



SCHOOL OF COMPUTATION, INFORMATION
AND TECHNOLOGY - INFORMATICS

TECHNISCHE UNIVERSITÄT MÜNCHEN

Bachelor's Thesis in Informatics: Games Engineering

**AR Companion Application for Physical and
Mental Health Especially for Elderly People**

Choi Shin-yu





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AR Companion Application for Physical and Mental Health Especially for Elderly People

AR Begleiter Applikation für die körperliche und geistige Gesundheit, insbesondere für ältere Menschen

Author: Choi Shin-yu
Supervisor: Klinker, Gudrun Johanna; Univ.-Prof. Dr.
Advisor: Eichhorn, Christian; Dipl.-Inf.
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I confirm that this bachelor's thesis in informatics: games engineering is my own work and I have documented all sources and material used.

Munich, 17.04.2023

Choi Shin-yu

Abstract

To address the growing interest in pets among the aging society, especially the retired baby boomers during the pandemic, we conducted a study on the awareness of virtual pets. Due to the time and financial commitments associated with raising a pet, many people may feel hesitant to adopt one. As a result, there has been a rise in the popularity of virtual pets as an alternative.

To explore this topic, we developed an Augmented Reality(AR) pet application called Lets Go Bailey. Through this application, we investigated whether a virtual pet could provide a similar experience to a real pet. We also explored whether a virtual pet could motivate its owner's physical activity in the same way as a real pet.

Furthermore, we examined the limitations of current AR technology and mobile devices for creating virtual pets. By doing so, we aimed to gain a comprehensive understanding of the feasibility of virtual pets as a substitute for real pets.

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1 Introduction

Due to the aging population and the impact of the pandemic on lifestyle changes, the demand for pets is increasing and the pet market is also growing. In 2022, \$136.8 billion was spent only for pet in the U.S, which is 10% more than 2021 [Fora]. It is also predicted to continue its growth trend, and the pet market is expected to reach \$143.6 billion in 2023, which is a 5% increase from 2022. Furthermore, the retirement of baby boomers is expected to drive an increase in pet ownership and interest in pets in the coming years.

On the other hand, there are also many concerns about the cost of pets. According to a research by Forbes, dog owners in the U.S spent \$ 730 for their dogs on average in 2022 [Ass]. these costs are expected to be a burden on baby boomers who are planning to retire. As interest in pets continues to grow, there is increasing attention on virtual pets, this is because of the expectation that virtual pets can become a substitute for real pets. Development of AR technology and increasing penetration rate of smartphone raises such expectation.

Recently, with the development of AR technology, it is possible to create virtual pets and interact with them in a realistic way. These technologies enable more realistic and interactive virtual animal experiences. In addition, there is an effect of consoling people who cannot raise real animals or those who cannot raise pets through virtual pets. Whether virtual pets can serve as a viable alternative to real pets is debatable [al07; al15a].

Because the interaction and immersive experience with a real pet cannot be replaced with a virtual pet.

Thus, it is necessary to investigate the differences in satisfaction and emotional aspects between interacting with virtual pets and real pets particularly when engaging in activities such as walking and feeding them food and snacks.

To explore this possibility, we developed a virtual pet application called Let's GO Bailey and investigated the awareness of people of various age groups, especially baby boomers. We also explored, if virtual pets can be a motivation to target group to exercise for their physical and emotional health. Lastly, we also conducted research on whether virtual pets can be substitutes for real pets.

2 Related Work

2.1 Aging

2.1.1 Changes due to aging

It is already well-known and considered as common sense that aging brings many physical and mental changes. As we age by one in numbers every year, we might think that aging occurs slowly. However, according to a recent study, people have three rapid aging phases at the ages of 34, 60, and 78, which result in changes to certain proteins in our bodies. The researchers analyzed the plasma proteins of 4,263 people aged 18 to 95 years and found that the levels of 1,379 of these proteins change with age. The changes in these proteins affect the body's hormones, resulting in drastic changes to both mental and physical health [al19a].

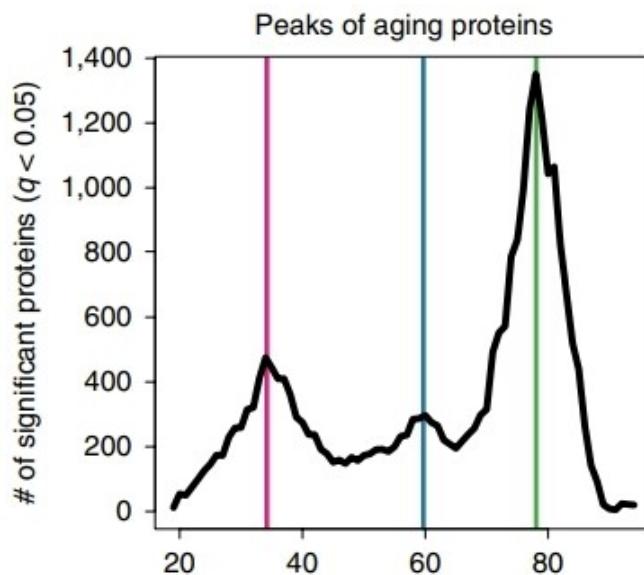


Figure 2.1: Changes in protein by age [al19a]

Blood vessels lose elasticity, which leads to erosion of fat-like deposits. Because of this, our heart has to work faster and harder to circulate blood in our body, which in turn leads to risks such as atherosclerosis or high blood pressure [Hea]. Furthermore, bones, muscles, and joints undergo many changes as well. As we age, our bone loses calcium and other minerals, and as a result its density and mass decrease, especially in women after menopause. Between each bone is a gel-like cushion (called a disk). With aging, disks lose fluid gradually and become thinner, which leads our joints become stiffer and lose its flexibility [Meda]. These

changes increase the risk of injury, instability and loss of balance. As a result, the mobility of the elderly is reduced, and this reduction in mobility leads to a cascading reduction in social activities, which can also isolate them socially, and as a result, have many psychological effects.

In addition to the above physical changes, many changes also occur mentally, which is due to brain aging and changes in the environment around the elderly. The brain aging brings a positive part in understanding the meaning of words and extensive vocabulary by experience, but generally, it shows problems in performing multiple tasks at the same time, including deterioration in memory speed and attention [War]. Literally, there are many opinions that mental health and age are not related [al84], but according to WHO(World Health Organisation), mental health is deeply related to physical health, and the damage to mental health is great due to events such as a bereavement and retirement, which are more influential than when you were young [WHO].

Plus, the psychological vulnerability of the elderly, especially events such as retirement, bereavement, and decline in economic status, cause isolation, loneliness, and psychological problems to the elderly. Furthermore, socioeconomic status was found to have a direct effect on mental health. As a result, the higher the social status, the better the mental health status, and the fewer the number of times that long-term treatment or observation was required. It was found to have a greater impact on males than on females [al19b].

2.1.2 Aged Society

The average age in Germany was 44.6 in 2021. It has risen steadily over the past half century, and this trend not only in Germany, but also worldwide [Car21]. This can be seen in a report called "Population Division" , which is published by the United Nation(UN) every year.

Figure 2.2 shows population by age group changes after 1950. As can be seen from the graph, the total number of the population increases every year, but the number of young people (under 25) is not keeping pace with the growth rate of the population. It can be concluded that the population growth is driven by an increase in the population aged 25 years and over, especially those aged 65 years and older. As a result of the above trend, in 2018, the population aged 60 and over overtook the population under the age of 5. [Han19a].

Definition of 'aged society' is suggested by The WHO. Based on the proportion of the population aged 65 or older, it is classified into 'aging society (7%)', 'aged society(14%)', and 'super-aged society(21%)', respectively [Yi-15]. France is considered the world's earliest aging country [Jér07]. France is the fastest and earliest aging country in the world. In the 19th centry, already entered an aging society, and it was estimated that more than 10% of the total population was 65 or older in 1960 [Bana].

As another example, Germany is also one of the fastest aging countries in the world. In 1960, in Germany, the population aged 65 and over already accounted for more than 11% of the total population [Banb], and it has been increasing almost steadily every year. In 2020, about 22% of the population is 65 years or older,which means, Germany has already entered a "super-aged society". Not only in France and Germany, but also worldwide, the number of people over 65 years old is growing steadily every year, from 5% in 1960 to 9.5% in 2020, and

2 Related Work

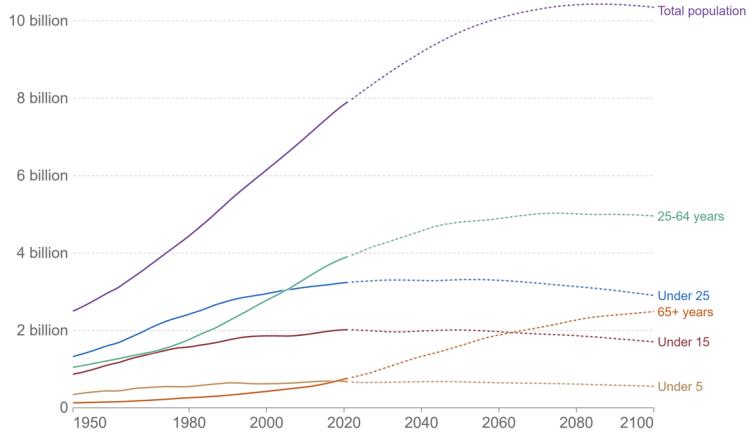


Figure 2.2: Changes world population group by age [Han19b]

the ratio has been increasing sharply since 2010. Furthermore, WHO estimates that between 2015 and 2050, 22% of the world's population will be over 60 [Org].

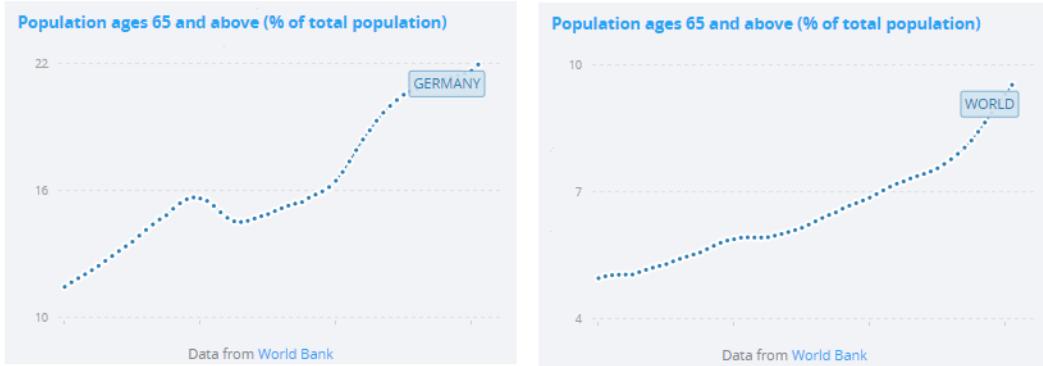


Figure 2.3: Comparison of populations whose age is 65 and above between Germany(Left) and worldwide(Right) [Banb; Banc]

2.2 Exercise

It is well-known that exercise is good for body and health. Exercise, especially regular, moderate exercise, gives us many benefits physically and mentally. It doesn't matter the age, ability, body type or size of the person, who exercises. Exercise strengthens bones and muscles and is very good for preventing cardiovascular disease. As a result, exercise improves the quality of our lives, increases the opportunity to live long [DPa]. Another study suggests that 10 minutes of exercise could reduce deaths of aged 40 to 85 by 110,000 annually in the United States. [Ped22]

2.2.1 Exercise for old people

Aging brings about physical and mental changes, as described above. To stay healthy, Centers for Disease Control and Prevention(CDC) claims that exercise is an essential and one of the most important activity for old people. CDC also recommends that older people should walk at least 150 minutes a week, and vigorous exercise, such as brisk walking should also do at least 75 minutes a week [DPb]. If we calculate the distance with the average speed by referring to the following statistics, the elderly should walk about 11 km per week. This means that the elderly should walk about 3 km for each walk, Assuming an average of 3.5 walks per week, this means the elderly should walk about 3 km per walk [al96]. Recently, many studies have been conducted on the effects of exercise and geriatric diseases such as dementia, depression, and osteoporosis, there is growing evidence that regular physical exercise can help prevent Alzheimer's disease and cognitive decline in affected patients [Ped20]. According to this study, regular physical exercise has been proven to be beneficial for traditional cardiovascular risk factors (e.g. reduced blood flow, diabetes) associated with the onset of Alzheimer's disease. Exercise also promotes neurogenesis through an increase in exercise-induced metabolic factors.

2.2.2 Mean of senior exercise

While the extent to which physical ability declines can vary depending on environmental factors such as personal medical history, health and chronic conditions, lifestyle choices, frequency of exercise, smoking, alcohol consumption, and other factors, as mentioned in section 2.1, it is common for individuals to experience a decline in physical ability as they age due to factors such as decreased muscle strength, flexibility, respiratory function, and endurance [al19c].

