



INSTITUTO SUPERIOR TÉCNICO  
Universidade Técnica de Lisboa

# **iPleo, the Emotional Pet**

## **Evaluating User Attachment in a Pervasive Pet Game**

**Tiago Gonçalves Tavares de Paiva**

Dissertação para obtenção do Grau de Mestre em  
Engenharia de Redes de Comunicações

**Júri**

Presidente:	Prof. Doutor Rui Jorge Morais Tomaz Valadas
Orientador:	Prof. Doutor Ana Maria Severino de Almeida e Paiva
Vogal:	Prof. Doutor David Martins de Matos

**October 2010**



# Acknowledgements

I would like to express my profound gratitude to my parents for their unconditional love and support and for their endless friendship.

During my work, I benefited from the fruitful collaboration with my coordinator Ana Paiva and with the remaining members of the GAIPS team working on the LiREC project, namely Iolanda Leite, André Pereira and Paulo Gomes.

Last but not least, I would like to express my most affective thanks to Cristina, among other reasons, for being always there.

Lisboa, October 2010

Tiago Gonçalves Tavares de Paiva



For my parents.



# Resumo

Esta tese aborda o problema de criar relações emocionais entre um utilizador e um animal de estimação artificial. O uso destes animais tem sido usado em diferentes domínios. No contexto de um jogo, propomos um modelo conceptual que usa um animal de estimação artificial na forma física (um robô), e um animal de estimação na forma virtual (num dispositivo móvel) com o objectivo de avaliar a qualidade das relações entre o utilizador e o agente. Nesta tese, desenvolvemos uma aplicação de um animal de estimação virtual contendo um comportamento cognitivo e emocional baseado na teoria PSI. Apresentamos também uma avaliação mostrando as vantagens de usar este tipo de modelo ao invés de um modelo tradicional que usa apenas uma das componentes, virtual ou física. O resultado dá a entender que os utilizadores se sentem emocionalmente mais ligados e têm uma experiência mais divertida quando interagem com o seu animal em ambos os meios do que se a interacção se restringir apenas ao meio físico.





# Abstract

This thesis addresses the problem of improving attachment between humans and synthetic pet characters. The use of these pets and its usefulness is recognized in different domains. In this context we propose a conceptual model contemplating the use of a physical pet (in a robotic embodiment) and a virtual pet (in a mobile device), aiming to improve the quality of the relationship between the owner and the pet agent. We provide an implementation of a virtual pet game with a cognitive and emotional behaviour based in the PSI-Theory. An evaluation showing the advantages of using our pervasive solution over a more traditional solution is also detailed. It suggests that users feel more emotionally connected when interacting with the pet in the physical form and in the virtual form, than if the interaction is only with the robotic character.



# Palavras Chave

## Keywords

### **Palavras Chave**

Agentes

Relação

Jogos Pervasivos

Migração de dados

### **Keywords**

Agents

Attachment

Pervasive Gaming

Data Migration



# Table of Contents

<b>1</b>	<b>Introduction</b>	<b>3</b>
1.1	Motivation . . . . .	3
1.2	Objectives . . . . .	4
1.3	Contributions . . . . .	4
1.4	Results . . . . .	5
1.5	Structure of the Document . . . . .	5
<b>2</b>	<b>Related Work</b>	<b>7</b>
2.1	Background and Theory on Human-Animal Interaction . . . . .	7
2.2	Relational Agents . . . . .	9
2.3	Artificial Pets in Virtual Environments . . . . .	10
2.3.1	Tamagotchi . . . . .	10
2.3.2	Nintendogs . . . . .	11
2.3.3	My-Mini-Pet and My-Pet . . . . .	12
2.3.4	Virtual Polar Bear . . . . .	13
2.4	Artificial Pets with Robotic Embodiments . . . . .	14
2.4.1	Pleo . . . . .	15
2.4.2	AIBO . . . . .	17
2.4.3	Paro . . . . .	18
2.5	PSI-Theory . . . . .	20

2.6	Pervasive Gaming . . . . .	21
2.6.1	EyePet . . . . .	22
2.6.2	SenToy . . . . .	24
2.6.3	Wii Sports . . . . .	25
2.7	Discussion and Comparison . . . . .	26
2.8	Robot and Mobile Device Integration . . . . .	27
2.8.1	Communication Between Robot and Mobile Device . . . . .	27
2.8.1.1	IEEE 802.15 - Bluetooth . . . . .	28
2.8.2	XML . . . . .	28
<b>3</b>	<b>Conceptual Model</b>	<b>31</b>
3.1	Introduction . . . . .	31
3.2	Conceptual Model of a Traditional Virtual Pet Game . . . . .	32
3.2.1	Virtual Domain . . . . .	32
3.3	Conceptual Model of a Traditional Pet Robot . . . . .	33
3.3.1	Social Domain . . . . .	33
3.3.2	Physical Domain . . . . .	33
3.4	Conceptual Model of a Pervasive Pet Game . . . . .	33
3.4.1	Physical Domain . . . . .	34
3.4.2	Virtual Domain . . . . .	35
3.4.3	Social Domain . . . . .	35
3.5	Detailed Conceptual Model . . . . .	35
3.5.1	Pet Agent . . . . .	35
3.5.1.1	Pet Needs . . . . .	36
3.5.1.2	Attachment . . . . .	37

3.5.1.3	Communicating Internal States . . . . .	38
3.5.2	Game Device / Robot . . . . .	39
3.5.3	Game Engine . . . . .	39
<b>4</b>	<b>Implementation</b>	<b>43</b>
4.1	Introduction . . . . .	43
4.2	Pet Agent . . . . .	44
4.2.1	Agent Needs . . . . .	44
4.2.2	Attachment . . . . .	45
4.2.3	Communicating Internal States . . . . .	45
4.3	GUI - Graphical User Interface . . . . .	45
4.4	Game Engine . . . . .	47
4.5	Integrating the Game with the Robot . . . . .	51
4.5.1	Network Communication . . . . .	51
4.5.2	Understanding the Data . . . . .	52
4.5.3	Enabled Actions . . . . .	52
<b>5</b>	<b>Evaluation</b>	<b>55</b>
5.1	Introduction . . . . .	55
5.2	Research Question . . . . .	55
5.3	Methodology . . . . .	55
5.3.1	Measurements . . . . .	56
5.3.2	Participants . . . . .	56
5.3.3	Procedure . . . . .	56
5.4	Results . . . . .	59
5.4.1	User Attachment . . . . .	59

5.4.2	Perceived Expressions . . . . .	64
5.4.3	Playing Games and Carrying Pleo . . . . .	65
5.4.4	iPleo Specific Questions . . . . .	65
<b>6</b>	<b>Conclusions</b>	<b>69</b>
6.1	Conclusions . . . . .	69
6.2	Future Work . . . . .	69
	<b>Bibliography</b>	<b>75</b>



# List of Figures

2.1	Tamagotchi. . . . .	11
2.2	My-Mini-Pet game. . . . .	13
2.3	Polar bear. . . . .	14
2.4	Pleo dinosaur. . . . .	15
2.5	Sony's AIBO. . . . .	17
2.6	Paro. . . . .	19
2.7	Eyepet. . . . .	23
2.8	SenToy. . . . .	25
2.9	Wii Remote. . . . .	25
3.1	Conceptual model of a pervasive pet game. . . . .	34
4.1	General implementation diagram. The focus of this thesis is on the left side. . . .	43
4.2	Interface for displaying the pet needs. . . . .	44
4.3	Different attachment levels. . . . .	45
4.4	Some expressive behaviour animations. . . . .	46
4.5	Graphical User Interface. . . . .	46
4.6	iPleo training track . . . . .	47
4.7	iPleo's state machine . . . . .	48
5.1	Participant's Use Questions. . . . .	57
5.2	Question 2 (Pleo provides me with pleasurable activity) answers distribution. . .	62

5.3	Question 3 (Pleo is a source of constancy in my life) answers distribution. . . . .	63
5.4	Question 5 (Pleo makes me play and laugh) answers distribution. . . . .	63
5.5	Question 6 (I enjoy watching my Pleo) answers distribution. . . . .	64
5.6	Resemblance with Pleo robot. . . . .	66
5.7	Interacting with Pleo when the battery is off. . . . .	66
5.8	Participant’s comments and suggestions. . . . .	66

# List of Tables

2.1	Summary of the artificial pets discussed. . . . .	26
3.1	Weight of each variable. . . . .	37
4.1	Relationship between attachment level and character expressions. . . . .	45
4.2	Initial values of each need. Max. value = 255. . . . .	49
4.3	Decreases of each need. Max. value = 255. . . . .	49
4.4	Changes in game character's needs. Max. value = 255. . . . .	50
4.5	Conditions and transitions of the game state machine. . . . .	51
4.6	Possible actions in the two environments. . . . .	52
5.1	User attachment Wilcoxon signed-rank test ranks. . . . .	60
5.2	User attachment Wilcoxon signed-rank test statistics. . . . .	60
5.3	Wilcoxon signed-rank test statistics for each question. . . . .	61
5.4	Perceived expressions Wilcoxon signed-rank test ranks. . . . .	64
5.5	Perceived expressions Wilcoxon signed-rank test statistics. . . . .	65
5.6	Carrying and Playing Games questions Wilcoxon signed-rank test ranks. . . . .	65
5.7	Other questions Wilcoxon signed-rank test statistics. . . . .	65



# Acronyms

**AI** Artificial Intelligence

**CCAS** Comfort from Companion Animals Scale

**GAIPS** Intelligent Agents and Synthetic Characters Group

**GUI** Graphical User Interface

**OS** Operating System

**PDA** Personal Digital Assistant

**PSI** Personality Systems Interaction

**USB** Universal Serial Bus

**XML** Extensible Markup Language



# 1 Introduction

## 1.1 Motivation

It is safe to assume that humans and animals have been interacting since the beginning of times and strong relationships between them can be established (Reeves 1994). In some countries, animals are being used as a therapeutic method to help patients with disabilities (Wada & Shibata 2006). Studies have revealed that pet ownership increases survival rate after heart attack and produces a calming effect in humans.

Humans are social beings and as such need support from each other. Support comes from interactions with others, and from relationships established during our lives. However, nowadays creating relationships with others is not always easy (for example, for elderly isolated people). As such, there is an increasing interest in the construction of systems, robots and virtual characters, that allow for the establishment of relations with users. In fact, in certain specific circumstances, syntetic characters can have an important role in addressing this problem. These relationships with syntetic characters may also be helpful in the performance of difficult tasks or in helping users with physical/mental problems performing simple tasks.

While the concept of owning a pet is ancient, it is only during the last decade that syntetic characters are being used to play the role of animals. These agents can be presented in robotic forms and can be used to simulate animals in places where an animal cannot be present. They are also used by people who, for some reason cannot own an animal.

Apart from robots, syntetic characters can also exist as game characters. During the past decade, several games containing an animal as a game character were created with the goal of emulating the life and relationships of an animal. Some of these games have been a huge success: Tamagotchi (Lawson & Chesney 2007) and more recently Nintendogs (S Lawson 2007) are good examples.

With the recent advances in technology, it is now possible to create games which combine

virtual world entertainment with real world entertainment (Magerkurth, Cheok, Mandryk, & Nilsen 2005). These pervasive games are no longer limited by the virtual domain of the computer but can also integrate and use aspects of the real world. These games intend to achieve a better playing experience by connecting elements of the virtual world with elements of the physical world. By making games more real, localized and aware of its context, it is now possible to try to improve the player's attachment with the synthetic agent in a virtual pet game.

## 1.2 Objectives

This work addresses the problem of creating attachment bonds between humans and syntetic characters . In particular, we are interested in knowing if humans can create stronger attachment bonds with a syntetic character by playing a pervasive pet game. Thus, the main question addressed by this thesis is the following one:

Do people create stronger attachment bonds with an artificial pet by playing a pervasive pet game (physical and virtual embodiment) than by interacting with a traditional pet robot?

To accomplish this goal we have developed a pervasive game containing a syntetic character with an emotional and cognitive behaviour model associated to a physical pet robot. The hypothesis of this thesis can be described as follows:

If we create a pervasive pet game by putting together a virtual game containing a cognitive and emotional behaviour, with a physical robot, we will be able to improve user attachment with an artificial pet.

## 1.3 Contributions

This work analyses, implements and evaluates a solution that aims to improve the relationship between a player and a synthetic character. As a result, the thesis makes the following contributions:

- It presents a conceptual model for a pervasive pet game;



- It proposes a cognitive and emotional behaviour for a pet character based on drives.

## 1.4 Results

The results produced by this thesis can be enumerated as follows:

- Implementation of a virtual pet game following a pervasive game conceptual model;
- An experimental evaluation of the implementation with users;
- An experimental evaluation of user's relationship with a pet robot.

## 1.5 Structure of the Document

This document is organized as follows. Chapter 2 describes the background related to our work. Chapter 3 presents the proposed architecture introducing the conceptual model that is behind our work. Then we describe how we have implemented the system (Chapter 4). Chapter 5 presents the results of the experimental evaluation study. Finally, Chapter 6 concludes this document by summarizing its main points and future work.



# 2

## Related Work

In this chapter we survey some of the related work on human agent interaction, artificial pets, both with virtual and robotic embodiments and pervasive games. Since the focus of this work is human interaction with virtual pets, a good knowledge of how humans interact with animals and how good they can improve humans life is discussed. Relational agents are also surveyed and can provide good learnings in how humans interact with virtual agents. As this work will be related with a virtual pet, applications and other agents related to the field are also studied. To conclude the section we discuss pervasive gaming in the context of virtual pets.

### 2.1 Background and Theory on Human-Animal Interaction

It is widely known that human-animal interaction has been beneficial to people. Animals interaction with people and its benefits have long been researched and proven scientifically by researchers who have studied the implications in children, elderly and demented people.

Friedmann (Friedmann, Katcher, Lynch, & Thomas 1980) was one of the first researchers to notice that animals could help people. He studied the survival rate of patients discharged from a coronary care unit and states that those who had pets have a higher survival rate than those who do not. After him, many other researchers started to study human-animal interactions and its benefits for humans. The connection between a human and a pet can be such that, some cancer survivors even attribute part of their cure to their pets, as described by Jack L. Stephens (Rebecca A. Johnson & Sevedge ):

” I firmly believe I won (my battle with cancer) in part because of my miniature pinscher Spanky. [...] He graped what was happening and made it his mission to buoyantly comfort me no matter what my disposition, to get me outside for wals, entertained us or was simply there - quiet and patient. [...] ”

That quote, said by a former cancer patient, shows how much owning a pet can improve human life. From a medical point of view, the pet did nothing to help curing the cancer; from an emotional one, it gave companionship and emotional strength.

Some researchers argue that owning a pet can decrease your systolic blood pressure and plasma cholesterol (Anderson, Reid, & Jennings 1992), while others affirm that cardiovascular diseases can be reduced (Patronek & Glickman 1993).

Children can be much rewarded by owning a pet. According to Filiatre *et al.* (J. C. Filiatre ), animal contact in childhood can improve the development of communication skills. Other study conducted by Melson (G. F. Melson 1997) suggest that children, specially males, can learn how to nurture. Moreover, Beck *et al.* (Beck 2001) states that owning a pet can motivate children and define how they see the world.

