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Supporting Fall Prevention for the Elderly by Using Mobile and Ubiquitous Computing

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Abstract

Approximately one third of the elderly (over age 65) fall each year. Falls are the one of the main reasons of injury-related cases and the leading cause of accidental deaths among the elderly. The overwhelming majority of studies about falls using ICT are related to fall detection, which copes with the fall accidents and injuries that have occurred. The fall prevention aims to avoid falls before falls occurred. Only few studies have investigated fall prevention by using ICT. Currently, there are no relevant studies to fall prevention by ubiquitous computing.

Objectives of this thesis are to investigate what are effective measures of fall prevention and how mobile and ubiquitous computing can support these measures for the elderly. This thesis project mainly applies several methods: Precaution Adoption Process Model to design the prototype applications, the iterative process, user participation in the whole process, and several other core design principles.

The outcome of this thesis project includes a use case, usage scenarios, a high-level and interactive prototype, a system overall architecture, implementation of two prototype applications (open source), and evaluations for a high-level prototype and two prototype applications using a modified heuristic evaluation method. The evaluation for high-level prototype was performed by using the semi-structured interview with 4 participants. The evaluation for prototype applications was conducted by using a street survey (9 participants) and semi-structured interviews (3 participants). The findings from evaluations reveal that the prototype applications using mobile and ubiquitous computing could support the fall prevention well in usefulness, ease of use, intention of use (on tablets).

The prototype applications works in two modes: interactive mode (fall risk assessments, fall prevention information, and social interactions), ambient display mode (smart photo frame: in the living room or the bedroom, and without requiring users' any direct interactions).

The prototype applications aim to demonstrate the mobile and ubiquitous technologies could support the elderly in fall prevention. This thesis also demonstrates: 1. The prototype applications are possible to meet the challenge of personal relevance by enabling the elderly to perform fall risk assessments. 2. They enable the elderly to acquire knowledge about fall prevention. 3. They are possible to support the fall prevention program on a large population with low costs and without requiring amounts of health professionals to participate in, unlike traditional prevention programs. 4. They are possible to increase the acceptability for fall prevention among the elderly and enable the elderly to have behavioral changes about lowering the chances of falling, in a non-obtrusive and unconscious manner (users casually glance while passing by the prototype system).

Problem Description

Approximately one third of the elderly (over age 65) fall each year. Falls are the one of the main reasons of injury-related cases and the leading cause of accidental deaths among the elderly. This thesis intends to investigate what are effective measures of fall prevention and how mobile and ubiquitous computing can support these measures for the elderly. It shall propose a use case, usage scenarios, a high-level and interactive prototype, a system overall architecture, implementation of the prototype applications, and evaluations for a high-level prototype and prototype applications. This thesis is expected to follow Precaution Adoption Process Model to design system, the iterative process, user participation in the whole process, and several other core design principles.

Preface

This Master thesis has been defined through consultations with Babak Farshchian, a researcher and research manager at SINTEF, associate professor at Norwegian University of Science and Technology (NTNU). My master project is a part of the preliminary study of this thesis.

I would like to appreciate Babak's helpful support and valuable feedback in my last year. I'm grateful for my parents and elder sister' support and encouragement. They also gave me valuable feedback about this thesis.

Abbreviations

ICT – Information and Communication Technologies

iOS - iPhone Operating System

IS- Information System

WiFi – Wireless Fidelity, a set of wireless standards for local coverage, known as 802.11

FR: states Functional Requirement.

NFR: states Non-Functional requirement.

PDAs: Personal Digital Assistants

UI: User Interface

UML: Unified Modeling Language

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1 Introduction

1.1 Motivation

Falls are one of main homecare issues for the elderly, not only in developed countries but also in developing countries. Falls are the primary reason for injury-related cases to emergency rooms and the leading cause of accidental deaths over the age of 65 years [1],[2].

Furthermore, each year, approximately one third of the elderly over age 65 fall; 46.5 % of the population over 65 years experience at least one fall [3]. Fall accidents make threats for old adults' health and result in mortality e.g. fracture, head traumas, and fatal injuries for themselves, which place considerable burdens for healthcare system in workloads and financial costs for societies. According to fall statistics, falls cost 0.07% to 0.20% of the GDP[4]. In 2000, direct costs of non-fatal fall injuries in the USA were $19 billion dollars[5]. One of main solutions for keeping the senior living independently is to reduce the incidence of fall accidence.

Moreover, in some developing countries like China, there are millions of elderly people living independently who have no enough pensions and no offspring to support them, facing tougher and worse situations where they lack healthcare and welfare insurances, communities' support . If they have fall-related injuries, they have to rely on themselves.

There are rare studies in the information and communication technology (ICT) area regarding fall prevention. An overwhelming majority of researches in terms of falls are related to fall detection, which aim at enabling seniors to get treatment in time and to reduce damages, whereas falls have happened and damages have been done, instead of avoiding the fall and reducing the risks of falling. Prevention is to reduce the risk of falls for elder people and to create high value to society and at the fairly low cost.

1.2 Problem Definition

The purpose of this project is to investigate what are effective measures of fall prevention and how mobile and ubiquitous computing can effectively support these measures for seniors, and to propose an effective fall prevention solutions for the elderly by using by mobile and ubiquitous technologies .This project aims at reducing the risks of falling for seniors, and increasing elderly people's awareness of preventing falls thereby avoiding fall injuries (e.g., fractures) and keeping them to live independently.

1.3 Research Questions

The aim of this research is to explore the fall prevention of falls for senior citizens by using ICT, the following research questions are defined:

1. What are effective measures of the fall prevention for senior citizens?
2. What are challenges for the existing fall prevention projects by using ICT and how to address them?
3. What and how feasible and effective ICT technologies can support measures of the fall prevention for the elderly?
4. Can mobile and ubiquitous computing support measures about the fall prevention for the elderly?
5. How do mobile and ubiquitous computing support measures about the fall prevention for the elderly?

The first, second and third questions guided the author to explore during the phase of preliminary study. The last two questions were inspired by previous questions, and guided the author to delve in the fall prevention by mobile and ubiquitous computing in the following phases.

1.4 Deliverables

The deliverables of this project are as follows:

1. A problem analysis of falls for elderly people.

2. A state-of-the-art analysis exploring related literature and relevant the fall prevention projects for seniors

3. A solution proposal consists of:

A set of overall requirements for

A use case

A set of usage scenarios

A high-level and interactive prototype

An evaluation (feedback) for high-level prototype

A system overall architecture

Implementation for two prototype applications (open source)

An evaluation for prototype applications

1.5 Research Method

This project adopted an investigative (due to a lack of relevant studies and projects to draw on) and the iterative approach. This project began with a literature review and an unstructured interview with two elder people in order to explore the fall problem among elder people and possible interventions with regard to fall injures. Then, it was followed by problem elaborations and analysis based on the literature review to find out effective measures of preventions, to delve into other related projects and available technologies. Lastly, this thesis proposed the overall requirements, a use case, usage scenarios for main functionalities, a high-level and interactive prototype, an evaluation for high-level prototype, design and Implementation, and an evaluation of prototype applications. The whole process is iterative so that the quality of project continually improves.

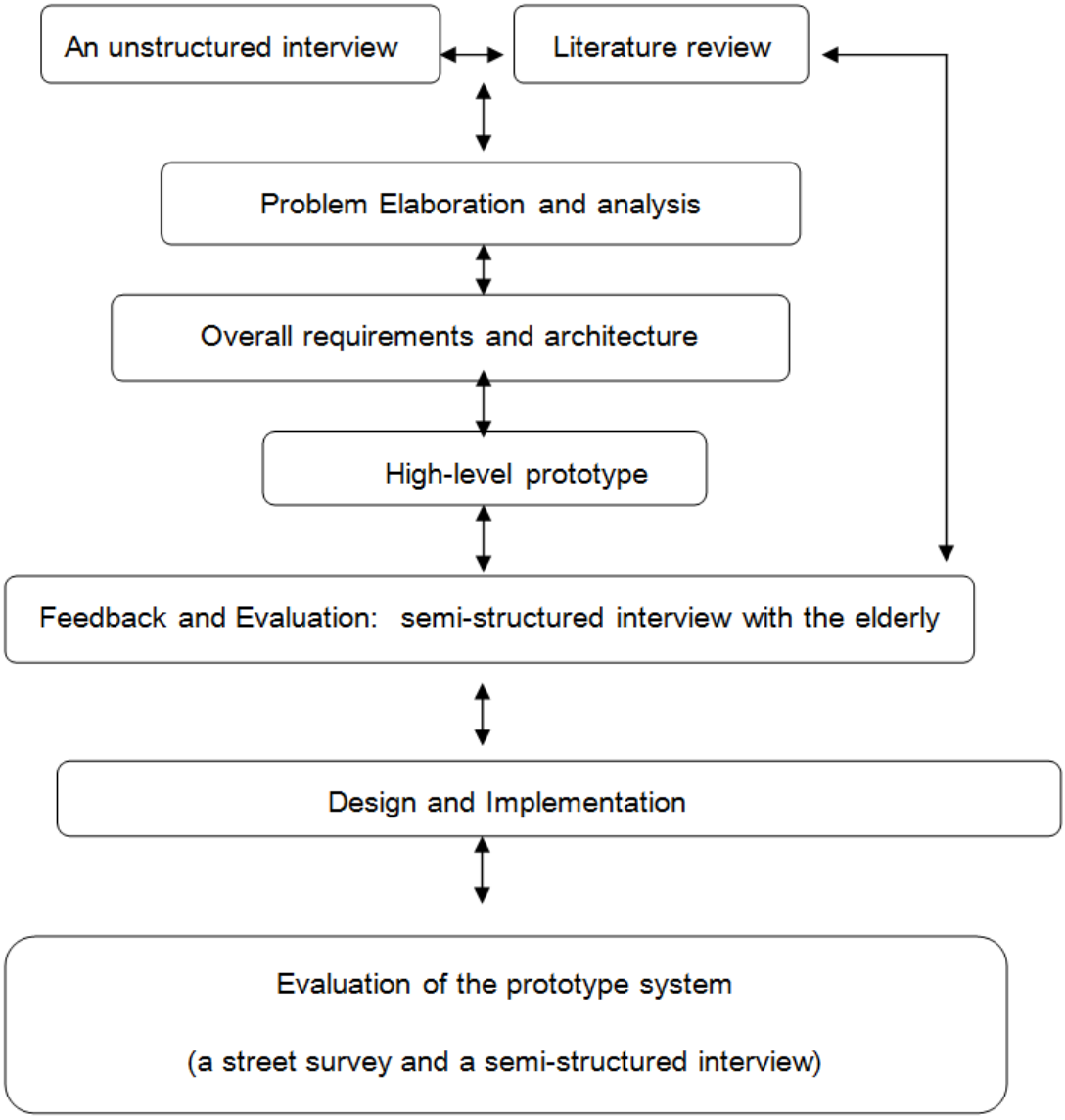

Figure 1-1: The research method utilized

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1.6 Report Outline

The master thesis report is organized into following chapters:

Chapter2 Problem Elaboration and analysis This chapter presents research problem in more detailed way, and the main findings of effective measures of fall prevention.

Chapter3 Background and State-of-the-Art This chapter provides the theoretical background and relevant ICT technology including mobile computing, ubiquitous computing and presents related studies in terms of fall prevention.

Chapter4 Requirements Specification, Use Case, Scenarios, Prototype, Usage scenarios. This chapter presents Requirements Specification, Use Case, Scenarios, Prototype, Usage scenarios and defines functional and non-functional requirements for the fall prevention based on analysis of the problem elaboration and State-of-the-Art.

Chapter5 Solution Proposal and Implementation This chapter includes the system overall architecture and design principles it follows, explains and presents tools and technical of implementation. Most importantly, it presents the System Functionalities.

Chapter6 Evaluation This chapter presents the strategy and deign of evaluation, prototype evaluation, the expert evaluation, and the evaluation of final prototype applications, method for data collection, designs of the Survey and the semi-structured interview, data analysis and discussion

Chapter7 Conclusions and Future Work This chapter sums up the whole report and provides suggestions for evaluation and the future work.

2 Problem Elaboration and Analysis

This chapter starts with discussing about the falls risk awareness and social interactions, explores performance continuum of senior citizens, barriers about using technologies, and then examines potential factors for the risk of falling. At last, it presents studies about fall interventions.

2.1 The Fall Risk Awareness and Social Interactions

Awareness refers to knowledge about a dynamic environment, and it is maintained through information gathered from the environment over time[6]. Here, fall risk awareness can be defined as the knowledge about what level of falls risk they are and how to reduce risks.

There are significant amount of papers regarding fall risks, however there are rare researches about seniors' awareness for risks of falling[7]. A study based on survey (120 seniors) shows that older adults did not regards themselves at risks of falling but consider other elder people are more likely to fall, because they tend to be overly optimistic for the state of health.[8]. Most elder adults are confident that they will recover soon after a serious fall, even though they realized that falls are an healthy issue[8].

Therefore, it is the vital first step to identify the elderly who are at high risk of falling and then take further steps to conduct the fall prevention programs. Awareness of elder people about their risk of falling is really pivotal, which enable older adults to be more receptive to accepting information about fall risks and to avoid them from fall-related injuries. Without this awareness, seniors tend to ignore information about reducing their risks of falling, even though they are at high risks of falling.

Seniors who fell in the past tend to seek helps or advices(fall risk information), and refer to social interactions (supporting, get empathetic responses), and they are more willing to receive fall intervention information and to be educated to prevent falls and injuries

again [9, 10]. Social interactions can significantly promote seniors to engage into the fall prevention program, especially for the elderly who have never fallen in the past[10].

2.2 Challenges for the Fall Prevention Programs

1.Personal relevance: an overwhelming majority of the fall prevention programs adopt awareness-raising strategies [11] [12]. The challenge to awareness-raising goals is a lack of personal relevance at risk of falls[13]. As mentioned in the previous sections, community-dwelling older adults consider they are not personally susceptible to falling[8].

2. Limited human resources (health professionals) for fall prevention: traditional fall prevention programs are conducted by practitioners, nurses and professional staff, which requires amounts of human resources. It is impossible to engage a majority of older adults into fall prevention programs by consultations with health professionals.

3. A lack of knowledge and awareness of fall prevention: during interviews (66 participants), most people just consider the fall prevention as hazard reduction, using aids. Only one person mentions that taking balance and strength exercise could also reduce fall risks[13].

4. Acceptability for fall prevention: In common cases, older adults consider falls prevention advices as good advices, but do not put them in practice. In a study, interviewers got booklets about the fall prevention information, and interviewers respond fall prevention booklets are attractive and useful; However, they said after several days they put booklets away and then completely forget them[13].

2.3 The Performance Continuum for the Elderly and Barriers for Using Technologies

The elderly are heterogeneous groups who are from walks of life, have different backgrounds, diverse needs. In order to propose reasonable requirements and effective solution for fall prevention, this part will explore the performance continuum for the elderly.

A performance continuum mainly consists of four aspects: vision, hearing, hand function and cognition [14] (see Table 2-1).

Table 2-1 : The effects of the aging and potential design solutions [14].

Factor	General effect on older users	Potential design solution
Vision	• more light required • ability to focus deteriorates • ability to deal with glare diminishes	• improve illumination • provide user interface options • if a display is required, use anti-glare coatings to display
Hearing	• loss of sensitivity to higher frequencies • general threshold deteriorates • complex sounds more difficult to process	• do not use high frequency audio feedback • couple auditory feedback with visual or tactile feedback • keep auditory feedback as simple as possible
Hand function	• general weakness (strength and grip) • dexterity often impaired • range of movement is more limited	• design casings that are easy to hold and keys so they are easy to press (oversized and/or easy press). • group keys by use and function.
Cognitive processes	• processing time – with working memory • long term memory (episodic) • reaction time • learning time required • problem solving capacity	• keep menu structures intuitive and consistent • make user interfaces as simple as possible

Aging leads to decreasing visual acuity (the ability for distinguishing detail), light accommodation (focus on far and near objects), and contrast sensitivity (discriminate between light and dark), and require more light to see details compared to young people. Meantime, the glare light results in discomfort for the elderly. The average near point of 50 year old people is 50cm because of reduction in elasticity in the lens, likewise, aging

leads to the gradual loss of hearing and other factors (e.g., pressure, genetic factor, diet habits [14] . Hand function tends to decrease in strength and range. [15]. Working memory remain stable but the process speed increase over time [14].

Therefore, they require technologies which are familiar artifacts for them because of limitation for learning skills and memory. Compared with other age group, senior citizens in high percentage are computer illiterate. They need really simple and intuitive User Interface (UI) and large fonts and apparent contrast.

2.4 Aetiology Factors for Falls

Intrinsic and extrinsic aspects are two dimensions to define the factors leading to falls. Intrinsic factors are related to the physical and mental aspects of older people. Extrinsic factors come from the environment the elderly live.

2.4.1 Intrinsic Factors

Physical and mental changes with respect to aging and diseases (see Table 2-2) render the senior to be vulnerable for falls.“Functions include vestibular, proprioceptive and visual functions, which are integrated in the cerebellum; cognition and musculoskeletal function are also important. Orthostatic hypotension, which is common among the elderly, is not a common cause of falls, but it often causes affected persons to sit down because of light-headedness. Frequent nocturia is associated with falls, probably because the elderly person has difficulty getting up and walking to the bathroom quickly at night. Metabolic disorders, anaemia and dehydration, and cardiopulmonary disorders may also contribute to increased risk of falls, as may acute illness.” ([16], P.192)

Table 2-2: Common causes of falls in the elderly from[16]

Neurological disorders	Stroke
	Transient ischaemic attack
	Parkinsonism
	Delirium
	Myelopathy
	Seizures
	Vertebrobasilar insufficiency
	Cerebellar disorders
	Peripheral neuropathy
	Dementia
Cardiovascular disorders	Myocardial infarction
	Orthostatic hypotension
	Arrhythmia
Gastrointestinal disorders	Bleeding
	Diarrhoea
	Defecation syncope
	Post-prandial syncope
Metabolic disorders	Hypothyroidism
	Hypoglycaemia
	Anaemia
	Hypocalaemia
	Dehyration
	Hyponatraemia
Genitourinary disorders	Micturition syncope
	Incontinence
	Nocturia
Musculoskeletal disorders	Arthritis
	Proximal myopathy
	Deconditioning
Psychological disorders	Depression
	Anxiety

2.4.2 Extrinsic Factors

Environmental hazards (see Figure 2-1) account for approximately 33–50% of falls. To deal with these environmental risks are more effective, and these risks is highly likely to be removed compared to Intrinsic factors.