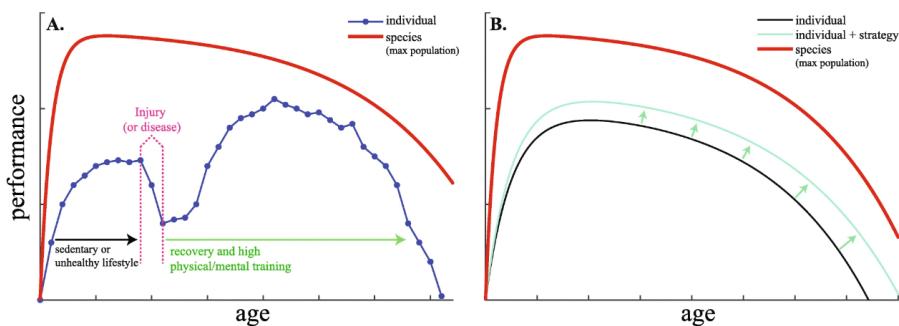


Figure 2.4: Average physical performance by age [al19c]

Figure 2.4 shows the average performance of individuals across various age groups, highlighting case (a) which illustrates a reduction in performance attributed to negative environmental factors such as illness, injury, and an unhealthy lifestyle in infancy, and case (b) which demonstrates that positive environmental factors such as exercise can enhance physical performance. However, even with positive factors at play, it is inevitable that a person's body

capabilities will eventually decline with age. In one study, the comfortable gait speed was calculated by age group, and it was found that it gradually slowed down with age from 143 cm/s in the 30s to 132 cm/s in the 60s and 130 cm/s in the 70s on average [Boh97]. In 2017, the average height and weight of Germans over the age of 65 were 170 cm and 78 kg, respectively [Sys]. If an elderly person of average height and weight walks at the speed listed above at a comfortable pace, 65 Calories will be burned every 15 minutes [ala].

2.2.3 Consistency and regularity

The most important thing in exercise is consistency and regularity [The; Staa]. Inconsistency in exercise routines can be detrimental to the body, as evidenced by a study which showed that irregular exercise can make the body more resistant to the same exercises. This is because inactivity leads to a decrease in essential proteins, making it harder for the body to perform at its peak [new]. Furthermore, irregular exercise can place undue strain on the body, potentially leading to injury. As the body tires during exercise, it becomes more difficult to maintain focus, increasing the risk of falls and other accidents [Agia]. For the elderly, who are particularly susceptible to serious injuries, it is especially important to maintain a steady and consistent exercise regimen. Therefore it is important to find an exercise routine that is enjoyable and sustainable for the elderly individual. For example, older adults may prefer low-impact activities such as aqua yoga or swimming, which can provide similar health benefits to higher-impact exercises without placing undue strain on the body [Far; Sen].

2.2.4 Benefits of walk

Walking is a very basic, but very effective exercise. It is an exercise that anyone can easily do, because it does not require any equipment or special skill. Furthermore, it is called a weight-bearing exercise like hiking, jogging and climbing stairs, because our body weight when we walk and let us force against gravity. Walking helps to prevent cardiovascular disease and strengthens bones and muscles [Cha].

In addition to these physical benefits, walking also has several mental health benefits. Walking has been shown to stimulate the release of endorphins, which are known to improve mood and reduce stress and anxiety. Additionally, regular walking has been linked to improved memory and cognitive function, which can be especially important for older adults [Gar]. Therefore, it is highly recommended to walk at least 30 minutes a day to improve and maintain our overall health [Cha].

2.2.5 Green space and health

Green spaces(German: Grünfläche), such as parks and gardens, have long been recognized for their positive impact on mental and physical health. Studies have shown that exposure to green spaces can have a significant impact on mental health, especially for elderly people. In addition to elderly people, exposure to green spaces has been shown to benefit people of all ages. For example, a study [Boz21], found that living in areas with more green spaces was

associated with lower levels of obesity and higher levels of physical activity in children. Green spaces also provide opportunities for social interaction, and exposure to nature, which have all been linked to reduced stress, improved mood, and increased cognitive function in older adults. For example, a study [al22a], published in the "International Journal of Environmental Research and Public Health" found that elderly people who regularly visited parks reported lower levels of stress and depression compared to those who did not. The benefits of green space are not limited to mental and physical health. It also has economic and environmental benefits. For example, green spaces can increase property values and reduce air and water pollution in urban areas [Com+19].

2.2.6 Importance of motivation in sports and physical activity

Motivation is a crucial factor in athletic performance and sport participation. It is necessary to maintain motivation over time, not just for short periods, as motivation resulting from self-determination becomes an energy source that keeps users engaged in games or applications. Self-determination theory (SDT), proposed by Deci and Ryan, divides human motivation into three types: intrinsic motivation, extrinsic motivation, and amotivation [Rya00].

Intrinsic motivation refers to engaging in an activity purely for the pleasure it brings, such as hobbies, creative pursuits, or sports. Extrinsic motivation, on the other hand, is driven by external factors like rewards or punishments, such as in work where individuals are motivated to perform in order to receive a paycheck or other forms of recognition. While extrinsic motivation can be effective, it is generally considered less desirable than intrinsic motivation, as it can lead to a focus on the outcome rather than the process of engaging in the activity. Amotivation refers to a lack of motivation to engage in an activity, which can lead to dropping out.

Many people give up on sports and physical activity despite their initial enthusiasm and desire to participate. Understanding why people give up and finding ways to promote continued participation are important for improving health outcomes. One potential solution is the use of pets as motivational partners in physical activity. Recent studies have suggested that pets can play a positive role in promoting physical activity and reducing the risk of dropout [Bes; Ein97; al15b].

For instance, a study [Ein97] found that pet owners who engaged in physical activity with their pets reported higher levels of enjoyment, motivation, and adherence compared to those who participated in physical activity without their pets. Another study [al20a] found that pet owners who used their pets as workout partners were more likely to engage in physical activity on a regular basis and reported higher levels of motivation and satisfaction compared to those who did not use their pets as workout partners. However, it is important to consider factors such as the pet's breed, age, and fitness level, as well as the owner's physical abilities and preferences, when engaging in physical activity with pets. Additionally, it is important to ensure that pets are properly trained and socialized to avoid injury or negative outcomes [al20a].

In addition to the benefits of pets as motivational partners, there are many other strategies for promoting motivation in sports and physical activity. For example, setting realistic

goals [al02], finding enjoyable activities [al00], joining a supportive community [al19d], and tracking progress [al11a] can all contribute to maintaining motivation over time.

2.2.7 Health care application

Health management and fitness apps are becoming increasingly popular as interest in health increases. According to one statistic, since 2020, the number of health apps available to iOS users has continued to rise, especially in the first quarter of 2021, with nearly 54,000 apps listed on the App Store [sta]. One example of a popular health management and fitness app is "MyFitnessPal". "MyFitnessPal" allows users to track their diet and exercise, set goals and monitor their progress. Another example is "Headspace", a meditation app that helps users manage stress and anxiety. These apps could be especially useful for older people who may have more difficulty accessing traditional health care.

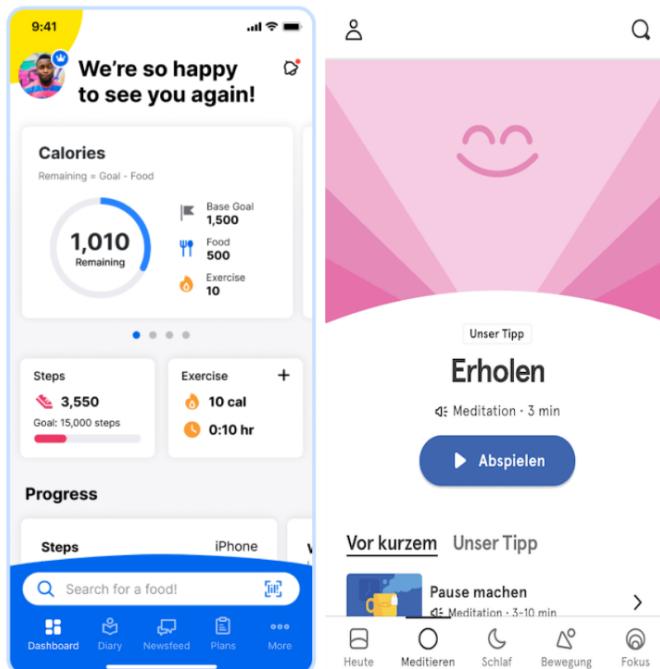


Figure 2.5: Image of Health care applications. "My Fitness Pal"(left) [Myf], "Headspace"(right) [Psy]

For walking enthusiasts, "Map My Walk" stands out as an application that tracks walking and running activities while also enabling social comparison [Map]. Users can see the distance they have walked or run displayed on a map and compete with friends to increase their steps. In addition, "Fitbit," a popular wearable device [Fit; McG], not only tracks distance traveled, but also monitors other physical activities such as sleep patterns and heart rate. Its innovative features include motivational messages and reminders that encourage users to maintain their physical activity levels. Overall, these tools serve as excellent companions for those looking to stay motivated and improve their physical health through walking and other exercises[Bum].

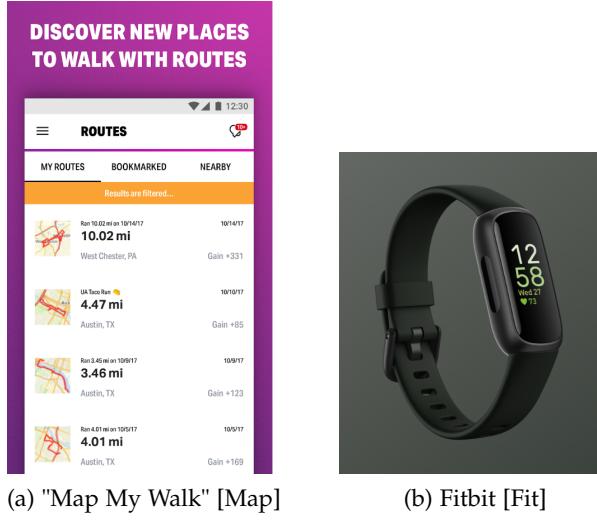


Figure 2.6: Image of application and wearable for walk

Physical activity tracking apps have gained popularity due to their ability to record and monitor exercise and overall health. These apps allow users to set fitness goals, track their progress, and make efficient use of their workout time. By creating a sense of accountability, these apps can help motivate individuals to maintain a consistent exercise routine, ultimately leading to a healthier lifestyle [Bir].

However, there are also concerns about using these applications as a tool for recording personal information. Although the European Union (EU) has already established guidelines on this issue [Unia], some companies related to certain applications and health apps have still been found to sell personal information to advertising companies, highlighting the importance of privacy protection [alb].

Additionally, individuals who are less tech-savvy or have limited access to devices may be less likely to use these apps accurately. According to one study, older adults in particular may face barriers to using health apps due to factors such as lack of familiarity with technology and limited access to devices [Xie11].

2.3 Pet

About one in three households owns a pet, which is estimated to be about 500 million dogs, 400 million cats, and 200 million birds [Cov]. Pets have historically been the result of the domestication of animals, but there is no precise record of when that history began. However, it is presumed that the first domesticated species were dogs. Dogs are humans' old friends, and in the past they helped humans with hunting and security, for that human rewarded him with food and safety. In Mesopotamia, it is been recorded that human hunted lions with dogs and in ancient Egypt, drawings similar to the role of modern pets as well as hunting have been identified, in which a dog is seated with its owner [Enc].

2.3.1 Cost and benefits of having pet

Owning something, raising it, and living together has both positive and negative aspects. And if the thing is a living being, we can get positive things through interaction with that creature, but the cost of it is also normally high.

Cost

It is also well known that pets are very dangerous for people with allergies. And some studies have suggested that exposure to pets have been linked to the development of cancer: birds and lung cancer, dogs and breast cancer, and cats and brain tumours or hematological malignancies [Mei19]. Also some studies show that interacting with pets has a positive impact on people's mental health and life. But having and owning a pet comes at a cost and risk. About 4 million people in the United States are attacked by pets each year, and 800,000 of them require medical attention. Most of the cases are children, as they do not know how to handle dogs better than adults. In this case, the cost of treating the injured person is not avoidable [Hor].

Furthermore, according to an article, on average, pet owners spend between \$500 and \$1,000 per dog and over \$600 per cat per year [Kim]. Table 2.1 shows average cost that people have to spend for their pet every year. If we consider the above cost plus the initial cost and one-time cost, it becomes \$2300 for a dog and \$1300 for a cat.

Table 2.1: Average costs per pet(Dollar) [Pre].

	Dog	Cat
Food	300	225
Toys	37	22
Treats	60	36
Insurance	516	348
Routine Medical costs	225	160
Preventative Medication	185	140
Sum	1323	931

In addition to these costs, pet owners are exposed to many diseases caused by pets. Rabies, Salmonella, and Campylobacter are typical examples, and all can be transmitted directly from pets to humans especially to owners [Gha15]. According to statistics, 30,000 to 70,000 people get rabies from dogs each year [Gha04], and one study reported that campylobacter was isolated from 47% of animal feces [J M06]. In addition, although there are differences by situation and region, there are studies that show that exposure to Salmonella bacteria ranges from as little as 1% to as much as 10% [Met13].

Benefits

Whether having a pet is good or bad for your health has not been definitively concluded, there are numerous studies that having a pet has positive effects on physical and mental health. Although there are effects resulting from physical contact with pets, such as reducing the risk of cardiovascular disease, asthma and allergic [Den02; P N01; AND92]. There are also many psychological effects resulting from owning a pet itself.

Figure 2.7 shows three mechanisms by which pet ownership affects human health. First, common factors such as personality, characteristics, age, economics, or health status influence the decision to have a pet, therefore there is a relationship between the decision to have a pet and health. In other words, the person who decided to have a pet is a person who has positive factors above [McN14]. Second, pets indirectly affect health by facilitating contact with others. That is to say that pet acts as 'social catalysts', which can influence social contact between pet owners [Jun00]. The third mechanism is that pet ownership can directly affect human health. The relationship between owner and his own pet reduces stress, anxiety and has great affects the owner's mental health. This is so-called social support, which can give the owner confidence that he or she can find a successful coping strategy, and furthermore, it improves their recovery from serious diseases such as stroke, myocardial infarction, and cancer [Jam88].