Some researches go beyond that. Allen *et al.* suggested that pet ownership can be used to treat hypertension (Allen, Shykoff, & Izzo 2001). Humans need others support, bonding with pets may not be enough, specially for elderly people who are not capable of performing common tasks by themselves (Simon 1984).

Animals are being used in Animal-Assisted Therapy (AAT) to fight dementia, loneliness and, even Alzheimer's disease (Verderber 1991). Batson *et al.* (Batson 1995) concludes that having a dog can increase social behaviours in elderly people. The problem appears when more people and more animals are put together. With a bigger environment, safety and hygiene becomes difficult to control. Even the most well trained animals can sometimes have reactions that are not controlled by humans and, although the results taken from human interaction with animals are good, there are always certain unexpected risks.

It is clear that in one way or another, animals are an important part of people's life. They can contribute to, in some ways, social interaction in terms of companionship and care. Animals can be trained to perform difficult tasks such as help demented people, nurture children and lead blind people. Their training is not easy and not all the animals are good for the job. It requires many human resources, money and time.

## 2.2 Relational Agents

Relational agents are computer artifacts designed to build and maintain long-term relationships with their users (Bickmore, Mauer, & Brown 2009). In order to achieve that goal, they need to create and remember past interactions with humans and, since relationships are based on emotion and affect, a relational agent is supported by findings in human psychology. Relational agents can provide benefits in education, care, rehabilitation, among others. They are being tested among elderly people, children and patients. A relational agent can be presented in several types of devices, such as hand-held devices, computers or robots.

Relational agents are used to simulate human conversations, as the one described by Bickmore (Bickmore, Mauer, & Brown 2009), which is a health counseling agent in a hand-held device designed to increase user physical activity. The agent is capable of simulating human behaviour by using facial and body expressions, social cues, empathy, affective reactions and so on. It also interacts with the user through dialogue by using predefined interaction scripts. As a result, the user is able to create bonds and trust the agent. The user needs to trust the agent suggestions and, for that he needs to see the agent like a skilled person that is able to help him in a particular problem.

Humanoid relational agents, like the one exhibited by Bickmore, are being tested in areas like healthcare. They are used to explain complex medical documents to patients, while creating bonds with them (Bickmore, Pfeifer, & Paasche-Orlow 2009). There are several advantages of using a relational agent in healthcare. First and foremost, the costs for the hospital can be substantially low and, for the patient, the agent can have the patience and time that the user requires to understand a specific situation, whereas doctors may not have it.

Although studies reveal that humans can interact and create bonds with a relational agent, relational agents still have a long way to go until they become fully autonomous. Dialogue still needs to be scripted prior to the interaction and the dialogue between the user and the agent is still very limited by the predefined options that are given to the user.

Besides relational agents, other methods of interaction are being used to create relationships with humans. Robots looking like humans (humanoid robots) and robotic pets (animal like robots) are the most common ones. The biggest advantage of a relational agent is its conversation skills. Although predefined, they are still similar to a human conversation, whereas relationships

with robotic pets lack the capabilities of a human-human interaction.

## 2.3 Artificial Pets in Virtual Environments

Since the great success of the Tamagotchi in 1997, virtual pets have been a permanent part of people's lives. For the game industry, virtual pets have been a huge source of income, like the virtual pet game Nintendogs, accountable for more than 7 million sales worldwide or the on-line pet nurturing website success neopets <sup>1</sup>. Some game creators also claim that virtual pets can be used as a test to see if the children has pet-ability (S Lawson 2007). Others argue that taking care of a virtual pet develops our attention spans and motor skills <sup>2</sup>.

A questionnaire deployed by Lawson and Chesney (Lawson & Chesney 2007) determined that virtual pet owners can experience companionship with their virtual pet, even though the results were better for younger subjects. Virtual pets can be used not only as a companion but also as an educational tool, care, entertainment, among others. The rest of this section presents different uses given to artificial pets in virtual environments.

### 2.3.1 Tamagotchi

Tamagotchi (Figure 2.1), created in the late 1990s by Bandai, a Japanese toy manufacturer, was the first of a series of key-chain virtual pets that flooded the toy market for several years. Tamagotchi has the physical shape of an egg, three buttons, a speaker, a microphone and a motion sensor (Lawson & Chesney 2007). Although the pet did not look much like a real animal, owners were able to feed, clean and play with their Tamagotchi, just like they would do with a known animal. Depending on the interaction between the owner and the virtual pet, Tamagotchi's were able to evolve and eventually die. If the owner did not interact enough or did not take care of his pet correctly, the pet would die.

It was such a big success that other virtual pets started to be developed. Initially Tamagotchi was commercialized targeting the female public but, male public was also very interested in owning a virtual pet. With that recent development, other Tamagotchi's forms were created:

---

<sup>1</sup><http://www.neopets.com/>, Accessed on 21/12/2009.

<sup>2</sup><http://www.gamesforhealth.org/news/archives/000086.html>, Accessed on 15/12/2009.



Figure 2.1: Tamagotchi.

dragons, cats, dogs, chickens and babies were the most successful. Other shapes like an alien or robot were also created, though without the same success as the previous ones.

It is clear that many owners became attached to its pet, some even mourned its death, created virtual cemeteries, and some others even created real cemeteries (Bloch & Lemish 1999).

Being the first virtual pet adopted worldwide, from children to adults, it marked the beginning of a new era where people would use virtual characters as a form of replacing their pets. Tamagotchi, due to the evolution of technology, lacked many of the features that new virtual pets have, but it served as an inspiration for the development of all the others that succeeded it.

### 2.3.2 Nintendogs

Just like Tamagotchi, Nintendogs was created with the purpose of replacing real pets and provide companionship to its owners. Nintendogs was created by Nintendo, a Japanese video-games manufacturer. It is a game that runs on a hand-held device console, with full bright color screen, Nintendo DS, and is aimed at children. Nintendogs provides a virtual pet to its owners, where they are able to feed, water, walk, play and train it. Unlike Tamagotchi, the touch screen provided by Nintendo DS allows owners to a more complete interaction with its pet, which is animated in the form of a realistic animal. A psychologist, hired by Nintendo states that <sup>3</sup> (Lawson & Chesney 2007):

”[...] it can not only help develop our attention spans and motor skills, but also improves our ability to solve problems and think creatively ... teaches us how to

<sup>3</sup><http://www.gamesforhealth.org/news/archives/000086.html>, Accessed on 15/12/2009.

bond and provides us with a sense of nurture and responsibility [...] (and has) emotional effects, helping to raise self-esteem and develop strategic thinking.”

The idea of gaining real benefits by owning a virtual pet can be misleading. Chesney and Lawson (Chesney 2007) concludes that Nintendogs does give some kind of companionship, but significantly less than the one given by a real pet.

Nintendo claims that Nintendogs sold more than 7 million units worldwide (S Lawson 2007), being one of the biggest successes of Nintendo DS. Nintendo was able to use the most recent technology to recreate the life of a real animal, making it almost real on the screen. With the evolution of technology, the bonds created between human and the virtual animal can, in some ways, be like the ones with a real animal, and the tendency is to increase, due to new technology developments discovered everyday.

Technology also enables new forms of interaction that were not possible before (just like in 1997, when the creation of Tamagotchi). By using the touch screen, Nintendogs users were able to touch their pets, even if not like touching a real animal (lack of pelage, etc), it increases the odds of bonding and attaching to it. Another big advantage of Nintendogs is their game scenario. Users can play with their pets much like they would play a real game and, since games are an old human habit, putting together a game and a pet can increase the relationship between the user and its character, in this case a virtual pet.

### 2.3.3 My-Mini-Pet and My-Pet

Liao *et al.* (Liao, Chen, & Chan 2008) developed a pet-nurturing hand-held game (My-Mini-Pet) to improve the motivation to learn by nurturing a virtual pet (Figure 2.2). During the game the user needs to learn new things about a specific subject in order to keep playing. The goal is to make the user attracted to the game to a point where he wants to learn, and after successfully solving assessment tests, he can see his pet growing. The pet will progress depending on how much the user learns. The user has the possibility to name his pet and buy food for him, making the interaction more like a real animal, which increases the probability of creating attachment with the virtual pet.

The same authors studied the effectiveness of the My-Mini-Pet game in terms of motivation and learning (Calvin C.Y. Liao ) when compared to other game with the same objective. The





Figure 2.2: My-Mini-Pet game.

results indicate that My-Mini-Pet was superior in terms of motivation, attention and relevance than the other game. The combination of pet-nurturing and game have increased the users motivation for learning, since they could see practical results of their study (the growth and evolution of a pet).

My-Pet (Zhi-Hong Chen a) was built with the same purpose as the My-Mini-Pet game, but instead of being developed for a hand-held device, it is for a desktop computer. The user is responsible for taking care (e.g.: buying food) of a virtual pet. During the game, the user needs to do assessment tests to prove his knowledge: if he shows that he is learning, both the game and the pet will progress. Depending on how much the user learns, the pet will grow and be happier.

A trial study showed that My-Pet, as it happened with the hand-held version My-Mini-Pet, can also motivate users to learn. However, in comparison to My-Mini-Pet, users improved more in a shorter period of time with My-Pet (Zhi-Hong Chen b). My-Pet was also used as a substitutive competition, where users would engage other pets as a way to increase their learning capabilities (Chen & Chan 2008). Not to forget that the studies with My-Pet are much more preponderant, since the experiment was performed with much more subjects than with My-Mini-Pet.

### 2.3.4 Virtual Polar Bear

(T. Dillahunst & Kraut ) developed an interactive polar bear with the goal of creating a positive impact on real-world decisions concerning the environment. The virtual polar bear (Figure 2.3) inhabits in an ice floe that increases or decreases its size depending on the good or

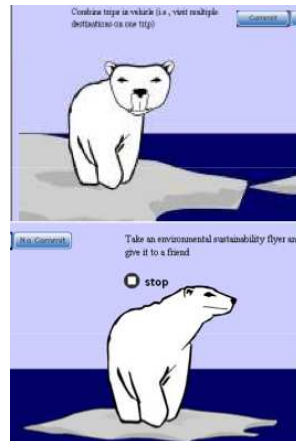


Figure 2.3: Polar bear.

bad environmental actions performed by its users. The study divided the subjects in two groups: subjects who were emotionally attached to the virtual polar bear and subjects who were not attached to it. The results demonstrate that users who were emotionally attached to the polar bear took more good decisions than the ones not attached to the bear. Although this study was realized with few subjects, the conclusions suggest that it is possible to create bonds with a virtual animal, and base some decisions in the well-being of that animal, even if its not a real one.

This study uses virtual animals in an innovative way by getting inspiration on animals that may be under extinction. It attempts to induce people to care about something.

## 2.4 Artificial Pets with Robotic Embodiments

As stated before, animals not only are a great form of entertainment and companionship but they are also used to improve peoples lives. They have been trained to help blind people and recently they are being used as a therapy tool for problematic people. However, even the best trained animals can be unpredictable. Therefore, there is always a risk by using animals in these situations.

Using animals to perform such tasks brings some problems, like safety and hygiene. To overcome such problems, robots are being created to replace real animals in those tasks. Their use go from entertainment (e.g.: AIBO), to therapy (e.g.: Paro) and beyond. Robots can be designed with several different ends. They are commonly used in industry (for example, in



Figure 2.4: Pleo dinosaur.

factories), to automate human tasks. Other robots have the goal to assist humans performing their job, like helping police forces to deactivate a bomb or, a fireman ceasing a fire. In some situations, robots even replace humans in tasks that were not humanly possible, just like space travelling to distant planets to collect samples and deprave the territory. But in the last few years a new area has emerged: social robots, which are robots especially designed to interact with people.

The following sections will focus on these kind of robots.

### 2.4.1 Pleo

Pleo (Figure 2.4) is a robotic toy designed in the form of a dinosaur to emulate the behaviour of a live pet. The main goal is to create long-term attachment with its owners and simulate the bonds created with a dog, cat or any other pet. He can "feel" and convey emotions, be aware of themselves, learn and evolve over time (PleoWorld ).

Pleo has three different life stages, and the progress depends on the level of interaction with the owner. As it progresses through the different stages, it shows different levels of understanding, movement and behaviours. The idea is to replicate the life of a real animal, from the first day of life until their death. During the first stage, the birth, he starts opening his eyes and starts adapting to the environment. Its movements are slow and he can barely stand on feet. Depending on the interaction with him, he evolves to the hatching phase where he starts begging for food, walking and exploring the environment. During this phase he also starts to sleep like a baby and show some emotions. The next and final stage is the juvenile, where he has the ability to learn and he is fully capable of moving.

Pleo has behavioral instincts, it can "feel" the need to eat, sleep, interact and explore and

he can respond to external stimuli's such as sound, light touch and objects. He can also express some emotions (happy, sad, curious and scared). Depending on the feeling it is experiencing, he responds to the environment using sounds, movements or taking a nap, just like a real animal would do.

Mattias Jacobsson (Jacobsson 2009) performed a study to know whether or not a human could create attachment bonds with Pleo. He started by reading the blogs of 520 Pleo owners, watching videos showing interactions between human-Pleo and analyzing the different feelings of the owners when their Pleo came to life, had a technology problem or was used as a social engagement tool. Jacobsson describes that some owners bought Pleo instead of a real pet or to forget the loss of a real pet. Other users described a great amount of emotion when Pleo went out of the box for the first time, connecting to him instantaneously, while others got so attached to their pet that when Pleo had problems in his skin or, any other technological problems, they did not allow the company to replace their pets with new ones with different personalities. The bond that some users feel with Pleo is so great that they do not resist to spend time without him while in the factory for fixing, voiding the guarantee and nursing the pet by themselves. The author also describes how some users use Pleo as resource for social engagement. A user reveals that he has friends come over to his home just to be entertained by Pleo, while other users who also have real animals describe situations where Pleo interacts with them as being a equally live being. Jacobsson concludes that interacting with Pleo can really create strong attachment bonds and can even replace the long-term bonds created with a real animal.

Another study exhibited by Ryoaki *et al.* (Ryokai, Lee, & Breitbart 2009), uses Pleo to interact with children and study their reactions to the robotic animal. Children had to create new stories using Pleo as a character, and the study reveals that after having all the children interacting with the robot, they not only like to interact with it, as they would with a teddy bear, but they also try to teach them how to perform different tasks and, expect different reactions from him, as they would with a real animal.

Pleo also has the ability to social assist inpatients. Secret Heart Hospital's Rehabilitation Center uses Pleo as a form of therapy for their inpatients. One of the residents in the hospital describes that during his time in the hospital, Pleo took the place of his dog and he will miss it. Other person reveals that the dinosaur was important to his staying in the hospital, in a way that he spent time watching it walking around and interacting with it, making the time more



Figure 2.5: Sony's AIBO.

enjoyable. The staff at the hospital is very happy with the results of using Pleo as a therapy tool as it enhances motor skills in inpatients (patients who reside in a hospital).

### 2.4.2 AIBO

Sony's AIBO, represented in Figure 2.5, is one of the most popular entertainment robots, and one of the first robot created for commercial uses. However, due to its interesting nature, it has been widely studied by researchers. AIBO is shaped in a form of a dog-puppy and its actions try to emulate a real dog. As a trained dog, commands like "sit down", "good boy", "don't do that", among others are recognized by the robotic pet and will result in a specific action. AIBO also recognizes a pink ball which it uses to play and perform tricks.