“The major environmental hazards are clutter, electrical cords in pathways, inadequate lighting, throw rugs, low chairs, soft chairs, uneven surfaces, raised threshold and

slippery surfaces. Many of these factors can be modified (Abram 1995; Alexandr 2002; Fuller 2000). Most falls occur indoors. Indoor falls occur most often in the bathroom, bedroom and kitchen (Alexandr 2002; Roberts 1989). No specific time of day or time of year is associated with falling. About 10% of falls occur on stairs, with descent being more hazardous than ascent. The first and last steps are the most dangerous. Common sites of outdoor falls are curbs and steps. In institutions, the most common sites of falls are the bedside and the bathroom (Abram 1995; Alexandr 2002; Roberts 1989).”([16],P.193)

Home Safety Checklist

Floor

Remove throw rugs

Secure carpet edges

Remove low furniture and objects on the floor

Reduce clutter

Remove cords and wires on the floor

Check lighting for adequate illumination at night

Pick up things (papers,magazines, books, shoes)

Kitchens

Step stool unsteady

Eliminate chairs that are too low to sit on and get out of easily

Bathrooms

Install grab bars in the bathtub or shower and by the toilet

Use rubber mats in the bathtub or shower

Take up floor mats when the bathtub or shower is not in use

Install a raised toilet seat

Stairs and steps

Secure carpet or treads on stairs

Pick up things on the stairs

Fix loose or uneven steps

Have only one light switch for stairs

Make sure handrails are on both sides of the stairs and

are as long as the stairs

Install handrails on staircases

Outdoors

Repair cracked sidewalks

Install handrails on stairs and steps

Trim shrubbery along the pathway to the home

Install adequate lighting by doorways and long walkways leading to doors

Bedrooms

Ensure the light near the bed can be reached

Install adequate lighting

Other safety tips

Keep emergency numbers in large print near each phone

Put a phone number near the floor in case of falling and cannot get up

Think about wearing analarm device that will bring help in case of fall

Figure 2-1: Checklist for evaluating safety during the home visit.([16])

2.5 Prevention of Falls

As mentioned above, intrinsic and environmental risk factors are presented in details. Therefore, fall prevention solutions are supposed to consider interventions with regard to these dimensions (see Table 2-3). From the perspective of medicine, there are several interventions for fall injuries: reduction for psychotropic medication, home-hazard assessment and management , eye surgery, and exercise for regular strength and balance, Vitamin D and Calcium supplementation [17]. Only several studies have indicated that fall-prevention did not curtail the incidence rate for falls [18]. However, the majority of studies have proved that fall-prevention programs reduced the incidence rate for falls.

According to other review study [20], They review 62 studies reporting a variety of settings, participants, and interventions. Seventy one percent of the studies are in two categories: 23 trials studied exercise or physical therapy interventions and 21 trials examined multidisciplinary, multifactorial risk factor screening and intervention. Exercise programmers (Like Tai chi), home safety assessment and intervention programs effectively reduce the rate of falls (see Table 2.4).

To sum up, the assessment for the risks of falling, hazards removal (home hazards and eyesight problem), withdrawals medication increasing the risks of falling and the exercise training programs for balance and strength are approved to be effective measures for the fall prevention and significantly decrease the risk of falling.

Table 2-3: Intervention to reduce the risk of falls in the elderly [16]

Risk factors	*Interventions*
Environmental hazards for falling	Activities that aim to reduce environmental risks include: decreasing environmental risks, obstacles and clutter • nightlights at bedside and toilet • stabilizing beds and bedside furniture • having grab bars near toilets, which are fitted vertically rather than in a horizontal position •
Use of four or more prescription medications	Activities related to medication that have been utilized include: reviewing prescribed medications frequently • checking patients receiving laxatatives and diuretics • limiting combinations of medications when possible (e.g. sedatives, analgesics) •
Any impairment in mobility	Interventions related to mobility that have been used in studies include: non-skid footwear • providing physical therapy • instructing patients to rise slowly • walking high-risk patients • repeating activity limits to patient and family • assisting high-risk patients transfer • walking patients in corridor once or twice per shift •
Altered mental status	Altered mental status was the most commonly identified risk factor for falling and interventions used in studies to address this problem include: reorientating confused patients • orientating patients to the hospital environment • moving confused patients near the nurses' station • asking family members to sit with confused patients • nursing confused patients in low bed •
Independent bed rest	Interventions that aim to reduce the risk of falling while the patient is in his/her bed include: ensuring bed is in a low position • ensuring bed brakes are on • using bedrails if appropriate • ensuring patient can reach necessary items • using half bed rails to reduce patient's need to climb over the rails to leave the bed •

Table 2-4: Conclusion for interventions that are likely to be beneficial (from [16])

Home hazard assessment and modification that is professionally prescribed for older people with a history of falling (3 trials, 374 participants)
Withdrawal of psychotropic medication (1 trial, 93 participants)
Cardiac pacing for fallers with cardio inhibitory carotid sinus hypersensitivity (1 trial, 171 participants)
Multidisciplinary, multifactorial, health/environmental risk factor
Screening/intervention programmes, in the community both for unselected population of older people (4 trials, 1651 participants), and for older people with a history of falling, or selected because of known risk factors (5 trials, 1176 participants)
Population of older people (4 trials, 1651 participants), and for older people with a history of falling, or selected because of known risk factors (5 trials, 1176 participants)
Multidisciplinary assessment and intervention programme in residential care facilities (1 trial, 439 participants).
A programme of muscle strengthening and balance retraining, individually prescribed at home by a trained health professional (3 trials, 566 participants) .A 15 week Tai Chi group exercise intervention (1 trial, 200 participants)

2.6 Summary of This Chapter

Meeting the challenge of personal relevance, the pivotal first step of the fall prevention is to identify whether the elderly are at high risk of falling or not. To find a way to strengthen social interactions (promoting participations) could be significantly beneficial for fall prevention programs.

In order to propose effective fall prevention solutions, four main challenges need to be addressed: personal relevance, a lack of health professionals for the fall prevention, a lack of awareness and knowledge about fall prevention, and acceptability for the fall prevention

Assessment tools for risk factors are effective solution for falls prevention since there are solid evidences of the above trials. In this master thesis project, objectives are how to conduct appropriate and effective assessment for risks of falling and how to effectively promote awareness of older adults for fall risks (e.g., reduction of fall hazards, promotion of exercise training for balance).

3 State-of-the-Art and Background

The purpose of this chapter aims to explore related or similar researches and provide associated background for this research. The selection criteria of related researches and background are based on research questions and problem elaboration and analysis. Therefore, some parts of this chapter are not directly related to the field of fall prevention. However, they could inspire this study to form requirements and design ideas.

Even though significant amounts of researches are related to falls detection and falls prevention program without using ICT technology, there are only several papers regarding falls prevention by using computer-based interventions. Currently, there is no study regarding falls prevention by using ubiquitous computing on research databases, which is proved by searching through Google Scholar, IEEE, and ACM.

3.1 Fall prevention by Using Computer-Based Solutions

Only several studies about the fall prevention by ICT are both internet-based fall prevention projects, including: SeniorGezond (see Figure 3-1), Blancetraining (see Figure 3-2). The Dutch website SeniorGezond provides good quality of the fall prevention information, and enables users to retrieve fall prevention information[21]. This study points out the fact that provision of adequate training how to use computer is the crucial success factor [22]. Even though senior adults(especially for young old people (55-65) are increasingly active users for using computer, there are a considerable portion of elder people have no interests in or afraid of computer usages.[22].

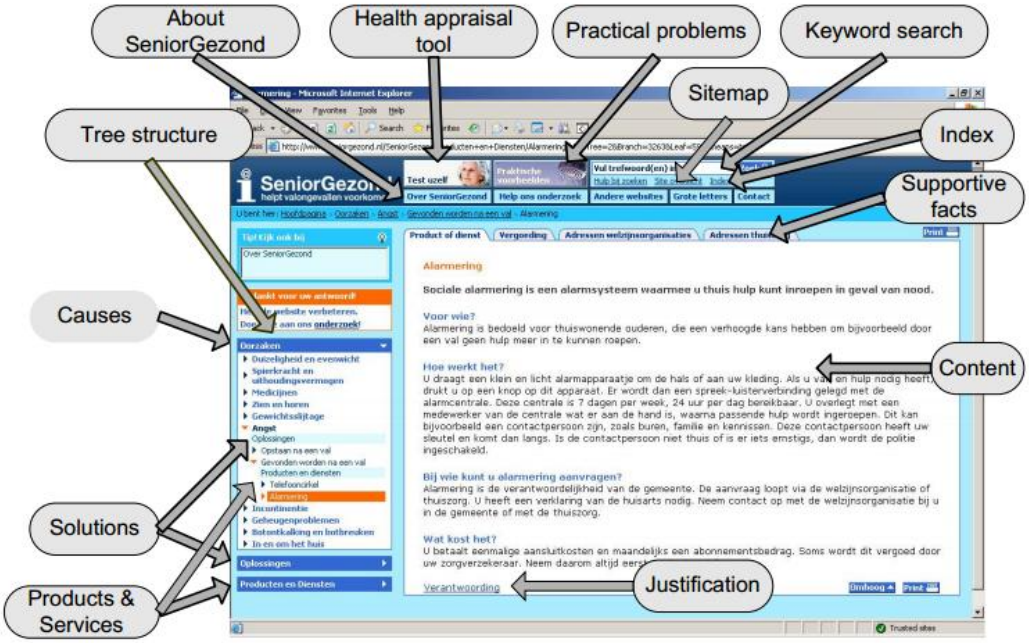


Figure 3-1 Screenshot with SeniorGezond

The website Blancetraining is developed to provide information about strength and balance training and encourage them to take strength and balance exercise(Yoga and Tai Chi)[23]. Most user of this website feel like they are not personal relevant and involves too much specific details, and some users regard this website too formal and a lack of graphics and colors [23]. The finding of this study is that some users say they do not apply the advices of the fall prevention for themselves, and some of seniors are not yet adequate computer literate to use the system.

Figure 3-2 Screenshot with Blancetraining

3.2 Mobile Computing

Mobile computing is the portable technology which is capable of wireless networking (e.g., personal digital assistants (PDAs), smart mobile phone, tablets etc.), enables users access digital information wherever and whenever they are and its main properties is mobility, portability, communication[24].

Wireless networking highly strengthens the utility of mobile computing by enabling mobile users to differently communication with others and to properly notice users with important events[24].

3.2.1 Mobile Computing in Medicine

Mobile computing can be beneficial to assisting healthcare in many aspects[25]. There is an example for mobile computing in medicine: a mobile touch-based questionnaire system is designed to assist patient filling out cancer survey during hospital visit [26]. It used the User-Centered Design methods(UCD) [27] (e.g., involves end-users in early phase, understanding user's real need etc.) and usability engineering methods[28]. This study indicated that it is important to adopt UCD methods to enable system to be more useful and easier to use. It used paper mock-ups to get a plenty of feedback for improving usability and reduce effort for technology details, and pointed out consistence for interface (includes works and motions) and graphical hint should be consider[28]. There was a challenging for this mobile system: some users were unwilling to use it because of technology illiterate [28]. Human-Computer Interaction could help design the usable interface and address the users' real requirements [29]. General usability methods can be effectively applied to mobile computing[28].

3.2.2 Tablets

Android tablets are increasingly inexpensive. Affordable android devices are available at market (Google Nexus 7: 199$ and Asus pad 7:120$). In China, the mainstream product of android tablets cost just 300-600 NOK.

Compared with computers, tablets are more intuitive and easier to use, because they enable users to directly manipulate objects by tab or drag action of finger gestures. Tablets are less convenient when it comes to web-surfing for traditional and complex websites, work usages, multiple tasks. However, tablets are less technology barriers for elderly, unlike PC that need to be intensively trained to use. It is highly impossible that tablets will be common household appliances (like televisions) in the near future.

3.3 Ubiquitous Computing

Weiser (1991) has presented a remarkable introduction with regard to main concepts of ubiquitous computing which is too far ahead of his time lacking hardware technology supported (e.g. Wireless LANs, portable computer etc.). Ubiquitous is opposite concept for virtual reality and it can be similarly defined as embodied reality, which minimizes distractions for users. The main characteristic of ubiquitous is invisible. The ubiquitous technology disappears as part of people's daily lives and fits into the background and is able to help meet the challenge of information overload. The study[30] provides the prototype of Pad and Smart phone (TAB) (see Figure 3-3) and points out the technology required for ubiquitous computing consists of three aspects: cheap, low-power computers and ubiquitous applications. Security and Privacy protection are main challenges for ubiquitous computing because it fits into our daily lives and personal information is vulnerable to be exposed. Next section, more challenges for ubiquitous computing will be discussed.

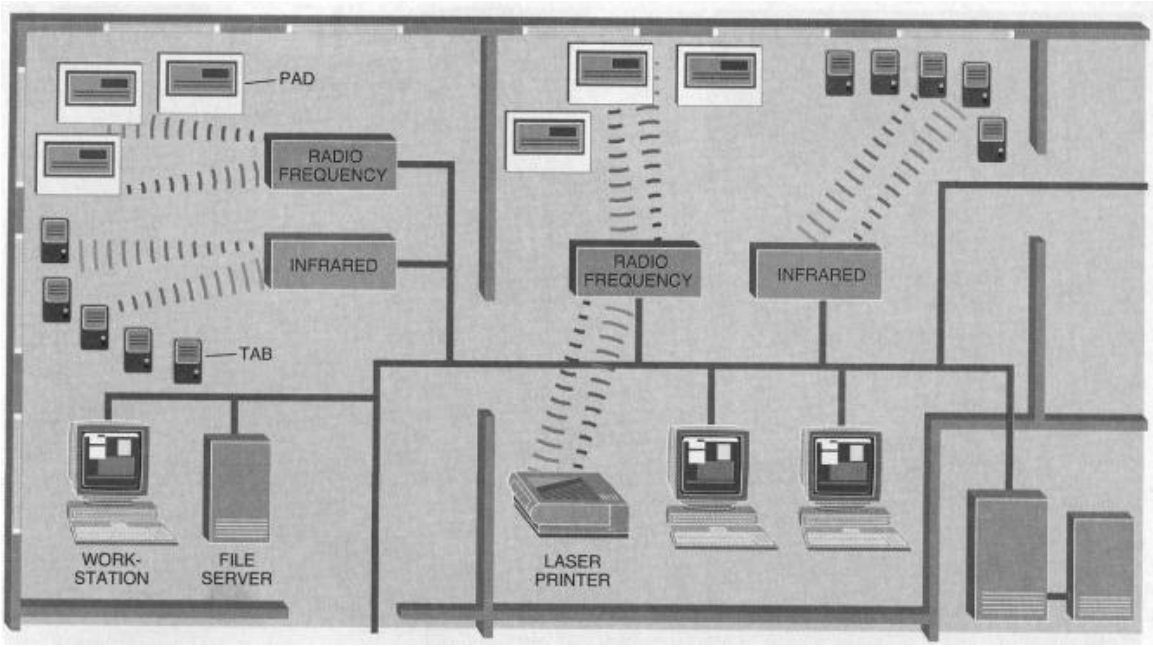


Figure 3-3: the wired and wireless network link computers and ubiquitous devices (from [30])

3.3.1 Main Goals for Ubiquitous Computing

Ubiquitous computing is also names as Pervasive Computing, and also called pervasive computing. The goals for ubiquitous Computing consist of “Effective Use of Smart Spaces, invisibility, localized scalability and masking uneven conditioning”[24]. Some parts of features of pervasive computing are based on Distributed System, Mobile Computing, (see Figure 3-4).

Effective use of smart spaces means that computing infrastructure is embedded into building infrastructure thereby integrate physical world into cyber space[24]. “scalability achieved by severely reducing distant interactions”[24]. Masking uneven conditioning is to “reduce the amount of variation seen by a user”[24]

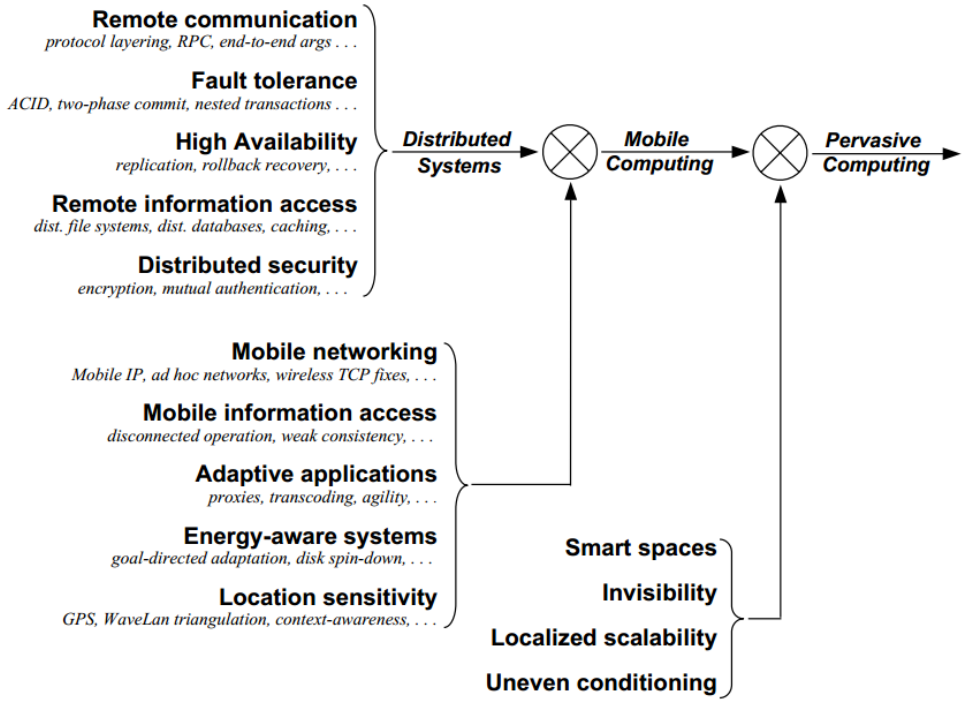


Figure 3-4: Taxonomy of Research Problems and goals in Distributed System, Mobile Computing and Pervasive Computing (Figure from [24])

3.3.2 Smart Artifacts

There are two types of smart artifacts: 1 system-oriented, which means that smart artifacts are able to take actions on the basis of information earlier collected. 2. People oriented, which asks for users feedback and allows users to take actions in control loop[31] Hello-wall is one of example for smart artifacts by using ambient displays that is nature-like metaphors to present information without constantly demanding the user's full attention"[31]. Hello-wall is to support social encounters and informal communication. When people pass by or watch the Hello wall, it will sent notifications or is interacted with people [31](see Figure 3-5 and Figure 3-6).