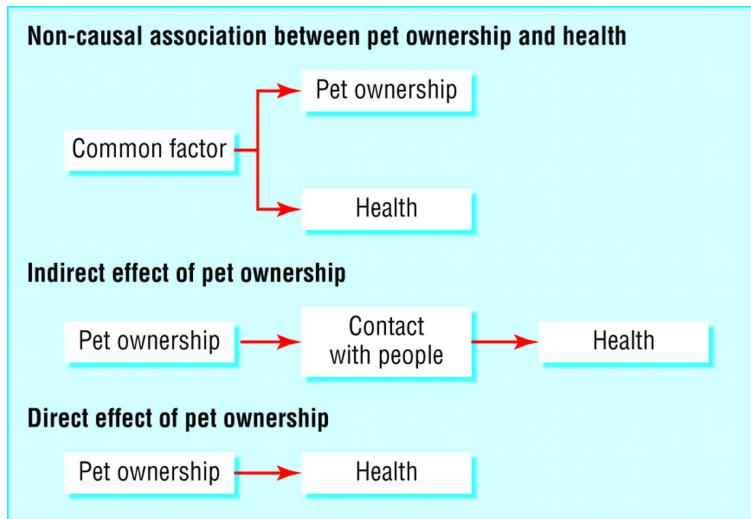


Figure 2.7: Three mechanisms of relation between pet ownership and health benefits [Jun05]

2.3.2 Pet for old people

There are many factors that gradually reduce social activities, such as retirement, the death of people around us, and the independence of children. Although feeling down is a part of life, sudden changes such as those mentioned above can take time to accept and may cause temporary, deep depression.. Long-term changes, such as retirement, can lead to lasting

depression and alter our thoughts and emotions, unlike temporary changes.. This is called clinical depression [Agib]. Some studies point out that while retirement has no short-term impact, it does have a strong, negative impact in the long-term. It is particularly noteworthy that this is a phenomenon experienced by retirees of all genders, education levels, and occupations, regardless of gender, education, or occupation [Gab17]. As mentioned in subsection 2.1.1, there are many cases in which there are significant restrictions on movement due to aging of joints and muscles. As a result, getting older can be very lonely and it can also lead to a lack of exercise.

"Healthy life" is only when people are physically and mentally healthy. Without either of these, we cannot say we are healthy. Forbes presented 15 tips for living a long and healthy life [Forb]. Among these, it is important to pay attention to regular exercise, weight loss, stress management, and positive thinking. These are all basic things we can do, but pets in particular can help with all four of the above. Studies have shown that simply petting dogs lowers the secretion of cortisol, which is a stress-related hormone [Medb]. Another survey [All03], which looked at post-traumatic stress patients and their dogs, found that 84% of post-traumatic stress patients who had dogs reported a significant reduction in symptoms, and 40% even reported being able to reduce the medications involved. It can be observed that owning a pet dog greatly impacts a person's psychological state and contributes to its stability.

In addition to the above-mentioned internal factors such as stress and hormones, pets are very helpful to maintain the health of the elderly externally. Even people know that they benefit from regular physical exercise, but starting a regular workout is not easy. Conversely, it is very easy to skip. Owning a dog can be a great way to make walking a regular part of their daily schedule. In several studies, it has been concluded that having a pet, especially a dog, is greatly beneficial for regular physical activity [al17; al19e]. So far, there have been many papers on the correlation between pets and their owner's physical activity, and a large number of papers have already proven the correlation. One study investigated the frequency and duration of walks by dog owners, with 60% of owners walking their dogs regularly, with the average duration and frequency being 160 minutes per week and 4 times per week, respectively [al19e].

Another study reported on the potential health-improving effects of owning a dog. For one year, 43 elderly couples were divided into two groups according to whether or not they owned a pet, their activity was observed, and their health effects were studied. The result was that the group with pets, especially dogs, had an average effect of 22 minutes and 2760 steps per day [al17].

2.3.3 Virtual Pet

Virtual pet, also known as a Cyber pet, is a kind of companion created by humans for companionship or pleasure. According to a study, the four most important elements of a real pet are being able to actually touch, interact socially with, communicate with, and sometimes play with the animal [al19f]. And the study also suggests that all of these elements can be replaced in the virtual world or through human and machine input devices.

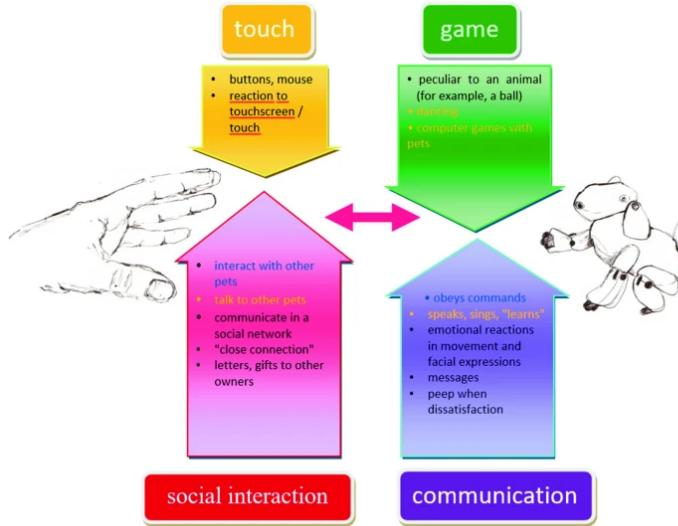


Figure 2.8: Four main elements changes in the human and virtual pet relationship [al19f]

Figure 2.8 illustrates how these elements can be replicated in the digital world and device. The benefits of virtual pets cannot be overstated. They not only serve as a replacement for a real pet for those who are unable to keep one, but also aid in personal development through interaction and learning, promoting the idea of a healthy lifestyle by having a virtual companion. A virtual pet can represent not only the real pet, but also the owner's physical self, acting as an anchor in virtual reality for an incorporeal avatar [al19f].

The first virtual pet game on PC, 'Dogz,' was released in 1995 by PF Magic [Maga]. In this game, users can play and interact with a virtual pet dog via a mouse. Users can interact with the virtual dog in ways similar to how they would interact with a real dog, such as feeding, playing with toys, and grooming. The virtual dog can roam freely on the screen, even interrupting the owner's interaction with their PC. If the user neglects to care for the virtual dog, it will eventually die. The game also provides information about the common sense and knowledge required to own a pet through quizzes, providing an indirect experience of raising a pet.

Tamagotchi and Digimon were the first examples of game consoles designed specifically for digital pets. Unlike life simulations, these pets don't usually breed [pix; Ada03]. Users can interact with Tamagotchi and Digimon by feeding, cleaning, and playing with them. Some studies suggest that virtual pets were popular during the Tamagotchi era, but are now in decline due to being virtual objects that cannot be touched and do not exist in reality [Jov].

Examples of virtual pet games that have been ported to conventional game consoles or mobile devices include 'Nintendogs' and 'Playing with My Pet'. 'Nintendogs', a puppy adopting and communication game released by Nintendo in 2007, sold 23.96 million copies that year [New]. Player can interact with the virtual pets in the virtual world, by using voice and touch. He can also participate in competitions and earn currency, which can be used to buy accessories or other puppies. Other interaction with the player and virtual

2 Related Work



Figure 2.9: Screenshots of "Dogz(1995)" [Magb]



Figure 2.10: Tamagotchi(left, 1996) [Del] and Digimon(right, 1997) [pix]

pet is 'go for walks' in the virtual world and 'meet other dogs' through Nintendo wireless communication. 'Playing with My Pet' is similar to Nintendogs, but has the concept of nurturing and growing [Min]. It is installed in Samsung Anycall feature phones in 2006. The game starts as a puppy, and if players call or text with the puppy out, the puppy will grow into an adult dog. Each time it grows, new interactions, trainings, and mini-games are added that can be played with the dog. When the pet's age is over 80 days, the game will reach an ending where players must say goodbye to their virtual pet.

2.4 Related Technology

2.4.1 Location based game

A location-based game is a game in which a player uses his or her actual location information. It appeared in the early 2000s with the commercialization of Global Positioning System(GPS). Usually, mobile devices that are easy to move are used for location-based games, which are called location-based mobile games [Leo]. Location-based games can be seen as starting from geocaching in that they actively utilize coordinate data received from GPS. 'Geocaching' is a game of hiding or finding containers called 'Geocaches' or 'Cache'. Usually the 'Cache' is in a small watertight box with a logbook that records the date it was found. It is a game where you can exchange the items you find, and in a word, it is a 21st century treasure hunt game. Currently, 1.3 million geocaches are registered, and it is known that there are 5 million players.

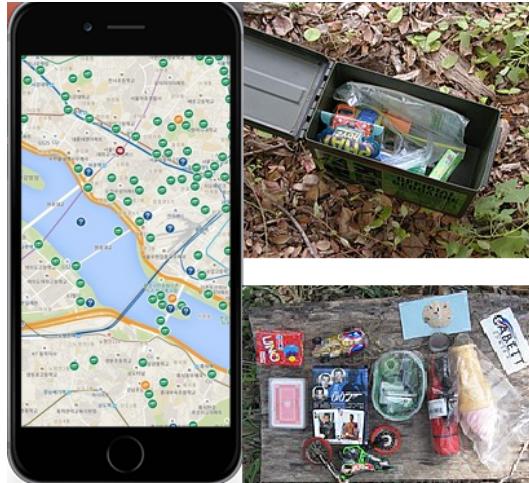


Figure 2.11: Interface of Geocaching from official page(Left) [Gro], Contents of a Geocache(Right) [Wik]

Another well-known example is pac-Manhattan. Based on a 6x4 area surrounding Washington Square Park, the game has similar rules to regular Pac-Man. In other words, it is a real-time Pac-Man game where four players become ghosts and one player becomes Pac-Man, and continues until the ghost catches Pac-Man or until Pac-Man eats all the dots on the map.

However, this game is not based on real-time GPS because it is a method in which players transmit each other's location in real-time to the controlling players, and the control center once again updates the location information to the actual game players. Therefore, there is a slight difference in technical elements from the previously mentioned geocaching. However, it can be seen as a Local based game in that it uses Manhattan, a map of the real world, as the background of the game, and in that it checks and updates people's movements [Man].

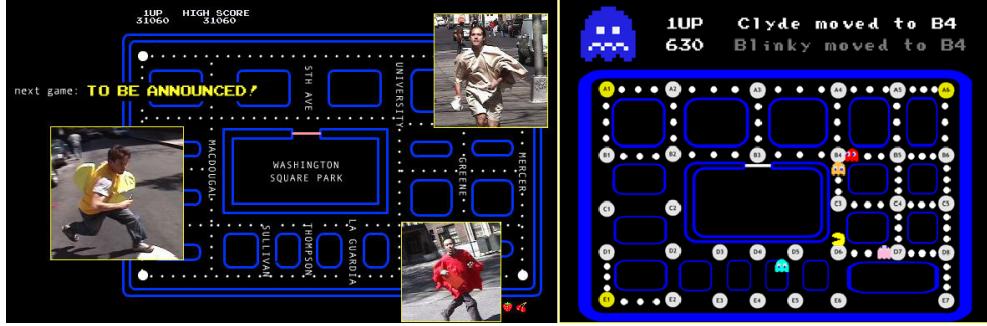


Figure 2.12: Local based game "Pac-Manhattan" [Man]

2.4.2 Smart phone and elder people

Smartphones have become a ubiquitous part of daily life for people of all ages. Initially, smartphones were mainly used to listen to music or internet browsing, however, these days the main features of smartphones are focused on entertainment, healthcare and lifestyle analysis for all age groups [al16]. A recent report [cen] showed that smartphone penetration among the elderly has risen significantly. There is a statistically significant difference between age groups, however Figure 2.13 (a) shows that more than 40% of the young senior group has a smartphone, and this percentage gradually declines with age. As a result, only 20% of oldest senior group has a smartphone, which is only a half of the young senior group. This shows that the old senior group has not yet adapted to the smartphones.

Also noteworthy is the correlation between smartphone penetration and education level and income, which is described on Figure 2.13 (b). According to the same study, even among the same seniors, the mobile phone penetration rate is similar, ranging from 60% to 80%. However, in contrast to 27% of those who graduated from high school or lower, 65% of those who graduated from college or higher own a smartphone. Depending on education level, the difference between the 20% mobile phone penetration rate and the 38% smartphone penetration rate is about twice as large.

Also, only about 27% of people making less than \$30,000 own a smartphone, but about 81% of people making more than \$75,000 own a smartphone. This is a significant figure, as the mobile phone penetration rate increased by about 30% from 73% to 97% depending on income. In contrast, the smartphone penetration rate increased by about 54%.