During its "life", AIBO has several stages of maturation. The first four stages are babyhood stages, where it starts to cry a lot, express its emotions, starts to recognize its pink ball and play with it and, after recognizing its name and, depending on the interaction that the user has with it, it will evolve to the later stages of maturation. In the last stages of maturation, AIBO is able to use the external information that it gets from its sensors and its own internal motivations to adapt to its owner and its surroundings. As for example, if an owner talks and interacts with AIBO since the first babyhood stages, AIBO will be more social and interact more with its owner and other humans, much like a real dog would do.

The quest for knowing if AIBO can replace a real pet has resulted in different studies testing that hypothesis. A study conducted by Friedman *et al.* (Friedman, Kahn, & Hagman 2003), focus in what online AIBO discussion forums reveal about the human-robot relationship. The study reveals that almost half of the participants referred to AIBO as having feelings, while only 26% think of him as a companion. Results showed that, although most of the participants think

that AIBO does not have rights (e.g., the right not to be abused) and knowing that AIBO is a robotic pet, they could ignore it whenever they desire, they also think that they can feel real affection towards it and have all the other benefits they would have with a real animal.

Bartlett *et al.* (Bartlett, Estivill-Castro, & Seymon 2004), suggests that people interact with AIBO as they would interact with a live-dog. Another study that examines preschool children behaviour while interacting with AIBO (Kahn, Friedman, Perez-Granados, & Freier 2004) compares different behaviors toward AIBO and a puffy dog, and concludes that children generally have the same kind of behaviors towards the two artifacts. Also, the study suggests that there is no difference in the form in which they interact with AIBO compared with a live-dog. Melson *et al.* (Melson, Kahn, Beck, Friedman, Roberts, & Garrett 2005) compared children's interactions with AIBO and a live-dog and, like the above authors, concluded that although they distinguished AIBO from a living dog, the majority of children interact with AIBO the same way as they interact with the live-dog.

Canamero *et al.* (Hiolle, Bard, & Canamero ), exhibited a study using two baby-AIBO's with different attachment profiles: one requiring less attention and the other more needy, requiring more attention. Although all the participants felt a high level of enjoyment while interacting with both versions, most of the participants considered the non-needy robot more boring and less entertaining as opposed to the needy-robot. The results diverged by age and gender, which indicates that those factors influence the enjoyment when interacting with AIBO.

Bartneck *et al.* (Christoph Bartneck & Nomura<sup>4</sup> ) also reveals that the human attitude towards robots can improve after interacting with a AIBO robot.

### 2.4.3 Paro

Paro (Figure 2.6) is a baby harp seal robot designed for therapy by interaction. Designed as a way to substitute animal therapy (Wada & Shibata 2006), Paro has been used in several different kinds of therapy involving children, elderly people and demented patients. Animal therapy is already recognized as being an effective form of therapy to patients. However, some hospitals do not allow animals to enter the installations, which completely deny the possibility of animal therapy. Paro was created to substitute animals in such hospitals, and since it is a robot, safety and sanitary problems are no longer a concern.



Figure 2.6: Paro.

Paro has the four primary senses: audition, tactile, sight and balance. Paro can also have three types of behaviour: proactive, physiological, and reactive (Wada, Shibata, Saito, & Tanie 2004). Interaction with it defines its character which makes it difficult to predict Paro's next action. Paro can also react to sounds and can memorize a frequent word such as its name. It also has spontaneous needs, such as sleep, just like any other animal.

This robot was used in a robot-assisted activity for elderly people and nurses at a day care center during five weeks (Wada, Shibata, Saito, & Tanie 2004). The interaction with the robot resulted in an improved mood state of the elderly and, this effect was unchanged during all the five weeks, having decreased after the fifth week. During the interaction with Paro, nurses reported that the elderly people were more active and communicative, not only among them but also with the nursing staff. An elder with dementia improved her state, becoming brighter and happier during the interaction with Paro. Another elder revealed that she stayed in the care center only to play with Paro. Urinary tests made after the interaction with Paro revealed that the levels of stress decreased and the amount of work by the nursing staff also decreased. The study concludes that Paro, a seal robot, can be used in elderly institutions as a form of therapy for elderly people.

Another experiment (Wada, Shibata, Saito, Sakamoto, & Tanie 2005) used Paro as a robot-assisted activity for elderly people during a year. The goal was to know if the levels of happiness during small interactions with Paro could be maintained during long-term periods, therefore, replacing real animals in animal therapy. During the year, the elderly people as well as the nursing staff, attached to the seal robot as it was a real animal. Users considered the interactions as if Paro were like human-animal, giving it a real animal name, stroking, kissing and hugging it. They even created a home for Paro to sleep, as it was a real pet. As in the prior study at a day care center, Paro improved the communication among elderly people and nursing staff. Even after a year, elderly people did not lose interest in Paro, as it is common when playing

with a toy.

Paro is not only helpful in elderly people therapy (Wada, Shibata, Saito, & Tanie 2004) (Wada, Shibata, Saito, Sakamoto, & Tanie 2005) but also in children therapy. Shibata *et al* (Shibata, Mitsui, Wada, Touda, Kumasaka, Tagami, & Tanie 2001) used Paro in a pediatric therapy at a university hospital. He concluded that the children were calm and, having fun during the interaction with Paro. One autistic child even regained his appetite and speech after three weeks with Paro.

## 2.5 PSI-Theory

Artificial pets referred in the previous sections (both in virtual environments or with robotic embodiments) aim to simulate real animals. So, their mind model should represent an intelligent, motivated, emotional agent.

PSI-Theory (Bartl & Drner 1998), is about human action regulation, intention and behaviour. The theory describes a comprehensive model of the human brain, its cognitive processes, emotion and motivation. The cognitive processes are modulated by emotional states and processes.

This theory was proposed by Dorner, and aims at explaining human behaviour by simulating it on the computer. The needs that constitute this theory are described as follows:

- **Need for Energy and Water** (basic preserving needs)
- **Need for Affiliation** (need to belong to a group; need for social interactions)
- **Need for Certainty** (being able to predict with a high degree of certainty the results of its actions)
- **Need for Competence** (being able to perform difficult tasks including being able to satisfy its own needs)

The architecture of this model comprises a motivational system, symbolized by tanks. Each tank represents a motivator. Each motivator is represented by a variable and when that variable deviates from its set point, the motivator becomes active. In order to restore the variable set



point, meaning that there is a need, activities need to be launched. Deciding which motivators are necessary have caused a great discussion but some conclusions have been reached. The organism needs to preserve its own existence, meaning that water and energy are essential and are the most important motivators. Also, the organism needs informational needs, meaning a need for certainty, competence and affiliation are also important.

Each need has its own weight. The organism has a great influence in the emerging needs (if it spends more energy than usual, the need for energy will emerge faster). The deviation from the set point and the weight symbolizes the strength of a need. Satisfying a need requires different approaches and several needs can be activated at the same time. Success probability and urgency, together with the strength of the need play an important role in deciding which need is activated. If the organism has very few possibilities of satisfying the need or if the need can only be satisfied during a defined moment in time, the urgency is very high and it will have great influence in which need is activated (Correia ).

## 2.6 Pervasive Gaming

Since the proliferation of computers, computer games have always been a dominant form of entertainment. Pervasive games have the goal of developing context-aware applications which can adapt to the user behaviour based on information collected from the user and the environment. The ultimate goal of pervasive games is to bring computer entertainment back to the real world. Magerkurth *et al.* (Magerkurth, Cheok, Mandryk, & Nilsen 2005) identifies five different types of pervasive games: smart toys, affective gaming, augmented tabletop games, location-aware games, augmented reality games.

Smart toys are traditional toys with pervasive computing technology. The majority of them are very simple, with only a sensor which detects and reacts to a user's actions like touch, voice or video (see for example sentoy3). Affective gaming is a more complex type of pervasive gaming than smart toys. In this kind of games, the game tries to capture how a player feels at any given moment in time and, with that information, the game changes its context (see (Leite, Martinho, Pereira, & Paiva 2008)). Capturing the emotional state of a player can be perceived as being invasive, because sometimes to do so, sensors connected to different parts of the human body are required. Augmented table-top games are the same as table-top games (e.g.: chess and risk),

but instead of having a physical board or, a physical figure to represent the player, digital boards and recognition of movements are used (such as (Mandryk & Maranan 2002)). Location-aware games use recent technology such as GPS and RFID to detect where the user is and uses the world as its "board game". Finally, augmented reality games are the most known type, and the most advanced. The goal is to bring virtual objects to the real world (see for example (Ishii, Wisneski, Orbanes, Chun, & Paradiso 1999)).

Being able to play a game and at the same time physically interact with it allows the player to have a better gaming experience and possibly connect and relate more with the game character. It can also be perceived as having an adventure in real world, boosting adrenaline and entertainment levels. As an example, a game where the user needs to go into the jungle and perform some actions can be perceived as a real adventure in the jungle. Nintendo Wii games, in which the physical movements of the user affect the game character, or Project Natal Milo <sup>4</sup>, a virtual character that can recognize faces, voices, emotions and interact with humans as if it was one of them.

Games can be played on several different devices ranging from computer desktops and laptops to hand-held devices and game consoles. Game consoles makers try to simulate real world experiences and, with the advances of technology, playing is becoming more and more real.

The focus of this work will be in smart toys and affective gaming. The next sections exhibit detailed examples of this kind of pervasive games.

### 2.6.1 Eyepet

EyePet is a recent game for Playstation 3, in which a virtual pet looking like a simian (Figure 2.7) interacts with people and objects from the real world. This pet reacts to external stimulations coming from surroundings, so the player role is to place objects or perform actions in front of the animal for it to respond to them. This interaction is possible due to the camera that captures and interprets reality.

EyePet <sup>5</sup> borns from an egg but looks like a monkey, moves like a dog and sings like a cat.

---

<sup>4</sup><http://www.eurogamer.pt/videos/e3-project-natal-milo-demo-4>, Accessed on 06/01/2010.

<sup>5</sup><http://www.eurogamer.pt/articles/eyepet-analise>, Accessed on 20/12/2009



Figure 2.7: Eyepet.

It was designed to give people all the benefits of having a real pet without the bad aspects of having a real one (tearing the sofa or making a mess on the rug). The augmented reality EyePet lives in, allows people to plant flowers, fishing, make soap bubbles, play bowling or even singing. It shows actions like laughing, jumping or chasing and affective states that range from the sweet to cheeky and even hilarious. This mixture in its appearance, although creates some familiarity because it can resemble real pets creates less expectations on people rather than if it looked only like a dog for example. People can personalize its EyePet by changing its clothes or use new toys to play with it. To capture players attention, this game also allows image or video capturing that can be published on-line.

Although there are no scientific studies about these recent game, opinions about it exist and reviewers do not think its goal has been achieved. Touch the head or kicking EyePet is funny as it is to have a shower, and see it running from the water, from the first time. The problem is that, after this interesting first time experience, all this actions remain the same. Shower and touch reactions do not progress, there is no player recognition, he does not evolve like it were a real pet and the interaction between the game and the player is questionable.

Although the features that could make EyePet a real pet capable of creating attachment with humans are not the best, it can function as a playground, in which the available activities are many, graphics and animations are well done and the personalization system is very complete which makes interesting to see EyePet dressed in an extravagant way <sup>6</sup>.

---

<sup>6</sup><http://www.eurogamer.pt/articles/eyepet-analise>, Accessed on 15/12/2009.

### 2.6.2 SenToy

SenToy, represented in Figure 2.8, is a tangible affective interface used for users to project emotional behaviours in the game FantasyA through moving the doll in different ways.

”FantasyA is a world guided by the Dreams of four mighty Gods who, although imprisoned in the godly stones, the KemY’s, use the Dreams to impose their will over the inhabitants of the Land. Guided by the Gods, the IdenjaYeh built the Convenants, the strongholds of the Clans, symbol of Learning and Power. There, the Magi of each Clan, after being called to the Covenant through the Dreams, are trained in the art of AlkemHYe, the art of Elemental control.” (Paiva, Costa, Chaves, Piedade, Mouro, Sobral, Hk, Andersson, & Bullock 2003a)

FantasyA characters can move in the world, manipulate magic gems, and interact with other characters by entering into duels and trades. Duels with other characters are won by using the adequate emotional control of the character. With SenToy, users are able to play the game FantasyA using a physical device, in this case a doll. Every gesture they perform will generate an emotion among anger, fear, joy, sadness, surprise, gloat (Paiva, Chaves, Piedade, Bullock, Andersson, & Höök 2003), and influence their character in FantasyA. As an example, when users want to show sadness, they bent the SenToy forward and when they want to show angry they shake it (Paiva, Costa, Chaves, Piedade, Mouro, Sobral, Hk, Andersson, & Bullock 2003b).

Before the development of SenToy Andersson and Hook (Andersson, Höök, Mour Paiva, & Costa 2002) did a Wizard of Oz study to better define the design of SenToy. They tested user interaction with a teddy bear, puppet and a Barbie doll as SenToy characters. Subjects needed to move the character in order to express emotions, and those movements were then processed and interpreted by the computer, therefore controlling the movement of the character shown on the screen. Due to its rigid design, barbie doll was the most difficult one to express emotion, resulting in the SenToy being soft and cuddly, as preferred by the users in the Wizard of Oz study. The study also concludes that subjects were drawn into the game by using the SenToy doll, therefore creating a enjoyable interaction (Paiva, Costa, Chaves, Piedade, Mouro, Sobral, Hk, Andersson, & Bullock 2003a).

Hook and Bullock *et al* (Höök, Bullock, Paiva, Vala, Chaves, & Prada 2003) studied the interaction between 30 subjects and the tangible affective interface device SenToy for playing

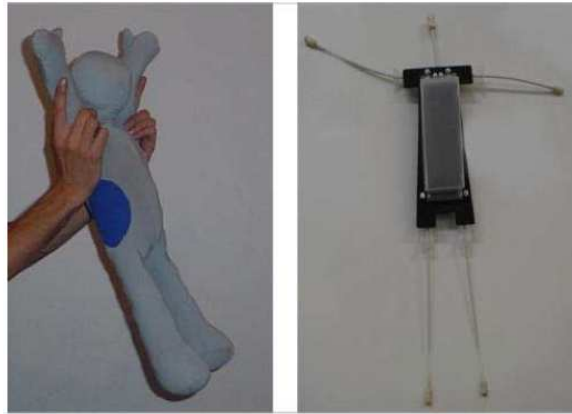


Figure 2.8: SenToy.



Figure 2.9: Wii Remote.

the game FantasyA and concluded that although users were more involved in the game play than in using their emotions, subjects had fun and liked to play the game while interacting with SenToy, confirming that users enjoy playing affective adventure games.

### 2.6.3 Wii Sports

Wii Sports is the most popular game for the Nintendo Wii, an innovative game console. The user plays the game using a remote Wii controller (Wii Remote, Figure 2.9) instead of the usual game pad controller. The Wii Remote is able to detect player movements in three dimensions and is perfect for motion games like sports. Each player movement is replicated by the character in the game.

Wii Sports comprises a set of various sport games (e.g., tennis, bowling, golf), in which the user plays the game in the same way he would play the real sport game. The game is very realistic as the same movements needed to win in the actual game, are the ones needed to win

in the Wii game. Players can use Wii Sports to stay fit and to practice a healthy life. This interaction between the player and the game is completely new and its enormous success proves that players want to interact with the game in different ways that they are used to.