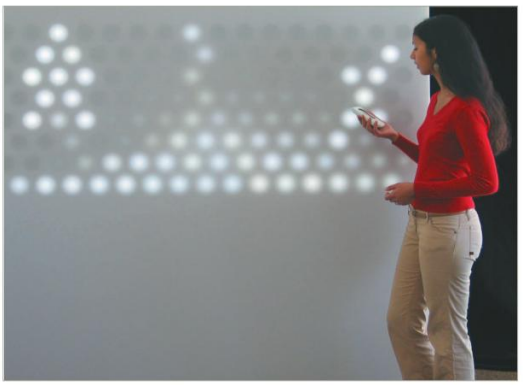


Figure 3-5: Hello. Wall [31]

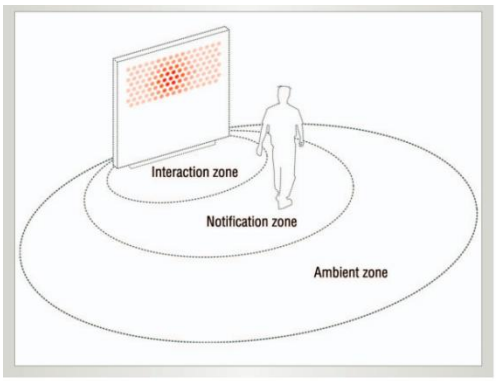


Figure 3-6: Communication zones of Hello. Wall [31]

3.3.3 Proxemic Interactions

Proxemics refers to spatial relationships which "people use interpersonal distance to understand and mediate their interactions with other people"[32]. There are four proxemic zones to explain spatial relationships: Intimate, personal, social and public[32]. The closer distance, the more intimacy is. People tend to adjust distance according to the relationship with others.

There are five dimensions of proxemic with respect to ubiquitous computing: distance, orientation, movement, identity and location [32].The distance is fundamental between users and device[33](see Figure 3-7, Figure 3-8).

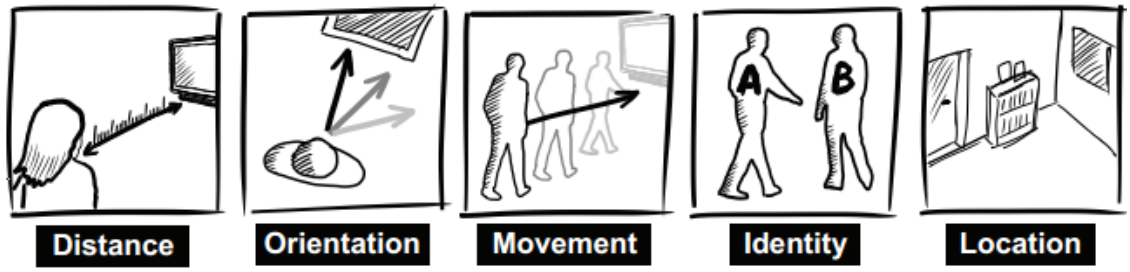


Figure 3-7 : The five aspects of proxemics

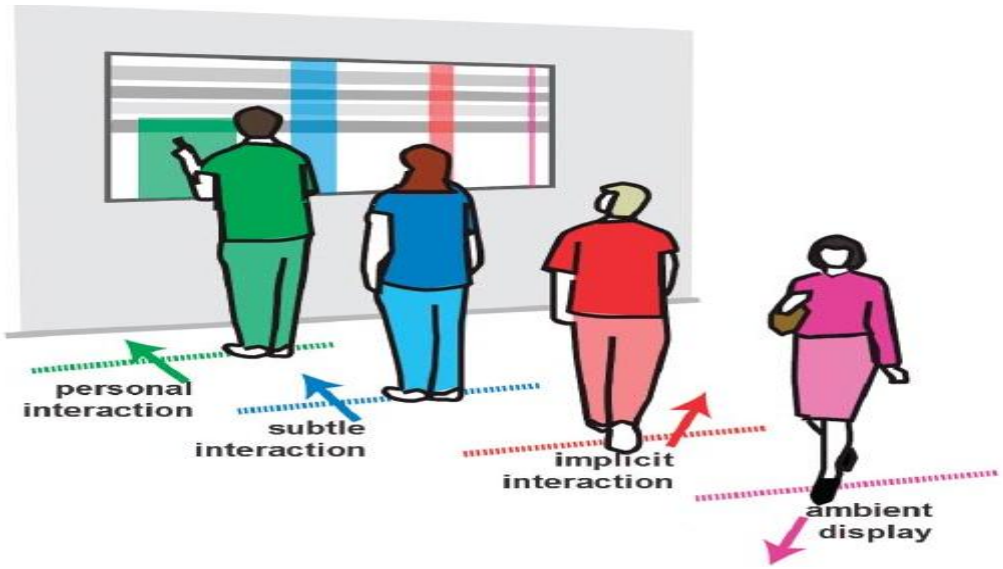


Figure 3-8 : Four interaction zones, (from [34])

3.4 Ambient Display

The Ambient display shows dynamic contents by a casually glance manner while passing by the device, without high antennal requirements[35]. The CareNet display [36](see Figure 3-9, Figure 3-10) is an ambient display for home setting as a digital photo frame, shares information about the status(e.g., meals, medication etc.) of elder

users to their family and related people who are concern for the older people , and it aims to make elder people live independently.

The study derives from idea of an early research: homecare digital portrait [37] (see Figure 3-11). It consist of two mainly usages: ambient m and interactive. The Main screen shows the portrait of the older user behaving as an ambient display, there are several action Icons (meals, activities, moods etc.) to be updated daily status. Older users often glance at the CareNet display to see whether Icons were red when they are passing by the display. Some users often interactive with the device to dig for details.

Figure 3-9 The CareNet Display at home

Figure 3-10: The CareNet Display prototype

Figure 3-11 Homecare digital portrait

The CareNet display promotes the awareness of family, friends, and care provider about older people's daily life. For instance, Children are able to be aware what parents ate at dinner and when their parents need transportation. Overall, the CareNet display enables to make positive influences on care of seniors and lives of their family and related people. There are several improvement for the device: the glow of the device in the evening disturbs them(this is the major issue for the system), elder users need to simplify operations, family member need more detail information about elder users, and privacy problem[36].

3.5 Human Behavior changes

Can ambient displays have impacts on persons' behavior? Some of people wonder whether it is or not, because they assume that people just have a glance while passing by and they could possible overlook. However, studies have proven that ambient device indeed impact human behaviors in a subliminal manner [38, 39]. For instance, Beakway [39], ambient display encourage people to frequently take breaks by a non-obtrusive manner(see Figure 3-12).

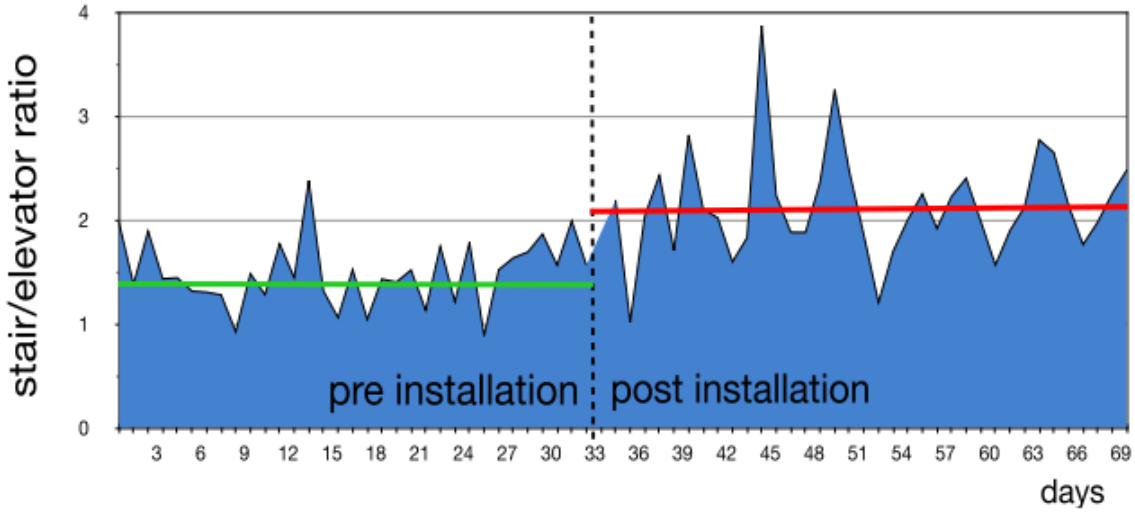
Figure 3-12 Actions in the sculpture design.

A more rigorous study indicates that the ambient device consciously results in significant changes on people. The project [38]aims to encourage people to take stairs instead of elevators for sake of their health. It adopts three ways of ambient displays: Twinkly Lights (see Figure 3-13), the History (see Figure 3-14), and the Clouds. When people are walking to staircase, Twinkly Lights indicate the way to stairs. The history is also an ambient display, revealing the usages of stairs and elevator.

The finding of this study has concluded that ambient displays can induce people to have behavioral changes(see figure 3.15), and this study also suggest that ambient displays could contribute to eating healthy, quitting unhealthy snacks etc.

Figure 3-13: Follow-the-Lights (Twinkly lights)

Figure 3-14: History



Ratio of stair/elevator usage before and after installation
(horizontal line represents mean ratio before and after installation)

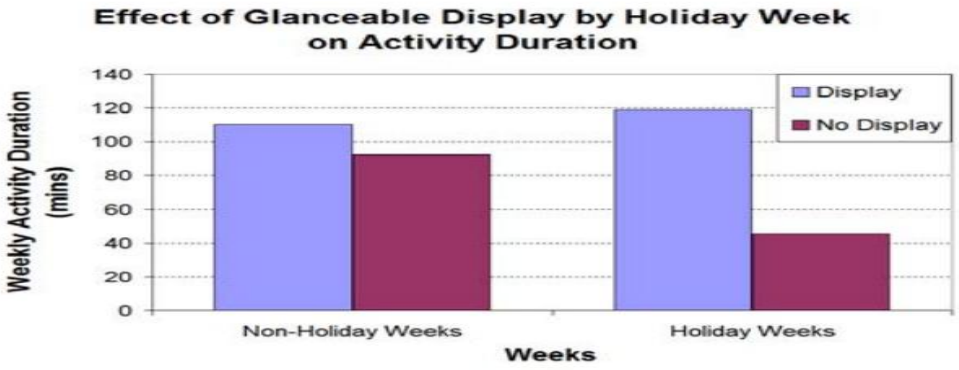
Figure 3-15 The comparison of results of implementation of ambient display

Notably, a glanceable display for awareness[40], shown in Figure 3-16 , is proven to increase awareness of the daily life and promote physical activity especially on Holiday Weeks. It is mobile app for self-monitoring of physical activity. It utilized garden

metaphors (flowers) as representations of physical activity. The level of physical activity without the glanceable display decreased significantly (see Figure 3-17).

. a) at the beginning of the week; b) after one cardio workout; c) a full garden with variety; and d) a full garden on the background screen of a mobile phone. Butterflies indicate met goals.

Figure 3-16: The Glanceable Display for promoting physical activity)



A statistically significant interaction between the availability of the Glanceable Display and Holiday Weeks on Activity Duration.

Figure 3-17: Comparison of Changes with and without awareness display

3.6 Fall-risk Assessment Tools

As mentioned in Chapter 2, in order to meet the challenge of personal relevance, the pivotal first step for the fall prevention is to identify whether the elderly who are at high risk of falling or not. The following sections discuss about fall-risk assessment Tools.

Sensitivity and specificity are two dimensions to evaluate the predictive value for results [41]. A recommendation for high predictive results: specificity > 75% and sensitivity >80% [42]. However, another study indicates that specificity sensitivity should be near 70% so as to achieve a tradeoff [43].

3.4.1 Timed Up & Go Test for Community-dwelling Older Seniors

Timed Up & Go Test (TUG) is an initial screening test for fall prediction [44]. Older people who are identified high risk by TUG are supposed to be referred to health professionals for in-depth assessments. The rationale of TUG is to test basic functional mobility. It is reliable, valid, quick and without needs of special tools or training: Timed the process of standing up from a chair ,walk 3meters(10 feet), turn back, and sit down again[45]. Older people are at a high risk for falls, if time of TUG is longer than 14.5 seconds[44]. TUG reaches relatively ideal scores in sensitivity, specificity compared with other assessment tools.

Table 3-1 Timed Up & Go Sensitivity, Specificity [44]

	Cutoff Score (s)	Sensitivity (% Fallers)	Specificity (% Nonfallers)	Overall Prediction	Predicted Probability
TUG	≥13.5	80%	100%	90%	.77
TUG_{manual}	≥14.5	86.7%	93.3%	90%	.5
$TUG_{cognitive}$	≥15	80%	93.3%	86.7%	.5

3.4.2 Morse Fall Risk Assessment for Inpatients

Morse Fall Risk Assessment (see Table 3-2) is widely used in setting of hospitals, and it is reliable assessment by conducting survey for patients[46]. It indicates high risk for

falling if Morse Score is more than 45. Sensitivity and Specificity of Morse score are 73.2, 75.1 separately [47].

Table 3-2: Morse Fall Scale

1. History of falling; immediate or within 3 months	No = 0 Yes = 25
2. Secondary diagnosis	No = 0 Yes = 15
3. Ambulatory aid	None, bed rest, wheel chair, nurse = 0 Crutches, cane, walker = 15 Furniture = 30
4. IV/Heparin Lock	No = 0 Yes = 20
5. Gait/Transferring	Normal, bed rest, immobile = 0 Weak = 10 Impaired = 20
6. Mental status	Oriented to own ability = 0 Forgets limitations = 15

Risk Level	**MFS Score**	**Action**
No Risk	0 - 24	None
Low Risk	25 - 50	See Standard Fall Prevention Interventions
High Risk	= 51	See High Risk Fall Prevention Interventions

4. Requirements Specification, Use Case, Scenarios, Prototype

This chapter presents use case, usage scenarios, architecture, defines functional and non-functional requirements for the fall prevention based on the problem analysis and use case and usage scenarios.

4.1 Requirements Specification

The process of requirements elicitation for this project is iterative and continuous improvement Process[48]. Overall requirements derive from: 1. previous chapters (problem elaboration and state-of-art) and analysis based on them. 2. It also came from feedback of expert (Babak Farshchian: supervisor of this project) at meetings. 3. Initial unstructured interviews(introduce fall topic and intrude as little as possible[49]) were conducted at the beginning of master project ,and get feedback from elder people through evaluation for interactive and high-level prototype.

This section specified both functional and non-functional requirements for prevention for falling based on the problem analysis. The overall requirements lay foundation for further specific requirement.

Each requirement is described by a term (ID, Description, and Priority) where:
ID: Unique identifier identification.
FR: Functional Requirement.
NFR: Non-Functional requirement.
To be more specific:

FR-IM: Interactive mode requirements
FR-AM: Ambient mode requirements

Description: brief explanation

Priority: The importance of requirement's priority measured by High, Medium, Low.

Difficulty: The estimate of difficulty for fulfilling the requirements measured by High, Medium, Low.

4.1.1 Functional Requirements

These functional requirements mainly involve needs of six functions in the interactive and ambient modes:

Interaction mode:

1. Conduct fall risk assessments to get a personal status (the level of fall risk) of the elderly, by using Timed Up & Go Test and fall surveys. This functionality is pivotal because it makes older people be aware of the status whether they are at risk of fall, and it aims to meet the challenge of "personal relevance" (mentioned at chapter 2).
2. Check the result of assessment and previous results. Older people are aware of their current and previous status. It can contribute to raise awareness of fall risk about them, which also strengthens personal relevance.
3. Browse fall prevention information (in the forms of pictures, texts, videos) and informally acquire knowledge about fall preventions. For instance, older people get information and knowledge about what and how to remove falls hazards, and what kind of exercise would be reduce risks of falling, and how to take strength and balance exercise (e.g., Tai Chi, Yoga).
4. Strengthen social interactions with their families, friends, neighbors to form fall prevention communities. Social interactions can effective encourage elderly to the prevention program and promote the level of participation.
5. Detect the lighting of their own home for fall risks. This function is a part of fall risk assessments, because lighting of home is one of most dangerous hazards for the elderly. This function helps the elderly to detect lighting condition whether is bright enough or not. If not, they are recommended to increase brightness of home.

Ambient mode:

6. Display information about the fall prevention and photos of their private photos.

This requirement is to informally educate users about fall prevention, intensify knowledge about the fall prevention and make their behavioral change about fall in a non-obtrusive and unconscious manner (user casually glance while passing by the device). The smart photo frame function can auto-start without user's operation and it also serves as the replacement for screensaver mode. The system is able to stop the system and switch off the glow of the device to avoid disturbing them when users go to sleep in the evening.

Table 4-1: Functional Requirements

ID	Description	Priority	Difficulty
Interactive mode			
FR-IM 1	Users should be able to perform the Timed Up & Go Test	H	M
FR-IM 2	Nurses or other health providers should be able to perform Morse Fall Risk Assessment	M	H
FR-IM 3	Users should be able to browse the result of assessment and previous results	H	M
FR-IM 4	Users should be able to have social interactions with their families, friend and the local community by using this system.	H	M
FR-IM5	Users should be able to browse fall prevention information (in the forms of pictures, texts, videos)	H	M
FR-IM6	The system should able to detect the lighting of home for fall risk	M	H
Ambient mode			
FR-AM1	The system should be able to show information about fall prevention	H	H
FR-AM2	The system should be able to show their private photos.	M	M
FR-AM3	The system should be able to stop the system and switch off the glow of the device to avoid disturbing them when users go to sleep in the evening.	H	H

4.1.2 Non-Functional Requirements

The system should be not only useful but also usable, because easy-to-use system facilitates the satisfactory of user experience so that users are encouraged to actively use this system.