Another study Figure 2.14 shows statistics about usage of smartphone in the United States. It was found that about 80% of seniors use the Internet, with over 60% of them relying on

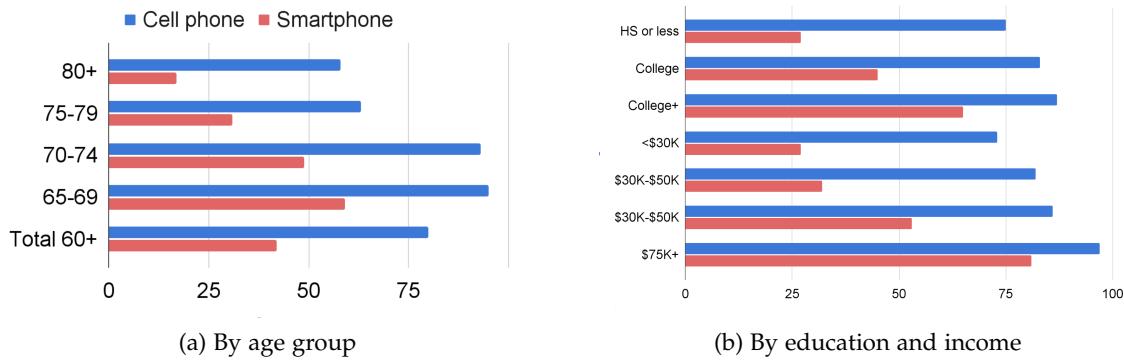


Figure 2.13: Percentage of seniors owning smartphones [cen]

smartphones for tasks such as event sharing, news viewing, and navigation, rather than computers [al16].

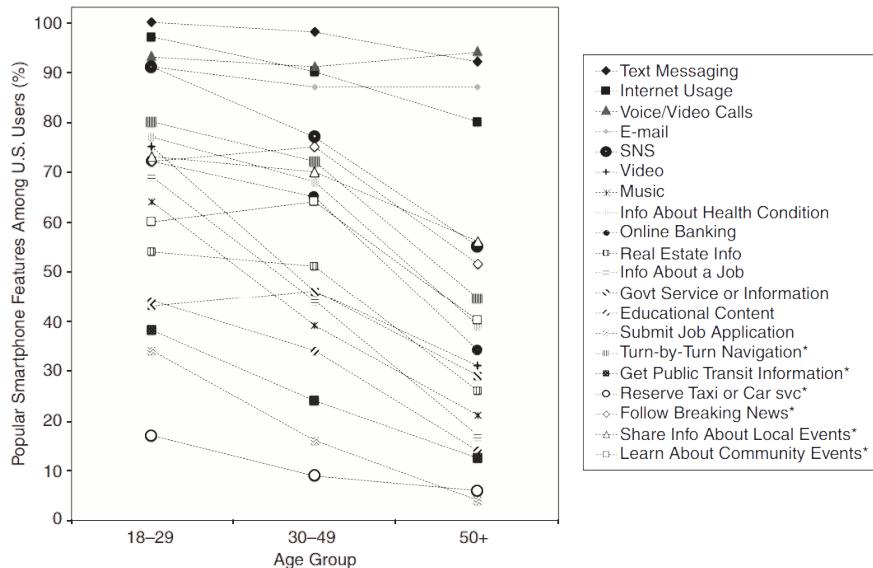


Figure 2.14: Smartphone features used by seniors [al16].

2.4.3 User Interface(UI) for elder people

As the population of the elderly increases and the spread of smartphones among seniors increases, applications targeting seniors are also increasing. [al11b]. As a result, studies on designing UI and applications suitable for seniors are on the rise. There are many reports that have made various comparisons and experiments on each element of the UI, and it's important to consider the user interface, font size, and overall design to create an intuitive and user-friendly experience.

First of all, for navigation, the use of Panorama or Pivot control for navigation should be avoided. Elderly people face challenges when they use dynamic UI that require the simultaneous processing of complex and diverse information [Bar14]. A simple and intuitive navigation structure is also recommended to minimize confusion and improve user experience. The usage of keyboard input and language that is popular among younger generations should be avoided as well. A study shows that the bigger font size the better intuitive and recognizable for elderly, but for the limited screen size, a font size for a button or text should be between 14-22 points [al22b]. When designing the UI, it is important to allocate enough space for each button and content and it is recommended to provide text to each button to provide clear description for their functions. In addition, a Home or Back button in each menu can offer the user a secure navigation point. The existence of these buttons on the screen in the UI gives seniors the comfort of being able to go to a safe place at any time. Finally, it is also recommended to add a color scheme that is easy to distinguish, such as high-contrast color combinations. It helps the elderly to easily identify buttons and text on screen [ELD].

2.4.4 Use of AR technology

AR is a technology with a lot of potential, therefore, it is currently being used in many fields, and the scope is expected to expand further in the future. In particular, it stands out in the mobile field that is easy for users to access, and the number of devices that can be used is increasing [Alsa]. According to a survey, the number of devices that can be used in the field of AR continues to increase, and there are statistics that 1.7 billion devices will be able to use AR by 2024. Among them, the field that is receiving the most attention is the AR-based game and entertainment content field [Alsb]. Starting with Pokemon Go in 2015, AR games have become a popular hobby worldwide, and a lot of investment and manpower are being invested in the game development industry.

In addition, AR can be usefully used in the business field [Meh]. In the manufacturing industry, AR technology can be used to check information necessary for process work in real time, to help maintain machines, and to prevent users from making mistakes in operating machines. It can also be used to prevent AR is gradually becoming an important part of our lives, such as increasing accuracy and stability in areas such as medical treatment and surgery by using AR technology in education and medical fields.

2.4.5 AR for elder people

The potential of AR is limitless and it can be used in various areas, such as travel, education, health, entertainment, and social interaction, especially for the elderly [al21a]. In particular, the recent trend is that a lot of research and development is being done on AR and VR(Virtual Reality) for tourism [al19g], and many other studies are in the field of health and entertainment. In the entertainment field, there have been many successful cases with Pokemon Go or other AR games in the past [al20b], and in the healthcare field, Studies are underway to prevent elderly diseases by enhancing their motor skills, physical strength, cognition, body

2 Related Work

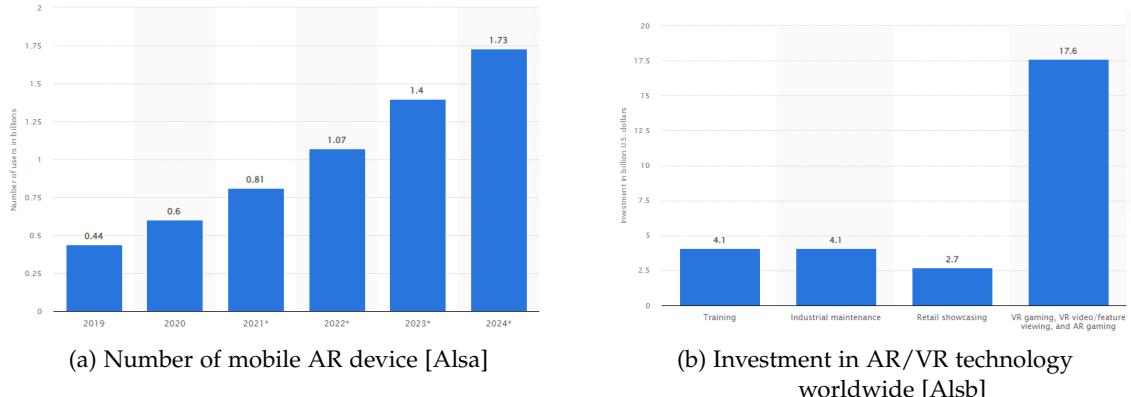


Figure 2.15: Current State and Future of AR



Figure 2.16: Examples of AR applied in industries [Unib]

2 Related Work

balance, and memory [al20c].

"Exer Health" is an example of using AR to patient and elderly [Lab]. It is an application, which helps patients to perform physical therapy movements with ease and effective at home. The application uses artificial intelligence and a camera to monitor the motion and calculate the angle of patient while performing exercises. As another example, the application called "Ddaddabook" application, which lets users color a provided background picture [Gmb]. The application then turns the colored picture into a puzzle that users can assemble. It is estimated that this application not only offers a hobby for the elderly, but it also has potential health benefits, such as checking mental health through color patterns, reducing stress and enhancing short-term memory.

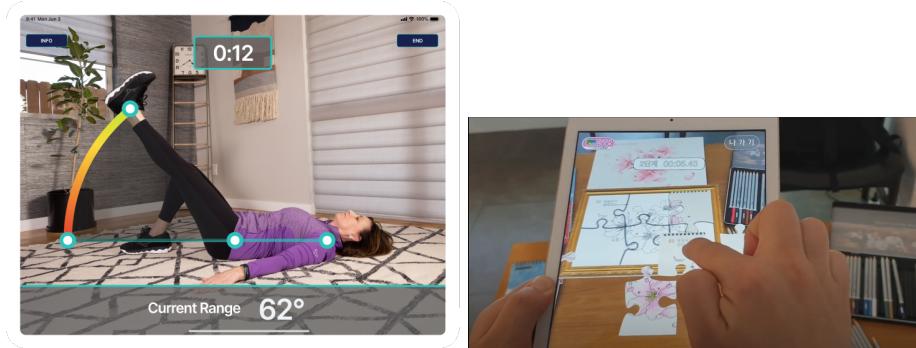


Figure 2.17: Screenshot of "Exer Health"(Left) [Lab], "Ddaddabook"(Right) [Gmb]

3 Preparation and Implementation

Base on the previous discussions, we have designed an AR companion application that uses a virtual pet for physical and mental health of elderly. In this chapter, we will describe the materials required for application design, the direction of development, important considerations, and precautions to ensure that the application is suitable for the elderly.

3.1 Preparation

The Google Pixel 6 was chosen as the test device for the AR application. The device specifications can be found in Table 3.1. The reason for selecting this mobile phone is its popularity and widespread use as AR hardware. According to global mobile phone usage statistics, approximately 70% of all mobile phone users [Stab], and 47% of seniors, use smartphones with the Android operating system [Pay]. Therefore, Android was chosen as the target operating system for development purposes. For the application development tool, Unity 2021.3.8f1 was selected as it is widely used for mobile device development and familiar to AR developers. AR Core was chosen as the AR framework due to its versatility, scalability, and compatibility with the Pixel. It is open-source and works on both Android and iOS, making it accessible to most of the target group. Furthermore, AR Core is easily programmable with Unity and well-documented [Sok].

Figure 3.2 shows the server and client structure of the application. A server running "Ubuntu 22.04" x64 Operating system(OS) was chosen for data storage and local information retrieval, hosted on Vultr's Cloud Compute service. The reason for choosing Vultr is due to its availability of public IP and its familiarity among developers. And Vultr provides enough CPU and Internet usage at a low price to sufficiently process the low-capacity packets that will be generated in server-client communication used in the thesis. MySQL 8.0 was selected as the database for the application, given its popularity as a widely-used and open-source relational database management system(RDBMS).

3.2 The Concept of "Let's Go Bailey"

According to a recent survey conducted in 2022, Bailey is a very popular dog name, ranking as the 8th most common dog name for females and the 44th most common dog name for males [Cut]. The reason why the application was named "Let's Go Bailey" is to make it easier for user who are new to the application to get the inspiration that it must be a dog-related application just by hearing the name. The concept of "Let's Go Bailey" is centered on enhancing user experience through two main features. First scene is an AR scene that utilizes



Figure 3.1: Teaser image of "Let's Go Bailey"

Table 3.1: Specifications of Google Pixel 6

Model	Pixel 6
Display	6.4-inch (163 mm) FHD+ (1080 x 2400 px) OLED
Dimensions(H x W x D) and Weight	158.6 x 74.8 x 8.9 (mm) 207 g
Processors Memory	Google Tensor / Titan M2 security coprocessor 8 GB LPDDR5 RAM
Rear Camera	50 MP Octa PD Quad Bayer wide camera - 1.2 <i>um</i> pixel with - 82° field of view 12 MP ultrawide camera - 1.25 <i>um</i> pixel with - 114° field of view
Front Camera	8 MP - 1.12 <i>um</i> pixel with - 84° wide field of view
Sensors	- Proximity sensor - Ambient light sensor - Accelerometer - Gyrometer - Magnetometer - Barometer



Figure 3.2: Client and server structure of application

AR technology to allow the user to interact with their own virtual pets and become familiar with them. The navigation scene encourages physical activity by providing a platform for the user to locate and navigate to nearby landmarks and green spaces. These two scenes are designed to work together to create a comprehensive and engaging experience for the user.

3.3 UI design

The application's background color has been carefully selected to promote the user comfort. By inverting the existing image, the app's background color now offers a calming effect. The buttons have been designed using high-saturation blue and green colors to create a visually appealing contrast with the white and red text, making it easier for the user to understand the information presented. To minimize the UI and buttons, the app's design has been optimized to ensure a seamless user experience without any inconvenience. Overall, these design choices are aimed at enhancing the usability and aesthetic appeal of the app.

3.4 Server

The server for this project was hosted on "Vultr's cloud hosting service", with the operating system of Linux 22.04 x64 and the database of MySQL 8.0. For the communication method between server and client, Rest API was implemented through Python Flask. Flask was chosen as the framework for several reasons, including its lightweight, minimal dependencies, well-documented, and convenience for testing. These qualities made it an ideal choice for this thesis project, which involved only small-scale communication [Sha]

3.5 Structure of Application

The structure of the application, denoted by chapter 2, is designed with a focus on accessibility and ease of use, especially for older users who may have difficulties using technology. To achieve this goal, most of the functions are accessible from the main menu, so complex navigation is not required. In addition, the menu has been designed to be intuitive and simple so that users can easily access each function and perform the necessary operations easily.

user_info		pet_info		item_list	
user_id	int	user_id	int	item_nr	int
last_login	date	happy	float	item_name	varchar(30)
		hunger	float	description	text
		thirst	float		

walking_records		item_status	
id	int	user_id	int
user_id	int	item_nr	int
distance	float	owned	int
thirst	float		
steps	int		
duration	int		
date	date		

Figure 3.3: MySQL table structure of "Let's go Bailey"

Table 3.2: Flask server endpoints and description

Method	Base-URL: /	Description
GET	/user/	Register a new user
GET	/user/<user_id>	Check if user_id exists and update last login time
GET	/item/<user_id>/all	Retrieve item purchase information of the user_id.
POST	/item/<user_id>/update	Update information about items purchased by the user.
GET	/pet_info/<user_id>	Request the pet's Happy, Thirst and Hunger values.
POST	/record_exercise	Save the exercise result of given user_id.
POST	/request_place	Request information about Green-space around the user.

