J Ambient Intell Human Comput (2012) 3:61–71
DOI 10.1007/s12652-011-0089-4

ORIGINAL RESEARCH

Design and implementation of an educational virtual pet using the OCC theory

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Received: 3 February 2011 / Accepted: 24 September 2011 / Published online: 28 October 2011

Abstract This paper presents the design and implementation of a virtual pet with educational purposes. Because owners experience a wide range of emotions as a result of interactions with their virtual pets, the goal of this software is capture the attention of children by taking advantage of the emotional ties which form, using playtime to introduce educative elements. With this in mind, it is possible to make conscious the process whereby children are most likely to quit eating candy to achieve healthy eating habits. It models a virtual pet using Ortony, Clore and Collins' theory as a framework to implement a cognitive structure of emotions and a Behavior Cognitive Task Analysis to elucidate the components necessary to simulate behaviors. The designed system utilizes a fuzzy cognitive map like engine inference. The latter is the product of a causal matrix that takes into account all the elements included in the behavior we want to simulate.

Keywords Virtual pet · Educational software · Emotion · Cognitive structure of emotions · Synthetic emotion · Cognitive model · Fuzzy cognitive maps · Behavior cognitive task analysis

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1 Introduction

The focus of this work is the analysis and design of an affective structure taking into account the three aspects of the Ortony et al. theory (1988). In this way we construct an appraisal macrostructure of emotions sound on the goals and their consequences. Last one for the behavior of the virtual pet that we are going to represent. Also, we integrate in this macrostructure the behavioral norms of a healthy diet. Thus, we design a reactive behavior taking into account two information sources: (1) the affective, which is intrinsic and comes from an internal vision of the world, and (2) the physical environment, connected through norms.

In this paper we present the development of a virtual pet with educational purposes. This digital pet is called PUMAGOTCHI, which is a portmanteau between the Spanish word *puma* (carnivorous mammal which is the official mascot of Universidad Nacional Autónoma de Mexico) and *Tamagotchi* (the name of the most famous virtual pet). Although the objective of our digital pet is different from that of most virtual pets, we maintain the fundamental principles of this kind of games.

PUMAGOTCHI is a software application which uses a graphical user interface. The interface contains buttons which allow the user to interact with the pet, and an image permanently displaying the pet's state. The pet looks like a puma, with a completely minimalist design in honor of the first virtual pets in history.

The pet is designed especially for children between 10 and 12 years of age, and aims to teach them lessons about how to maintain a healthy eating style and the importance of being vaccinated, and includes an easy mathematical game (suited to the child's age) which develops the ability to perform arithmetical operations. Lessons of responsibility in the care of animals can be added to the list, because the children should have a daily care routine with their pet. Moreover, we try to emphasize the consequences of children's actions to strengthen their power of decision.

The Article is divided as follows. Section two contains a brief overview of virtual pets. Section three then discusses the emotional ties which are formed as result of the interaction between a digital pet and its owner. In section four we present the framework under we designed PUMAGOTCHI (the OCC theory). Section five discusses how we can integrate synthetic emotions in the pet, offering the opportunity of a more impactful design which allows the user to develop a higher degree of empathy with the digital pet. Section six presents a methodology which facilitates the computational implementation of the pet (mental models). Finally, in section seven, we explain how the system can be improved by incorporating fuzzy cognitive maps in the decision-making process.

2 Virtual pets: definition, historical review, and applications

A virtual pet is a simulation of a living being (a domestic or exotic animal, a plant, or an imaginary creature). The owner's goal is to raise the pet in the best possible way.

Virtual pets first appeared in Japan in the year 1996. The earliest virtual pet toys were small handheld electronic devices with fairly primitive artificial intelligence. The pets were egg-shaped and responded to how much they were played with (Oxoby 2003). Tamagotchi, one of the earlier products, whose name comes from the Japanese word *tamago* (egg) combined with the affectionate suffix *tchi* (meaning cute) was a runaway success in its early days. The initial version (1996) was a small, colorful egg with a miniscule black and white LCD screen and three buttons. The game starts with the birth of a digital creature, which the owner must feed, train, discipline, and clean up after using the simple three button interface. A well cared-for Tamagotchi goes through several life stages, from toddler to teen to adult to grandparent, and develops positive attributes. A poorly cared-for Tamagotchi will develop undesirable characteristics and either die (in the Asian versions) or fly off (in the North American versions) (Klopfer 2008). To make the pets more endearing, makers showed the pet's facial expressions on the LCD, making it quite clear when it was happy, angry, or sleeping (Oxoby 2003).