Table 4-2: Non-Functional Requirements

ID	Description	Priority	Difficulty
NFR-1	The system should be easy to use.	H	H
NFR-2	The user interface of this system should be clear and intuitive.	H	H
NFR-3	Users should be able to easily conduct the risk-assessments.	H	M
NFR-4	Information provided in the system is relevant to users.	H	M
NFR-5	The system should produce the result within a short time	M	M
NFR-6	Users are able to easily check (monitor) information by using this system.	H	M
NFR-7	The system should be unobtrusive and do not interrupt (distract) users, if users put the system at home.	H	H

4.2 Use Case

This section presents a use case so as to clearly explain to readers what the system is and how actual users interact with the system. The use case (see Figure 4-1) summarizes high-level functionalities and is illustrated by usage scenarios, which is based on previous sections. The main operations of this system consist of 1.Perform fall risk assessments. 2. Check current and previous results of fall assessment. 3. Detect the lighting condition for fall risks. 4. Browse information and acquire knowledge about fall prevention. 5. Contact with their families, friends to gradually form a local fall prevention communities. 6. Casually glance information about fall prevention and their private photos while passing by the system.

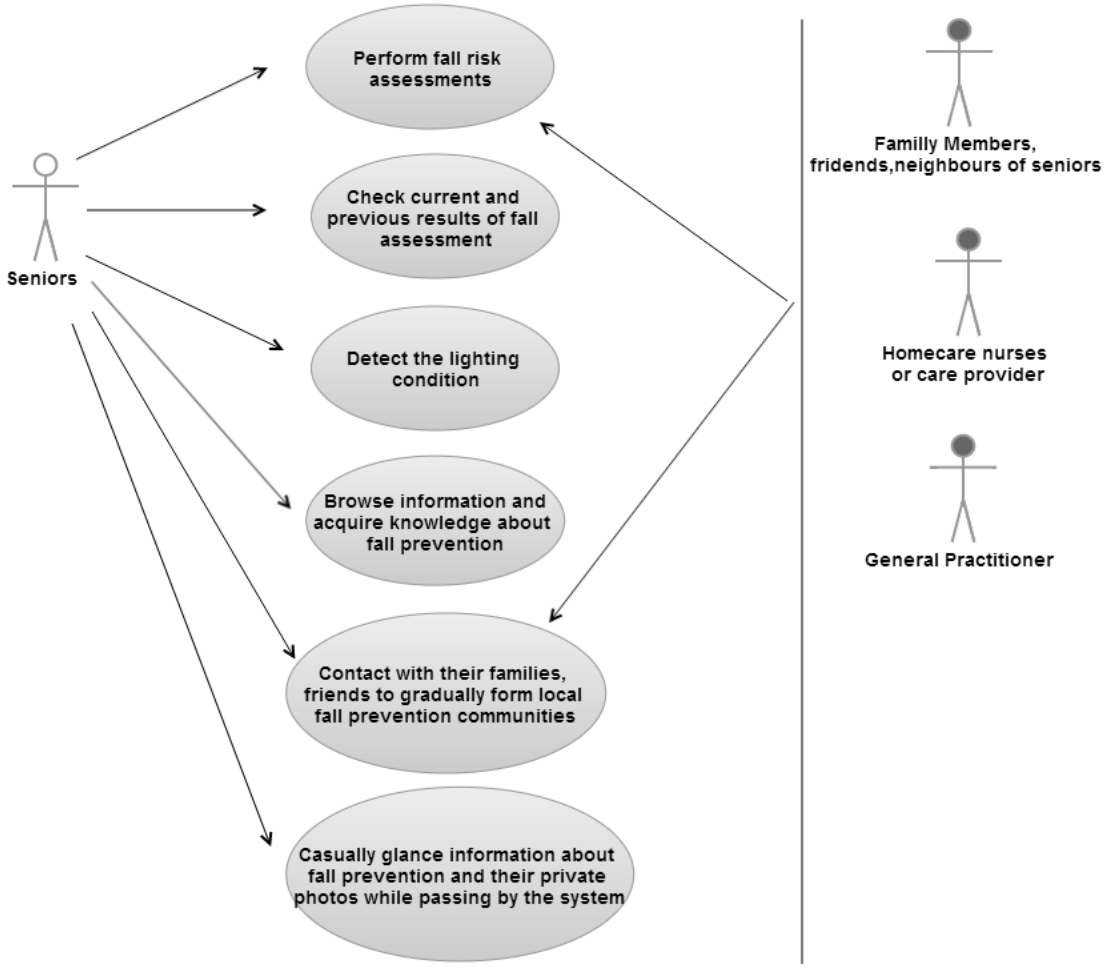


Figure 4-1: The use case diagram

4.3 Usage Scenarios for Main Functionalities

This section presents usage scenarios for the prototype system according to the use case. The user can use mobile phone or tablets to operate in following scenario.

4.3.1 Personas

Stakeholders related to the system can be classified by as follows:

1. Primary users: The elderly, Family members
2. Secondary users: Neighbors, homecare nurse or provider
3. Stakeholders: General Practitioner

This section demonstrates the personas containing an older person and her/his family member. The system can be used by the elderly themselves or others. Family members of older people can assist them in conducting fall risk assessments. Neighbors, homecare nurse or provider can also help elder people use this system, but family members are more feasible and available to help older people to perform risk assessment for real situations because some regions lack home care nurses and social workers to assist the elderly.

Sofia, 60 years old, was retired two years ago. She is married, lives with her husband Thomson (62 years old), and they have a son Simon. She has a high school education. Sofia have used mobile phone for 10 years and sometime she uses her son's tablet to watch his son's pictures, videos, and play with some mobile games (e.g., angry birds and Plants vs. Zombies etc.).

Simon, 32 years old, Sofia's son, works in oil industry and lives in other city which is around ten-hour drive from her mother. He visits Sofia once every several months. He has a college degree. He bought a touch-screen smart phone 2 years ago, which is android platform, and bought a tablet one year ago. He is planning to purchase a new phone and give the older one to Sofia. He is also considering to buy an android tablet (the prices range from 400 to 3500 Norwegian Kroner).

4.3.2 Scenario 1 – perform an assessment and check current and previous results of fall assessment, detect the lighting condition

Sofia let her husband, her son (neighbors, or homecare provider) use this system to perform Timed Up & Go Test assessments, and check the lighting of the house for her. After Sofia finished a series of questions, she will get a result for risks of falling. If she is at relatively high risk of falling, she will be suggested to visit health professionals (General Practitioner). In the meantime, results convey to face awareness display: when

she got result for a low risk of falling, a smiley face appears, in contrast, a sad face show up. Every 6 month, the face turns questionable face to remind her to test again.

4.3.3 Scenario 2 – browse Information and acquire Knowledge about fall prevention

Sofia launches the system and browses fall prevention information in forms of texts, pictures or videos, to gain more knowledge about fall preventions: what and how to remove falls hazards, and what kind of exercise would reduce risks of falling, and how to take the strength and balance exercise (e.g., Tai Chi). For instance, the system guides her make home safer: find and fix home falls hazards by using a fall risks checklist: remove low furniture or other objects and throw rugs are on the floor, whether grab bars is installed at bathrooms, and whether the light is reached around the bed etc..

4.3.4 Scenario 3– social interaction with their families, friends, neighbors to gradually form fall prevention communities

Sofia contacts their families, friends and the local community using this system. She can check out the local online community whether hold fall prevention seminars or professional lectures, or group exercise activities. She can share her fall accident experiences using system or warn others not to fall, which strengthen people's fall prevention awareness in her network. For instance, she uses voice recognition to type: "I fell yesterday round exit of the park, too dark there. :(" "I want to have and study a balance exercise (Tai Chi) on this weekend, anybody wants to join me together??". Therefore, other people could be aware of the fall risk round exit of the park, and perform balance exercise to lower chances of falling by social promotion.

4.3.5 Scenario 4 – casually glance information about fall prevention and the user's private photos while passing by the system without requiring any direct interaction from the user

Sofia uses the system (see figure 4.2) to turn her devices (her mobile phone or her son's obsolete mobile phone, tablets) to turn them into a smart photo frame (ambient display). However, it is recommended to use the tablet (because of large screen and large font size) as ambient display.

She puts the smart photo frame in the living room or in her bedroom. The smart photo frames can auto-start without Sofia's operation, and it also serves as replacement for screensaver when Sofia does not use it for other usages. The smart photo frame runs without requiring any direct interaction from Sofia. Sofia casually glance information about fall prevention and the user's private photos while passing by the smart photo frame. The smart photo frame auto-start without Sofia's direct interaction and it also serves as the replacement for screensaver mode. The system is able to stop the system and switch off the glow of the device to avoid disturbing them when users go to sleep in the evening.

Sofia acquires knowledge and has behavioral changes about lowering her chances of falling, in a non-obtrusive and unconscious manner (casually glance while passing by). The system makes the tablet works as a smart photo frame (ambient display) to fit into Sofia's daily life. The smart photo frame occasionally can display customized fall prevention information according to the data of assessment results (Illustration by texts, pictures or videos for home hazards removal, balance exercises like Tai Chi etc.).

Figure 4-2 The illustration for two usage mode: ambient display mode and interactive mode

4.4 Prototype

Before designing and implementing the prototype applications, the project utilizes a high-level and interactive prototype that can run on mobile and computer platforms to easily get evaluate feedback from actual older people. Compared with paper prototype, it is

closer to final system and users can be easier to give feedback. However, it is more time-consuming than the paper prototype. Figure 4-3 illustrates the overview of the high-level and interactive prototype.

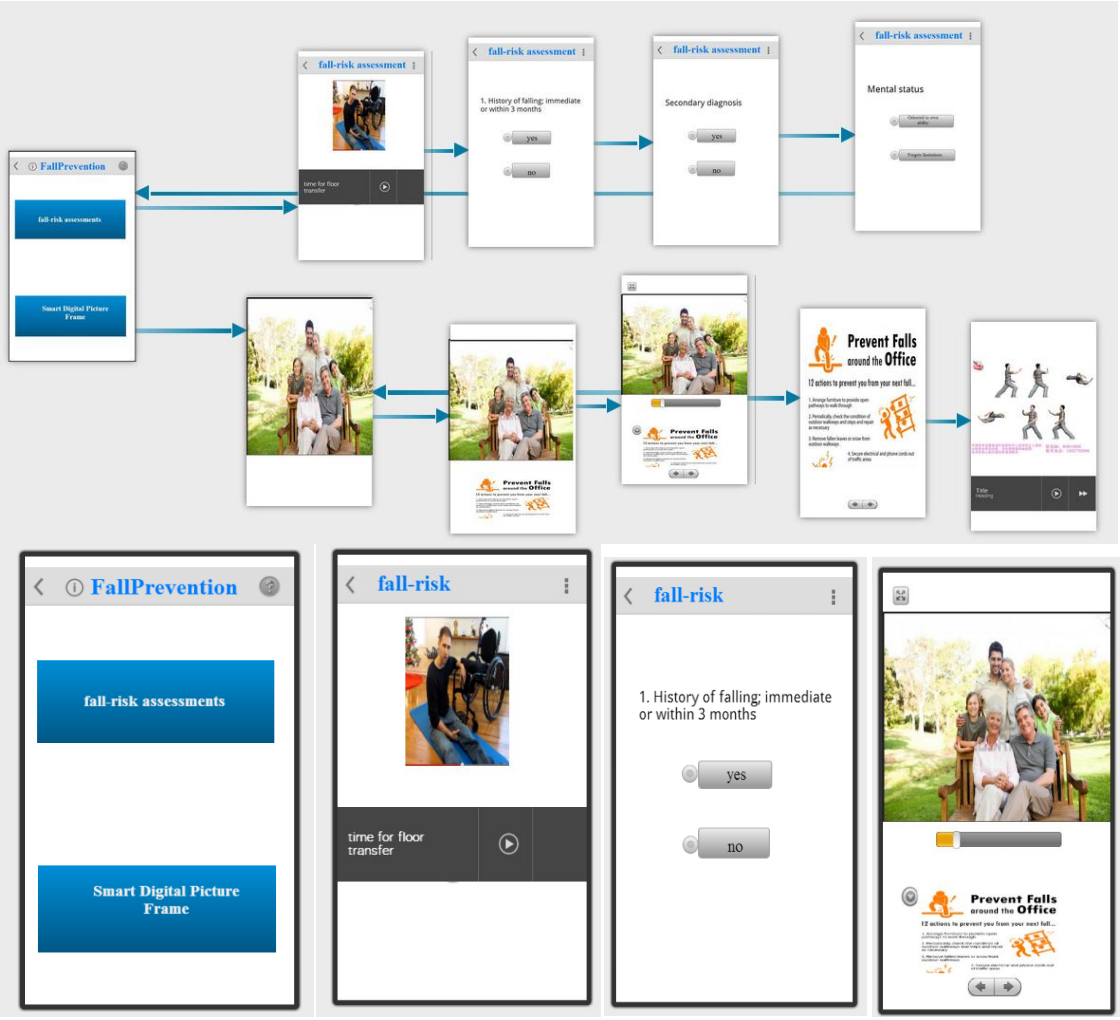


Figure 4-3 Overview of the high-level and interactive prototype

5 Solution Proposal and Implementation

This chapter includes a system overall architecture and design principles, explains and presents tools and the techniques for implementation. Most importantly, it presents the system functionalities for the implementation.

The prototype application works in two modes: interactive mode, ambient display mode (Smart Photo Frame).The main functionalities are as follows:

(1). Conducting fall risk assessments (Timed Up & Go Test and Fall surveys) to get a personal status for fall risks, and presenting a personal result report with the awareness display. These Functions aim to meet the challenge of personal relevance. These functions are pivotal because they make older people aware of the status whether they are at risk of fall or not.

Detecting the lighting of their own home for fall risks is a part of fall risk assessments, because lighting of home is one of the most dangerous hazard for the elderly. This function helps the elderly to detect lighting condition whether enough is or not. If not, they are recommended to increase brightness at home.

If users are at relatively high risk of falling, he is suggested to visit health professionals (General Practitioner). If it is just high risk of falling, the system provides more tailored information about fall prevention for users. For instance, more information about strength and balance exercise. In the meantime, results will be shown as faces: when users got result for a low risk of falling, a smiley face appears, in contrast, a sad face show up. Every 6 month, the face turns questionable face to remind her to test again.

(2). Fall prevention information (picture, texts, videos forms) browsing function aims to meet the challenge of seniors' limited knowledge about fall prevention. This function

aims to (1) Increases seniors' awareness about fall prevention. (2) Enables users to browse fall prevention information and gain more knowledge about fall prevention (meet the challenge of seniors' limited knowledge about fall prevention). (3) Guides them to make home safer: find and fix falls hazards at home by using a fall risks checklist, because around half of falls happen at home [53]. For instance, the system guides them to remove shoes or other things from stairs (which trip users), remove small rugs; use non-strip mats, improving lighting of home. (4) Encourages them to take strength and balance exercise (like Tai Chi) and remind them to have their vision and medication checked [53]. User can be browsing fall prevention information in the forms of pictures, texts, videos.

Fall prevention information can be modified according to the test results of fall assessments. For instance, if user's test result is at a high risk of falls (Timed Up & Go Test), the system will provide more tailored information about fall prevention, like more information about strength and balance exercise. If user is tested as low risk for falls, the system will are less and general information about fall prevention, but remind them to check again every 6 months.

(3). Strengthening social interactions with their own families, friends, neighbors to gradually form fall prevention communities. Social interactions can effectively encourage elderly to join the prevention program, and to promote the level of participation (motioned at chapter 2). This function is implemented by integrating with Facebook that is the most famous online social networking and facilitates informal communication.

(4). Ambient Display Mode (Smart Photo Frame), displays information about fall prevention and users' private photos. This function is to informally educate users about fall prevention, intensify knowledge about fall prevention and make their behavioral changes about lowering chances of falling in a non-obtrusive and unconscious manner (user casually glance while passing by the device). The smart photo frame function can auto-start without the user's operation and it also can serve as replacement for the

screensaver mode. The system is able to stop the system and switch off the glow of the device to avoid disturbing them when users go to sleep in the evening.

The function of casually glancing at customized information about fall prevention while passing by the device is to meet the challenge of acceptability for fall prevention. As mentioned in chapter 2, seniors got booklets, flyers, or leaflets about the fall prevention and then they would say it is useful and good, but after several days, they threw it and completely forgot. Displaying users' private photos could increase the adoption and utilization ratio of this system. This system enables users to acquire fall prevention knowledge and make behavioral changes about lowering the chances of falling, in a non-obtrusive and unconscious manner (casually glance while passing by the system).

5.1 System according to Precaution Adoption Process Model

This system design of this project is based on a stage theory "Precaution Adoption Process Model", which describes stages from unaware of the issue to completed preventive action[50](see Figure 5-1). Firstly, the prototype system makes older users aware of fall issues and personally engaged, through performing the personal fall risk assessment. It also provides reliable, professional and simple information about fall prevention to encourage older people to take action. Smart digital photo frame (ambient display) serves to motivate and impact people to take fall prevention actions for the final phases (decide not to act and maintenances) in a non-obtrusive and unconscious manner.