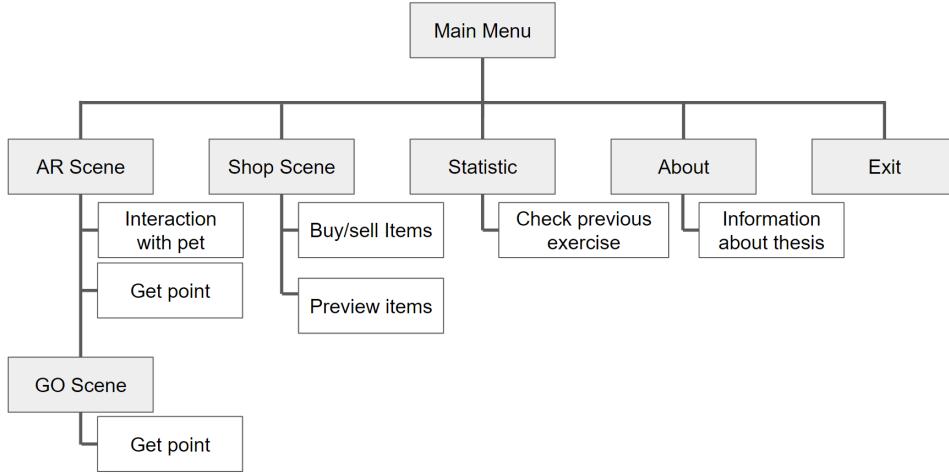


Figure 3.4: Scene structure of application

3.5.1 Menu-Scene

The main menu is the primary navigation tool through which the user can access various functions, and is an important component of software applications. A well-designed main menu enhances the user experience by improving usability, reducing frustration, and increasing efficiency. Additionally, the visual design of the main menu can contribute to the overall aesthetics of the software, and can affect users' perceptions of quality and professionalism. [Bar11]. The main menu of the pet application is designed to provide the user with an intuitive and accessible experience. Figure 3.5 shows a screenshot of main menu. The menu features clear and recognizable button images, eliminating the need for complex navigation. The color scheme has been carefully selected to provide high contrast and enhance readability, making it easier for elderly users to interact with the app.

With a simple tap of the menu button, the user can access a variety of features. Users can access the AR-scene, choose and purchase pet accessories from a store, or view their exercise statistics. These features are designed to engage and entertain, while also promoting physical activity and fostering healthy habits. In addition to this, detailed information is available both within the app and within the accompanying thesis so that the user can clearly understand the application and the purpose of this bachelor thesis.

3.5.2 Main AR-Scene

UI aspect

The Home button, which returns to the main menu at the top of the screen, is colored in a saturated green. It also displays the amount of 'Happy' currency and the status of Bailey's hunger and thirst. At the bottom, various buttons are placed that can interact with the dog, such as feeding, watering, snacking, and going for a walk. As mentioned in the previous



Figure 3.5: Menu-Scene

chapter, the UI was designed in green, a highly saturated color that is not burdensome to the eyes. The UI indicating a warning was made in purple to clearly indicate the meaning of the warning.

Functionality

The Main AR Scene, as mentioned earlier, is one of the most important scenes in this project. The main purpose is to give the elderly familiarity with AR technology, including gesture and UI. Upon execution of the scene, the device recognizes the AR Plane, and if the part touched by the user was a point recognized as an AR Plane, it created a Prefab for the pet, the pet's bed, and the food bowl. Pets periodically perform actions, such as being still, sitting, sleeping, and roaming.

In the case of sitting, there are two actions, which are activated randomly: sitting and looking in the direction where Bailey is sitting, and sitting and looking at the owner. The sitting time is also triggered randomly and ranges between 5 and 10 seconds.

There are two types of sleep: short sleep, which lasts for 5 seconds and is triggered randomly, and long sleep, which occurs in real time. In the case of a short sleep, either sleeping in place or going to the bed created above. However, long sleep occur between 02:00 and 04:00 in the morning, and Bailey unconditionally sleeps on a bed created with a prefab. Therefore, even if the user runs this application at between 02:00 AM and 04:00 AM, Bailey is in a long sleep and cannot interact with the user.

When the scene runs, the client requests the server for information, such as the Bailey's

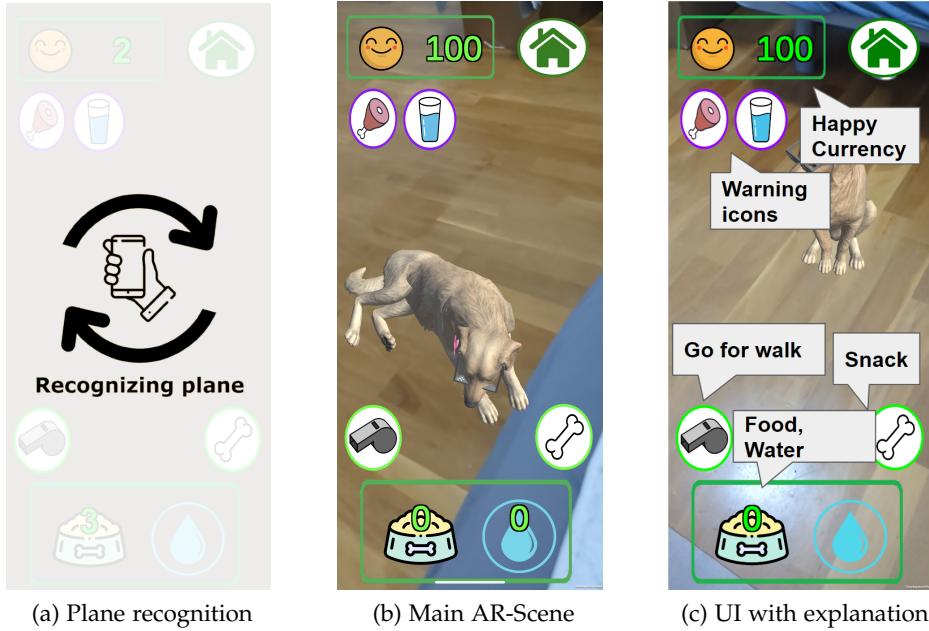


Figure 3.6: Main AR-scene

item status, the Bailey's degree of thirst, and hunger. Device starts recognizing the plane, and the user can know it through a message Figure 3.6 (a). If the plane is recognized, Bailey and his objects are created simultaneously at the position where the user touches the screen Figure 3.6 (b). After Bailey is created the user can interact with him. When the player touches Bailey on the screen, Bailey stops what she is doing and looks at the user. Within 10 seconds, if the user swipes down on the screen, there is a chance that Bailey will sit down. The user can then click the "Snack" icon to give Bailey a treat. After receiving the treat, Bailey has a higher chance of sitting down when the user swipes again. The above actions were implemented using 'AR Raycast' and 'Unity Input System', especially Touch Recognizer, respectively.

The minimum values for thirst and hunger are zero, and the maximum values are 100. Since the server continuously reduces the hunger and thirst levels by 1 every 5 minutes, the reduced hunger and thirst levels can be observed over time even if the application is closed. If the thirst and hunger levels fall below 40, warning icons will be displayed. At this point, user can give food or water through clicking food and water drop button. Then Bailey will move to his bowl and he will eat or drink it.

3.5.3 Navigation-Scene

The Navigation Scene is a critical component of our application, alongside the Main AR Scene. By simply pressing the whistle button in the Main AR Scene, the user can enter the Navigation Scene. Here, the app retrieves the user's current longitude and latitude and sends this information to the server. Using this data, the server searches for green spaces in the

around the user and retrieves their longitude and latitude coordinates. After converting these coordinates into an address, the server returns address, photo, name, and calculated distance from the user's current location in JavaScript Object Notation(JSON) format. This progress is calculated using the Google Map API.

Upon receiving the results, the app parses the data and presents it to the user. This allows user to easily select his desired destination. Once a destination has been chosen, the app initiates full-fledged navigation. Navigation shows user the path to their destination using AR graphics. On the screen, a blue circle indicates the direction the user should walk, and signs are created to indicate the direction the user should take. At the top of the screen, there is a "More" button to check additional information and an "Emergency" button to request help in case of an accident or emergency while walking. At the bottom of the screen, the user can check the route again through a small mini-map showing the current location and directions.

When the user clicks the "More" button, the app displays the time spent walking, distance traveled, and percentage of progress. It also shows a directional arrow indicating the user's correct direction. In addition, the app displays a picture reminding the user to drink water after walking for a certain amount of time to prevent dehydration. It also estimates calorie consumption based on the time spent. This data is calculated based on the average height and weight of the elderly mentioned in subsection 2.2.2, as well as the calories and water consumption required for walking exercise.

The "Emergency" button is used in case of an emergency and can be triggered by pressing the button or tapping the screen three or more times within two seconds. The user can call the emergency center or get directions back home in case of an emergency. To prevent false alarms, a UI will ask the user to confirm an emergency.

The destination is marked with a red arrow in AR graphics. Upon reaching the destination, the user receives 'Happy' currency.

3.5.4 Shop-Scene

As mentioned in subsection 2.2.6, extrinsic motivation means that an individual is motivated by an external reward or punishment. In games, items are often provided as extrinsic rewards, which motivate individuals to enjoy the game longer or to feel a sense of accomplishment within the game. In a study [Yee07], motivation in games, which leads players to keep playing, was divided into three types, and customization was considered as a motivation to become immersed in games. Customization was defined as a game reward for this thesis. Users can purchase various items for the dog in the store using "Happy" obtained from the "Main AR-Scene" and "Navigation-Scene". The composition of the screen shows the quantity of goods at the top so that the amount of goods that the user can purchase is well displayed. In addition, this display has the same shape as the goods of "Main AR Scene" where goods can be obtained, so that user can recognize them at a glance. The middle section lists the items that the user can purchase. The user can purchase or sell the corresponding item by clicking on these icons. The list is divided into accessories, food and toys, so that they can be well classified according to the purpose of use.



Figure 3.7: Navigation-Scene

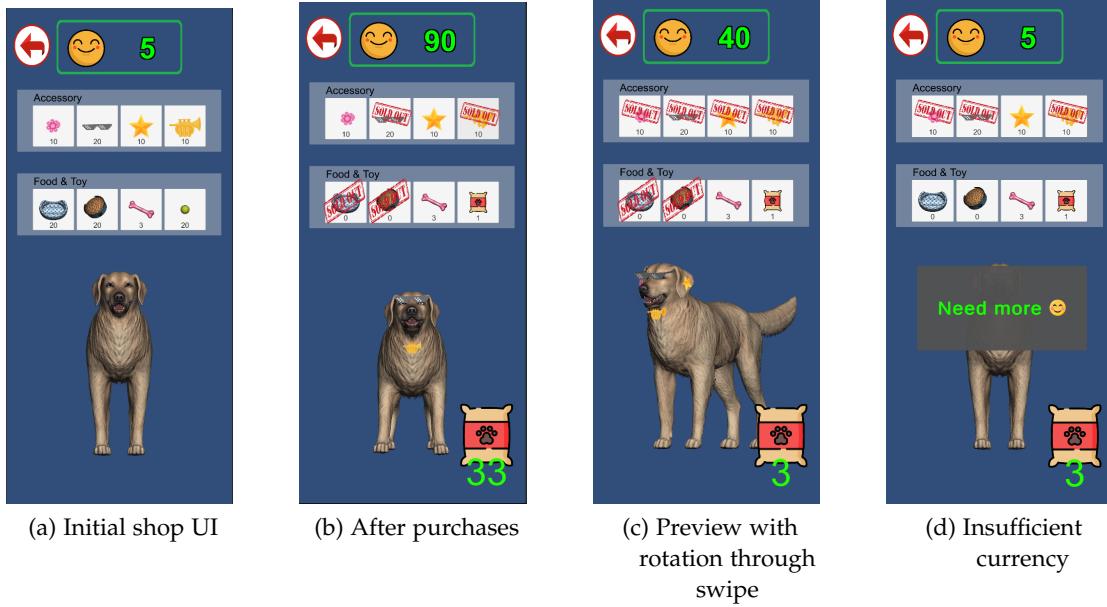


Figure 3.8: Shop-UI

The bottom screen shows the current appearance of the pet and the items it is wearing. This allows the user to easily distinguish between before and after wearing the item.

In order to avoid duplicate purchases, items that have already been purchased are displayed in large letters indicating that they have been sold so that the user can easily identify them. The server stores information about the items and wearable, so when the scene is launched, the system automatically retrieves the purchase status and item information from the server. Based on this information, a preview and item purchase status are displayed to the user.

