ViPleo and PhyPleo: Artificial pet with two embodiments

Paulo F. Gomes
INESC-ID and
Instituto Superior Técnico
Av. Prof. Dr. Aníbal Cavaco
Silva, 2744-016 Porto Salvo,
Portugal

Elena Márquez Segura
Mobile Life Centre at SICS
Box 1263, 164 29 Kista,
Sweden

Henriette Cramer
Mobile Life Centre at SICS
Box 1263, 164 29 Kista,
Sweden

Tiago Paiva
INESC-ID and
Instituto Superior Técnico
Av. Prof. Dr. Aníbal Cavaco
Silva, 2744-016 Porto Salvo,
Portugal

Ana Paiva
INESC-ID and
Instituto Superior Técnico
Av. Prof. Dr. Aníbal Cavaco
Silva, 2744-016 Porto Salvo,
Portugal

Lars Erik Holmquist
Mobile Life Centre at SICS
Box 1263, 164 29 Kista,
Sweden

ABSTRACT
In our current work we have designed and implemented an artificial pet with two embodiments. In both embodiments behavior is driven by needs, that are used to maintain coherence and motivate user interaction. These needs are transferred between embodiments, with only one embodiment being active at a time. We performed an evaluation with 10-year old children participants. The retrieved data indicated that many children understood the concept of an artificial pet with two bodies, even without being given clues. Nevertheless, children did perceive differences between the two embodiments, which contributed for many stating that they interacted with two pets. Among other aspects, the physical version was perceived as less obedient due to problems concerning action recognition. Although caused by technical issues, this result raises the question if virtual embodiments should simulate action recognition problems that their physical counterparts have.

Categories and Subject Descriptors
I.2.11 [Artificial Intelligence]: Distributed Artificial Intelligence—Intelligent agents

General Terms
Human Factors, Experimentation, Design

Keywords
Human-Robots Interaction, Mobile and Ubiquitous Entertainment

1. INTRODUCTION
Since the great success of the Tamagotchi (© Bandai) in 1997 [14], the concept of virtual pets has grown to a widespread awareness. There were other cases of considerable commercial success: more than 7 million Nintendogs labeled games sold worldwide; the online pet nurturing website success Neopets (© Neopets Inc.) [17].

Inspirational to these games, actual human-animal interaction has been proven to have numerous benefits. Some former cancer patients attribute part of their cure to their pets [10]. It is argued that owning a pet can decrease systolic blood pressure and plasma cholesterol [1], as well as reduce the probability of having cardiovascular diseases [18]. Animals have already been used in Animal-Assisted Therapy to fight dementia, loneliness and, even Alzheimer’s disease [20]. Moreover, animal contact during childhood, can improve the development of communication skills [8].

In spite of all these benefits, their training requires many human resources, money and time. Additionally, when many people and animals are put together, safety and hygiene become quite difficult to control. These are specially relevant issues in health care facilities. Furthermore, there are always certain safety risks linked with the unpredictability of animal behavior.

In opposition, a robotic pet does not present such drawbacks. One such robotic pet is Pleo (© Innvo Labs Corporation), that has a toy dinosaur appearance, touch sensors, several motion motors, speaker capabilities, and some limited object recognition attributes. In long-term study of this robot, it was shown to have some limitations in what concerns keeping users engaged for long periods of time [7]. Some of the issues revealed were the following:

- short battery duration: the battery lasted around one hour and took about four to charge. This issue was particularly upsetting for children.
- battery maintenance was not integrated with play; while
children were playing with Pleo, the robot would sometimes freeze due to the lack of battery, and an adult would have to interrupt play to change it.

- unfulfilled expectations: participants had very high expectations about the robot’s response to voice commands, its ability to train and its mobility. In part fueled by company marketing information, these were largely unfulfilled.

Regardless of these issues, the robot appears to have potential for maintaining some affective connection with users. In another study that analyzed posts in Pleo user forums, situations were identified in which users, when faced with a malfunction, preferred voiding their warranties and fixing the robot themselves, rather than sending it to support and risking not getting the same one back [9].

Some of the issues revealed, can possibly be transposed to other robotic pets. Considering the potential of robotic pets, their limitations, and the commercial success of virtual pet games, we were motivated to design an artificial pet with two embodiments: a virtual embodiment in a hand-held device (ViPleo) and a physical embodiment (PhyPleo). With such a structure new ways of addressing the two first issues revealed in the long-term study could be devised (e.g. the artificial pet’s mind could go to the virtual embodiment when the physical embodiment was low on battery). Finally, as today’s robots still have mobility restrictions, and battery duration limitations, we believe that analyzing dual embodied pets can help us understand how to better design artificial pets in the future.