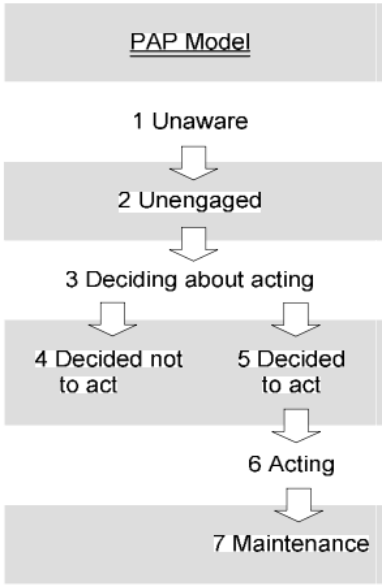


Figure 5-1: Precaution Adoption Process Model[21, 50]

5.2 System Overall Architecture

The feedback from older people by interviews is that the major functionalities of the system should run independently without internet, because a high proportion of older people have limitations of internet access for mobiles or tablets. However, advanced features (e.g., social interaction) can be supported if users have internet access. This section presents a high-level architecture for the fall prevention system, which consists of three main parts: Client, Database and Interface (see Figure 5.2). Choosing client-server architecture based on three layers is to provide a better user experience and to be beneficial to fulfill feasible solution. The client layer is to record user motion data and input. The application layer includes Interface, web service and local service. Some advance functionalities (social interactions to form the fall prevention community) are through web service, which enables the system to have the better cross-platform (Android, iOS and Windows Mobile) ability and flexibility. However, main basic functionalities are based on local service so that the users can perform the fall risks assessment without internet access like Wi-Fi. The data layer concludes Local Database and Remote Database.

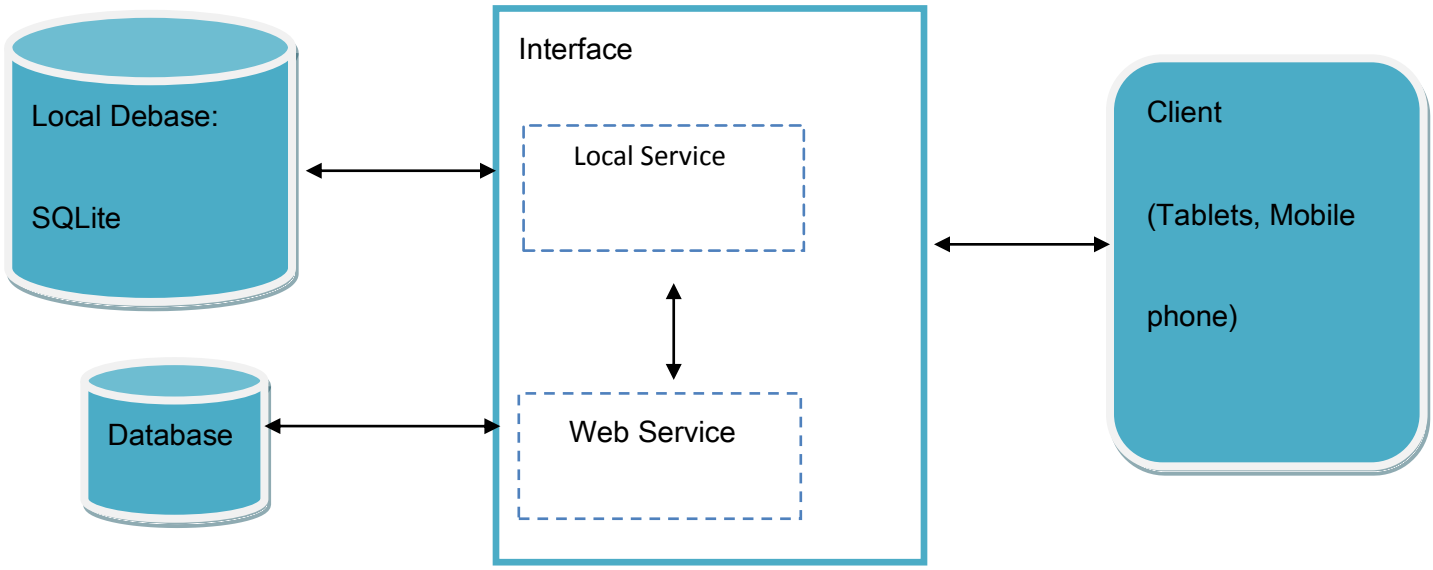


Figure 5-2: Overall Architecture for the fall prevention system

5.3 Design Principles

During the process, this project adopted iterative cycles and continuous improvement process[48]. Older users were engaged in the prototype evaluation phase before system design. Other core design Principle includes: knowing the user (e.g., limitation for cognitive, visual impairment).

As for usability design, the project generally complied with Nielsen' ten heuristics principles[51] as rule of thumb: "Visibility of system status(appropriate and in-time

feedback), match between system and the real world(simple , plain and familiar language for users), User control and freedom(Support undo and redo, emergency exit),Consistency and standards(platform conventions),Error prevention (careful design, confirmation option), Recognition rather than recall (visible or easily retrievable) ,flexibility and efficiency of use (accelerators, tailor frequent actions)Aesthetic and minimalist design, Help users recognize, diagnose, and recover from errors ,Help and documentation (easy to search, user's task oriented, concrete steps)" [51].

However, as for specific designs, the system applied Android Design Guide from Google to the usability design. For instance, 48dp Rhythm principle (see Figure 5-3): Touchable UI components should be at forty-eight dp for both height and width in order to touch components reliably and accurately.

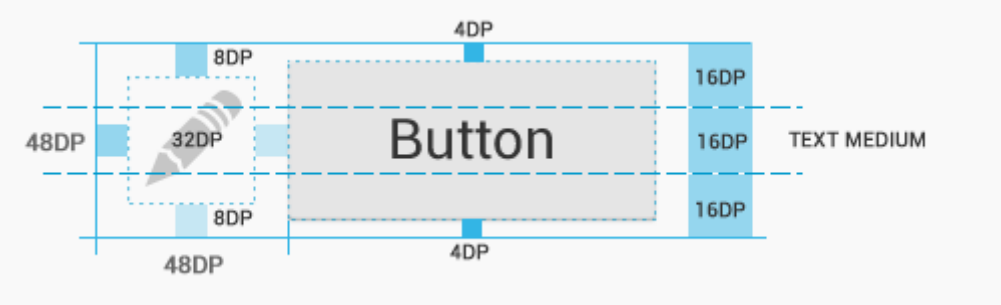


Figure 5-3: 48dp Rhythm From (http://developer.android.com/)

5.4 Tools and Technologies

5.4.1 Android OS

Android OS is an open and free mobile operating system which is based on a modified version of Linux and released under the open source Apache License. The Android OS mainly consists of five sections in four main layers: Linux kernel, Libraries, Android runtime, Application framework, Applications[52] (see figure 5-4). Android OS are able be installed at Smart phones, Tablets E-reader devices, Smart TV etc. Android OS 4.0 and later version can well support both tablets and Smartphone.

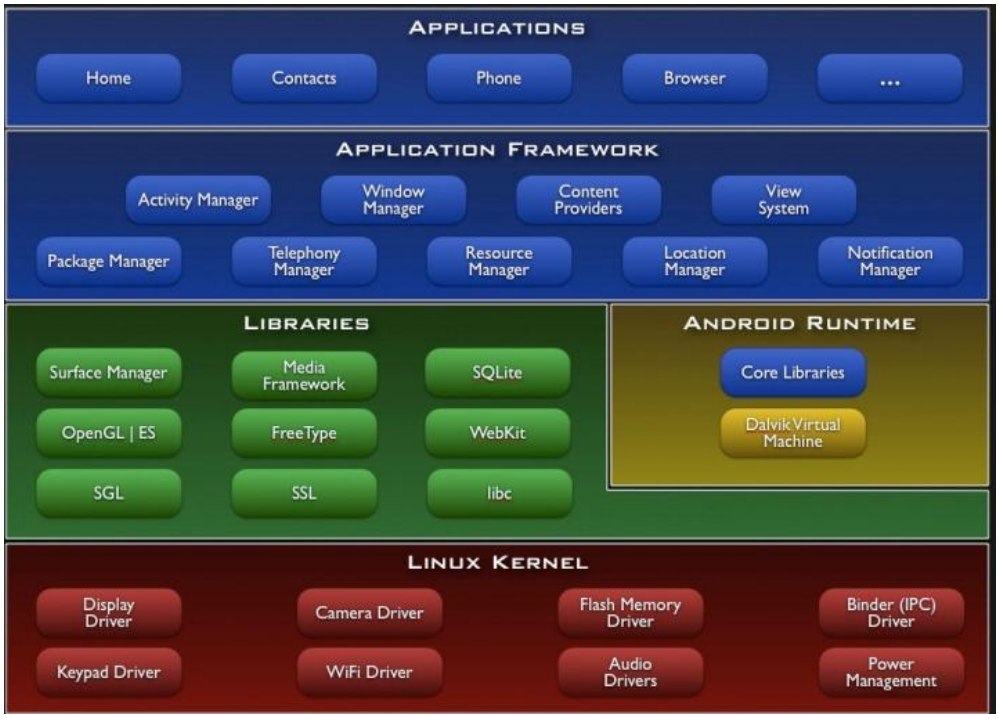


Figure 5-4: The architecture of Android OS [53]

5.4.2 Activity, Fragments and Intent

An activity (see Figure 5-5) is an interactive window that contains the user interface; Fragments are similar to activities and can be regard as “miniature” activities; Android 3.0 introduces the fragments feature for tables(large screens) and they are able to be grouped to form an activity. An intent resembles the “glue” that enables different activities to work together[52].

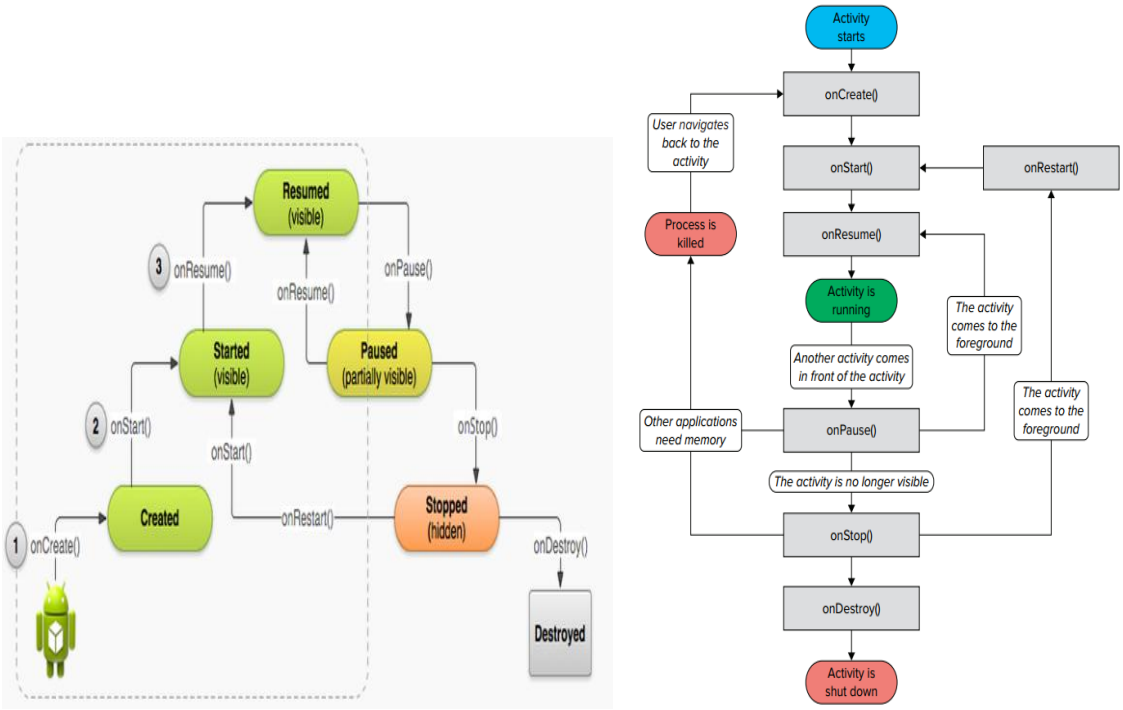


Figure 5-5: Two illustration for Life of circle of activity [53]

5.4.3 SQLite database

SQLite database is an light-weight relational database management system, and it is mainly used for saving relational data. For instance, it is really efficient to store the exams results of all the students. It is recommended to use the SharedPreferences when it comes to simple unstructured data[52].

5.5 Prototype System Functionalities

The fall prevention prototype system is to support the elderly in preventing falls, which uses mobile and ubiquitous computing to help the elderly to increase their awareness about fall prevention, enable them to acquire more knowledge of fall prevention, remove hazards and take action to prevent, thereby lowering their changes of falling. It works in two modes: interactive mode, ambient display mode (smart photo frame, without requiring any direct interaction from user). The main functionalities are introduced in the mfollowing sections. The application overview is shown in figure 5-6. Figure 5-7 shows Screenshots of the system on a tablet. (Some sources of pictures for the fall prevention in Screenshot are from Centers for Disease Control and Prevention).

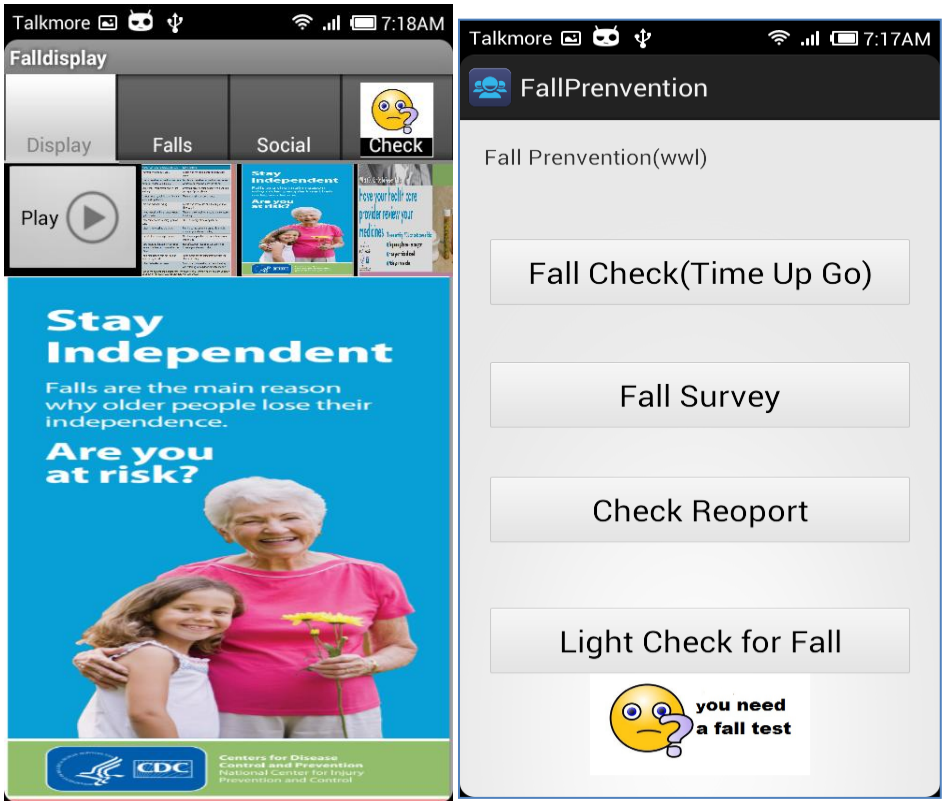


Figure 5-6: Screenshot of the application overview on a mobile phone

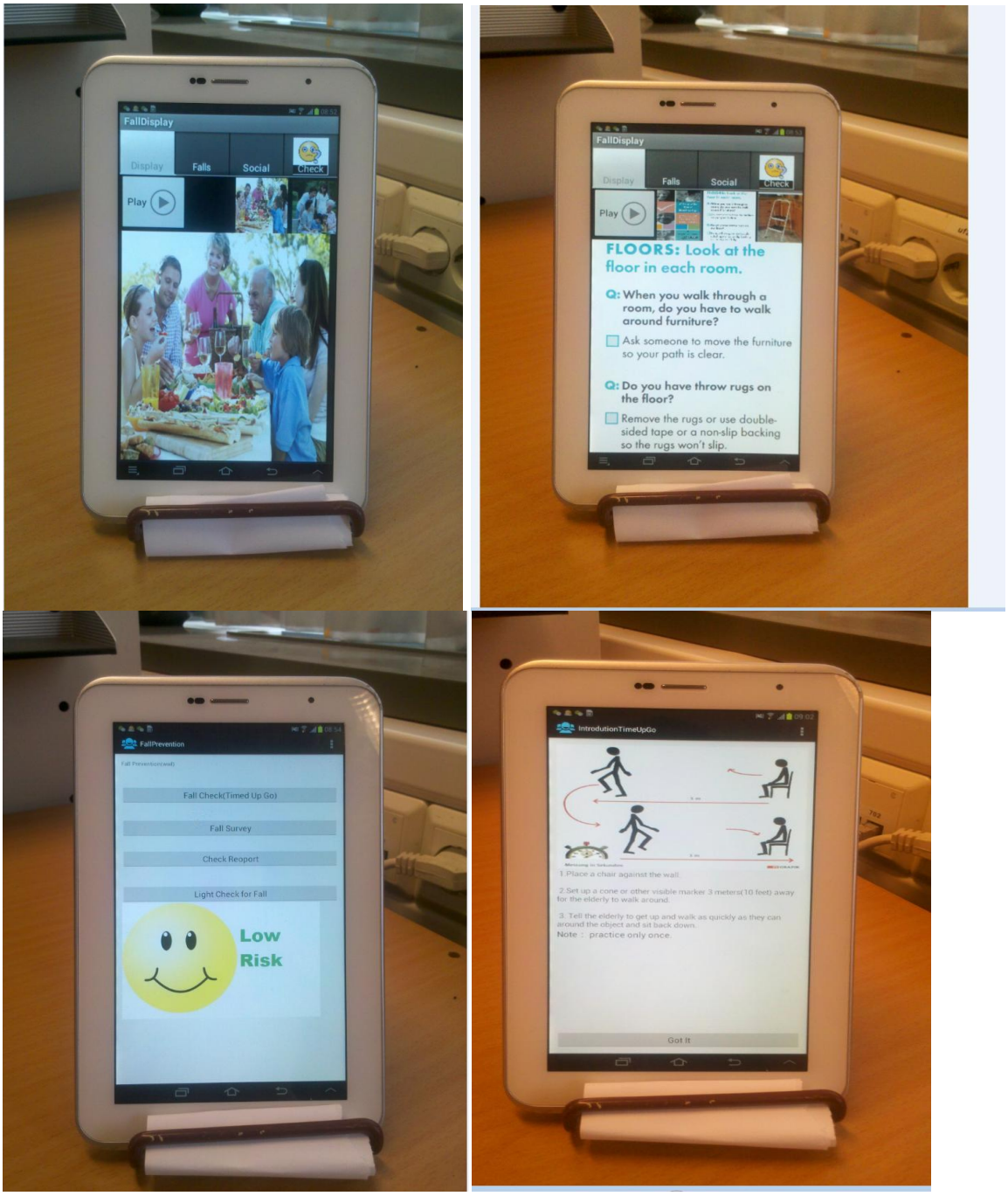


Figure 5-7: Screenshots of the application on the tablet

5.5.1 Interactive Mode

(1) Fall risk assessments

The view of the fall risk assessment (Timed Up & Go) is shown in figure 5-8, and fall surveys is illustrated in figure 5-9, and presenting personal result report with the awareness display(see Figure 5-10).