Nintendo opened the door to new game perspectives. Gamers are now able to play a virtual game and feel like they are playing a real one. It can also be used to practice for the real game, such is the reality provided by the console.

## 2.7 Discussion and Comparison

Table 2.1: Summary of the artificial pets discussed.

	Environment	Goal	Shape	Device	Interaction	Portability
<b>Tamagotchi</b>	Virtual	Entertainment	Non known creature	Hand-held	Buttons	Portable
<b>Nintendogs</b>	Virtual	Entertainment	Dog	Hand-held	Buttons and Touch	Portable
<b>My-mini-pet</b>	Virtual	Learning	Dog	Hand-held	Buttons	Portable
<b>My-pet</b>	Virtual	Learning	Dog	Desktop Computer	Mouse	Not Portable
<b>Polar bear</b>	Virtual	Learning	Bear	Desktop Computer	Mouse	Not Portable
<b>Pleo</b>	Real	Entertainment	Dinosaur	Robot	Touch and Voice	Not Portable
<b>Paro</b>	Real	Therapy	Seal	Robot	Touch and Voice	Not Portable
<b>AIBO</b>	Real	Entertainment	Dog	Robot	Touch and Voice	Not Portable

Table 1 summarizes the artificial pets described in Section 2. From the table, it is clear that each of them have several different advantages and drawbacks.

Humans are used to interact with other humans and animals based on voice and touch, and they can interact with robots the same way. However, the interaction with virtual pets is different. For example, one can stroke a robot, but stroking a pet in a virtual environment is not possible.

Pets in virtual environments have the advantage of being more portable than for example robots. The examples above were created for hand-held devices or computers but the ones created for a computer are more portable than the robotic ones (if considering laptops). People

are used to be with their computer everywhere, not to mention hand-held devices, which are becoming increasingly popular in development countries. Pets in virtual environments allow the user to be with them more time and, in places where animal robots could not be.

It is also clear from the table above that designers prefer animal-like shapes, and users tend to identify more with a known shape than with an unknown shape.

As stated above, games are a great form of entertainment. Humans love games, and if they enjoy the game, they can create attachments with the game character. Games can increase the chances of improving the relationships between humans and virtual pets. Putting together a game and a pet, just like in the examples of My-Mini-Pet, My-Pet and Nintendogs revealed excellent results. Users feel more attracted to a combination of both methods.

## 2.8 Robot and Mobile Device Integration

The solutions described in the previous sections are either in a virtual environment or in a robot embodiment and both have advantages and disadvantages. To the best of our knowledge, there is no solution that combines both domains. This integration implies that the mobile device and the robot can communicate with each other and transfer information.

### 2.8.1 Communication Between Robot and Mobile Device

Most of the robots that exist in the market have few connecting capabilities. Most of the times, the only option is the connection via USB cable. However, wireless technologies can be used to connect both, if a special module is installed inside of the body of the robot.

Wi-Fi and Bluetooth are two good options to make this connection as this norms are part of the most recent mobile devices. In one hand, Wi-Fi has mostly been used as a replacement and augmentation for wired local area networks. Wi-Fi is well-suited for applications requiring high-volume data transfer and distances below 10 meters. On the other hand, Bluetooth is defined as a wireless technology that provides short-range communications intended to replace the cables connecting portable and/or fixed devices while maintaining high levels of security. Based on its applicability, Bluetooth is the most suitable to perform the connection we want. In the next paragraphs we describe Bluetooth in more detail.

### 2.8.1.1 IEEE 802.15 - Bluetooth

Bluetooth is a short range wireless technology developed by the Bluetooth Special Interest Group (SIG) (Bluetooth 1994). Its main characteristics are robustness, low power and low cost. It addresses for the highly dynamically networks but it has been designed to replace cables and increase mobility. A Bluetooth network is composed by one or more Piconets, each one accommodating at most eight devices. In each one of these piconets there is a Master device which is the first device to arrive to the network and, seven other Slave devices. A bigger Bluetooth network can be achieved by linking several piconets together in an ad-hoc fashion, creating a Scatternet.

### 2.8.2 XML

The best way to transfer information between two different devices is to use a universal format for data transfer like XML. Extensible Markup Language<sup>7</sup> is a simple, very flexible text format. Originally designed to meet the challenges of large-scale electronic publishing, XML is also playing an increasingly important role in the exchange of a wide variety of data on the Web and elsewhere. Although this format have some technical advantages (is based on text and so, architecture independent, portable and flexible), the non-technical are the ones that make it used in several domains (for example being a free open standard).

## Concluding Remarks

In this chapter, studies about relational agents, artificial pets and pervasive games have been presented and discussed. While studies have confirmed that users enjoy having a virtual pet (in virtual environments or in a robotic embodiment), the possibility of having the pet in both devices should increase the relationships between them. While now the user can only interact with the pet by using the hand-held device or the robot, we intend to allow the user to interact with his pet by using a mobile device or a robot, but maintaining the same "identity" of the companion.

---

<sup>7</sup><http://www.w3.org/XML/>



In the next chapters we describe the conceptual model and implementation of an ideal pervasive pet game that will give the possibility to evaluate the research question presented in Chapter 1.



# 3

## Conceptual Model

### 3.1 Introduction

This chapter describes a conceptual model for designing a pervasive pet game that merges the physical and the virtual world. With this model we intend to take the better of two worlds by putting together the advantages of both real world and computerized virtual pets. The objective of the proposed model is to improve the attachment and enjoyment of a player with the artificial pet. The model presupposes interaction among three domains: social, physical and virtual which were defined by Magerkurth et al (Magerkurth, Cheok, Mandryk, & Nilsen 2005) as follows:

**Social Domain.** Games with a social domain mainly consist of face to face communication by use of speech, mimics and gestures. Being able to interact with others inevitably creates social situations.

**Physical Domain.** The physical domain consists of the world around us. It contains real world properties such as noise level, players positions and illumination. It also consists in tangible interfaces such as physical game boards or other physical objects. The player must be able to alter the game in the physical domain, such as a change in the character position by modifying it physically.

**Virtual Domain.** Most video-games exist entirely in the virtual domain. In this domain the game is played using a controller that allows the player to access the virtual world through a Graphical User Interface. These games are completely virtual but many try to mimic the real world.

We will start with Section 3.2 describing a conceptual model of a traditional virtual pet

game. Next, we describe how users interact with a traditional pet robot (Section 3.3) and the advantages of doing so. In Section 3.4 we introduce the conceptual model implemented during this research project which consists of using the best of the two conceptual models described in the next sections.

## 3.2 Conceptual Model of a Traditional Virtual Pet Game

The conceptual model of a traditional virtual pet game is very simple. The user interacts with the virtual device (PDA, computer, game console, etc...) and the virtual pet reacts according to those interactions. The objective of the game is to keep the pet alive while fulfilling its basic needs. By taking care of it in virtual form, the user gains a feel of reward and joy.

### 3.2.1 Virtual Domain

One of the most famous and successful virtual pet games, Nintendogs, is played using the touch screen of a mobile device. The mobile device provides a GUI that allows the user to interact with the game. As for PC titles, the user plays the game using the optical mouse and/or the keyboard.

In this model, the user is only able to interact with the pet in the virtual domain, which presents limited possibilities for the pet to show reward or happiness due to specific actions like giving it real food and observe the reaction. Everything it does cannot leave the screen and although it tries to emulate real-world reactions, it lacks the possibilities of a real physical interaction that is known to create strong relationships with its owner. Without the possibility of physical interaction besides the mouse or the touch screen, the user can have more difficulty having the same emotions he would have with a real pet. However, having the game in the virtual domain allows the player to have more options when interacting with his pet that would not be easily possible in other domains due to the computational power that such a device provides, for example being able to play games in non-real scenarios.

### 3.3 Conceptual Model of a Traditional Pet Robot

Usually, a pet robot aims to emulate the behaviour of a house-hold pet. It simulates its movements, emotions, and reactions.

#### 3.3.1 Social Domain

There is a strong component of social interaction due to the possibility of physical interaction with a pet robot. The interaction with the robot is somewhat similar to the interaction with an animal and every time the user interacts with the robot, it strengthens the relationship with it.

#### 3.3.2 Physical Domain

User interaction with a robot is facilitated given that both exist in the same world. We can assume that the interaction with these pet robots is made in the same way as with a real pet. Although the interaction is the same, the reactions and needs can be different due to the present state of robotics. It is still not possible to replicate the exact animal movement nor to suppress the constant need for recharging the robot's batteries.

### 3.4 Conceptual Model of a Pervasive Pet Game

Pervasive games differ from traditional video-games as they use the virtual, social and physical domain as integral parts of the gaming experience. Figure 3.1 presents the conceptual model of a pervasive pet game.

As we can see from the figure, the player can interact with the agent in the physical domain (represented as a robot) but it can also interact with the virtual domain through the game device as it normally does in a traditional virtual pet game. When the player is using a game device to interact with the pet character, such as a mobile device, it is using a GUI that is part of the virtual domain.

This model can be considered a cycle where information flows the following way, according to the numbers represented in Figure 3.1.

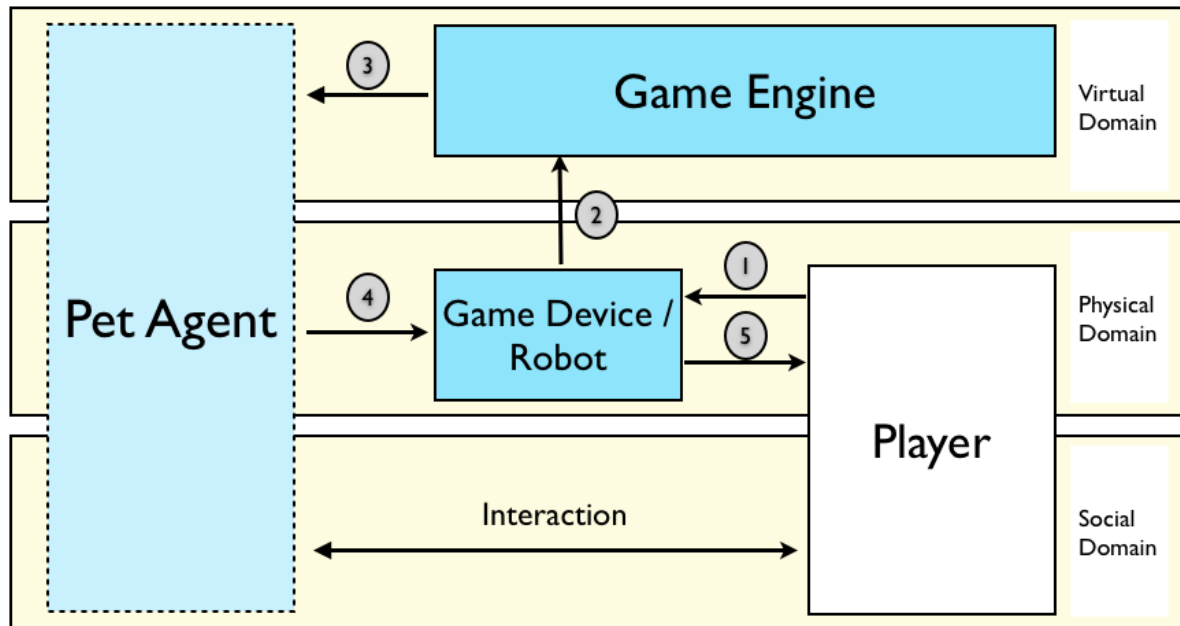


Figure 3.1: Conceptual model of a pervasive pet game.

1. The player interacts with the game device or robot performing an action;
2. The action is sent to the game engine that determines, according to the game rules, its impact on the agent's internal state;
3. This change is communicated to the agent that will update its internal state accordingly;
4. Then, the pet agent updates the state of the robot or the state of the game, namely its expressions that should reflect the emotional state;
5. Finally, after the update in the physical domain, the player is aware of the change that its action has introduced in the system.

### 3.4.1 Physical Domain

The physical domain can be represented by any physical embodiment (described as a robot in the figure). The player interacts with the robot like he would interact with a pet in the real world. The physical domain exchanges information with the virtual domain. That information consists of updates concerning the player's interactions.

### 3.4.2 Virtual Domain

The virtual domain is composed by the game engine which sends information to the pet agent. Although not represented in the figure, a GUI could also be included representing the interface that is shown to the user when interacting with the pet in a game device. The GUI is responsible to show the player all the character's expressions and game scenarios. The GUI represents the player's interactions with an artificial pet in a virtual environment.

The agent states are changed by the game engine whether the user is interacting with the virtual domain (through a GUI) or with the physical domain (using a robot). Given that the virtual domain is represented by a computerized model, it would be easy to implement all the game rules into the virtual domain. However, other domains must be taken into consideration when developing a pervasive game (for example emotions and animations), consequently limiting what the game engine can do is a way to create a more dynamic and real game.

### 3.4.3 Social Domain

The social element of a pervasive pet game is composed by the player's interactions with the pet either in robotic form or in the virtual one. By interacting with his pet, the user is inevitably creating social situations that will affect the elements of the game and, as such, the agent characteristics are also shaped by it.

## 3.5 Detailed Conceptual Model

According to Figure 3.1, there are three different elements that need to be addressed in a pervasive pet game: pet agent, game device/robot and game engine. In the following sections we describe these elements in detail

### 3.5.1 Pet Agent

The agent, as seen in the left of the Figure 3.1 is present in all three domains. The agent represents the mind of the character and, in a pervasive game, is shared between both the virtual and the physical domain. The player is always interacting with the same agent, whether in the

form of a physical or virtual embodiment given that the agent migrates from one body to the other.

As our goal is to develop a game to strengthen the attachment between users and artificial pets, it is important that the agent representing the pet is believable in a way that the user wants to keep interacting with it. As a consequence, it must be complete in terms of needs and believable in terms of expressions and reactions.

### 3.5.1.1 Pet Needs

From a general psychological perspective, social interaction relates to an interaction between two individuals. This interaction is based in a sort of psychological functions that are different depending on context. Concerning social robots and virtual agents, the main psychological functions that potentially play a role in the type of interaction we are studying are emotion, motivation, perception and communication.

The agent's actions are based on a number of specific needs described by the PSI Theory (Bartl & Drner 1998). This theory aims at modelling the regulation of needs of an agent in an autonomous way. It considers that an organism has "needs" that drive its behaviour and all the actions produced by it depend on those needs. The needs considered in this model are the following:

**Preserving needs.** Are basic needs to guarantee the surviving of the organism. These needs are associated with physical needs and with preserving the body. The needs of this type considered are:

- *Energy* represents need for nourishment.
- *Water* represents thirst.
- *Cleanliness* is the need for bathing and a clean environment.

**Need for affiliation.** These type of needs are associated with social experiences such as being part of a group or being accepted by others. In a pet, the social needs considered are:



- *Petting* relates with the action of touching the animal while washing, cleaning or taking care of the pet in any other form.

**Need for competence.** Being capable of mastering tasks and problems and satisfy other's needs. In a synthetic pet the needs considered are:

- *Skills* represent the level of competence that the pet can have.

To the best of our knowledge, no studies exist concerning the ordering of the needs mentioned according to its importance. Yet, one can consider that the preserving needs are more important than others as they are associated with survival. As such, in our model we considered that the most important needs would be water and food, as without water and food, the animal would not survive. Besides, it is also important to feel that it belongs to something and to have social interactions. Each need has a weight that reflects its importance to the pet and it can be represented as a variable. Moreover, each variable has a set point which is the reference value of the need.