2. RELATED WORK

Artificial pets with a virtual embodiment have been studied in educational contexts. Examples of such use are My-Mini-Pet [15], My-Pet [4] and Virtual Polar Bear [5]. In My-Mini-Pet and My-Pet, the game’s progress and pet’s growth depend on the user successfully completing subject specific tasks (e.g. solving simple arithmetics expressions). In the case of the Virtual Polar Bear, the user is faced with environmental decisions, and according to them the ice floe in which the bear lives increases or decreases. In these applications, the possibilities of how a user can attend to the virtual pet’s needs are quite limited. Furthermore, there is not a physical embodiment to the artificial pet.

The idea of an agent having different embodiments was explored in [16]. Here the idea was to have agents teleport between geographically separated locations, and in each location interact with one another. The agent’s mental state, that included a lexicon and concepts, was transmitted over the Internet. Through the interaction, the agents create a community knowledge base, gathering input from the different locations. Related to the concept of teleportation, is the concept of migration: an agent interchanging between different embodiments, even if they are physically close. In [13] the perception of migration from school students is studied in regard to the migration of an agent between two robots. The display of an ‘energy bar’ decreasing in the departing robot, and increasing on the arriving robot, and alternatively a smiley face passing from one display to another, seemed to transmit the idea of agent’s transition. Nonetheless, in these examples a border between virtual and physical world is not crossed: there is not both a physical and virtual embodiment.

The authors in [19] considered an object that exists both in the real world and on a screen. In a mixed reality game, the user controls a robot, that in turn can interact with a ball that moves between the real world and a virtual one: it is projected on the floor in the real world, and is displayed as a three-dimensional object on a screen wall in the virtual one. There is a strong emphasis on maintaining the continuity of movement when the ball passes between dimensions. Additionally, virtual characters with similar physionomy and animation to the controlled robot are displayed in the virtual environment. These are responsible to push the ball back to the physical space, maintaining a Pong like game. It is claimed that the physical embodiment, and the ball, serve as links to the virtual world, potentiating how emersed a user can feel in it. However, the transition of an actual character between physical and virtual worlds is only discussed as future work. Lastly, in [6] the authors considered a virtual and physical version of Pleo. However, there was no actual migration between physical and virtual embodiments.

In conclusion, despite research on virtual pets, migration, and mixed reality entertainment, we believe combining these elements in an unified prototype and analyzing its capabilities, is a fresh perspective in the field of computer entertainment.

3. TWO EMBODIMENTS

When designing the artificial pet, we followed a soul-shell approach [12]. The embodiments serve as a shell to the pet’s soul, with the pet only being active in one of the embodiments at a time. This soul should be reflected in both embodiments in a consistent way.

The Analysis of commercial virtual pets served as a good starting point to define this soul. In [11], the author points out that successful commercial artificial pets tend to try to make the owner feel guilty if he, or she, does not take care of its pet. Additionally, he suggests that pets should have an interaction need: the pet may present exploratory behavior, but when the need is active, the pet starts to seek the owner’s attention; additionally, when the owner gives the demanded attention, this need would cease to be active.

In line with Kaplan’s ideas, and also with the desired consistency, in both embodiments the behavior is driven by needs. The current needs are the following (organized into the PSI-Theory categories [2]):

- Preserving needs: energy, water (thirst) and cleanliness;
- Affiliation need: petting (need for affection);
- Competence need: skill;

Each need has a corresponding numeric value that ranges from 0% (need completely unfulfilled) to 100% (need com-
Currently we have an artificial pet (Pleo) that migrates between a robot embodiment (PhyPleo) and a virtual version on a mobile phone (ViPleo). Only one embodiment is active at a time: when ViPleo is activated, PhyPleo freezes; when ViPleo is deactivated, PhyPleo reactsivates.

In PhyPleo there are two ways to affect the needs (see Figure 1): petting (touching PhyPleo's skin in sensor locations), which increases the petting value; and feeding (inserting an object into its mouth) which increases the energy value. PhyPleo has three main behavior types depending on the energy and petting needs: if the energy value is low, it will sniff the ground and bite downward; if the petting value is low (and the energy value is not low), it will give a discontent growls; if neither of these two needs are low, it waggles its tail and gives high pitch barks.