3.5.5 Statistic-Scene

As previously stated in subsection 2.2.3, consistency and regularity are key factors in exercising and keeping track of one's progress can serve as a motivating factor. The Statistic-Scene provides the user with a clear view of their exercise records for the past 7 days. To provide detailed information, the Statistic scene is designed to operate only in landscape view. Upon scene initialization, the server receives the user's exercise records in JSON format and generates relevant graphs and statistics. In order to protect personal information, the server does not record the location or coordinates that the user has visited, but only the amount of exercise. On the left side of the scene, the user can view their total exercise distance, number of steps, and calorie consumption for the past 7 days, while the right side presents a daily comparison of their exercise in the form of a graph. The calculation was based on the figures mentioned in subsection 2.2.2 and the average stride length was assumed to be 74 cm, as stated in [al21b]. A reference point has been set at a distance of 3.5 km, and the points are marked in red if they are lower than the reference point and in green if they are higher,

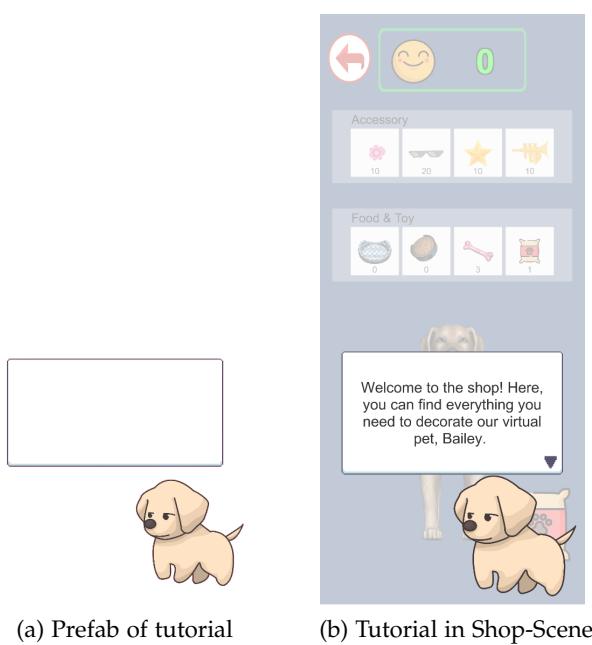


Figure 3.9: Statistic-Scene

allowing users to easily identify their level of physical activity. By clicking on a specific data point in the graph, the user can access detailed information about their exercise on that day to better track their progress.

3.5.6 Tutorial

New applications can be challenging for users, especially when they are unfamiliar with the features and interface. In order to provide a better user experience, tutorials play a crucial role in helping users learn how to use and enjoy the application with ease [Liq]. Thus, in this thesis, it is proposed that tutorials should be integrated into the application launch process. These tutorials should be designed to guide new users through each scene and provide step-by-step instructions on how to navigate the application. This includes, but is not limited to, teaching the user how to purchase items in the store, explaining the UI, and demonstrating how to interact with the application's virtual pet, Bailey. By implementing tutorials in this way, users can quickly and efficiently learn how to use the application, which can lead to increased satisfaction and engagement.



(a) Prefab of tutorial

(b) Tutorial in Shop-Scene

Figure 3.10: Tutorial

4 Evaluation of Let's go Bailey

4.1 Methods and questionnaire

The evaluation of this application was conducted through a comprehensive questionnaire. Although the target group for this application was seniors aged 65 or older, we surveyed as many age groups as possible to compare the thoughts of younger people. We used a research method that involved conducting 1:1 interviews through direct visits, street interviews and online survey and for the section related to the application, we showed photos of the scene and some scenes directly and asked for their thoughts. Additionally, we also distributed the questionnaire to the target groups known by acquaintances and obtained their responses. Here is a questionnaire used:

1. Personal Information

a) what is your age group?

under 35 35-44 45-54 55-64 65-74 74+ no answer

b) Do you have a pet?

Yes No

2. If you have pet(s),

a) Which pet(s) do you have? _____

b) What motivated you to have pet(s)? _____

c) What are the advantages of having pet(s)? _____

d) What are the disadvantages of having pet(s)? _____

3. If you don't have a pet,

a) Is there any reason you do not have pets?

- It is difficult to take care
- I do not have enough time to spend with
- Because of high costs
- Person I live with, does not like
- Because of lost or died I had in the past.

Allergic to animals and fur
 others : _____

b) Are you planning to have a pet in the future?

Yes No Maybe

4. Interest about technology

a) How often do you play video/smartphone/computer game?

Not at all - - - - A lot

b) How much interest do you have about technology

Not at all - - - - A lot

c) Have you ever heard about "location-based" game?

Yes No I don't know

d) Have you ever played "local-based" game?

Yes No

e) If yes how was it? _____

f) Have you ever played "virtual pet" game like Tamagotchi?

Yes No

g) If yes how was it? _____

h) I think emotional connection with pets is the most important.

Strongly disagree - - - - Strongly agree

i) I think if I can interact with and feed my virtual pet, I can feel like owning a real pet.

Strongly disagree - - - - Strongly agree

j) Virtual pets could be a substitute for people who cannot afford pets.

Strongly disagree - - - - Strongly agree

5. About "Let's go Bailey"

a) I like the concept of the application.

Strongly disagree - - - - Strongly agree

b) The interface of the app is easy to understand and clear.

Strongly disagree - - - - Strongly agree

c) Navigation on the camera screen actually helps a lot in finding a path.

Strongly disagree - - - - Strongly agree

d) it is necessary to display water and calorie consumption while walking.

Strongly disagree - - - - Strongly agree

- e) In order to buy customizing items, I think I will go for a walk or interact with my dog more..

Strongly disagree O - O - O - O - O Strongly agree

- f) The emergency call system is very useful.

Strongly disagree O - O - O - O - O Strongly agree

- g) Do you have any suggestions that could improve this application?
-

4.2 Feedback and comments

Although the response rate from the intended target group was lower than anticipated, the online survey yielded valuable insights from participants in the 30s to 50s age range. Although the concept and user interface received positive responses from all age groups, skepticism towards virtual pets was expressed, with concerns raised about the potential ethical implications of widespread adoption. Respondents consistently differentiated between virtual and real pets, with emotional bonding being a crucial criterion.

Regarding this, almost all participants rated the virtual pet differently from the real pet, and evaluated that it was very important to form an emotional bond and interact with the pet through skin-ship. While virtual pets can be an alternative to real pets, there are many limitations that have been pointed out, such as the lack of tactile feedback and visual inconsistencies due to graphics. There were also comments that it would be nice to be able to interact with virtual pets with more interactivity.

There were also many responses to AR technology. Most of them gave negative opinions about the technical limitations and unfamiliarity of AR. However, many negative opinions were expressed about the irony of seeing the created pets through a device, despite the positive reactions to the amazing virtual objects created in the real world image. Reviews of the Navigation-Scene and its functionality were mostly positive. The display of AR navigation and emergency functions was positively received, with feedback indicating that directly displaying the path on the screen is very helpful for finding one's way. However, there were also concerns about the potential dangers of inaccurate path recognition due to technological limitations.

By automatically searching green space around the user, there was a positive opinion that the user can learn about unknown areas. While some feedback suggested that the technology could serve as a motivation to explore and visit less familiar places, there were also many who disagreed with the idea of having to walk more or work harder for the sake of obtaining custom items.

Opinions on location-based games varied among participants. Many had a positive view of the games, citing their ability to motivate physical activity. Participants particularly appreciated the direct engagement with the game through body movement, as opposed to more traditional computer or smartphone games. However, some participants expressed annoyance and boredom with the games after a short time.

Finally, there were many concerns raised about the digitization of pets, with some voices expressing particularly cautious and serious reservations about the matter. An opinion, as an example, suggested the following: pets are living beings that require mutual exchange and coordination rather than being seen as toys that fulfill human desires. However, virtual pet applications that prioritize human desires over mutual exchange and coordination with pets can lead to the perception of pets as objects of one-sided control. This kind of perception is concerning as it may result in people viewing pets as a means of fulfilling mechanical human desires during interactions with them. Thus, it is important to consider the attitude and perception towards pets in the development of such virtual pet applications.

4.3 Technical limitations

Although the server and client structure allows the server to calculate and process as much information as possible, and the client receives the only the necessary information from the server and processes it graphically, there are some limitations.

4.3.1 Inaccuracy of mobile GPS

A mobile device uses GPS technology to communicate with satellites and collect user location information for calculating user's position. However, in this process, errors often occur due to signal interference or changes in the path, which may affect the accuracy of the calculated position [Zan09]. In this study, location calculation errors and inaccurate results were observed when there was significant signal interference from surrounding structures such as large buildings or in downtown areas. This negatively affects the user experience. To minimize this problem and improve user experience, it is recommended to consider supplementing GPS location information with other sensors such as Wi-Fi signals, accelerometers, and gyroscopes. These sensors can help to provide additional location information that can compensate for the errors caused by signal interference or changes in the path.

4.3.2 Challenges Mobile AR Camera and ARCore

ARCore is a platform for developing AR applications on Android devices. It utilizes the device's camera, sensors, and software to provide an AR experience. However, the performance of ARCore is limited by the camera, sensors, and hardware capabilities of the mobile device. Problems often occurred when using the mobile camera as an AR camera. First of all, a problem appeared in the accuracy of plane recognition. The smartphone camera is a camera that is not fixed, and there are many vibrations and movements, so the recognition accuracy often decreases or the recognition takes a long time. In the dark or when there is no light, inaccurate limits appeared for both indoor and outdoor use. Lastly, there was a problem that recognition took time or was not properly recognized because of various element signs or objects on the road as well as the road outdoors. As a result, there are often cases where a road or a bicycle path that people should not go on is recognized as a sidewalk and marked as a road, which can increase the risk of accidents. In order to solve this problem,

we need to consider ways to improve accuracy and stability by using methods such as a camera vibration [a120d] correction function or artificial intelligence technology [a121c].

4.3.3 Inaccuracy of metabolic cost

There was also a problem in accurately calculating measured values such as information on the body's metabolic cost. Since water consumption or calorie consumption changes due to environmental factors such as physical condition, basal metabolic rate, temperature, etc., it is an unsolvable problem that cannot be accurately calculated with a mobile device held in the hand. Therefore, in this study, the calculation was based on the average value found in other studies subsection 2.2.2, but in the case of users, who are far from the average value, such as being too short in height or weighing more than average, can affect negative user experience. In order to increase accuracy, it is necessary to consider how to provide more accurate information by using wearable equipment and combining with artificial intelligence technology in consideration of individual physical conditions and environmental factors.

4.3.4 Challenges for recommending green spaces

When app recommends green spaces to walk around, server searches and retrieves information through Google API. However, Google Maps often displays places that are not accessible to outsiders, such as 'Kleingarten', which is classified as a 'park' on Google platform. Furthermore, Photos are also not managed by Google, but rather uploaded by individuals. And Google API offers only the first photo of such places, therefore, photos often contains personal information, such as picture of family or friends. To improve the user experience and accuracy of information, further research and countermeasures are needed.

5 Further Potential for Let's go Bailey

Although we've received good feedback on Let's Go Bailey's concept and direction, the app still has some technical and content potential to be improved.

5.1 Technical potential

A pet is a living being that exhibits its own behaviors and makes decisions based on its self-awareness through surrounding environments and experiences and other factors. It also grows and learns over time through interactions with human and adapts to humans as a result. During this process, the pet can do various patterns such as reading the user's emotional state and reacting differently based on it. However, there are currently technical limitations in conveying the user's emotional or psychological state to virtual pets on mobile devices. To enhance the realism of virtual pets, technical solutions such as new sensor implantation on smartphone and AI for pet's decisions and awareness, could be utilized to provide a more diverse and realistic experience for users. In addition, deep learning and artificial intelligence technology can be used to make the appearance and behavior of virtual pets more realistic. This allows users to create their own unique virtual pet, which allows them to enjoy a different experience.

5.2 Content potential

Multiplayer content can be added to the application. For example, the app can recommend green spaces based on locations that other users have visited or the user's own preferences. Additionally, community features can be added so that users can go for walks with other players, show off their pet to others, and update information on green spaces based on app users' review and photos.

Additionally, new features and content can be added to the app for users who are reluctant to have a new pet due to the death or separation of their previous pet. The app can create a virtual pet based on the user's photos or videos of their previous pet. In this case, by analyzing the appearance of the photo and video, the pet's appearance and behavior can be made as similar as possible, so that users can feel as if they still have their beloved pet with them, even in a virtual form. Additionally, the addition of this content can help improve the psychological state of users who have sad memories of their previous pet.

Lastly, the app can provide users with the ability to customize their virtual pet according to their personal taste, such as, set the appearance or type of the pet to their preference, or a function that let them manage and set their own pet's meals and interactions by themselves.

This can give users the feeling that they have a unique pet, providing them with a different experience from other users.

6 Conclusion

This study investigates the elderly individuals perception of virtual pets, and whether interactions and walks with virtual pets created through mobile AR can provide a sense of satisfaction similar to raising a real pet. We also examine the potential for virtual animals to promote physical and mental health in the elderly through walking exercise. For this study, we created Lets Go Bailey, a mobile application that simulates these functions, and collected opinions through direct feedback from the target group and online surveys.

As our study showed, virtual pets may have some potential in providing a sense of satisfaction to people who cannot have a real pet, but their ability to promote physical exercise and improve mental health is limited, due to many technical limitations, including GPS, mobile device, camera and algorithms. Further research, such as, improvements in algorithms, cameras, processors, and AI for behavior analysis and interaction with virtual pets, can provide users with a more realistic and immersive experience with virtual pets in AR.

Additional contents, such as community features between users, social interaction with other users and gamification features, can motivate users to engage in physical activity with their virtual pets and helps to get positive user experience.