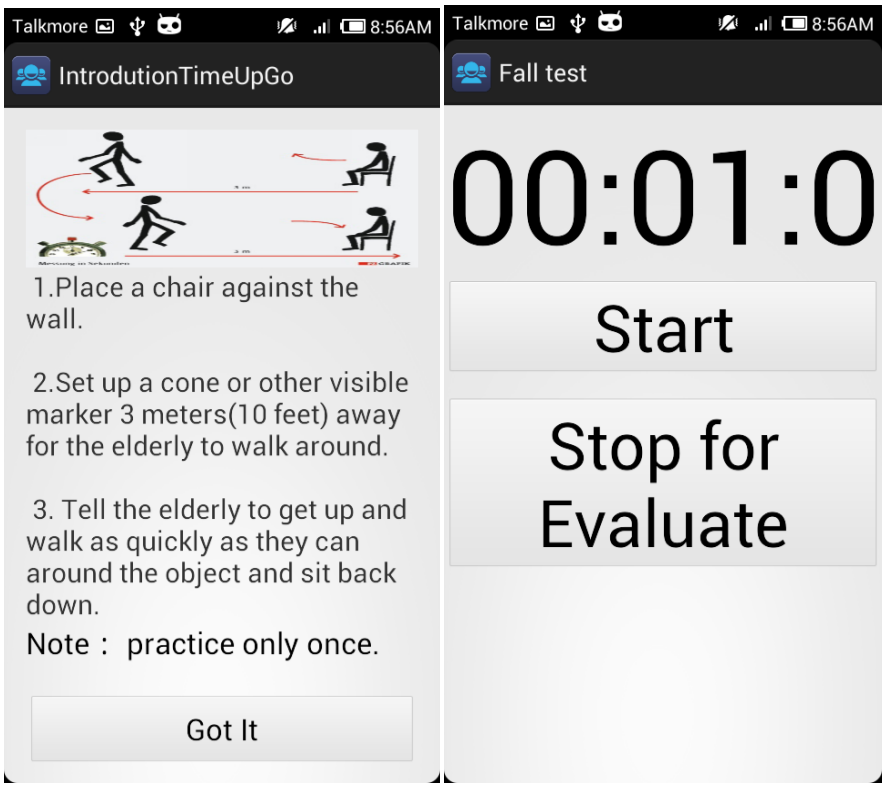


Figure 5-8: Screenshot for fall risk assessments

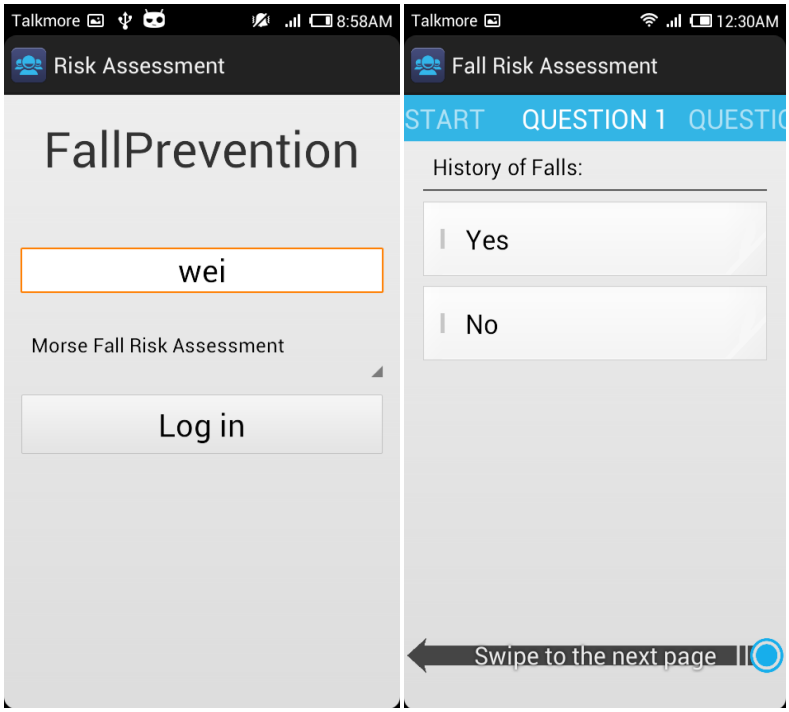


Figure 5-9: Screenshot for fall survey

If the result of the user is the high risk for falls, the system provides more tailored information about fall prevention: for instance, more information about strength and balance exercise. If the low risk for falls, the system provides less and general information about fall prevention, but reminds the user to check again every 6 months. If users are at relatively high risk of falling, the ones are suggested to visit health professionals (General Practitioner).

The system presents the personal result with the awareness display (see Figure 5-10) and the history report (see figure 5-11). Older adults are aware of their current and previous status. The system promotes their awareness about fall risks and also strengthens the personal relevance, by enabling them to check the result of assessment and previous results.

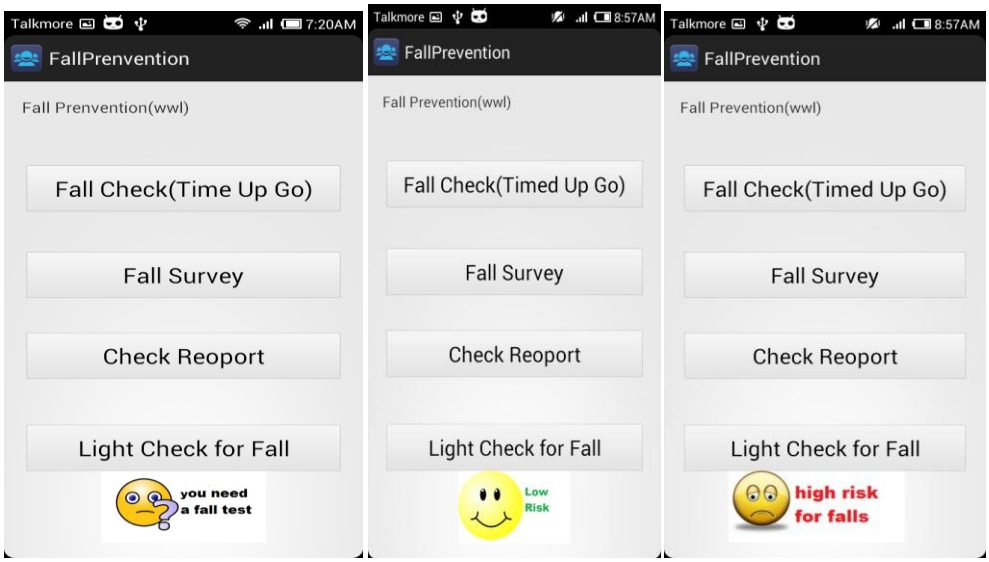


Figure 5-10: Screenshot of result report with awareness display (questionable face, smiley face, and sad face)

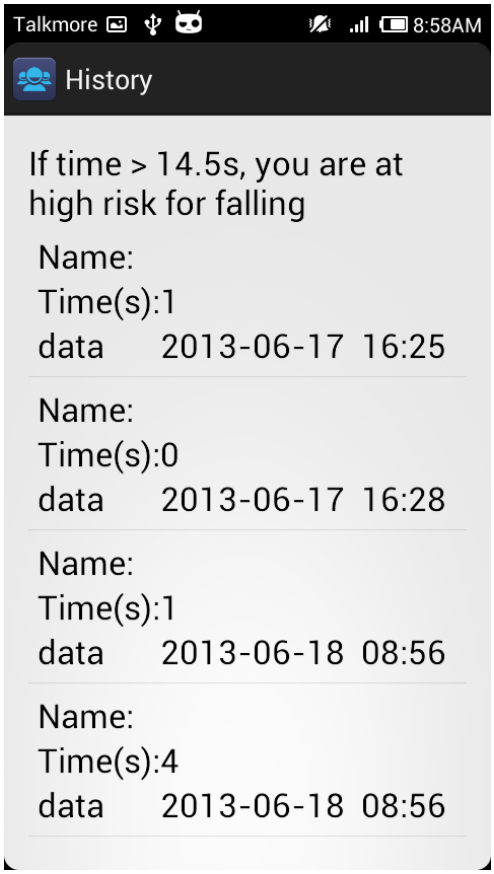


Figure 5-11: Screenshot of history report

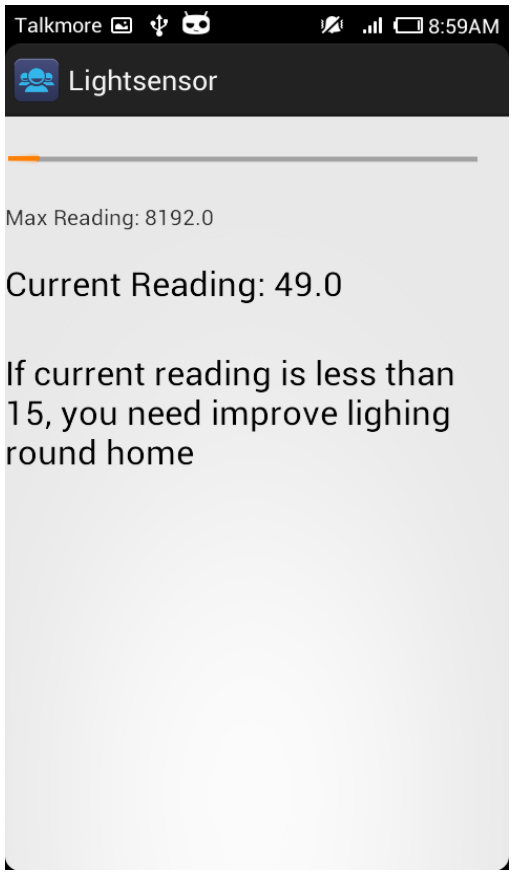


Figure 5-12: Screenshot of lighting detection

Figure 5-12 demonstrates that the function for detecting the lighting of home for fall risks. The lighting of home is one of most dangerous hazard for the elderly. This function helps the elderly to detect lighting whether is bright enough or not; if not, they are recommended to increase brightness of house.

(2) Fall prevention information browsing function

This functionality aims to (1) increase seniors' awareness about fall prevention (demonstrated in figure 5-13). (2) enable users to browse fall prevention information and gain knowledge about fall prevention (meet the challenge of seniors' limited knowledge about fall prevention)(shown in figure 14). (3) guide them to make home safer : find and fix falls hazards at home by using a fall risks checklist , because around half of falls happen at home[54]. For instance, the system guides them to remove shoes or other things from stairs (which trip users), remove small rugs, use non-strip mats, improving lighting of home (see figure5-15). (4) encourage them to take strength and balance exercise (like Tai Chi) and remind they have their vision and medication checked[54] . User can browse fall prevention information as in the forms of picture, text, and video (see figure 5-16).

