpful for them to manage their health. At the same time, the functionality of '*Aegis'* that makes this application attractive to caregivers is that caregivers can link and monitor their elderly effectively. Hence, they recommended the future adoption of the system in their daily lives, particularly in aged care.

Although promising, some usability and user experience issues were discovered during the pilot usability testing that can be insightful for future enhancement and further development of aegis. The findings from the study confirm that the visibility of system status is important in designing, particularly for elderly users. This is in line with the existing research [25]. For instance, one elderly participant was unsure if the sign-up was complete and if linking with a caregiver was done after reaching the QR code page. Some elderly participants were concerned that the feedback after pressing the emergency button was unclear; thus, they were unsure if the task was successful. Also, the findings suggest that clear and accurate information, feedback, and message are essential for elderly users, consistent with the existing research [25]. We noticed during the usability test that there existed some inappropriate wordings. For instance, some elderly users had a

difficult time understanding the meaning of some Thai words such as 'ฟีเจอร์' (features) or 'ดูการวิเคราะห์' (view analytics), which can be considered technical.

Furthermore, an elderly participant also questioned what '*taking care of yourself*' meant on one of the onboarding pages. Besides the minor issues we discussed, the elderly participants and caregivers suggested adding more features to the system. For example, most participants recommended adding more features to the emergency module, and they suggested adding an option to call a nearby hospital or an immediate video call functionality.

VI. Discussion and conclusion

Thailand is predicted to transform into a hyper-aged society soon, meaning that the country will have a higher elderly-to-worker dependency ratio in the near future. This increasing ratio will generate more responsibility for family members to care for their aging elders. Also, as the age of the elderly increases, more chronic diseases and deterioration of their physical health will be more extreme, causing specific daily tasks such as house chores or traveling to be limited, and caregivers' help will be needed. However, due to the demands of modern life, caregivers have limited time and resources to take care of their elderly family members constantly. The existing approaches (e.g., phone calls, text messaging, or face-to-face communication) require time and do not guarantee the success of task completion. As suggested in the literature [10], there has been an upward trend in the use of mobile phones among elderly people in Thailand. Furthermore, recent improvements in internet technologies (e.g., 5G in Thailand) have made the adoption of mobile apps for aged care possible [26]. Hence, the application of such a mobile-based elderly-care system has become practical and feasible for both the elderly people and caregivers in Thailand. Thus, the '*Aegis'* application was implemented using the design thinking approach to provide a feasible solution for caregivers to take care of the elderly effectively and to increase the overall well-being of the elderly.

The findings from the pilot usability testing indicate that the mobile-based application can effectively facilitate elderly caretaking, particularly in Thailand. This study has confirmed the existence of the need for an innovative and feasible method to effectively promote the well-being of elderly people while helping caregivers reduce their burden in aged care. Through this study, we discovered that effective communication between elderly people's caregivers could be achieved by using ubiquitous mobile technologies. Using the '*Aegis*' application can help caregivers manage elderly care easily without a physical presence, while the elderly people themselves may gain confidence in managing their activities of daily living. Through the findings from the interview study, we have also learned that physical health and support and emotional and mental health support for elderly people are equally important. We can achieve this aim using the latest technologies (e.g., ubiquitous mobile apps). Other than the usefulness of the features and functionalities of '*Aegis',* we have also learned that due to its human-centric nature, the '*design thinking'* methodology is suitable for designing an innovative system or product for users with distinct needs (e.g., the elderly), which is consistent with the existing literature [27]. The study also shows the importance and significance of user interface design and user experience considerations when designing an application for elderly people with distinct limitations, such as low technology literacy and health conditions like eyesight and dry fingers. For instance, we applied the existing and well-established user interface design guidelines and usability heuristics in this study.

Interestingly, we found that these UX/UI guidelines and laws suit the elderly. The findings suggest that these guidelines (e.g., Nielsen's ten heuristic guidelines) can be applied to designing an interface for elderly people. Furthermore, the well-established and widely-accepted Fitts's Law is suitable for mobile-based applications and for developing an age-friendly application/system. With that in mind, it is suggested that the user interfaces, particularly for the elderly, must be easy to use, uniform, and follow UX/UI rules not to create confusion for the elderly and caregivers.

In conclusion, this study has shown that a mobile-based caretaking system has a high potential to solve the pain points of elderly people and caregivers in Thai society. Using the '*design thinking'* approach, the aim to create an innovative solution for the elderly-care can be achieved. The key takeaways of the study are as follows. First, to create an elderly caretaking system that can address their needs, we should pay great attention to the distinct limitations of two groups of users with different needs and conditions. Second, empathy-based '*design thinking* is an effective technique for the elderly. Third, the existing HCI guidelines, such as Nielsen's ten heuristics, are suitable for designing an interface for elderly people. Fourth, the current UX Laws (e.g., Hick's and Miller's Law) are promised to be used to design age-friendly systems and products. However, due to the study design and limitations, further research is recommended to understand if the existing UX/UI laws and principles (e.g., Fitts's law) are suitable for elderly user groups. Lastly, modern technologies, including ubiquitous mobile computing, are the potential for aged care. This study had a few limitations. First, the sample size was small due to the availability of participants. Second, the study duration was short. If we can conduct a longitudinal study in the future, the results can elaborate more on the usability and usefulness of the system. Third, the currently available modules are limited in the '*Aegis'* application. Lastly, the type of data collected in this study was limited. For instance, collecting more qualitative data to understand user experiences and usability issues better is essential. Despite having some limitations, the findings from this study can create insights for UX/UI designers, researchers, and developers in designing and developing an age-friendly system for elderly users. Furthermore, this study suggests the promise of using technologies effectively and efficiently for the aged care sector in Thailand and worldwide.

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