Additionally, additional features, such as customized and personalized virtual pets, such as changing their appearance or behavior, can also increase user engagement and attachment to their virtual pets. If these advancements are made, we may see a future where virtual and real pets coexist, allowing for physical activity with both types of pets?

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Bibliography

- [Fora] Forbes. *Pet Ownership Statistics* 2023. URL: <https://www.forbes.com/advisor/pet-insurance/pet-ownership-statistics>.
- [Ass] A. P. P. Association. *Pet Industry Market Size, Trends Ownership Statistics*. URL: https://www.americanpetproducts.org/press_IndustryTrends.asp.
- [al07] T. C. et al. "The illusion of love: Does a virtual pet provide the same companionship as a real one?" In: *Interaction Studies* 8.2 (2007), pp. 1–3. DOI: <https://doi.org/10.1075/is.8.2.09che>.
- [al15a] J.-L. et al. "Pets in the Digital Age: Live, Robot, or Virtual?" In: *Frontiers in veterinary science* 2.11 (2015), pp. 1–3. doi: <https://doi:10.3389/fvets.2015.00011>.
- [al19a] B. L. et al. "Undulating changes in human plasma proteome profiles across the lifespan". In: *Nat Med.* 25.12 (2019), pp. 1843–1850. doi: [10.1038/s41591-019-0673-2](https://doi:10.1038/s41591-019-0673-2).
- [Hea] J. M. Health. *9 Physical Changes That Come With Aging*. URL: <https://blog.johnsonmemorial.org/9-physical-changes-that-come-with-aging>.
- [Meda] Medlineplus. *Aging changes in the bones - muscles - joints*. URL: <https://medlineplus.gov/ency/article/004015.htm>.
- [War] J. Warner. *Multitasking Gets Harder With Age*. URL: <https://www.webmd.com/healthy-aging/news/20110411/multitasking-gets-harder-with-age>.
- [al84] M. H. et al. "Mental Health and the Elderly: Factors in Stability and Change Over Time". In: *Journal of Health and Social Behavior* 25.2 (1984), pp. 100–115. DOI: <https://doi.org/10.2307/2136663>.
- [WHO] WHO. *Mental health of older adults*. URL: <https://www.who.int/news-room/fact-sheets/detail/mental-health-of-older-adults>.
- [al19b] F. K. et al. "The Relationship between Socioeconomic Status, Mental Health, and Need for Long-Term Services and Supports among the Chinese Elderly in Shandong Province—A Cross-Sectional Study". In: *International journal of environmental research and public health* 526.16 (2019), pp. 1–19. DOI: <https://doi.org/10.3390/ijerph16040526>.
- [Car21] A. Carter. *Germany is getting older: Average age rises by five years*. iamexpat, 2021.
- [Han19a] M. R. Hannah Ritchie. *Age Structure*. 2019. URL: <https://ourworldindata.org/age-structure#the-world-population-is-changing-for-the-first-time-there-are-more-people-over-64-than-children-younger-than-5>.

Bibliography

- [Han19b] M. R. Hannah Ritchie. *Age Structure*. 2019. URL: <https://ourworldindata.org/age-structure#what-does-the-age-structure-of-future-populations-look-like>.
- [Yi-15] C.-S. H. Yi-Yin Lin. "Aging in Taiwan: Building a Society for Active Aging and Aging in Place". In: *The Gerontologist* 56 (2015), pp. 176–183.
- [Jér07] L. K. Jérôme Bourdieu. "Surviving Old Age in an Ageing World Old People in France, 1820-1940". In: *Population* 62.2 (2007), pp. 183–211. doi: https://www.cairn-int.info/article-E_POPU_702_0221--surviving-old-age-in-an-ageing-world-old.htm.
- [Bana] T. W. Bank. *Population ages 65 and above for France*. URL: <https://fred.stlouisfed.org/series/SPP0P65UPT0ZSFRA>.
- [Banb] T. W. Bank. *Population ages 65 and above (% of total population) - Germany*. URL: <https://data.worldbank.org/indicator/SP.POP.65UP.TO.ZS?locations=DE>.
- [Org] W. H. Organization. *Ageing and health*. URL: <https://www.who.int/news-room/fact-sheets/detail/ageing-and-health>.
- [Banc] T. W. Bank. *Population ages 65 and above (% of total population)*. URL: <https://data.worldbank.org/indicator/SP.POP.65UP.TO.ZS>.
- [DPa] C. for Disease Control and Prevention. *Benefits of Physical Activity*. URL: <https://www.cdc.gov/physicalactivity/basics/pa-health/index.htm>.
- [Ped22] R. P. T. P. Pedro F. Saint-Maurice PhD Barry I. Graubard PhD. "Estimated Number of Deaths Prevented Through Increased Physical Activity Among US Adults". In: *Jama Internal Medicine* 182.3 (2022). doi: <https://jamanetwork.com/journals/jamainternalmedicine/fullarticle/2788473>.
- [DPb] C. for Disease Control and Prevention. *How much physical activity do older adults need?* URL: https://www.cdc.gov/physicalactivity/basics/older_adults/index.htm.
- [al96] R. W. B. et al. "Walking Speed: Reference Values and Correlates for Older Adults". In: *Journal of Orthopaedic Sports Physical Therapy* 24.2 (1996), pp. 86–90. doi: <https://www.jospt.org/doi/10.2519/jospt.1996.24.2.8>.
- [Ped20] e. a. Pedro L Valenzuela Adrián Castillo-García. "Exercise benefits on Alzheimer's disease: State-of-the-science". In: *Science Direct* 62 (2020). doi: <https://doi.org/10.1016/j.arr.2020.101108>.
- [al19c] G. B. et al. "The age-performance relationship in the general population and strategies to delay age related decline in performance". In: *Archives of Public Health* 77.51 (2019), pp. 1–9. doi: <https://doi.org/10.1186/s13690-019-0375-8>.
- [Boh97] R. W. Bohannon. "Comfortable and maximum walking speed of adults aged 20-79 years: reference values and determinants". In: *BMC Geriatrics* 26.1 (1997), pp. 15–19. doi: <https://doi.org/10.1093/ageing/26.1.15>.

Bibliography

- [Sys] T. F. H. M. System. *Average height (in meters) and weight (in kilograms) of the population. Classification: years, Germany, age, sex.* URL: https://www.gbe-bund.de/gbe/pkg_isgbe5.prc_menu_olap?p_uid=gast&p_aid=86532378&p_sprache=E&p_help=0&p_indnr=223&p_indsp=&p_ityp=H&p_fid=.
- [ala] T. F. et al. *How Many Calories Do You Burn From Walking? Here's How to Calculate.* URL: <https://www.goodhousekeeping.com/health/fitness/a47008/calories-burned-from-walking>.
- [The] O. P. Therapy. *THE 1 REASON YOU NEED CONSISTENT EXERCISE.* URL: <https://www.osrpt.com/2018/06/reason-you-need-consistent-exercise>.
- [Staa] M. C. Staff. *Exercise: 7 benefits of regular physical activity.* URL: <https://www.mayoclinic.org/healthy-lifestyle/fitness/in-depth/exercise/art-20048389>.
- [new] H. news. *Why exercise gets harder the less you do.* URL: <https://www.leeds.ac.uk/news-health/news/article/5035/why-exercise-gets-harder-the-less-you-do>.
- [Agia] Agingcare. *Why Are Falls So Dangerous for the Elderly?* URL: <https://www.agincare.com/articles/falls-prove-fatal-for-elderly-patient-149687.htm>.
- [Far] S. J. Farahani. *Aqua Yoga for Seniors, Benefits and How to Get Started.* URL: <https://livingmaples.com/mag/aqua-yoga-for-seniors-benefits-and-how-to-get-started>.
- [Sen] Seniorlink. *6 Benefits of Swimming for Older Adults.* URL: <https://www.seniorlink.com/blog/6-benefits-of-swimming-for-seniors>.
- [Cha] B. H. Channel. *Walking for good health.* URL: <https://www.betterhealth.vic.gov.au/health/healthyliving/walking-for-good-health>.
- [Gar] J. Garden-Robinson. *Walking Can Help Relieve Stress.* URL: <https://www.ag.ndsu.edu/news/newsreleases/2011/aug-8-2011/walking-can-help-relieve-stress/>.
- [Boz21] M. Bozkurt. "Metropolitan children's physical fitness: The relationship between overweight and obesity prevalence, socioeconomic status, urban green space access, and physical activity". In: *Urban Forestry Urban Greening* 64.1 (2021), p. 127272. doi: <https://doi.org/10.1016/j.ufug.2021.127272>.
- [al22a] T. X. et al. "Urban Green Space and Subjective Well-Being of Older People: A Systematic Literature Review". In: *International Journal of Environmental Research and Public Health* 19.21 (2022), pp. 891–921. doi: <https://doi.org/10.3390/ijerph192114227>.
- [Com+19] E. Commission, J. R. Centre, S. Günther, J. Maes, M. Thijssen, G. Zulian, and J. Raynal. *Enhancing Resilience Of Urban Ecosystems through Green Infrastructure (EnRoute) : final report.* Publications Office, 2019. doi: [doi/10.2760/689989](https://doi.org/10.2760/689989).

Bibliography

- [Rya00] R. M. e. a. Ryan. "Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being." In: *American Psychologist* 55.1 (2000), pp. 68–78. doi: <https://doi.org/10.1037/0003-066X.55.1.68>.
- [Bes] L. Bessonova. *Role of companion animals in promoting physical activity and positive health outcomes*. URL: https://www.researchgate.net/publication/266898618_Role_of_companion_animals_in_promoting_physical_activity_and_positive_health_outcomes.
- [Ein97] A. Einstein. "Potential benefits of pet ownership in health promotion". In: *Annalen der Physik* 15.4 (1997), pp. 358–372. doi: <http://10.1177/089801019701500404>.
- [al15b] S. J. (A. et al. "Using Virtual Pets to Promote Physical Activity in Children: An Application of the Youth Physical Activity Promotion Model". In: *Journal of Health Communication* 20.7 (2015), pp. 807–815. doi: <https://doi.org/10.1080/10810730.2015.1018597>.
- [al20a] M. P. et al. "Understanding the Relationship Between Pet Ownership and Physical Activity Among Older Community-Dwelling Adults—A Mixed Methods Study". In: *Journal of Aging and Physical Activity* 28.1 (2020), pp. 131–139. doi: <https://doi.org/10.1123/japa.2019-0056>.
- [al02] E. L. et al. "Building a practically useful theory of goal setting and task motivation: A 35-year odyssey". In: *American Psychologist* 57.9 (2002), pp. 705–717. doi: <https://doi.org/10.1037/0003-066X.57.9.705>.
- [al00] E. L. et al. "The What and Why of Goal Pursuits: Human Needs and the Self-Determination of Behavior". In: *Psychological Inquiry* 11.4 (2000), pp. 227–268. doi: https://doi.org/10.1207/S15327965PLI1104_01.
- [al19d] N. S. et al. "A community-based exercise program to increase participation in physical activities among youth with disability: a feasibility study". In: *Disability and Rehabilitation* 41.10 (2019), pp. 1152–1159. doi: <https://doi.org/10.1080/09638288.2017.1422034>.
- [al11a] L. E. B. et al. "Self-Monitoring in Weight Loss: A Systematic Review of the Literature". In: *Journal of the Academy of Nutrition and Dietetics* 111.1 (2011), pp. 92–102. doi: <https://doi.org/10.1016/j.jada.2010.10.008>.
- [sta] statista. *Number of mHealth apps available in the Apple App Store from 1st quarter 2015 to 3rd quarter 2022*. URL: <https://www.statista.com/statistics/779910/health-apps-available-ios-worldwide>.
- [Myf] Myfitnesspal. *Your Home Screen is Getting a Makeover*. URL: <https://blog.myfitnesspal.com/your-home-screen-is-getting-a-makeover>.
- [Psy] O. M. PsyberGuide. *Headspasce Review*. URL: <https://onemindpsyberguide.org/apps/headspace>.
- [Map] I. MapMyFitness. *Walk with Map My Walk*. URL: https://play.google.com/store/apps/details?id=com.mapmywalk.android2&hl=en_US.