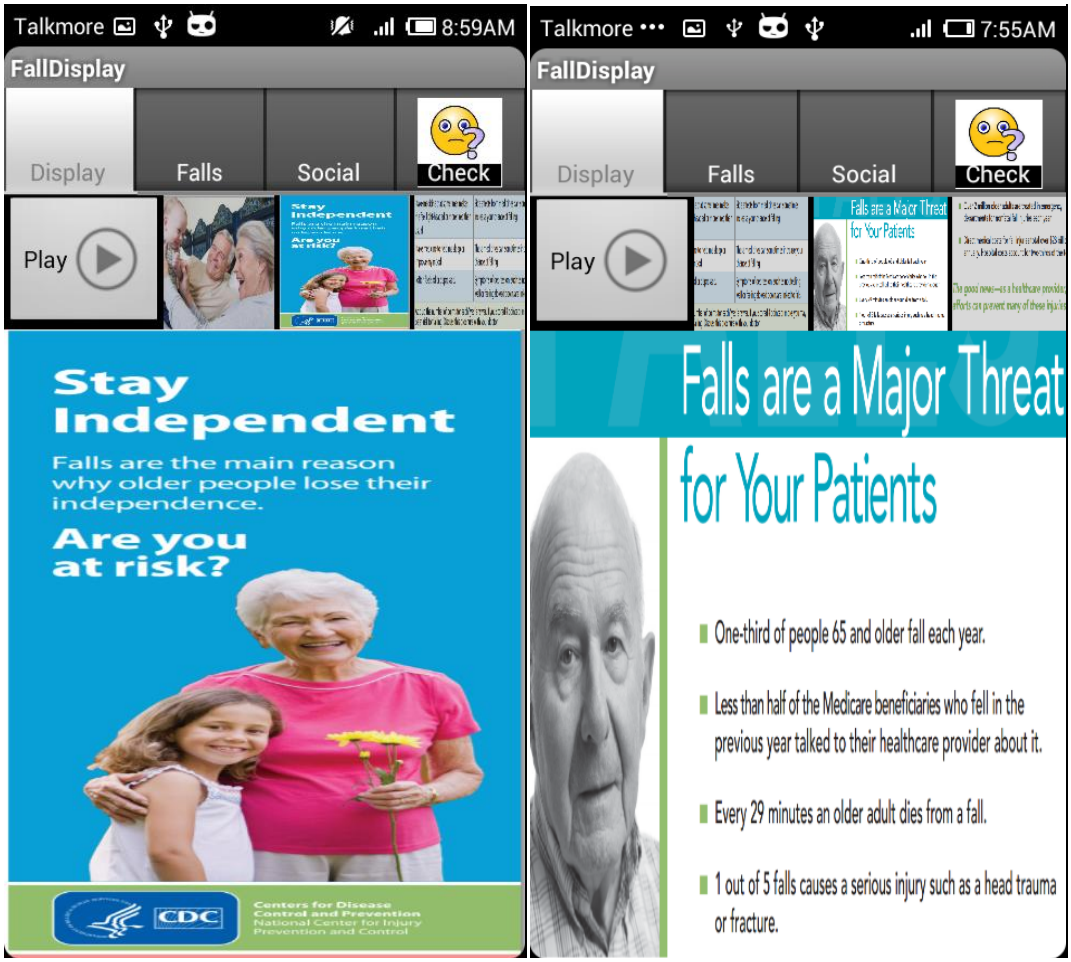


Figure 5-13: Screenshot of awareness promotion

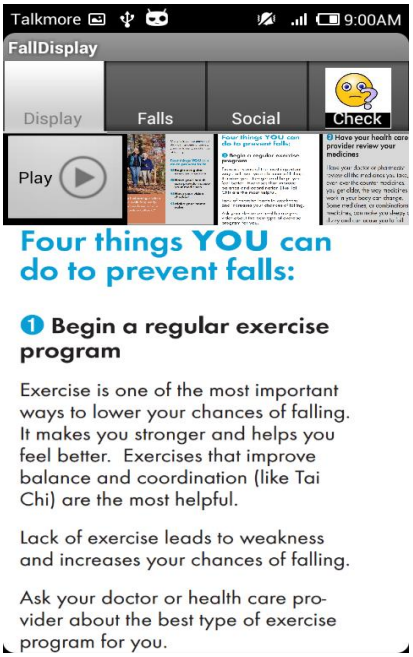


Figure 5-14: Screenshot of fall prevention information

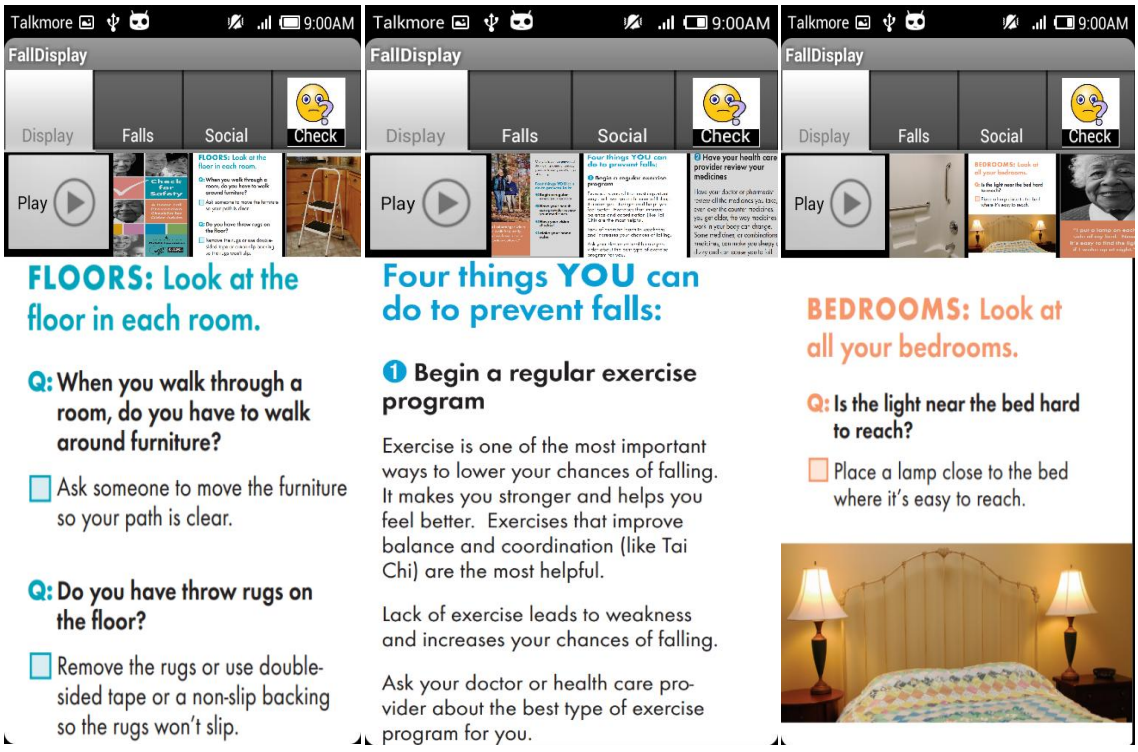


Figure 5-15: Screenshot of a fall risks checklist

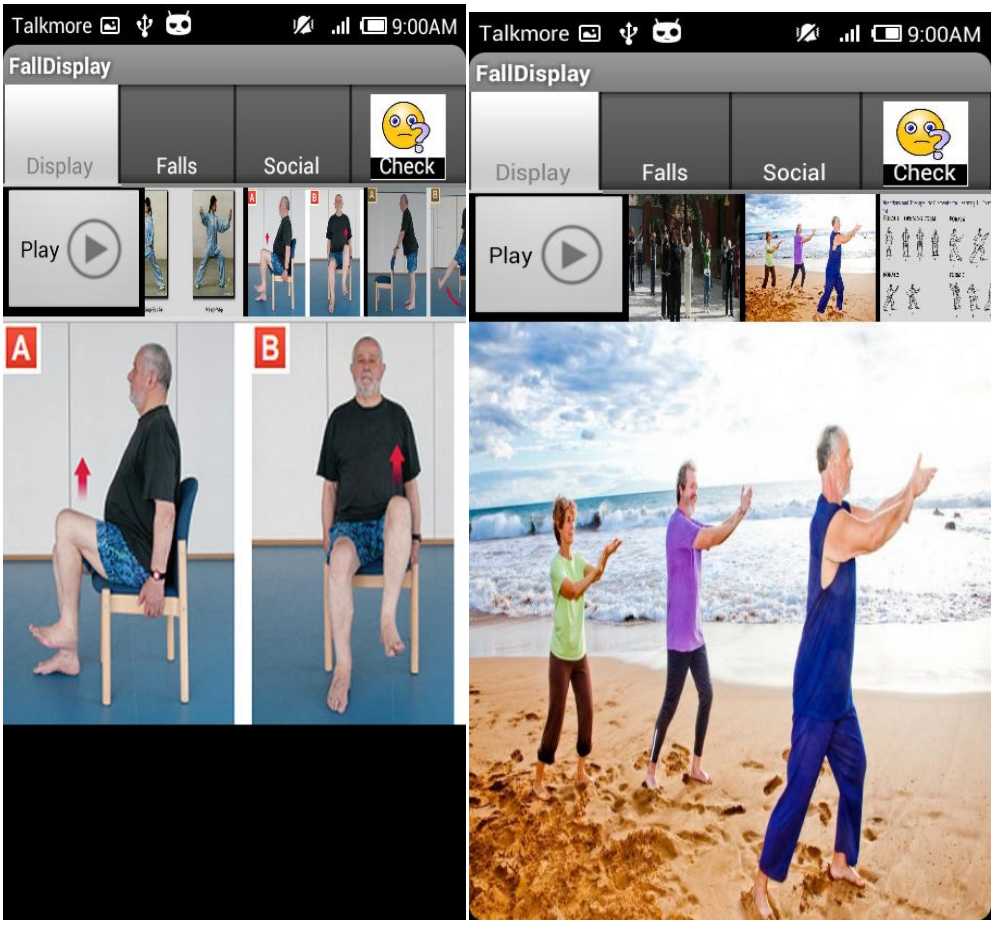


Figure 5-16: Screenshot of encouraging them to do strength and Balance exercise

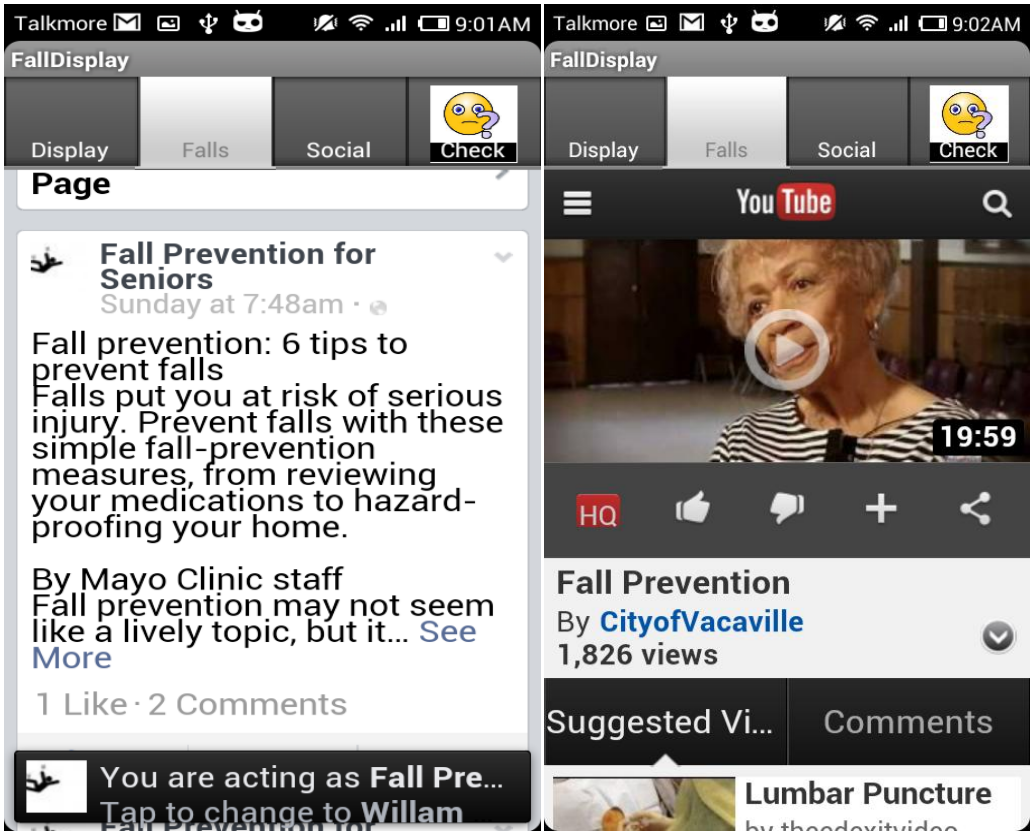


Figure 5-17: Screenshot of the text and video about fall prevention information

(3) Strengthening social interactions

Strengthening social interactions is to form fall prevention communities (with their families, friend and the local community). Social interactions can effectively encourage elderly to the prevention program and promote the level of participation. This function is implemented by integrating with Facebook that is the most famous online social networking and facilitates the informal communication.

Figure 5-18: Screenshot of social interactions examples (personal status and social event for fall prevention)

5.5.2 Ambient Display Mode (Smart Photo Frame)

(1) Ambient Display Mode (Smart Photo Frame) displays information about fall prevention and private photos. This function is to informally educate users about fall prevention, intensify knowledge about fall prevention and make their behavioral changes about fall in a non-obtrusive and unconscious manner (user casually glance while passing by the device). Casually glancing at customized information about fall

prevention while passing by the device is to meet the challenge of the acceptability for fall prevention: as mentioned in chapter 2. Seniors got booklets, flyers, or leaflets about the fall prevention and then they would say it is useful and good, but after several days, they threw it and completely forgot. Displaying their private photos could increase the adoption and utilization ratio of this system.

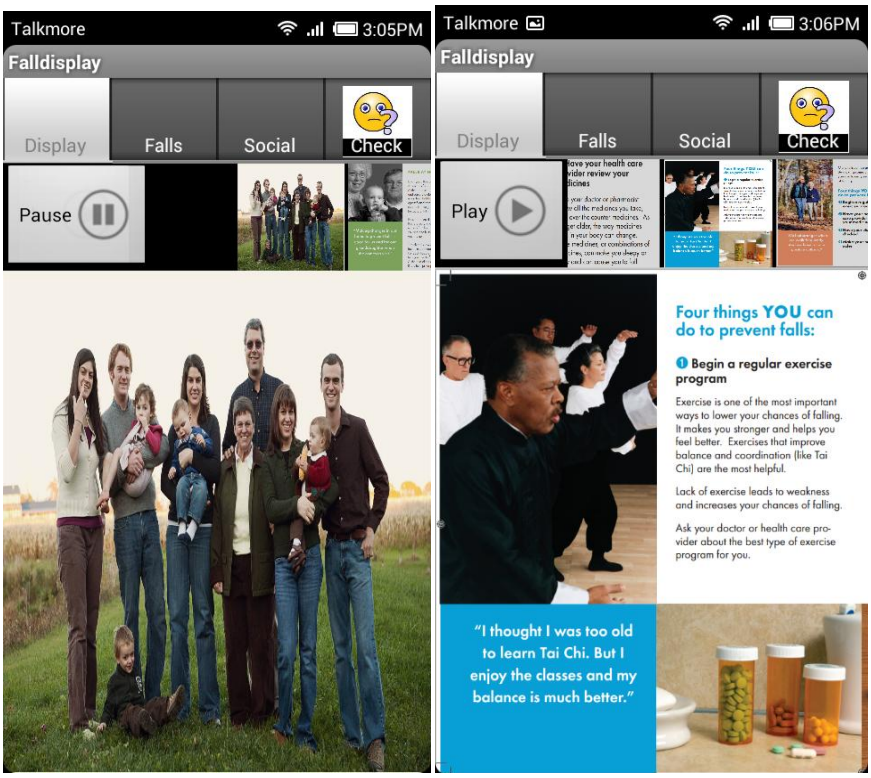


Figure 5-19: Screenshots of Smart Photo Frame

Smart photo frame function can auto-start without the user's operation and it also serves as replacement for the screensaver mode. This system enables users to acquire fall prevention knowledge and make behavioral changes about lowering the chances of falling, in a non-obtrusive and unconscious manner (casually glance while passing by the system), which meets the challenge of the acceptability for fall prevention.

5.6 Installation Guide for Prototype Applications

To run the applications:

1) Install Ubifalldisplay.apk(Android 2.1+)) and Ubifallprevent.apk (Android 4.0+)

2) Run FallDisplay

This is open source project according to Apache License 2.0, so the reader can check the Github link: https://github.com/weilinwang/FallPrevention

6 Evaluation

The strategy and deign of evaluations derive from requirements and relevant studies. This project manages to use effective and discount evaluation techniques, including the qualitative evaluation (the semi-structured interview: with list of questions to cover[49] and the quantitative evaluation (the street survey: is performed by stopping persons in the street[55]). This project combines the formative evaluation with thesummative evaluation: evaluations are not only conducted during the lifetime of this project but also conducted in the end with concrete and predefined objectives[56].

6.1 High-level Prototype Evaluation and the Expert Evaluation

Before deigning the prototype system, this project conducted the semi-structured interview with four seniors (the median age: 61 years old) by utilizing the high-level and interactive prototype which can run at the mobile platform and the computer platform. During semi-structured interviews, seniors revealed that they need larger Icons and font-sizes and suggested the complexity of this prototype can be simplified. The feedback from them and Babak Farshchian (the supervisor of this project) contributed to requirement specification and the system design, which are similar to iterative evaluations.

6.2 Evaluation of the Prototype Application

In the end of this project, the evaluation of the prototype application was conducted by using the street survey and the semi-structured interview.

6.2.1 Participants

Nielsen recommend that the number of 3-5 experts or 8-12 novices are sufficient for the usability evaluation by using heuristic evaluation, because 5 participants can find 80% of issues when conducting a heuristic evaluation [57]. Nine participants (the median age:

63 years old) were recruited in a street survey. Three participants among the street survey were continued with a semi-structured interview. The street survey was performed by stopping seniors near the entrances of supermarkets (Kiwi, Remi and Coop around Moholt, Trondheim). The main reasons for choosing these places are that there are a large flow of seniors at supermarkets to make sure conducting the randomized survey, and tables or benches at the supermarkets facilitate conducting the survey and the semi-structured interview.

6.2.2 Methods for data collection:

The evaluation of the prototype application adopted (1). a street survey (the quantitative evaluation: was conducted by stopping seniors at the supermarket to collect standardized and measurable data. (2). a semi-structured interview (the qualitative evaluation: with list of questions to cover[49] , enabled participants to provide more detailed and useful feedback, advices and subtle opinions for improving the prototype system.

This project mainly used a modified heuristic evaluation (e.g., useful and relevant information, clear and intuitive UI: minimal cognitive loads, and peripherality of display), derived from several studies:Nielsen's heuristic evaluation[57], heuristic evaluation of Ambient displays[58], and other studies[59] [60], which inspired the author to come up with questions of the street survey and the semi-structured interview. The think-aloud method was used for the semi-structured interview.

6.2.3 Procedure and Task

Before the street survey and the semi-structured interview, participants were given introduction of this system, and were informed about the main functions. During the process survey and the semi-structured interview, participants were guided and explained by the interviewer when they were confused or had any questions about the prototype system. Three participants among the street survey were continued with the semi-structured interview to collect more detailed information.

6.2.4 Design of Survey and Semi-structured Interview

This final evaluation focused on these aspects: usefulness, usability and adoption(willingness and rates of use)[61], clear and intuitive UI, peripherality (unobtrusively and easily monitor the display). Interviews and surveys were conducted to measure these aspects.

Questionnaire Questions:

Usefulness

The system is useful.

I can acquire more knowledge about fall prevention by using this system.

Information provided in the system is relevant to me.

Ease of use:

I find the system easy to use.

User interface (appearance, layout, interaction etc.) of this system is clear and intuitive.

Adoption:

I will use the system on a Smartphone if I have a Smartphone

I will use the system on a tablet if I have a tablet (like iPad).

Smart Digital Photo Frame: Peripherality (unobtrusive and easily monitor the display)

I will not interrupted(distracted) by the system if I put it at home.

I can easily check (monitor) information by using this system.

Semi-Structured Interview Questions:

What is your first impression about this system?

Would you want to get this system to have a test for fall risk?

Would you follow and take action according the fall prevention information?

Is there any way the system could be improved?

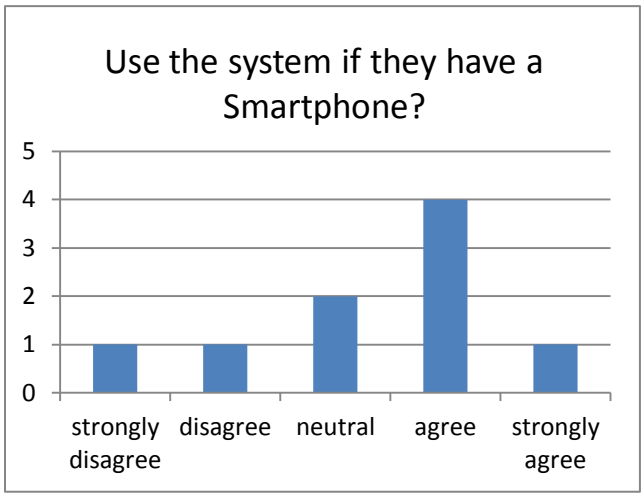
6.2.5 Data Results, Analysis and Discussion

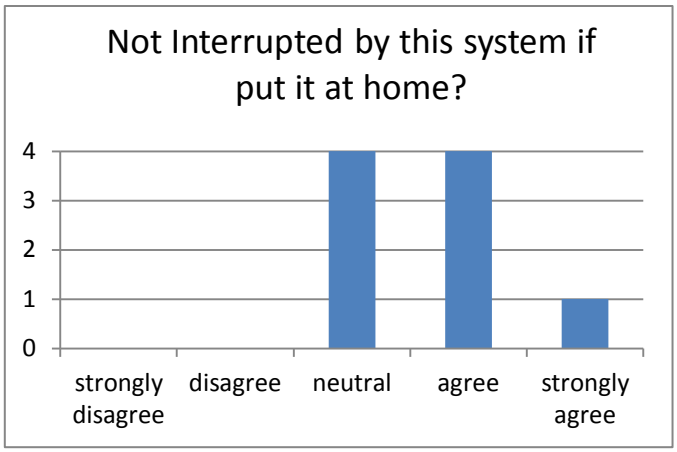
All of nine responders agreed that they can acquire knowledge about fall prevention (6 responders for agree and 3 responders for strongly agree). Most responders agreed that the system is useful (1 for neutral, 5 for agree,3 for strongly agree), easy to use (1 for neutral,4 for agree, 4 for strongly agree), UI is clear and intuitive(1 for neutral, 5 for agree,3 for strongly agree), they would use it at tablets if they have tablets (1 for neutral ,6 for agree, 2 for strongly agree), they easily check information by using this system (1 for neutral,5 for agree,3 for strongly agree).

However, results of other three evaluation aspects varied, and half of people responded as neutral or disagree(see figure 6.1):use the system if they have a Smartphone? not interrupted by this system if put it at home? Information provided in the system is relevant to you?).

(Use the system if they have a Smartphone?): one of participants who strongly disagreed the statement responded that she has no mobile phone and do not like using the mobile phone. Others who disagree and hold neutral opinions said the screen of mobile phone is too small to browse information.

(Not Interrupted by this system if put it at home? Information provided in the system is relevant to you?): Both four participants responded as neutral answers for these, and some of they said they were not sure about these. It is probably that street survey is in a rush time, participants do not have enough time to know more about this system, so they are not sure how it works at home. In the follow-up the semi-structured interview, after participants got to know more about this system, they both gave positive responds.





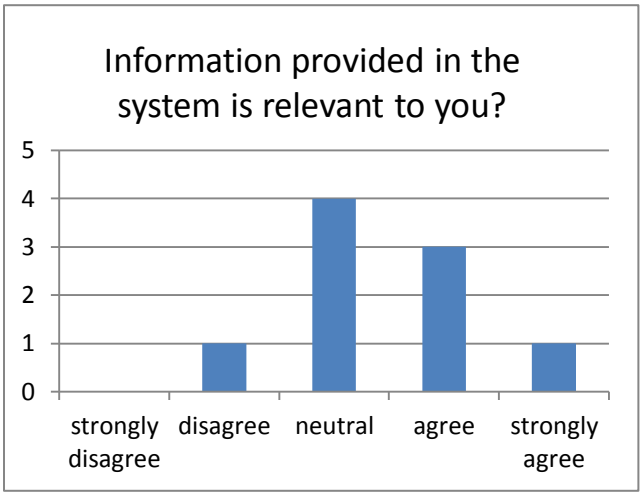


Figure 6-1 Bar charts for results

During the process of the street survey, several people refused to participant in the survey, because they thought that fall accidents seem irrelevant to them; they thought

they could recover soon after fall, and falls are issues for people who are older than them, which is consistent with studies (mentioned in chapter 2, falls are not relevant to them and lack of awareness about fall prevention). For these people, their family members (sons or daughters) or health professionals could encourage them to join the fall prevention program.