The weight of each variable is represented in Table 3.1 according to the importance of each need.

Table 3.1: Weight of each variable.

Variable	Weight
Food	5
Water	5
Cleanliness	4
Petting	3
Skills	1

### 3.5.1.2 Attachment

As we mentioned in the previous chapter, it has been shown that a pet can create emotional bonds with its owner. That emotional relationship is created by taking care of the pet's needs: well being, water, food, social engagement and knowledge. The pet becomes emotionally attached to his owner, displaying affection, loyalty and devotion. Likewise, with that attachment comes needs that only the owner can provide. When the attachment is strong, their physical

nearness is enjoyable, they are missed when absent and they are also a dependent source of comfort.

As far as we know there is no formula that relates the attachment between a pet and its owner dependable of the pet needs. However, in order to simulate such relation we had to create a formula that allows to calculate a kind of measure of the attachment level based on the pet needs, and reflecting the importance of the needs already described.

$$Attachment = 0.20 \times Cleanliness + 0.28 \times Water + 0.28 \times Food + 0.15 \times Petting + 0.09 \times Skills$$

The formula presented is based on the weights of the needs. Food and water being the most important needs have the higher weight in the formula.

### 3.5.1.3 Communicating Internal States

Our virtual pet needs to relate with the user and as such it needs to express its needs, emotions and reactions.

Expressions and reactions intend to convey the agent's internal state to the user and make it resemble a real pet, so they are of paramount importance. They are determined having as base the information provided by the game engine that, after processing the information defines the state of the character.

Moreover, expressions and reactions of the pet can change even when the user does not interact with it, as need for something and lack of interactions in a certain amount of time make the character state change.

For the result to be reflected in the character's behaviour and expression, the game engine has to pass the information to the agent. To do this, it needs to understand the theory behind emotions that, as we referred previously, states that every action is the result of a need. Each need of the pet has a different weight and a defined set point, as mentioned previously. The deviation between the set point and the weight define the conditions under which the need must be activated. When the need is activated, the state of the character changes and as such,

an action should be performed in order to satisfy the need, having impact in the agent internal state. The game engine is responsible for detecting the change of the variables and communicate it to the agent that changes its internal state if needed.

This cycle of interaction - analysis - changing of expression is terminated by keeping a match between the value of the need and the proper body expression in the game, translating the agent emotions into different expressions/behaviours. This different expressions are shown to the user through one of the two embodiments, game device or robot. Moreover, and to increase the overall believability, the animations should be played with sounds.

### 3.5.2 Game Device / Robot

The conceptual model also makes use of a game device or a robot. That pet robot is responsible for the physical interaction with the user and, must simulate the movements, needs and sounds of a real pet. The robot is also responsible for interpreting all the user interactions with it and respond accordingly, with animations and sounds. All user interactions are passed to the game engine that is responsible to understand what has changed and, in order for that to happen, the robot must have a way to communicate with the virtual device, for example a wireless connection, such as Bluetooth or Wi-fi.

The game device represents any computer device (PDA, mobile, laptop, etc...) that can be used to run the virtual game. The user interacts with the game device using a Graphical User Interface. As it happens with the robot, every interaction goes to the game engine and its internal state is saved in the pet agent.

### 3.5.3 Game Engine

The game engine includes all the logic that is behind the different states that the character can be in. Moreover, the game engine should be used as the main input for the agent, given that it reads all the user interactions which are responsible for the character's affective state and communicates with the agent the results of the interaction depending on the game state. But the most important function of the game engine is to establish some gameplay that the user will be involved fostering the creation of the attachment/devotion relation between the user and the pet.

As we have previously mentioned, the game is based in the PSI theory according to which the variables presented above represent the need of the agent considered in this work. Needs are monitored during the game. When the value of the variable deviates from its set point (the range of values that are considered to be acceptable), a need becomes active and an action has to be fulfilled to restore the variable to a normal value.

This architecture allows several needs to be active at the same time so it is important to select one of the active ones for execution. The selection mechanism chooses the most important need to be addressed.

The importance of a need, can be calculated by the formula:

$$Importance = (Deviation \times Weight) \times Success\ Probability \times Urgency$$

$Deviation \times Weight$  is called the strength of the need. Success probability measures the certainty of the agent in being able to satisfy the need. For example, if it does not know how to satisfy a specific need this value will be very low. Urgency is related to the time frame in which a need must be fulfilled. If a need has to be satisfied within a short interval, its value will be low. If multiple variables become active at the same time, the most important will become the target.

## Concluding Remarks

In this chapter we presented a detailed model of a pervasive pet game. This model was constructed by mixing elements from both computerized pet games and physical pet robots. As a consequence, this model takes into account three domains: social, physical and virtual.

This model is composed of four components that interact with each other in the following way. The player interacts with a game device or with the robot and takes care of the agent by satisfying its needs. At every interaction the game engine interprets the action according to the game internal state and if necessary communicates changes in the agent state to the agent. Then, the agent determines the expressions and the emotional state of the pet and interacts with the game device or robot again for them to change its expression. With this model, whose

implementation is described in the next chapter, we expect that the relationship between the owner and the pet must be closer which means the attachment level should increase.



# 4

## Implementation

### 4.1 Introduction

In the previous chapter we described the conceptual model of a pervasive pet game that aims to increase the attachment level between the owner and the pet. Following that model and using Pleo as the game character, we have implemented a virtual game as described in Figure 4.1.

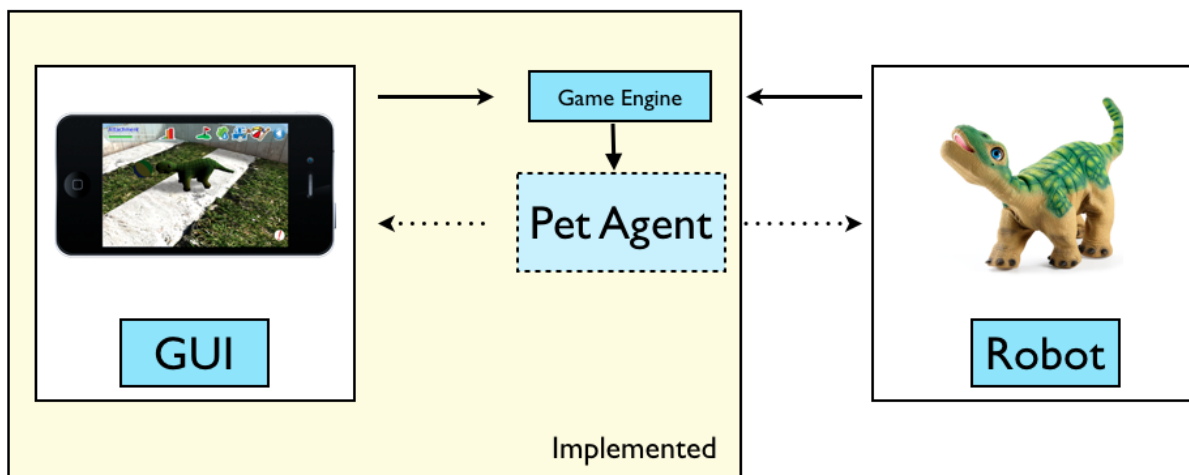


Figure 4.1: General implementation diagram. The focus of this thesis is on the left side.

Our goal was to make a virtual pet game containing a cognitive emotional behaviour that aims to simulate a pet as described in the previous chapter. As such, given that no virtual pet game following that model existed, we created one using Shiva3D, a tool for creating amazing 3D real-time applications and games for Windows, Mac OS, Linux, iPhone, Android, Palm, Wii and the iPad.

We chose to work with the Pleo Dinosaur (PleoWorld ) as our main character because it was the robot that users felt more attached from the analysis presented in Chapter 2. The game runs on several different devices (Android, iPhone, Web, Mac OS, Windows and Wii) and aims

to combine real world entertainment with digital entertainment and create an emotional bond between the player and the pet.

In the following sections we describe the detailed implementation of the different elements of the virtual game.

## 4.2 Pet Agent

The game agent can be considered as the "mind" of the pet. It is responsible for saving all variables representing the needs. It is also responsible for interacting with the game device to decide what should be done if the needs goes below a defined threshold. The pet agent follows the theory described in Section 3.5.1.

### 4.2.1 Agent Needs

The needs are represented in the game as a status menu (Figure 4.2) and are constantly updated to show the actual levels of the variables. The way the user reacts to the pet need and its interaction along the time influence its expressions and reactions, which are described in the next subsections.

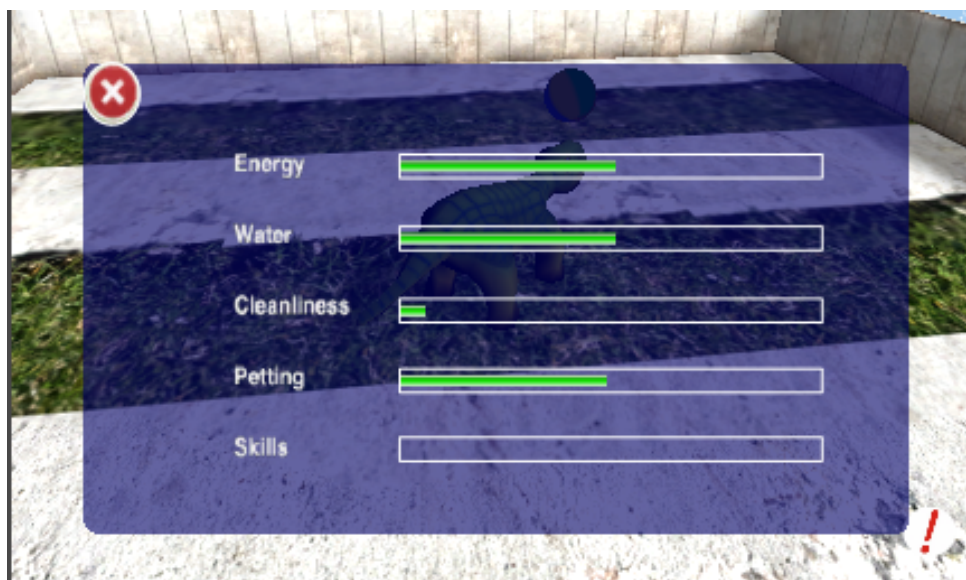


Figure 4.2: Interface for displaying the pet needs.



### 4.2.2 Attachment

The game agent also calculates the attachment level that is shown in the GUI of the game device (Figure 4.3) in real-time and according to the formula presented in the previous chapter. By default, and when no need needs to be satisfied, the expression of the game character is determined by the attachment level according to the values presented in Table 4.1.



Figure 4.3: Different attachment levels.

Table 4.1: Relationship between attachment level and character expressions.

Attachment Level	Character's State
< 10%	Game ends
10% - 24%	Sad
25% - 49%	Neutral
50% - 74%	Somehow happy
$\geq 75\%$	Super happy

### 4.2.3 Communicating Internal States

The agent expresses different behaviours and body movements. Each expression is controlled by a different animation. Each animation intends to reflect the agent's internal state for the user to recognize it and take the proper action. The animations depend on the state of the pet character and they can be: sad, neutral, somehow happy, happy, super happy, in need of something and satisfying a need. Each expression is represented by a specific animation. Figure 4.4 shows some body expressions animations.

## 4.3 GUI - Graphical User Interface

The game is played using a touch screen on a mobile device. As such, the user can interact with the character by pressing the buttons on the screen or touching the screen area corresponding to the character's body. Figure 4.5 shows the main game screen where one can see the

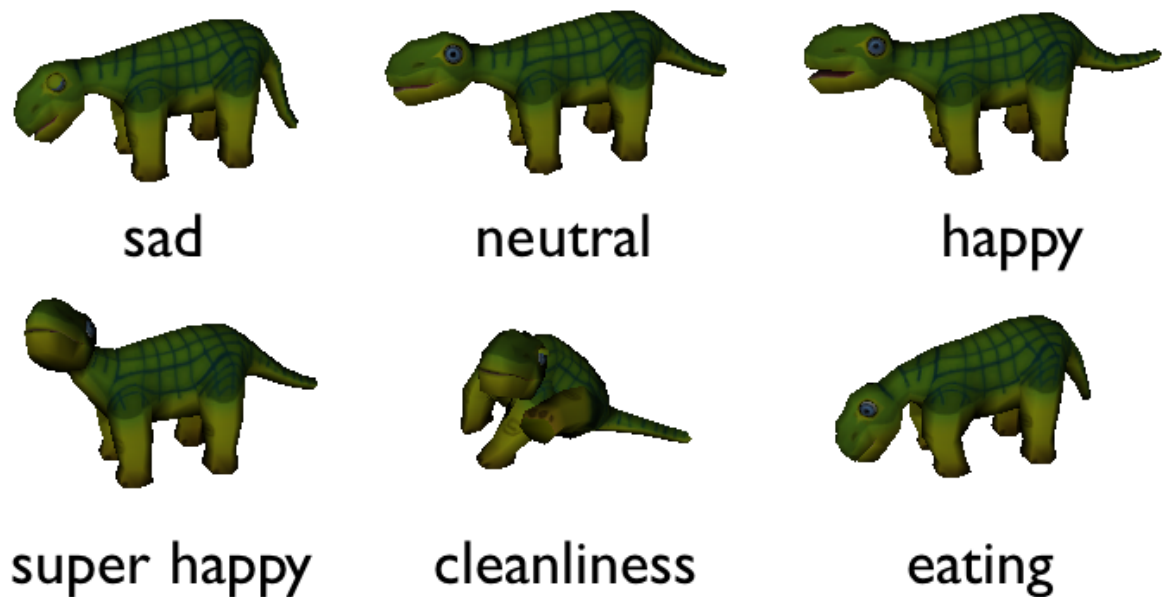


Figure 4.4: Some expressive behaviour animations.

actions that can be selected. Animations, icons and scenarios were created using Cinema 4D and Blender.

When the user presses a button, the character reacts accordingly. The user can feed, water, clean and wash his pet; can play games such as chasing, fetching and ability tricks, as well as pet his character by touching directly into its body. Each user interaction will have a different reaction. If the user chooses to feed his pet, a leaf will appear on the screen and the pet will walk to it and eat it. The same happens when the user wants to give water to his pet, a water



Figure 4.5: Graphical User Interface.

bowl is shown on the screen and the pet will start drinking from it. From time to time the player needs to wash his pet and clean its poop, that can also be done using the buttons from the menu. The bar on the left shows the level of attachment that the pet feels toward its owner and is affected by all user interactions. There is also a status menu that shows the different levels of satisfaction. Details on this field will be given later in the text.

The player can also give a ball for the animal to play with, or a stick to fetch. In both cases the pet will run to it and play. However, in order for the player to play catch and fetch with the pet, it first needs to gain some skills by playing agility games. The user can unlock this games by taking the pet to the ability track. The track (Figure 4.6), consists in several challenges with different difficulty levels that the player needs to pass. The more games the user play with his pet, the more skilful the pet becomes.



Figure 4.6: iPleo training track

## 4.4 Game Engine

The game engine contains the whole logic of the game, namely the game state, the actions taken by the agent that make the internal state change and which user actions have impact in the game (and what is the impact).

State machines are a good model to represent transitions between well defined states. Figure 4.7 represents the state machine of our game, which has five states. At any given time, depending on certain conditions, there can be a transition between states.