Turning now to ViPleo, there are several ways to affect the pet’s needs:

- Placing a patch of leaves in the virtual playground will cause Pleo to move towards the patch and eat it. After eating it (Figure 2.a), its energy value is increased by the same value as when PhyPleo is given a leaf. Additionally, it will poop after a while (Figure 2.b), which will decrease its cleanliness value.
- Placing a water bowl in the virtual playground will cause Pleo to move towards the bowl and drink it (Figure 2.d), which will increase its water value.
- Touching the screen in the area in which Pleo is shown causes it to raise its neck (Figure 2.c). Additionally the petting value is increased by the same value as when PhyPleo is petted.
- Selecting the washing option causes Pleo to also raise its neck, removes any poop that might be in the playground, and increases the cleanliness value.
- A user can play a mini-game that consists of taking ViPleo through an obstacle course (Figure 2.e). The skill value is increased in this situation.

Additionally to the described functionality, ViPleo walks around the playground when the user does not interact with it. Currently, ViPleo only has one behavior activated by a need: if its energy value is low (same threshold as in PhyPleo), it sits down and cries (Figure 3.f). Lastly, the need values can be visualized as a graph bar.

In both embodiments the energy, water, cleanliness and petting values decay with time. The decay rate is the same in PhyPleo and ViPleo. Moreover, the initial values for all needs are also the same in both embodiments.

4. ARCHITECTURE AND MIGRATION

The artificial pet with its needs is schematically represented in Figure 3. The PhyPleo’s behavior was defined in Pawn script using the robot’s operating system (LifeOS - ©2010 Innvo Labs Corporation) SDK. It was not possible to extent the robot’s original behavior with additional functionality because we did not have the original code, nor the possibility of linking a compiled version of it to our code. The behavior was based on one of the example behaviors supplied together with the SDK.

Need values are stored in a property section of memory. These properties are accessible by all scripts running in LifeOS as well as from the exterior via the monitor interface. We connected to this monitor interface via a serial connection (UART) linking a bluetooth dongle to it, thus enabling wireless communication with the robot.

ViPleo, on the other hand, is an Android (©Google Inc.) application written in Java that has a module using the Shiva3d graphical engine (©2010 Stonetrip). This module is the interactive part of the application and is internally scripted in Lua. The android application is responsible for communicating with PhyPleo, loading the needs values from an xml file in which they are stored persistently, and starting up the Shiva module.

When the Shiva module is started, the need values in the xml file are loaded to local variables. These variables are updated according to the user interaction and to the previously mentioned decay with time. When the Shiva module is exited, the values on the local variables are used to update the xml file.

The migration between embodiments is conceptually performed by sending need values via Bluetooth. Need values are only sent when one of the embodiments is activated (and the other deactivated). The migration process is triggered in the hand-held device. For the migration to take place, the robot must be turned on and the Android application running.
We present the steps of the PhyPleo to ViPleo migration:

- Need values in LifeOS properties are requested via Bluetooth by the Android application;
- These values are sent to the Android application via Bluetooth;
- In ViPleo the values in needs.xml are overwritten by the received values;
- The Android application sends a command to PhyPleo so that an "empty behavior script", in which Pleo stands still, is loaded;
- The Shiva module is started;
- Need values are loaded from the xml to the Shiva module;

The migration from ViPleo to PhyPleo has the following steps:

- Local need values in the Shiva module are stored in the xml file;
- The Shiva module exits;
- The Android application loads the need values from the xml;
- Setting commands for the need properties are sent via Bluetooth to PhyPleo;
- The Android application sends a command to PhyPleo so that the "empty behavior script" is unloaded and the normal behavior of the pet is performed;

Commands sent to the monitor interface have a tendency to be received with noise due to the serial connection being prone to electro-static discharge. Additionally, if the monitor receives too much noise it shuts down. Moreover, the monitor can only be reused after the robot is turned off and on. To address this issue, when the Android application sends a command, it waits for a command success acknowledgment. A lesson learned from these problems could be that if a robot’s interface detects too much noise, it should not simply turn off. It should probably first try to call attention to the problem, and the shutdown behavior should be settable somehow.

5. EVALUATION

We performed two evaluations with the described artificial pet: in the first we explored how adult owners of a virtual pet felt towards the possibility of having a second embodiment for their robotic pet; in the second evaluation, we explored too what extent children could understand the concept of an artificial pet having two bodies.

Preliminary Evaluation

We performed a preliminary evaluation of ViPleo with participants already familiar with the Pleo robot. This study was performed before migration was fully functional, and with it we explored three items: if users perceived ViPleo as being similar to the Pleo robot; if users valued a second embodiment of the artificial pet; and if ViPleo could potentially bring them more comfort.