During the semi-structured interview, they had in-depth interactions with the prototype system and were explained more about the prototype system. One of them even performed the fall TUG test and asked the author to provide the system with the device for her. After in-depth interactions, two participants, who responded as neutral answers to “not Interrupted by this system if put it at home? Information provided in the system is relevant to you?” both agreed the two statements. One of them pointed out that she cannot accept if the system makes some noisy sounds. After the author explained that the system do not make any noisy sounds, the participant agreed that “not Interrupted by this system if put it at home”. It was suggested that more ways for navigations of fall prevention information and smarter fall prevention suggestions could be supported. The results of semi-structured interview inspire the author to perform *in situ* evaluation (for real usages at home) in the future work.

Overall, participants gave positive responds regarding usefulness, ease of use, intention of use on tablets. Three other aspects existed apparent differences. It is possible that after they get to know more about this system, they could give more positive answers. The *in situ* evaluation (for real usages at home) could be conducted in the future work.

6.3 Requirements Fulfillment

Table 6-1 Functional Requirements Fulfillment

ID	Status	Comments
Interactive mode		
FR-IM 1	Satisfied	Users can perform the Timed Up & Go Test
FR-IM 2	Satisfied	Nurses or other health providers are able to perform Morse Fall Risk Assessment
FR-IM 3	Satisfied	Users are able to browse the result of assessment and previous results
FR-IM 4	Satisfied	Users are able to have social interactions with their families, friend and the local community by using this system.
FR-IM 5	Satisfied	Users are able to browse fall prevention information (in the forms of pictures, texts, videos).
FR-IM 6	Satisfied	The system is able to detect the lighting of home for fall risk.
Ambient mode		
FR-AM1	Satisfied	The system is able to show information about fall prevention.
FR-AM2	Satisfied	The system is able to show photos of their private photos.
FR-AM3	Satisfied	The system is able to stop the system and switch off the glow of the device to avoid disturbing them when users go to sleep in the evening.

Table 6-2 Non-Functional Requirements Fulfillment

ID	Status	Comments
NFR-1	Satisfied	The system is able to be easy to use.
NFR-2	Satisfied	The user interface of this system is clear and intuitive.
NFR-3	Satisfied	Users are able to easily conduct the risk-assessment.
NFR-4	Partially Satisfied	Information provided in the system is relevant to users. But some users are not sure about this, need an *in situ* evaluation to verify it.
NFR-5	Satisfied	The system produces the result within a short time
NFR-6	Satisfied	Users are able to easily check (monitor) information by using this system.
NFR-7	Partially Satisfied	The system is able be unobtrusive and do not interrupt (distract) users, if users put the system at home. But some users are not sure about this, need an *in situ* evaluation to verify it.

7 Conclusions and Future Work

7.1 Conclusions

This thesis utilized Precaution Adoption Process Model to design the system, iterative process, user participation in the whole process, and several core design principles. It proposed a use case, usage scenarios, a high-level of interactive prototype, a system architecture, the implementation of the prototype system (it facilitated to illustrate the concept for participants during the survey and the semi-structured interview), and evaluations of the high-level prototype and the final prototype applications according to modified heuristic evaluation. The evaluation of final prototype applications used the semi-structured interview and the street survey.

Five research questions inspired and guided the project:

1. What are effective measures of the fall prevention for senior citizens?
2. What are challenges for the existing fall prevention projects by using ICT and how to address them?
3. What and how feasible and effective ICT technologies can support measures of the fall prevention for the elderly?
4. Can mobile and ubiquitous computing support measures about the fall prevention for the elderly?
5. How do mobile and ubiquitous computing support measures about the fall prevention for the elderly?

The findings from evaluations reveal that the prototype applications using mobile and ubiquitous computing could support the fall prevention well in usefulness, ease of use, intention of use (on tablets). More ways for navigations of fall prevention information and smarter fall prevention suggestions could be supported.

This thesis also demonstrates: 1. The prototype applications are possible to meet the challenge of personal relevance by enabling the elderly to perform fall risk assessments. 2. The prototype applications enable the elderly to acquire knowledge about fall prevention. 3. They are possible to support the fall prevention program on a large population with low costs and without requiring amounts of health professionals to participate in, unlike traditional prevention programs. 4. They are possible to increase the acceptability for fall prevention among the elderly and enable the elderly to have behavioral changes about lowering the chances of falling, in a non-obtrusive and unconscious manner (users casually glance while passing by the system). This study could contribute to further studies about mobile computing and ubiquitous computing for fall prevention.

7.2 Limitation and Future Work

The main limitation of this thesis is a lack of enough funds and resources to conduct large randomized controlled trials to assess fall incidence rate of population in regions by using the prototype applications.

The future research could use an observation or an *in situ* evaluation to verify the fall prevention system for real usages at home. It could conduct a large randomized controlled trials [62] (scientific experiment: 200 participants with the system at home and 200 participants without the system at home) to assess fall incidence rates of population in regions and to verify the information relevance and interrupting issues by using the *in situ* evaluation.

Appendix A

Survey of a Fall Prevention system for older people

We hope you take a few minutes to answer question. This app tries to help you to learn more knowledge about fall prevention, lower your changes of falling. Thank you!

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Usefulness:					
The system is useful.	0	1	2	3	4
I can acquire more knowledge about fall prevention by using this system.	0	1	2	3	4
Information provided in the system is relevant to me.	0	1	2	3	4
Ease of use:					
I find the system easy to use.	0	1	2	3	4
User interface(appearance, layout, interaction etc.) of this system is clear and intuitive.	0	1	2	3	4
Intention of use:					
I will use the system on a Smartphone if I have a Smartphone	0	1	2	3	4
I will use the system on a tablet if I have a tablet (like iPad).	0	1	2	3	4

Smart display (Picture Frame)

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I will not interrupted(distracted) by the system if I put it at home	0	1	2	3	4
I can easily check (monitor) information by using this system	0	1	2	3	4

General information:

Age(e.g. 60 years):

Gender(Female/Male):

Do you have experience with a smart phone? NO YES(___years)

Do you have experience with a tables(like Ipad)? NO YES(___years)

Additional Comments:

Appendix B

Overview of UML Diagram

Implementation of prototype System is illustrated by following figures, including the

1. The UML diagrams of The UML diagrams of fall risk assessments, personal result report with awareness display, detecting the lighting see figure B-1)
2. The UML diagram of fall surveys. (see figure B-2)
3. The UML diagrams of fall prevention information browsing, social impact, and ambient display mode (Smart Photo Frame). (see figure B-3)

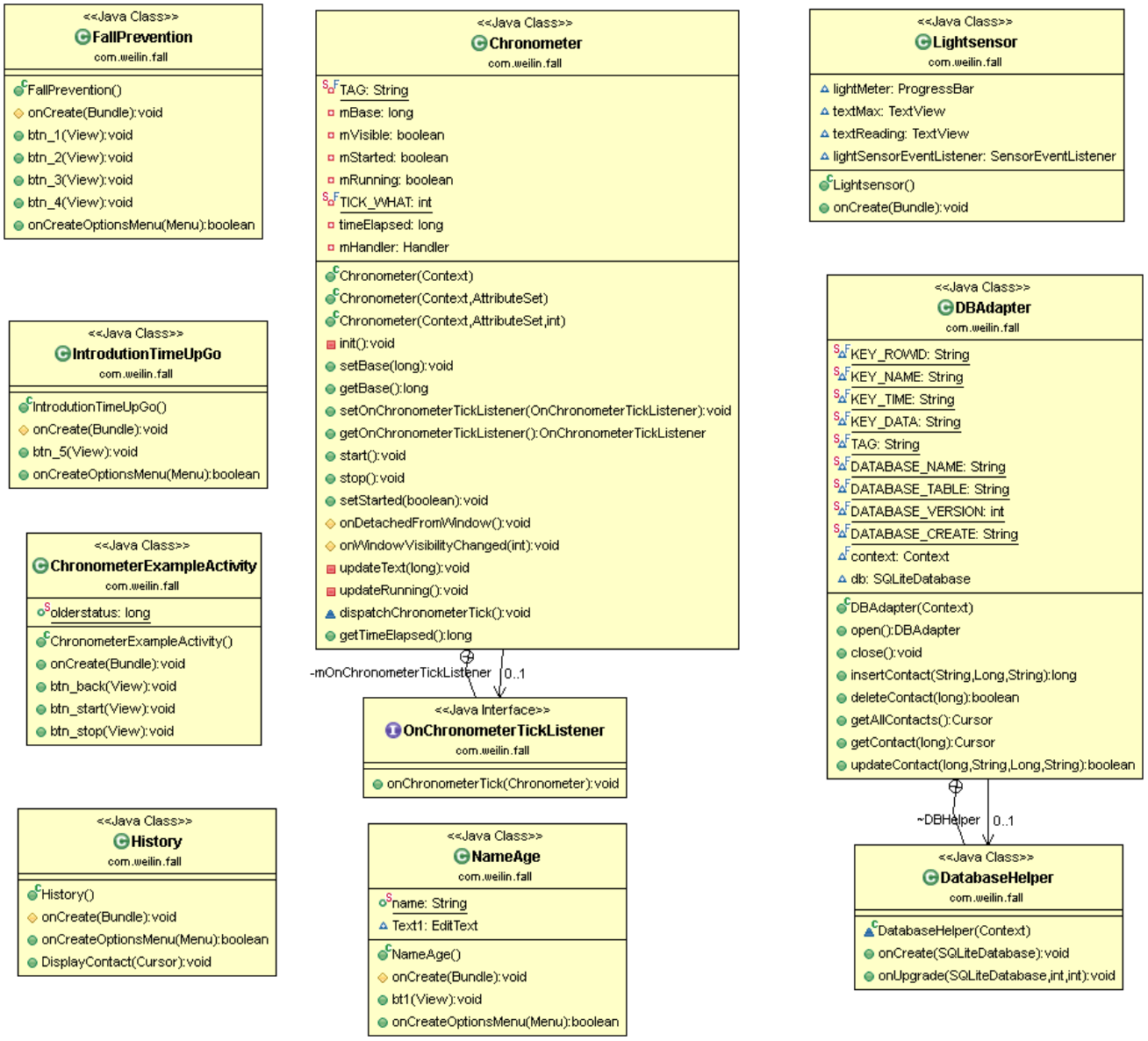


Figure B-1 The UML diagrams of fall risk assessments, personal result report with awareness display, detecting the lighting

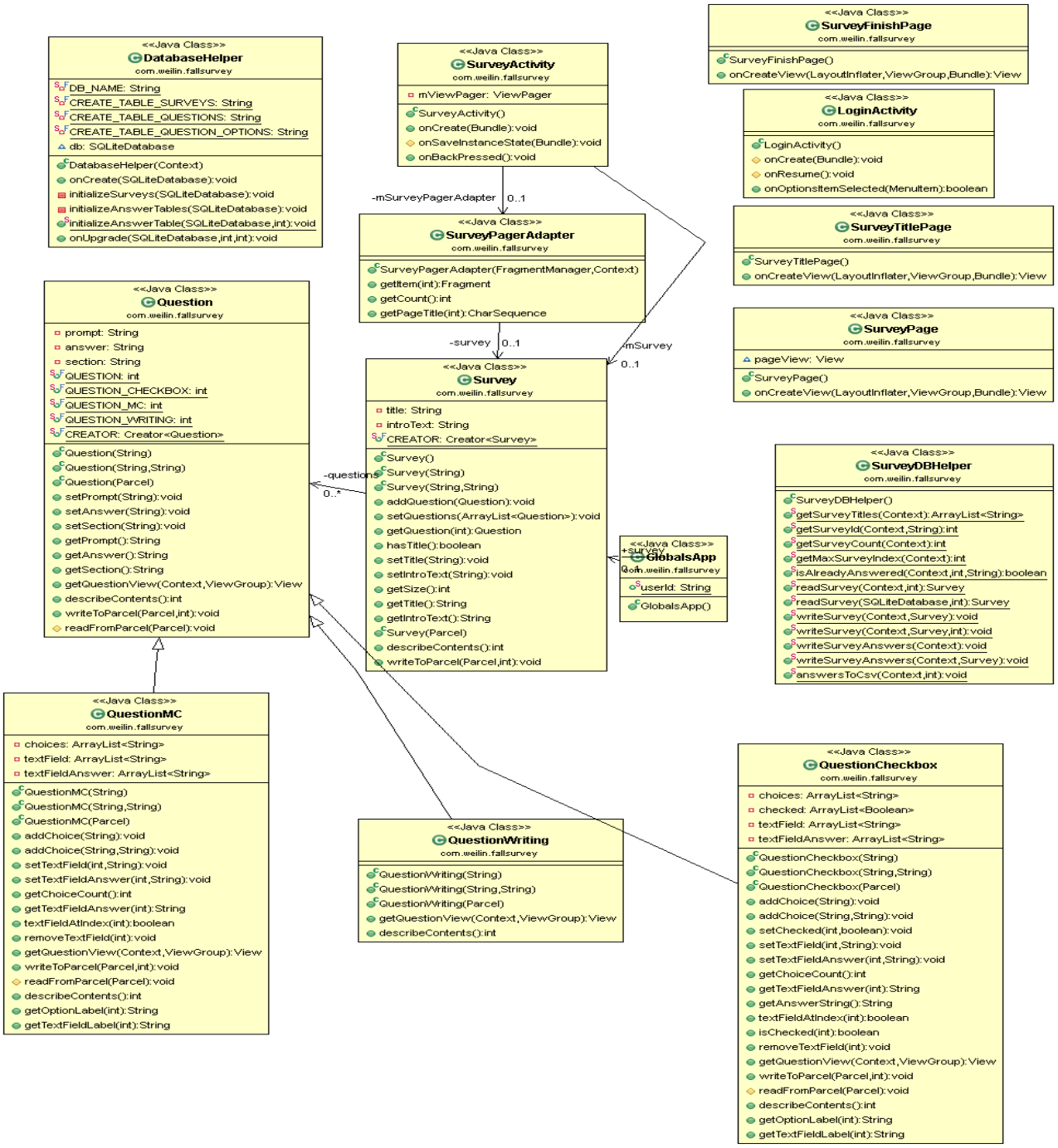


Figure B-2 The UML diagram of fall survey function

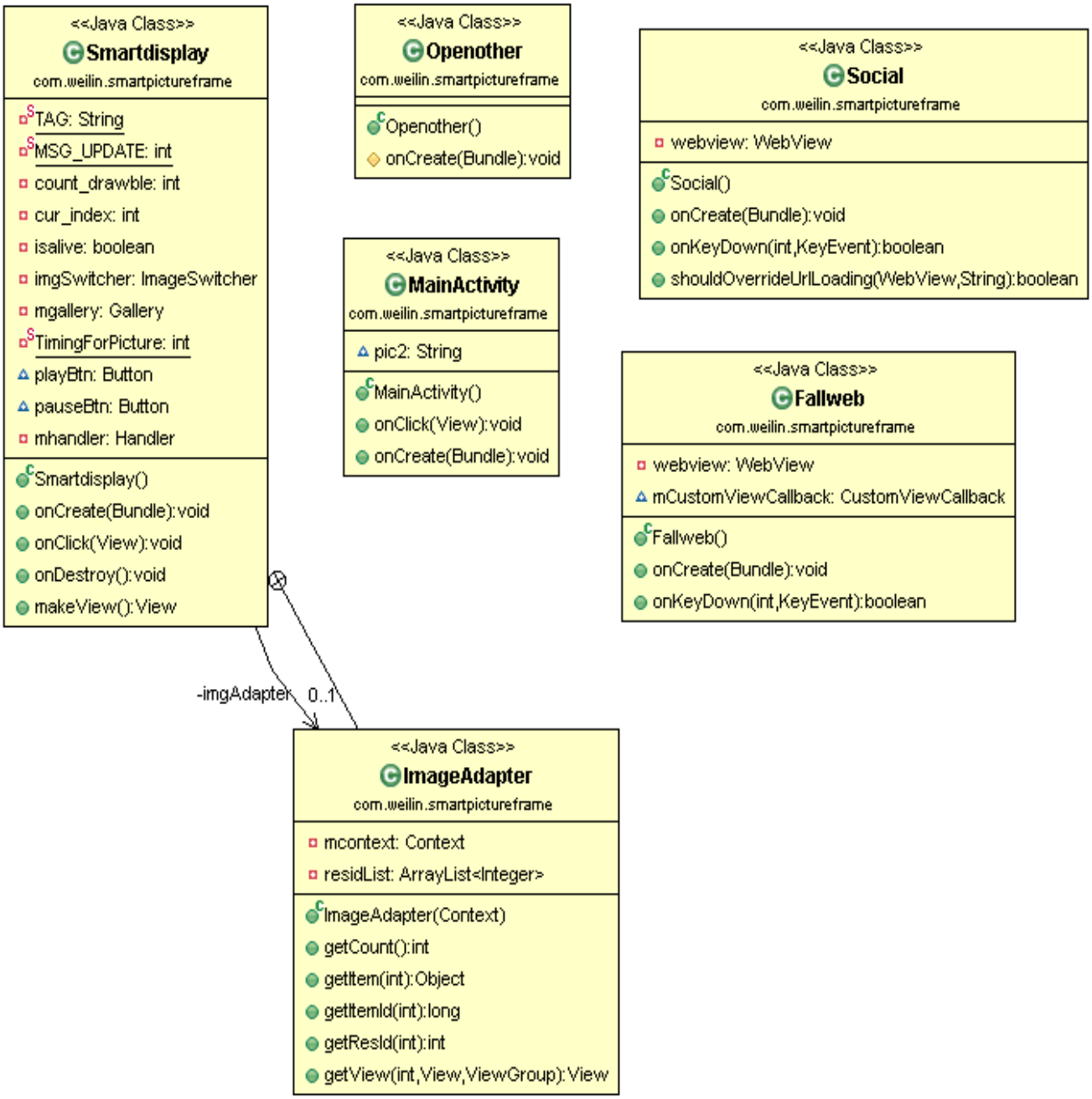


Figure B-3. The UML diagrams of fall prevention information browsing, social interactions, and ambient display mode (Smart Photo Frame).

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