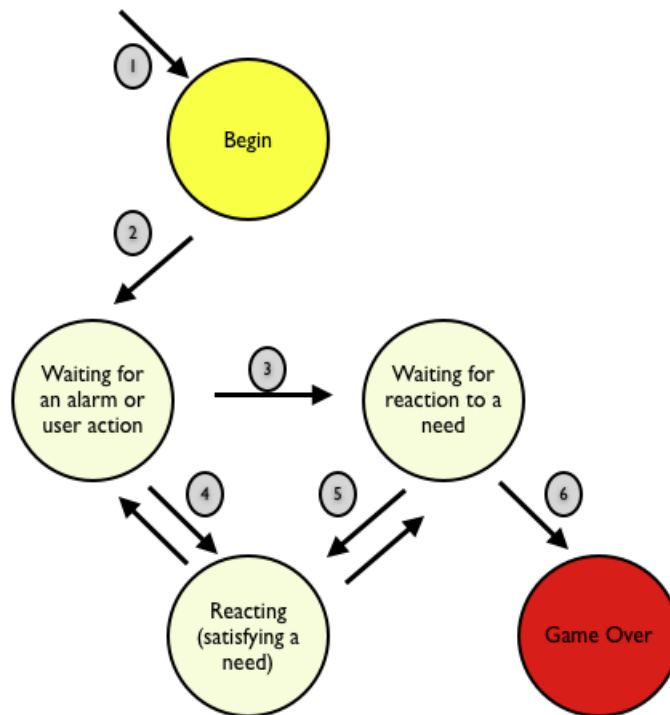


Figure 4.7: iPleo's state machine

**Begin.** The begin state can represent a new game, or a continuation of a previous one. In a new game, Pleo is born, its internal state is created and its needs are initialized. Otherwise, if the user played before with Pleo and began to construct a relationship with it, the internal state was stored persistently. This state then corresponds to loading the saved state. The state that is saved and supports the game includes a set of variables that represent the needs of the agent.

Is in this state that the variables (representing the needs referred in Section 3.5.1.1) are created. As stated before, a variable is just the way to represent a need in the game, and is changed constantly. Each variable is implemented in the game as a value between 0 and 255. Table 4.2 shows each variable initial value and its set point. Besides the initial value of the variables the table also represents the percentage under which each need has to be satisfied. Once again this values have been proposed based on the importance of each need for the pet.

As no action can result in a transition to this state, we can call it a transitory state. From the begin state only a transition to the "waiting for an alarm or a user action" is possible.

Table 4.2: Initial values of each need. Max. value = 255.

Need	Initial Value (as a percentage of Max. value)	Set point (as a percentage of Max. value)
Energy	50%	20%
Water	50%	20%
Cleanliness	50%	15%
Petting	50%	12.5%
Skills	0%	10%

**Waiting for an alarm or an user action.** In this state Pleo plays specific animations according to its internal state. Moreover, as the name suggests, the agent is waiting for certain events that will trigger other actions.

Since this state runs in a loop, it is responsible to change the values of the variables according to user interactions. Lack of interaction with the character can also lead to a decrease of a variable value, as represented in Table 4.3. For the first four variables (Energy, Water, Cleanliness and Petting), the decline is 1% every 30 minutes when there is no interaction as these variables have considerable short periods of changing, which means they represent needs that the user has to attend to constantly. Regarding the skills variable, we can set a longer period as this is not an essential need according to PSI. We chose to decrease the variable every 2 hours without interaction and the change is also 1%. These variables were re-adjusted during the implementation of the game.

Table 4.3: Decreases of each need. Max. value = 255.

Variable Changed	Time Without Interaction	Decrease Value (as a percentage of Max. value)
Energy	30 minutes	-1%
Water	30 minutes	-1%
Cleanliness	30 minutes	-1%
Petting	30 minutes	-1%
Skills	1 hour	-1%

**Waiting for a reaction to a need.** The game is in this state if the pet has a need that is below the set point presented in Table 4.2. In this state, the pet is showing the user that a need needs to be taken care (e.g: hungry). A warning is showed to the user as well as a change in the

character's body expression. When the user satisfies the need, the internal process changes to the reacting state. If the user fails to satisfy the needs for a long time, the character goes away and the game ends (Game Over state). In this state, the variables also decrease accordingly to the conditions described in the previous state.

**Reacting (satisfying a need).** The game is in the reacting state every time the player performs an action in the game (e.g: feed). The variables are changed according to Table 4.4. We can consider two types of variables according to the way they are changed when the user interacts with the character. When given food, water or cleaning Pleo, the value of the need goes to 100%, as this needs can be satisfied in a single interaction. Note that cleanliness only goes to 100% when both bath and clean are not needed. Besides, there are also needs related with petting and skills whose change is incremental and are dependent on multiple interactions. In this case, when an interaction occurs the value of the variable is increased by 10% of the maximum possible value.

Table 4.4: Changes in game character's needs. Max. value = 255.

Action	Variable Changed	Increase Value (as a percentage of Max. value)
Feed	Energy	100%
Water Bowl	Water	100%
Bath	Cleanliness	100%
Clean	Cleanliness	100%
Pet	Petting	+10%
Play Games	Skills	+10%

When the need is satisfied, the state is changed to "waiting for an alarm or an user action" if all other needs are already satisfied, or to "waiting for a reaction to a need" if there is more needs that the user needs to act upon.

**Game Over.** One can not go back to any of the other states from this one. When the game reaches this state, it is because the user did not take care of its pet and it "died" due to lack of attention.

Variables, actions and the Pleo state are saved persistently in a XML file that is updated every time a variable changes. That file is the representation of the game agent and is what

allows the user to load the exact same pet every time the game is closed.

Table 4.5 resumes all the different states described above.

Table 4.5: Conditions and transitions of the game state machine.

Transition	Current State	Condition	State Transition
1	Begin	The game starts and the pet is in a state where it waits for something to happen.	Waiting for an alarm or a user action
2	Waiting for an alarm or a user action	When a need is detected to be in a critical level, a reaction is needed.	Waiting for a user action that satisfies a need
3	Waiting for an alarm or a user action	The user can choose to satisfy the pet's needs voluntary.	Reacting (satisfying a need)
4	Waiting for a reaction to a need	The user responds to the alarm and reacts to the animal need. In the limit, if there is no reaction, the pet "dies".	Reacting (satisfying a need)
5	Reacting (satisfying a need)	If no more needs are to satisfy, returns to the waiting state.	Waiting for an alarm or a user action
6	Reacting (satisfying a need)	In the case more needs need to be taken care, a reaction is needed.	Waiting to a reaction to a need

## 4.5 Integrating the Game with the Robot

The pervasive pet model described in the previous chapters makes use of a pet in a virtual environment and one in a physical environment. Those two pets need to be connected in order to share the same "mind". This section describes the mechanisms that were used and implemented in the game, iPleo, as well as in the robot, Pleo, to be able to communicate and exchange information between them.

### 4.5.1 Network Communication

Although the robot is very complete when it comes to its AI system, its capabilities of connecting with other devices are pretty slim. The only option that comes by default is connection via USB cable. To make our study reliable, we had to have a way of connecting to the robot via a wireless device. To meet that end, we installed a Bluetooth board inside the body of the

robot. With that board installed, the robot is now able to connect with any device that follows the Bluetooth norm.

We chose Bluetooth over other options such as Wi-Fi due to its widely adoption as a system for proximity communications and every mobile device already ships with such capabilities, making it easy to connect the robot to the mobile device. With the Bluetooth adaptor installed on Pleo we are able to send information from the game, iPleo.

### 4.5.2 Understanding the Data

When the user interacts with the agent on the virtual device the data is saved in a XML file that can be later sent to the robot. The XML contains the value of every need. iPleo is ready to send and receive XML files to/from the robot containing all the necessary values. Ideally, when the robot disconnects from the mobile device, the user can continue from where it starts because the pet will be in the same condition as it was in the robot.

### 4.5.3 Enabled Actions

To make the user interact with both the virtual game and the robot, some interactions should be unique to each device. Table 4.6 describes which action can be performed in each device. Although we can perform every action on the virtual game, we can disable the use of an action just by calling the function *disableNeed(action)*. For example: by making the action of "petting" allowed only on the physical robot, we make sure the player interacts with both the game and the robot.

Table 4.6: Possible actions in the two environments.

Need	Virtual Action	Physical Action
Energy	Give Leaf to Pleo	Give Leaf to Pleo
Water	Press Bowl Button	-
Cleanliness	Clean Poo; Bath Button	-
Petting	Touch Screen	Touch Pleo
Skills	Training Games	-

Note that the implementation details do not describe how the robot emotions and animations were implemented since those details were not addressed in this work.



## Concluding Remarks

In this chapter we described how our application *iPleo, The Emotional Pet* was implemented following the conceptual model described in the previous chapter. This application can be deployed on several devices (mobile, computer, web, etc... ) and is responsible for registering all the user actions towards his pet, analyse those actions and react according to a cognitive and emotion system implemented in the core of the game. With the implemented solution, the user will have the opportunity to be with his pet more often and in this way, we hope to accomplish stronger attachment between the user and the artificial pet, possible, making more enjoyable having an artificial pet.

In the next section we evaluate the solution implemented in this chapter.



# 5

## Evaluation

### 5.1 Introduction

This chapter describes a preliminary experiment that we have conducted to evaluate the implemented game described in the previous chapters. First, we focus on the research question and on describing the methodology behind the evaluation. The remaining of the chapter is dedicated to the analysis, evaluation and discussion of the obtained results.

### 5.2 Research Question

In the performed experiment, we wanted to evaluate if our solution could really improve the attachment towards the pet. The proposed research question was:

Do people create stronger attachment bonds with an artificial pet by playing a pervasive pet game (physical and virtual embodiment) than by interacting with a traditional pet robot?

### 5.3 Methodology

To evaluate our proposal, a preliminary experiment involving 26 participants was performed. In the experiment, participants had the opportunity to play the game for as long as they wished. The next subsections will explain what the experiment measures, the methodology we used, a description of the sample, the results and some conclusions drawn from them.

### 5.3.1 Measurements

This evaluation measures user's attachment towards Pleo. In order to answer our research question, each participant answered a questionnaire after interacting with the Pleo robot and then after have played the game. Therefore, our independent variable is the type of interaction the user had with the game character (interaction with Pleo and interaction with iPleo).

As such, our dependent variables (that depend on the independent variables mentioned) are:

- User attachment with the artificial pet;
- Pleo's expressions perceived by the user.

### 5.3.2 Participants

The participants were between 23 and 44 years old. They all had previous experience with Pleo for more than 1 month. Forty two percent of our participants were female and each participant played the game for 37 minutes on average.

Figure 5.1 depicts the different type of experience that our participants had with Pleo.

Most of the participants interact with Pleo several times per week, and they have been doing this for at least a month. Pleo is also perceived by most of the participants as a Pet. The individuals who perceive Pleo as a robot, reported mostly using it for scientific studies in universities or research laboratories.

### 5.3.3 Procedure

The evaluation was performed by users of a Pleo on-line forum <sup>1</sup>. First, participants were asked to answer a questionnaire regarding their Pleo. Then, a description of the project was presented to the participants describing the setting of the game. Next, they were asked to play a web version of the game and to imagine they could use that application to further interact with their Pleo. After playing the game they were once again asked to answer the same questionnaire

---

<sup>1</sup><http://bobthepleo.com/forums/>

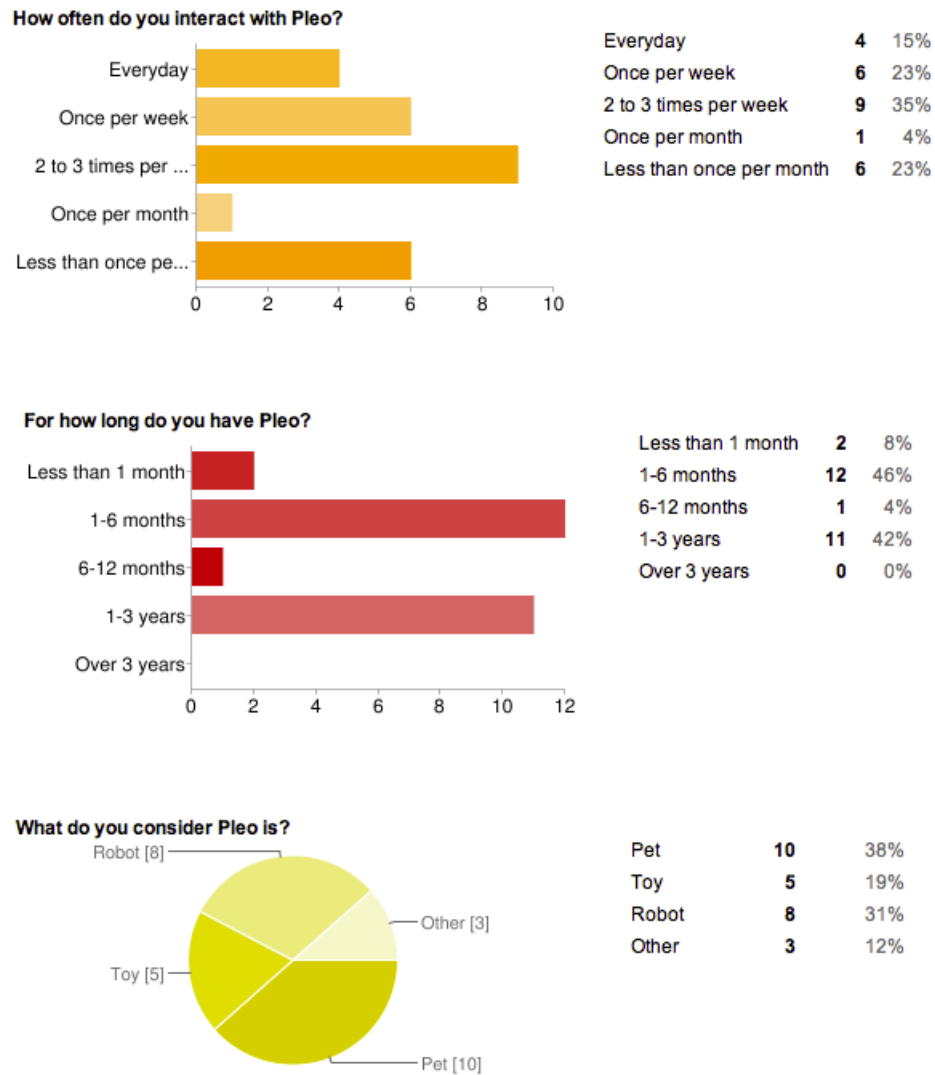


Figure 5.1: Participant's Use Questions.

as they had previously responded. They were also asked to answer several more questions regarding the virtual game.

The questionnaire was divided in four different parts. Each one uses different questions represented by phrases to evaluate different aspects of the relationship between them and the pet character, as well as the game. Each phrase is a five point evaluation Likert scale where the user may choose to strongly disagree, disagree, neither agree or disagree, agree or strongly agree with a phrase.