First, participants answered a questionnaire regarding their own Pleo robot. Then, a description of the project was presented to the participants defining the setting of ViPleo. Next, they were asked to play a web version of ViPleo and to imagine they could use such an application to interact with their own Pleo. They could play for as long as they wished (on average they played for 37 minutes). After playing, they answered the same set of questions as before. Finally, they were asked other questions specifically regarding ViPleo.

Participants were recruited from the on-line forum, bobthepleo [3]. There were 26, ages ranging from 23 to 44, 58% of
which were male. Most of the participants reported interacting with the Pleo robot at least once a week (73%), and almost all had the robot for more than one month (92%).

To evaluate the potential comfort that ViPleo could add to the user-pet relation, we asked participants to rate their level of agreement (five point likert scale) with phrases adapted from the “Comfort from Companion Animal Scale (CCAS)” [21]. The CCAS was initially created to measure attachment of an individual towards a live pet. We compared results before, and after interacting with ViPleo.

In Table 1 we present the phrases, the mean ratings before and after interacting with ViPleo, as well as the significance of the two being different according to a Wilcoxon signed-rank test. Considering an α-level of 5%, results were significantly different for questions 2, 3, 5 and 6. In these cases the mean was higher after interacting with ViPleo (higher level of agreement).

Participants were also asked to rate how well they understood Pleo’s expressive behavior before, and after interacting with ViPleo. With an analogous analysis as the just presented, the mean rating after interacting with ViPleo was significantly higher (p<0.05). Additionally, we asked how much users would enjoy carrying Pleo, and again the mean was significantly higher (p<0.05) after the interaction with ViPleo. Finally, concerning the questions specifically aimed at ViPleo, 84% agreed that ViPleo was similar to the Pleo robot, and 73% of participants valued interacting with Pleo when the battery would be weak.

In conclusion, the results appear to indicate that Pleo robot adult users would value having a second embodiment for their artificial pet. Moreover, that this duality could potentially contribute to enhanced feeling of comfort. However, participants had to answer “as if” they had the artificial pet with two embodiments, which may affect the result’s validity.

Second Evaluation: PhyPleo and ViPleo
This second evaluation was carried out after the implementation of migration, so in opposition with the previous one, participants were exposed to both PhyPleo and ViPleo. Our aim in this workshop was threefold: i) exploring the way children understood the companion and the process of migration ii) their assessment of the game experience, and iii) their assessment of their relationship with the pet. We will be focusing on the first topic, and thus will describe the evaluation focusing on elements relevant to it.

We considered that if a child understood the companion as being only one entity, when asked about how many dinosaurs it interacted with, the answer should be one. Additionally, when testing the evaluation structure with 6 children, we had comments that indicated that ViPleo was perceived as more obedient and PhyPleo as more independent. The two related hypothesis we considered were the following:

1. Children indicating they interacted with only one entity after being exposed to the prototype.
2. Children rating ViPleo as more obedient than Phy-Pleo.

The evaluation was performed with 10 year-old children from two classes of the same school, 51 in total. There were 25 sessions, each of them of approximately half an hour. There were two children per session (except for one session, consequence of the uneven number of children). The sessions were video recorded with two cameras positioned orthogonally.

The children were told a storyline to motivate their interaction with the companion. They had to imagine that a neighbor had left Pleo to their care. The neighbor supposedly told them to keep track of how many times it was fed, and also that it liked being petted. Apart from that, they could interact as they wished. Later on, if they asked how to do something with Pleo, the evaluation guide would answer that in the story the neighbor did not say.

The structure of the sessions had two main parts. During the first one, children would interact with one of the embodiments during approximately 5 minutes. Then, they would do a closed questionnaire regarding their interaction with this first embodiment. This questionnaire was designed mostly using 5 point likert scales.

Before answering, children were asked to rate a phrase using a likert scale so they would be comfortable with the method. One of the actual questions concerned obedience versus independence: 1 meant a ‘more independent’ attitude and 5 meant a ‘more obedient attitude’ perceived in the pet.

In the second part of the evaluation they would witness the migration to the other embodiment and could still interact with the artificial pet. In the end there more likert questions and a semi-structured interview. In this interview they were asked about how many dinosaurs they interacted with. In order not to guide the answers in any specific direction, more effectively assessing how intuitive the migration concept was, the concept was not described at any time. Furthermore, in the second part of the evaluation children were not told that something would happen in the second embodiment, only that they could interact with it (we actually used the term ‘here’ instead of ‘this’ not to induce individuality of the embodiment).