Bibliography

- [Fit] I. Fitbit. *Fitbit official website*. URL: <https://www.fitbit.com/global/de/home>.
- [McG] J. McGuire. *Best Fitbit in 2023: Choose the right fitness tracker*. URL: https://www.tomsguide.com/us/best-fitbit_review-3203.html.
- [Bum] W. Bumgardner. *Best Free Walking Apps for Fitness Walkers*. URL: <https://www.verywellfit.com/best-walking-apps-3434995>.
- [Bir] A. Bireline. *7 Reasons to Track Your Fitness Progress*. URL: <https://www.nifs.org/blog/7-reasons-to-track-your-fitness-progress>.
- [Unia] E. Union(EU). *Privacy code of conduct on mobile health apps*. URL: <https://digital-strategy.ec.europa.eu/en/policies/privacy-mobile-health-apps>.
- [alb] T. H. et al. *Health apps share your concerns with advertisers. HIPAA can't stop it*. URL: <https://www.washingtonpost.com/technology/2022/09/22/health-apps-privacy/>.
- [Xie11] B. Xie. "Effects of an eHealth literacy intervention for older adults". In: *Journal of medical Internet research* 13.4 (2011), p. 90. DOI: <https://doi.org/10.2196/jmir.1880>.
- [Cov] T. Covington. *Pet Ownership Statistics*. URL: <https://www.thezebra.com/resources/research/pet-ownership-statistics/#pet-ownership-statistics-by-state>.
- [Enc] T. E. of Encyclopaedia Britannica. "pet". In: Britannica.
- [Mei19] G. T. R. e. a. Mei Mei Chan. "The "pet effect" in cancer patients: Risks and benefits of human-pet interaction". In: *Annalen der Physik* 143 (2019), pp. 56–61. DOI: <https://doi.org/10.1016/j.critrevonc.2019.08.004>.
- [Hor] D. Horwitz. *Dog Behavior Problems - Aggression to Family Members - Introduction and Safety*. URL: <https://vcahospitals.com/know-your-pet/dog-behavior-problems-aggression-to-family-members-introduction-and-safety>.
- [Kim] G. Kim. *Here's how much it costs to own a dog or cat in 2021*. URL: <https://www.cnet.com/personal-finance/heres-how-much-it-costs-to-own-a-dog-or-cat-in-2021/>.
- [Pre] A. S. for the Prevention of Cruelty to Animals(ASPCA). *Cutting Pet Care Costs*. URL: <https://www.aspca.org/pet-care/general-pet-care/cutting-pet-care-costs>.
- [Gha15] N. S. Ghasemzadeh I. "Review of bacterial and viral zoonotic infections transmitted by dogs". In: *JOURNAL of MEDICINE and LIFE* 8.4 (2015), pp. 1–5. DOI: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5319273/>.
- [Gha04] N. S. Ghasemzadeh I. "Rabies surveillance in the United States during 2003". In: *Journal of the American Veterinary Medical Association* 255.12 (2004), pp. 1837–1849. DOI: <https://doi.org/10.2460/javma.2004.225.1837>.

Bibliography

- [J M06] e. a. J. Michael Janda Margot H. Graves. "Diagnosing Capnocytophaga canimorsus Infections". In: *Emerging Infectious Diseases* 2.12 (2006), pp. 340–342. doi: <https://doi.org/10.3201/eid1202.050783>.
- [Met13] P. A. B. . U. Methner. *Diagnosing Capnocytophaga canimorsus Infections*. Emerging Infectious Diseases. Cabi, 2013. ISBN: 9781845939038.
- [Den02] E. L. P. Dennis R Ownby Christine Cole Johnson. "Exposure to dogs and cats in the first year of life and risk of allergic sensitization at 6 to 7 years of age". In: *JAMA Network* 288.8 (2002), pp. 963–972. doi: 10.1001/jama.288.8.963.
- [P N01] P. I. G. P Nafstad P Magnus. "Exposure to pets and atopy-related diseases in the first 4 years of life". In: *Allergy* 56.4 (2001), pp. 307–312. doi: 10.1034/j.1398-9995.2001.00881.x.
- [AND92] W. ANDERSON. "PET OWNERSHIP AND RISK-FACTORS FOR CARDIOVASCULAR DISEASE". In: *Allergy* 157.5 (1992), pp. 298–301. doi: 10.5694/j.1326-5377.1992.tb137178.x.
- [McN14] J. McNicholas. "The benefits of pets for older people: a review". In: *Working with older people* 18.3 (2014), pp. 128–133. doi: <https://doi.org/10.1108/WWOP-06-2014-0014>.
- [Jun00] G. M. C. June McNicholas. "Dogs as catalysts for social interactions: Robustness of the effect". In: *Psychology* 91.1 (2000), pp. 61–70. doi: <https://doi.org/10.1348/000712600161673>.
- [Jam88] D. U. James S. House Karl R. Landis. "Social Relationships and Health". In: *Science* 241.4865 (1988), pp. 540–545. doi: <http://DOI:10.1126/science.3399889>.
- [Jun05] A. R. June McNicholas Andrew Gilbey. "Pet ownership and human health: a brief review of evidence and issues". In: *The BMJ* 331 (2005), pp. 1252–1254. doi: <https://doi.org/10.1136/bmj.331.7527.1252>.
- [Agib] AgingCare.com. *Warning Signs of Depression in the Elderly*. URL: <https://www.agingcare.com/articles/elderly-depression-warning-signs-to-look-for-110498.htm>.
- [Gab17] GabrielHeller-Sahlgren. "Retirement blues". In: *Journal of Health Economics* 54 (2017), pp. 66–78. doi: <https://doi.org/10.1016/j.jhealeco.2017.03.007>.
- [Forb] Forbes. *15 Ways To Live Longer*. URL: https://www.forbes.com/2006/04/28/longevity-longlife-advice_cx_sy_0501health_ls.html?sh=2900b12f3d4c.
- [Medb] J. H. Medicine. *The Friend Who Keeps You Young*. URL: <https://www.hopkinsmedicine.org/health/wellness-and-prevention/the-friend-who-keeps-you-young>.
- [All03] K. Allen. "Are Pets a Healthy Pleasure? The Influence of Pets on Blood Pressure". In: *Current Directions in Psychological Science* 12.6 (2003), pp. 236–239. doi: <https://doi.org/10.1046/j.0963-7214.2003.01269.x>.

- [al17] P. M. D. et al. "The influence of dog ownership on objective measures of free-living physical activity and sedentary behaviour in community-dwelling older adults: a longitudinal case-controlled study". In: *BMC Public Health* 17.496 (2017), p. 496. DOI: 10.1186/s12889-017-4422-5.
- [al19e] C. W. et al. "Dog owners are more likely to meet physical activity guidelines than people without a dog: An investigation of the association between dog ownership and physical activity levels in a UK community". In: *Scientific Reports* 5704.9 (2019), pp. 1–10. DOI: 10.1038/s41598-019-41254-6.
- [al19f] D. B. et al. "Virtual Pet: Trends of Development". In: Springer, 2019. Chap. 2.
- [Maga] P. Magic. *Dogz-ComputerPet*. URL: <https://archive.org/details/Dogz-ComputerPet>.
- [Magb] P. Magic. *Dogz: Your Computer Pet*. URL: <https://www.mobygames.com/game/macintosh/dogz-your-computer-pet/screenshots/gameShotId,895443/>.
- [pix] pixelmood. *Digimon*. URL: <https://www.tamatalk.com/pixelmood/digimon.htm>.
- [Ada03] A. R. E. Adams. "Andrew Rollings and Ernest Adams on Game Design". In: New Riders, 2003. Chap. 16.
- [Jov] J. Jovi. *The life and death of Tamagotchi and the virtual pet*. URL: <https://wellcomecollection.org/articles/WsT4Ex8AAHruGfWb>.
- [Del] M. Delgado. *Keeping Tamagotchi Alive*. URL: <https://www.smithsonianmag.com/innovation/keeping-tamagotchi-alive-180979264/>.
- [New] futurezone Newsletter. *Nintendogs bekommt geistigen Nachfolger auf der Switch*. URL: <https://futurezone.at/games/nintendogs-bekommt-geistigen-nachfolger-auf-der-switch/400422437>.
- [Min] Minimap. *play with my pet*. URL: <https://minimap.net/game/playing-with-my-pet>.
- [Leo] D. Leorke. *A Definition and Brief History of Location-Based Games (2001–08)*. URL: https://doi.org/10.1007/978-981-13-0683-9_2.
- [Gro] Groundspeak. *Geocaching*. URL: <https://www.geocaching.com/play>.
- [Wik] Wikipedia. *Geocaching*. URL: <https://en.wikipedia.org/wiki/Geocaching>.
- [Man] T. P. Manhattan. *Pac Manhattan*. URL: <https://www.pacmanhattan.com>.
- [al16] A. B. et al. "Are Smartphones Ubiquitous?: An in-depth survey of smartphone adoption by seniors". In: *IEEE Consumer Electronics Magazine* 6.1 (2016), pp. 104–110. DOI: <http://10.1109/MCE.2016.2614524>.
- [cen] P. research center. *Tech Adoption Climbs Among Older Adults*. URL: https://www.silvergroup.asia/wp-content/uploads/2017/07/Technology-use-among-seniors_-_Pew-Research-Center.pdf.
- [al11b] I. P. et al. "Mobile applications in an aging society: Status and trends". In: *Journal of Systems and Software* 84.11 (2011), pp. 1977–1988. DOI: <https://doi.org/10.1016/j.jss.2011.05.035>.

Bibliography

- [Bar14] A. C. de Barros et al. "Design and evaluation of a mobile user interface for older adults:navigation, interaction and visual design recommendations". In: *Procedia Computer Science* 24.10 (2014), pp. 369–378. doi: <http://10.1016/j.procs.2014.02.041>.
- [al22b] G. H. et al. "How to design font size for older adults: A systematic literature review with a mobile device". In: *Frontier in Psychology* 13.931646 (2022), pp. 1–19. doi: <https://doi.org/10.3389/fpsyg.2022.931646>.
- [ELD] M. ELDERTECH. *Color in Designing Technology for Seniors*. URL: <https://eldertech.org/color-in-designing-technology-for-seniors/>.
- [Alsa] T. Alsop. *Number of mobile augmented reality (AR) active user devices worldwide from 2019 to 2024*. URL: <https://www.statista.com/statistics/1098630/global-mobile-augmented-reality-ar-users>.
- [Alsb] T. Alsop. *Investment in augmented and virtual reality (AR/VR) technology worldwide in 2024, by use case*. URL: <https://www.statista.com/statistics/1098345/worldwide-ar-vr-investment-use-case>.
- [Meh] Z. Mehkri. *How AR and VR are Driving the Next Era of Manufacturing*. URL: <https://industrytoday.com/how-ar-and-vr-are-driving-the-next-era-of-manufacturing>.
- [Unib] Unity. *Error-free maintenance and on-the-job training with AR*. URL: <https://unity.com/case-study/taqtile-augmented-reality-training>.
- [al21a] A. S. et al. "The Use of Virtual and Augmented Reality by Older Adults: Potentials and Challenges". In: *Frontiers in Virtual Reality* 2.1 (2021), pp. 1–5. doi: <https://doi.org/10.3389/frvir.2021.639718>.
- [al19g] S. M. et al. "Analysing recent augmented and virtual reality developments in tourism". In: *Journal of Hospitality and Tourism Technology* 10.4 (2019), pp. 571–586. doi: <https://doi.org/10.1108/JHTT-07-2018-0059>.
- [al20b] S. L. et al. "Location-based Games as Exergames - From Pokémon To The Wizarding World". In: *Annalen der Physik* 7.1 (2020), pp. 79–95. doi: <https://doi.org/10.17083/ijsg.v7i1.337>.
- [al20c] A.-I. C.-S. et al. "Effectiveness of Virtual Reality Systems to Improve the Activities of Daily Life in Older People". In: *International Journal of Environmental Research and Public Health* 17.6283 (2020), pp. 1–21. doi: <https://doi.org/10.3390/ijerph17176283>.
- [Lab] E. Labs. *Exer Health*. URL: <https://www.exer.ai/>.
- [Gmb] S. GmbH. *Ddaddabook*. URL: <http://iddadda.com/>.
- [Stab] Statcounter. *Mobile Operating System Market Share Worldwide*. URL: <https://gs.statcounter.com/os-market-share/mobile/worldwide>.
- [Pay] PaymentsJournal. *What Age Groups Own What Type of Smartphone?* URL: <https://www.paymentsjournal.com/what-age-groups-own-what-type-of-smartphone/>.

Bibliography

- [Sok] A. Sokolov. *ARkit vs ARcore: Which Development Kit Is Best for Building Augmented Reality Apps?* URL: <https://www.modelry.ai/blog/arkit-vs-arcore>.
- [Cut] M. Cutolo. *The Most Popular Puppy Names of 2022.* URL: <https://www.rd.com/list/most-popular-puppy-names>.
- [Sha] H. Shah. *6 Reasons Why Flask is Better Framework for Web Application Development.* URL: <https://able.bio/hardikshah/6-reasons-why-flask-is-better-framework-for-web-application-development--cd398f73>.
- [Bar11] J. A. Bargas-Avila. "Old wine in new bottles or novel challenges: a critical analysis of empirical studies of user experience". In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* 1.10 (2011), pp. 2689–2698. doi: <https://doi.org/10.1145/1978942.1979336>.
- [Yee07] N. Yee. "Motivations of Play in Online Games." In: *Journal of CyberPsychology and Behavior* 9.9 (2007), pp. 772–775. doi: <https://doi.org/10.1089/cpb.2006.9.772>.
- [al21b] I. B. et al. "Stride Length Predicts Adverse Clinical Events in Older Adults: A Systematic Review and Meta-Analysis". In: *Journal of CyberPsychology and Behavior* 26.10 (2021), pp. 1–12. doi: <https://doi.org/10.3390/jcm10122670>.
- [Liq] Liquid1ce. *The Importance of Tutorials in Games.* URL: <https://gameverse.com/2013/01/07/the-importance-of-tutorials-in-games>.
- [Zan09] P. Zandbergen. "Accuracy of iPhone Locations: A Comparison of Assisted GPS, WiFi and Cellular Positioning". In: *Transactions in GIS* 13.6 (2009), pp. 5–25. doi: <https://doi.org/10.1111/j.1467-9671.2009.01152.x>.
- [al20d] M. C. et al. "Real-time video stabilization via camera path correction and its applications to augmented reality on edge devices". In: *Computer Communications* 158 (2020), pp. 104–115. doi: <https://doi.org/10.1016/j.comcom.2020.05.007>.
- [al21c] Z. L. et al. "Real-time image processing for augmented reality on mobile devices". In: *Journal of Real-Time Image Processing* 18 (2021), pp. 5–25. doi: <https://doi.org/10.1007/s11554-021-01097-9>.