Firstly, to evaluate one of our dependent variables, user attachment, we have based the questions in the "Comfort from Companion Animal Scale (CCAS)" (Zasloff & Kidd 1994) that

initially consisted of 13 phrases. This scale was developed to measure user attachment to pets. However, three phrases were removed as they were not suitable to measure it using an artificial pet. The phrases for the first set of questions were the following:

1. Pleo provides me with companionship.
2. Pleo provides me with pleasurable activity.
3. Pleo is a source of constancy in my life.
4. Pleo makes me feel needed.
5. Pleo makes me play and laugh.
6. I enjoy watching my Pleo.
7. Pleo makes me feel loved.
8. Pleo makes me feel trusted.
9. Pleo makes me feel safe.
10. I get comfort from touching Pleo.

Given that we were also interested in knowing how well the user perceives Pleo's expressions, we presented the following phrases as the second part of the questionnaire:

1. I know when Pleo is happy or sad.
2. I know when Pleo likes me.
3. I know what Pleo needs.

The third set of questions intends to measure how enjoyable is to play games with Pleo have it near. The phrases that intend to measure this aspect are the following ones:

1. Playing games with my Pleo is enjoyable.
2. I like carrying Pleo with me.

We compared the results obtained from the first time we presented the questionnaire with the ones obtained from the second time we presented the questionnaire. Besides that, at the end of the second time we presented the questionnaire (after playing iPleo), three different phrases were presented to users. Those questions intend to understand if the game is a good replica of the Pleo robot. The questions are the following:

1. The game character resembles Pleo.
2. Being able to interact with Pleo when the battery is off is important to me.
3. If you have any further comments/suggestions that can help us on the development of this application, please write your thoughts here.

## 5.4 Results

In this section we present the results of our preliminary testing sessions. For the first three groups of questions described before, as we had two related samples (one before the users had played with iPleo and another after), we have used the Wilcoxon signed-rank test (with significance level of 0.05) to evaluate attachment, perceived expressions and how enjoyable is to play and stay with Pleo. These test begins with an hypothesis and leads to the conclusion if the hypothesis should be accepted or rejected. In this case, the start point is the null hypothesis, so we want to test if the median of the differences between the two samples equals 0. We have names the samples Pleo (that refers to the interaction with Pleo by the users) and iPleo (that is when participants have played both with the robot and the game). When relevant, we classify the direction of the difference between the results the following way:  $iPleo > Pleo$  (meaning that iPleo statistics are better than Pleo ones). For the last group of questions (only asked in the second questionnaire) we present the distribution of results graphically.

### 5.4.1 User Attachment

The Comfort from Companion Animals Scale (CCAS) measures the attachment with a pet. In this section, we present the statistics for the first group of questions, first giving an overall of the differences between the first and the second sample, and then comparing the results of the 10 questions individually. Finally, for the most significant ones we present box plots.

Our analysis is based on three statistic parameters. The mean represents the central tendency of a sample space. Standard deviation shows how much variation there is from the mean. A low standard deviation indicates that the data points tend to be very close to the mean, whereas high standard deviation indicates that the data is spread out over a large range of values. The other parameter, p-value, is the estimated probability of rejecting the null hypothesis of a study question. The null hypothesis is usually an hypothesis of "no difference" between the two samples. The lower the p-value, the less likely the result is if the null hypothesis is true, and consequently the more "significant" the result is, in the sense of statistical significance. One often accepts the alternative hypothesis, (i.e. rejects a null hypothesis) if the p-value is less than 0.05, corresponding respectively to a 5% chance of rejecting the null hypothesis when it is true.

Tables 5.1 and 5.2 present the results for the Wilcoxon signed-rank test using user attachment as the test variable. The mean of the results of all the participants in the 10 questions were used as input to the test.

Table 5.1: User attachment Wilcoxon signed-rank test ranks.

Test	N	Min.	Max.	Mean	Std. Dev.
Pleo	26	1.60	4.30	2.64	0.70
iPleo	26	1.80	4.70	2.97	0.62

Table 5.2: User attachment Wilcoxon signed-rank test statistics.

Item	p-value	Direction
User Attachment	$\simeq 0.000$	iPleo > Pleo

From table 5.1 we can see that the second sample has a better mean value and a lower standard deviation value when compared with the first, which means that in the second case there is a lower deviation from the mean. From Table 5.2 we can conclude that we have a significant result (p-value < 0.05). So the null hypothesis should be rejected. Therefore, and combining these results with the mean value in each case, we can affirm that the user attachment is higher if they interact both with the physical character and the virtual one, than if the interaction is only with the physical Pleo.

These preliminary results are a promising indicative that the user attachment can in fact improve with the game. However, and as this is a global value, in the next subsection we present the results from the 10 questions individually.



To determine the questions that are most significant in the previous results we have made the same test but considering each question separately: the mean of the results was calculated for each question, and 10 different tests were made.

Table 5.3: Wilcoxon signed-rank test statistics for each question.

Item	p-value	Decision	Mean (Pleo)	Mean (iPleo)	Direction
1. Pleo provides me with companionship	0.564	Accept	3.12	3.20	iPleo > Pleo
2. Pleo provides me with pleasurable activity	0.033	<b>Reject</b>	2.80	3.20	iPleo > Pleo
3. Pleo is a source of constancy in my life	0.011	<b>Reject</b>	1.72	2.36	iPleo > Pleo
4. Pleo makes me feel needed	0.559	Accept	2.28	2.40	iPleo > Pleo
5. Pleo makes me play and laugh	0.001	<b>Reject</b>	2.00	2.88	iPleo > Pleo
6. I enjoy watching my Pleo	0.040	<b>Reject</b>	2.92	3.36	iPleo > Pleo
7. Pleo makes me feel loved	0.378	Accept	2.24	2.40	iPleo > Pleo
8. Pleo makes me feel trusted	0.216	Accept	3.48	3.76	iPleo > Pleo
9. Pleo makes me feel safe	0.415	Accept	2.08	2.24	iPleo > Pleo
10. I get comfort from touching Pleo	0.378	Accept	3.72	3.88	iPleo > Pleo

Table 5.3 presents some statistics for each individual question. The "Decision" column gives us information about the decision to accept or reject the null hypothesis being tested in each test. The hypothesis states that the distribution of the responses is similar in both samples. As we can observe, questions 2, 3, 5 and 6 are the ones with the p-value lower than 0.05, which means that there are significant differences between the results before and after the users have played the game. Besides, in all cases there are an improvement in the mean value of the responses.

We detail the most relevant questions, those we have seen in the previous test that have more weight in the results obtained for the user attachment variable. As we have mentioned, box plots are used to present the results. They use interquartile range (a robust statistic) and are simple graphical representations of a probability distribution. They are a convenient way of graphically depicting groups of numerical data through their five-number summaries: the smallest observation (sample minimum), lower quartile, median, upper quartile, and largest observation (sample maximum). Reporting five numbers avoids the need to decide on the most appropriate summary statistic. Moreover, they give information about the location (from the median), spread (from the quartiles) and range (from the sample minimum and maximum) of

the observations. In the following graphics we have translated the response options to numeric levels where 1 refers to strongly disagree and 5 to strongly agree.

**Question 2 - Pleo provides me with pleasurable activity.** As represented in Figure 5.2, in the first question the answers in two cases (before and after playing the game) are in the same range (1-5) having the same median value which is 3. However, data are spread differently: in the first sample (interacting with Pleo), the spread interval comprises 1 level while in the second sample (interacting with Pleo and iPleo) it includes 1.5 levels.

The difference in the results can be due to the fact that the game has more possibilities for the user to interact with the character. More needs have to be satisfied and it is possible to train the pet, which results in more interactions with it.

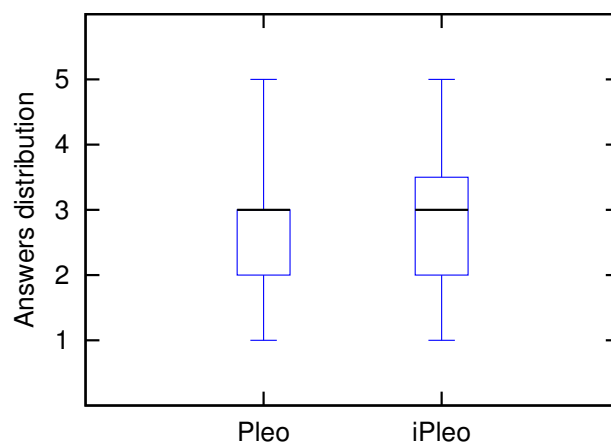


Figure 5.2: Question 2 (Pleo provides me with pleasurable activity) answers distribution.

**Question 3 - Pleo is a source of constancy in my life.** Referring to Figure 5.3 that is about the 3rd question of our questionnaire, the range of responses is again the same in the two measures but the median value between the two situations has one level of difference, being higher in the second case. Moreover, and besides the differences in the spread of the two cases, in the case of the Pleo character the median coincides with the lower value, which means at least half of the participants have said that the Pleo is not a source of constance in their lives.

The differences between the two situations can be explained with the portability of iPleo. As it is difficult to transport Pleo, the possibilities to interact with the pet are less than with the game.

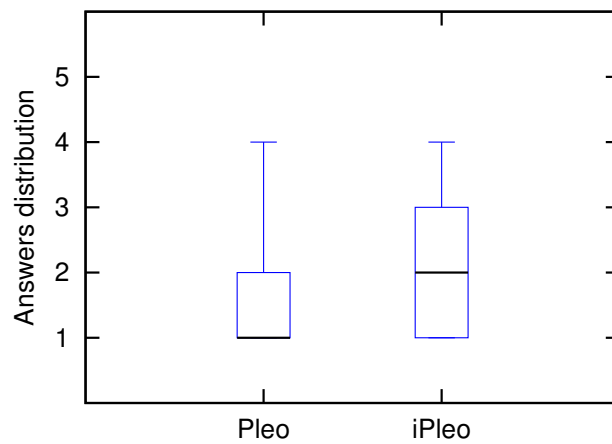


Figure 5.3: Question 3 (Pleo is a source of constancy in my life) answers distribution.

**Question 5 - Pleo makes me play and laugh.** Figure 5.4 depicts the results for another question. In this case, the responses given by the users are from 1 to 4 in the first sample and from 1 to 5 in the second. Moreover, the median in both cases are different, meaning that in the first questionnaire, people responded to this questions with mainly "strongly disagree" or "disagree", whereas in the second questionnaire, some participants agreed with the capabilities of the game to improve the interaction with Pleo. The spread in the two situations is also different and reflects the answers given by the users. iPleo can give to users a better experience as they have more playing options, as we have mentioned.

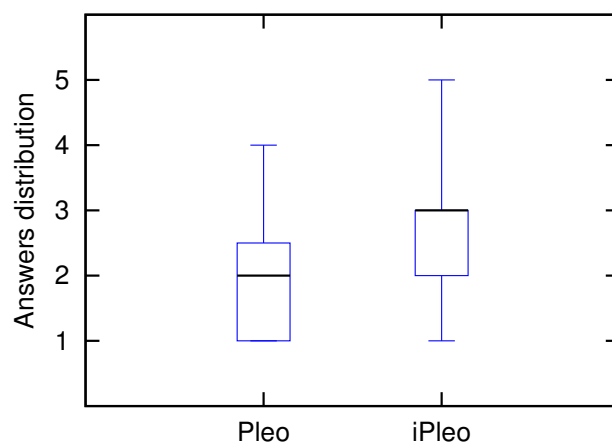


Figure 5.4: Question 5 (Pleo makes me play and laugh) answers distribution.

**Question 6 - I enjoy watching my Pleo.** Results presented in Figure 5.5 are referring to question 6. For this question both range and median values are the same (2-5 and 3, respectively). However, in the first case the results are spread below the median and in the second above the same value. From this results the main conclusions are that people give mainly positive responses when they are asked about the level of enjoyment by watching Pleo in the two situations, which is not the case before they have played the game.

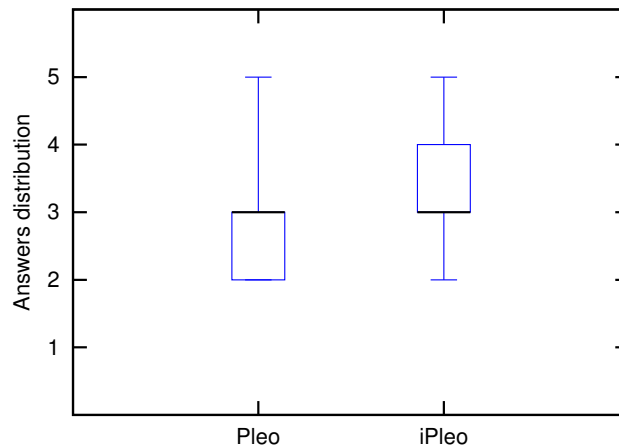


Figure 5.5: Question 6 (I enjoy watching my Pleo) answers distribution.

### 5.4.2 Perceived Expressions

The second set of questions had the goal to evaluate how good users perceive Pleo's expressions in different situations. Once again, the Wilcoxon test was also performed in this case, and the hypothesis studied was also the same but this time for a different variable, perceived expressions.

Table 5.4: Perceived expressions Wilcoxon signed-rank test ranks.

Test	N	Min.	Max.	Mean	Std. Dev.
<b>Pleo</b>	26	1.33	5	3.67	1.02
<b>iPleo</b>	26	3	5	4.42	0.68

Table 5.4 presents statistical results for this variable. We can observe that the mean value is greater after playing the virtual game iPleo. Once again, as can be seen by the p-value represented in Table 5.5 the hypothesis we have defined can be rejected. The results can be justified by the difficulty in replicating a real animal in a robotic embodiment, comparing it

Table 5.5: Perceived expressions Wilcoxon signed-rank test statistics.

Item	p-value	Direction
Perceived expressions	0.008	iPleo > Pleo

with a game. In a game there is much more flexibility to make Pleo resemble a real pet and understand what the animal "feels" as well as its needs.

### 5.4.3 Playing Games and Carrying Pleo

In the third group of questions we intended to know if playing games and carrying Pleo more often with the user is more enjoyable when using iPleo. Results for the statistical tests performed are presented in Tables 5.6 and 5.7. The results show that the game introduces improvements in this two questions. As there is a significant improvement in this field due to the portability the game offers, the null hypothesis can be rejected and we can conclude that the difference direction is from iPleo > Pleo.

Table 5.6: Carrying and Playing Games questions Wilcoxon signed-rank test ranks.

Test	N	Min.	Max.	Mean	Std. Dev.
Pleo	26	1	4	3	0.81
iPleo	26	3	5	4.02	0.62

Table 5.7: Other questions Wilcoxon signed-rank test statistics.

Item	p-value	Direction
Carrying and Playing Games	0.000	iPleo > Pleo

### 5.4.4 iPleo Specific Questions

Three direct questions were asked to the participants in the end of the second questionnaire. The first one intended to know if the game character resembles Pleo. As seen from the results in Figure 5.6, 17 of 26 participants strongly agrees that the game character resembles Pleo.