The embodiment used in the first part of the session was changed every other session to be able to compare the two embodiments in isolation. Additionally, this choice contributed that on average the answers to the semi-structured interview were not excessively influenced by one of the embodiments alone (the one being interacted with last).

Results
Concerning the number of dinosaurs, there were about half claiming to have interacted with one (47%). The frequency distribution for other numbers is presented in Figure 4.

Concerning the obedience question, we conducted a between groups test comparing the answers from children interacting first with ViPleo, to children interacting with PhyPleo, with a Wilcoxon Rank-Sum/ Mann-Whitney test. ViPleo presented significantly (p>0.05) higher values for obedience.
Table 1: Wilcoxon signed-rank test for adapted CCAS

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

Discussion

The data does not seem to support our first hypothesis: about half of the children considered there was more than one dinosaur. However, we must take into account that the concept of migration was not explained to the children. Faced with two separate objects, children had the challenge to abstract the concept of a common entity. In a more natural scenario, upon receiving an artificial pet with two embodiments, there would probably be indications, clues, of such a process. Having this in mind, we believe that the retrieved data indicates that for children of the considered age, the concept of an artificial pet is probably easy to grasp if it is to be explained.

Nevertheless, it is interesting to analyze the reasons that led to the perception of two different entities. The different perception of obedience is probably one of them. The data supports our hypothesis that ViPleo is considered more obedient. During the interviews, children claimed that PhyPleo did not always obey them. Namely, that it would sometimes decide not to eat, even when presented with a leaf. When looking at the videos, two types of situations appeared more relevant to this phenomenon: when PhyPleo was not hungry, it would sometimes coincidentally turn his head to the side at the same time a child would be trying to feed him; some children did not took the initiative to stick the leaf in PhyPleo’s mouth as he would not open it that much, nor for that long. Although these were technical artifacts of the prototype, they apparently gave the illusion of the pet having its own will. This fits rather well with Kaplan’s idea [11] that we have a tendency to attribute agency to machines that do not work, thus appearing not to be obeying. If we analyze ViPleo from the same perspective, it always obeys: it always goes to eat when we give him a leaf.

We believe that one possible idea to take from this, is that if we have a companion with two embodiments, and one has problems recognizing certain actions, then the other should possibly try to simulate such problems, or have alternative mechanisms of appearing to be not obedient. That is, if we are truly interested in having a one entity perception. Of course if pure action responsiveness is more important, than such mechanisms should not be added.

6. CONCLUSIONS

In conclusion, we have designed and implemented an artificial pet with two embodiments. I both embodiments behavior is driven by needs, that are used to maintain coherence and to motivate user interaction. These needs are transferred between embodiments during a soul-shell type migration.

We evaluated how adult users of a robotic pet perceived the possibility of being able to interact with a second embodiment of their own pet. Users indeed seemed to be interested in having an alternate interaction method, namely
when their robot’s power battery was low. However, they did not actually experience an interaction with the whole prototype, only with the virtual version.

We performed a second evaluation, this time with children and using the complete prototype (virtual and physical). The retrieved data indicated that many children understood the concept of an artificial pet with two bodies, even without being given clues. Nevertheless, children did perceive differences between the two embodiments, which contributed for many stating that they interacted with two pets. Among other aspects, the physical version was perceived as less obedient due to problems concerning action recognition. Although caused by technical issues, this result raises the question if virtual embodiments should simulate action recognition problems that their physical counterparts have, in order be perceived as having a will of their own.

Future development should include changing the behavior displayed by PhyPleo and by ViPleo so that they are as similar as possible. Moreover, there should be identifiable changes in behavior if any of the needs reach a critical value. Additionally, we hope to use migration to better integrate the robot’s maintenance into play. One possibility would be to have the pet appearing to go to sleep in one embodiment and waking up in the other. Finally, the remaining data from the second evaluation, such as the recorded interaction and interviews, need to be more thoroughly analyzed.

7. ACKNOWLEDGMENTS
This work is partially supported by the European Community (EC) and is currently funded by the EU FP7 ICT-215554 project LIReC (Llving with Robots and IntEractive Companions), and FCT (INESC-ID multiannual funding) through the PIDDAC Program funds. The authors are solely responsible for the content of this publication. It does not represent the opinion of the EC, and the EC is not responsible for any use that might be made of data appearing therein.

8. REFERENCES