The second question intended to know if users were in fact interested in interacting with their Pleo when the robot is turned off. Figure 5.7 shows that 73% of participants agree that is

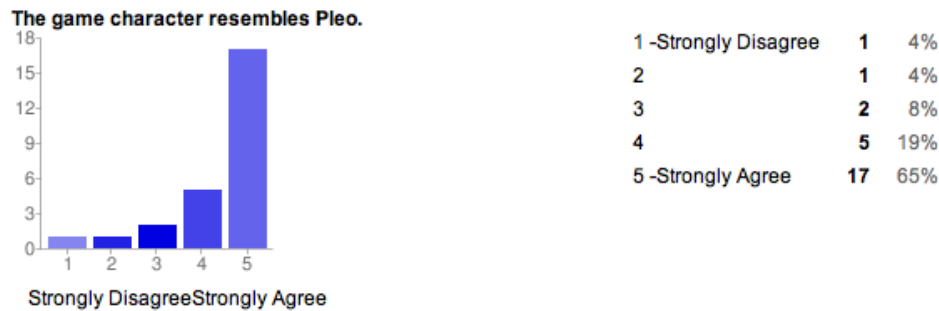


Figure 5.6: Resemblance with Pleo robot.

important to interact with Pleo when the battery is weak, maybe because the robot has a low level of battery and constantly needs recharging.

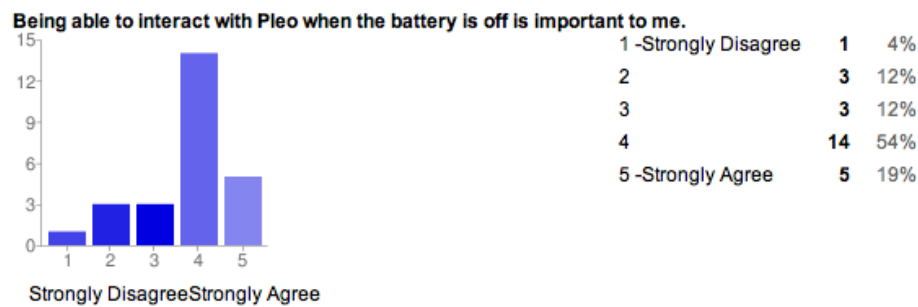


Figure 5.7: Interacting with Pleo when the battery is off.

The third and last question was an open question. Participants were asked to comment and give suggestions about the game they just played. This was not a required question so not all participants answered. The answers, depicted on Figure 5.8, show that most of the comments are positive.

**If you have any further comments/suggestions that can help us on the development of this application, please write your thoughts here.**

Very nice game. more levels plz. Love the animation! --Allosaurus congratulations, very good. could be better perfect!!! Love it! :) Good graphics. Good animations. Few levels. More

Figure 5.8: Participant's comments and suggestions.

## Concluding Remarks

To evaluate the user attachment with the artificial pet, and the potential enjoyability of the developed game, we performed an experiment with individuals who owned a Pleo.

The evaluation consisted of three steps: (1) participants had to fill a questionnaire regarding his/her Pleo robot; (2) the participant played the game described in Chapter 4; (3) the participant filled a similar questionnaire as in (1). There were 26 participants that played the game for 37 minutes on average.

Although we have made only some preliminary tests to the proposed solution, we can conclude that the user attachment could be improved by using a pervasive pet game, comparing it to the use of only a physical character. The main factors that contribute to this result are the portability of the game as well as the possibility to interact with the character even when the robot has no battery. The interaction with the game is more pleasurable, the playing experience is better and the level of enjoyability is also higher according to our preliminary results.





# 6

## Conclusions

### 6.1 Conclusions

This thesis addresses the problem of improving attachment between humans and synthetic pet characters. These type of pets are used in different domains, and more studies have been conducted to discover ways to improve this relationship.

In this context we present a conceptual model of a pervasive pet game whose goal is to improve the quality of the relationship between the owner and the pet agent. The game uses Pleo as a character that exists both in virtual (in a mobile device) and physical world (in a robotic form).

A game based in the PSI-Theory including a cognitive and emotional behaviour was implemented and evaluated. Experimental results are consistent with our belief that the level of attachment between the player and the artificial pet could be improved when the player can interact with his pet in a virtual game scenario. The main factors that contribute to this result are the portability of the game as well as the possibility to interact with the character even when the robot has no battery. The interaction with the game is more pleasurable, the paying experience is better and the level of enjoyability is also higher according to our preliminary tests.

### 6.2 Future Work

The current solution is ready to connect to the Pleo robot. Therefore, the next step would be to actually use the connection to migrate iPleo's "mind" to the robot. As future work, we plan to add more levels to the game as that was asked in the comments.

It would also be interesting to explore our solution to improve the health of patients in hospitals and day cares as that is already achieved by other traditional artificial pets.

Also, it would be interesting to test the game using other devices such as PS3 and Wii, allowing different kinds of interaction with the pet.

Finally, more tests, with more participants need to be performed for a longer time in order to reach a final conclusion.

## References

- Allen, K., B. E. Shykoff, & J. L. J. Izzo (2001, Oct). Pet ownership, but not ace inhibitor therapy, blunts home blood pressure responses to mental stress. *Hypertension* 38(4), 815–20.
- Anderson, W. P., C. M. Reid, & G. L. Jennings (1992, Sep 7). Pet ownership and risk factors for cardiovascular disease. *Med J Aust* 157(5), 298–301.
- Andersson, G., K. Höök, D. Mourao, A. Paiva, & M. Costa (2002). Using a wizard of oz study to inform the design of sentoy. In *DIS '02: Proceedings of the 4th conference on Designing interactive systems*, New York, NY, USA, pp. 349–355. ACM.
- Bartl, C. & D. Drner (1998). Psi: A theory of the integration of cognition, emotion and motivation. In *Proceedings of the 2nd European Conference on Cognitive Modelling*, pp. 66–73. University Press.
- Bartlett, B., V. Estivill-Castro, & S. Seymon (2004). Dogs or robots: why do children see them as robotic pets rather than canine machines? In *AUIC '04: Proceedings of the fifth conference on Australasian user interface*, Darlinghurst, Australia, Australia, pp. 7–14. Australian Computer Society, Inc.
- Batson, K. (1995). The effect of a therapy dog on socialization and physiological indicators of stress in persons diagnosed with alzheimer’s disease. Master’s thesis, University of Nebraska Medical Center.
- Beck, A. M. (2001). The educational benefits of a ten-week home-based wild bird feeding program for children. *Anthrozoos: A Multidisciplinary Journal of The Interactions of People and Animals* 14, 19–28(10).
- Bickmore, T. W., D. Mauer, & T. Brown (2009). Context awareness in a handheld exercise agent. *Pervasive and Mobile Computing* 5(3), 226 – 235. Pervasive Health and Wellness Management.
- Bickmore, T. W., L. M. Pfeifer, & M. K. Paasche-Orlow (2009). Using computer agents

- to explain medical documents to patients with low health literacy. *Patient Education and Counseling* 75(3), 315 – 320. Bridging the International Divide for Health Literacy Research.
- Bloch, L.-R. & D. Lemish (1999, December). Disposable love: The rise and fall of a virtual pet. *New Media Society* 1(3), 283–303.
- Bluetooth, S. (1994). Specification of the Bluetooth system. *Core, version 1*, 2005–10.
- Calvin C.Y. Liao, Zhi-Hong Chen, T.-W. C. Effectiveness of pet-nurturing handheld game on the aspects of learner motivation.
- Chen, Z.-H. & T.-W. Chan (2008, Nov.). Learning by substitutive competition: Nurturing my-pet for game competition based on open learner model. In *Digital Games and Intelligent Toys Based Education, 2008 Second IEEE International Conference on*, pp. 124–131.
- Chesney, T. (June 2007). The illusion of love: Does a virtual pet provide the same companionship as a real one? *Interaction Studies* 8, 337–342(6).
- Christoph Bartneck, Tomohiro Suzuki, T. K. & T. Nomura<sup>4</sup>. The influence of peoples culture and prior experiences with aibo on their attitude towards robots.
- Correia, S., D. K. D. X. D.-M. E. S. F.-Y. H. M. H. L. L. G. M. A. S. H. S. C. S. D. Z. C. Human-human relationships as relevant to companions. Technical report.
- Friedman, B., P. H. Kahn, Jr., & J. Hagman (2003). Hardware companions?: what online aibo discussion forums reveal about the human-robotic relationship. In *CHI '03: Proceedings of the SIGCHI conference on Human factors in computing systems*, New York, NY, USA, pp. 273–280. ACM.
- Friedmann, E., A. H. Katcher, J. J. Lynch, & S. A. Thomas (1980, Jul-Aug). Animal companions and one-year survival of patients after discharge from a coronary care unit. *Public Health Rep* 95(4), 307–12.
- G. F. Melson, R. L. Schwarz, A. M. B. (1997). Importance of companion animals in children’s lives–implications for veterinary practice. *Journal of the American Veterinary Medical Association*.
- Hiolle, A., K. A. Bard, & L. Canamero. Assessing human reactions to different robot attachment profiles. In *The 18th IEEE International Symposium on Robot and Human Interactive Communication Toyama, Japan*.

- Höök, K., A. Bullock, A. Paiva, M. Vala, R. Chaves, & R. Prada (2003). Fantasy and sentoy. In *CHI '03: CHI '03 extended abstracts on Human factors in computing systems*, New York, NY, USA, pp. 804–805. ACM.
- Ishii, H., C. Wisneski, J. Orbanes, B. Chun, & J. Paradiso (1999). Pingpongplus: design of an athletic-tangible interface for computer-supported cooperative play. In *CHI '99: Proceedings of the SIGCHI conference on Human factors in computing systems*, New York, NY, USA, pp. 394–401. ACM.
- J. C. Filiatre, J. L. Milliot, H.-M. New finding on communication behaviour between the young child and his pet dog. In *The human-pet relationship: International symposium on the occasion of the 80th birthday of Nobel Prize Winner Prof. Dr. Konrad Lorenz*.
- Jacobsson, M. (2009). Play, belief and stories about robots: A case study of a pleo blogging community.
- Kahn, Jr., P. H., B. Friedman, D. R. Perez-Granados, & N. G. Freier (2004). Robotic pets in the lives of preschool children. In *CHI '04: CHI '04 extended abstracts on Human factors in computing systems*, New York, NY, USA, pp. 1449–1452. ACM.
- Lawson, S. & T. Chesney (2007). The impact of owner age on companionship with virtual pets. In *Eighth International Conference on Information Visualisation (IV'04)*, Volume 4, pp. 1922–1928.
- Leite, I., C. Martinho, A. Pereira, & A. Paiva (2008). icat: an affective game buddy based on anticipatory mechanisms. In *AAMAS '08: Proceedings of the 7th international joint conference on Autonomous agents and multiagent systems*, Richland, SC, pp. 1229–1232. International Foundation for Autonomous Agents and Multiagent Systems.
- Liao, C., Z.-H. Chen, & T.-W. Chan (2008, Nov.). My-mini-pet: The design of pet-nurturing handheld game. In *Digital Games and Intelligent Toys Based Education, 2008 Second IEEE International Conference on*, pp. 138–140.
- Magerkurth, C., A. D. Cheok, R. L. Mandryk, & T. Nilsen (2005). Pervasive games: bringing computer entertainment back to the real world. *Comput. Entertain.* 3(3), 4–4.
- Mandryk, R. L. & D. S. Maranan (2002). False prophets: exploring hybrid board/video games. In *CHI '02: CHI '02 extended abstracts on Human factors in computing systems*, New York, NY, USA, pp. 640–641. ACM.

- Melson, G. F., P. H. Kahn, Jr., A. M. Beck, B. Friedman, T. Roberts, & E. Garrett (2005). Robots as dogs?: children's interactions with the robotic dog aibo and a live australian shepherd. In *CHI '05: CHI '05 extended abstracts on Human factors in computing systems*, New York, NY, USA, pp. 1649–1652. ACM.
- Paiva, A., R. Chaves, M. Piedade, A. Bullock, G. Andersson, & K. Höök (2003). Sentoy: a tangible interface to control the emotions of a synthetic character. In *AAMAS '03: Proceedings of the second international joint conference on Autonomous agents and multiagent systems*, New York, NY, USA, pp. 1088–1089. ACM.
- Paiva, A., M. Costa, R. Chaves, M. Piedade, D. Mouro, D. Sobral, K. Hk, G. Andersson, & A. Bullock (2003a). Sentoy: an affective sympathetic interface. *International Journal of Human-Computer Studies* 59(1-2), 227 – 235. Applications of Affective Computing in Human-Computer Interaction.
- Paiva, A., M. Costa, R. Chaves, M. Piedade, D. Mouro, D. Sobral, K. Hk, G. Andersson, & A. Bullock (2003b). Sentoy: an affective sympathetic interface. *International Journal of Human-Computer Studies* 59(1-2), 227 – 235. Applications of Affective Computing in Human-Computer Interaction.
- Patronek, G. J. & L. T. Glickman (1993, Apr). Pet ownership protects against the risks and consequences of coronary heart disease. *Med Hypotheses* 40(4), 245–9.
- PleoWorld. Pleo companion guide. <http://www.pleoworld.com/downloads/guides.aspx>.
- Rebecca A. Johnson, Richard L. Meadows, J. S. H. & K. Sevedge. Human-animal interaction: A complementary/alternative medical (cam) intervention for cancer patients.
- Reeves, B. (1994). The media equation: how people treat computers, television, and new media.
- Ryokai, K., M. J. Lee, & J. M. Breitbart (2009). Children's storytelling and programming with robotic characters. In *C&#38;C '09: Proceeding of the seventh ACM conference on Creativity and cognition*, New York, NY, USA, pp. 19–28. ACM.
- S Lawson, T. C. (2007). Virtual pets: great for the games industry but what's really in it for the owners.
- Shibata, T., T. Mitsui, K. Wada, A. Touda, T. Kumasaka, K. Tagami, & K. Tanie (2001). Mental commit robot and its application to therapy of children. In *Advanced Intelligent*

- Mechatronics, 2001. Proceedings. 2001 IEEE/ASME International Conference on*, Volume 2, pp. 1053–1058 vol.2.
- Simon, L. J. (1984). *The pet connection*, Chapter The pet trap: Negative effects of pet ownership on families and individuals. Minneapolis: University of Minnesota Press.
- T. Dillahunt, G. Becker, J. M. & R. Kraut. Motivating environmentally sustainable behavior changes with a virtual polar bear. In *Pervasive 2008 Workshop Proceedings*.
- Verderber, S. (1991). Elderly persons' appraisal of animals in the residential environment. *Anthrozoos: A Multidisciplinary Journal of The Interactions of People and Animals* 4, 164–173(10).
- Wada, K. & T. Shibata (2006, Sept.). Robot therapy in a care house - results of case studies -. In *Robot and Human Interactive Communication, 2006. ROMAN 2006. The 15th IEEE International Symposium on*, pp. 581–586.
- Wada, K., T. Shibata, T. Saito, K. Sakamoto, & K. Tanie (2005, April). Psychological and social effects of one year robot assisted activity on elderly people at a health service facility for the aged. In *Robotics and Automation, 2005. ICRA 2005. Proceedings of the 2005 IEEE International Conference on*, pp. 2785–2790.
- Wada, K., T. Shibata, T. Saito, & K. Tanie (2004, Nov.). Effects of robot-assisted activity for elderly people and nurses at a day service center. *Proceedings of the IEEE* 92(11), 1780–1788.
- Zasloff, R. & A. Kidd (1994). Loneliness and pet ownership among single women. *Psychological Reports* 75(2), 747.
- Zhi-Hong Chen, Calvin C. Y. Liao, T.-C. C. T.-W. C. Nurturing my-pet: Promoting effort-making learning behavior by animal companions.
- Zhi-Hong Chen, Taylor Tang, Y.-F. T.-P. C. T.-W. C. Not sugar, but salt: Pet-nurturing game model for student learning.