Hundreds of virtual pets have been created over the years. Nowadays, most virtual pets have abandoned the egg shape. We can find them on websites (like Neopets) and as part of videogames (e.g. *Pokemon*). There are even robots that function as virtual pets, like Poo-chi (a robot dog).

Virtual pets are not just toys. They can be used in a variety of applications. For example, they can promote sports and a healthy lifestyle. Nintendo's Pocket Pikachu was a perfect example of a virtual pet doing exactly that. Like other digital pets, Pikachu required care and feeding, but with a twist: the device contained a pedometer that could register and record the owner's movements. For the digital creature to thrive, its owner had to be physically active on a consistent basis. The owner had to walk, run, or jump to activate the pedometer (Fogg 2003).

Another application of a virtual pet is using it as an educational tool. As part of the daily care routine, it is possible to include specially designed games which collaborate with children's learning. Interacting with the educational virtual pet allows the child to learn new things (including lessons of responsibility associated with playing the role of owner). Interactive activities could also include scientific, artistic, or humanistic content.

On the internet it is relatively easy to find educational virtual pets, for example CyPet 2.02 or Global Pets 2002. However, it's difficult to find serious research about how to design one. Most published works only report on the interaction between children and their virtual pets. Consequently, we consider that the strength of this project lies, precisely, in proposing a suitable methodology for the design and implementation of this kind of applications. Moreover, to build our digital pet we are taking as our starting point OCC theory, which will be fully explained in section four, and we are seeking to maximize the use of emotions in the design of the digital pet.

3 Virtual pets and users: emotions and relationships

It was not until the late 1990s that a new branch of research related to emotions, called affective computing (AC), emerged (Picard 1997), marking the time when emotions gained importance as part of various aspects of behavior, among them the *decision making process* (Loewenstein and Lerner 2003).

Because emotions are a crucially important aspect of human behavior, the idea of including, in addition to physical stimuli received from the dynamic environment, a cognitive structure of emotions derived from an internal interpretation of that same environment is an appealing one. This will be represented by an abstraction, which will be the sum of events, that will combine to form an emerging behavior (Laureano-Cruces et al. 2010b).

Some people forget that virtual pets are artificial and are ready and willing to engage in emotional relationships, even when some virtual pets offer little or no reward or *warmth* in return. This offers some promise for the public's acceptance of the concept of a more advanced virtual friend (Stern 2002).

The Tamagotchi phenomenon in the 1990s proved that virtual pets can arouse a lot of emotions in users. The literature abounds with anecdotes about Japanese Tamagotchi owners going to great lengths in order to preserve the life and well-being of their virtual pets (businessmen who postponed or cancelled meetings to feed their Tamagotchi or the passenger who left an aircraft prior to takeoff because a flight attendant insisted she turn off her Tamagotchi, which the passenger felt was akin to killing it) (Levy 2010).

Tamagotchi was perhaps the first dramatic demonstration of how interacting directly with a computer could be a social experience. People interacted with virtual pets as though they were alive (Fogg 2003). That happens because when we attribute autonomous mental process to an object we tend also to view the object as having biological properties. Similarly, when we engage another as an interactive partner, or social companion, we often attribute mental and biological characteristics to it (Melson et al. 2009).

Owners experience a wide range of emotions as a result of their interaction with their virtual pets. They feel joy, pride, and satisfaction from maintaining the well-being of the digital creature. They experience disappointment, sadness, guilt, or self-reproach if they lose the game (and the pet dies or leaves). In addition the user forms a bond of love that grows as they spend time together.

The most interesting aspect of the relationship is that almost all virtual pets express only if they are happy or unhappy. Under this simple duality (happiness/unhappiness), the pets can generate a wide range of feelings in their owners.

This point raises the fundamental question of this investigation. If a very basic simulation of feelings (with only one variable measuring the pet's happiness) can generate a wide range of emotions in the owner, what would happen if that pet were designed under a complex emotional macrostructure which includes a greater number of emotions? But first, we need a framework that supports working with feelings in the computational context.

4 Modeling a virtual pet using the OCC theory

In 1988, Ortony, Clore and Collins proposed a theory about the cognitive structure of emotions. This theory proposes a cognitive structure of emotions based on personal and interpersonal descriptions of situations. The global analysis divides emotions in three general classes: reactions to events, reactions to agents, and reactions to objects. It is summarized in Fig. 1.

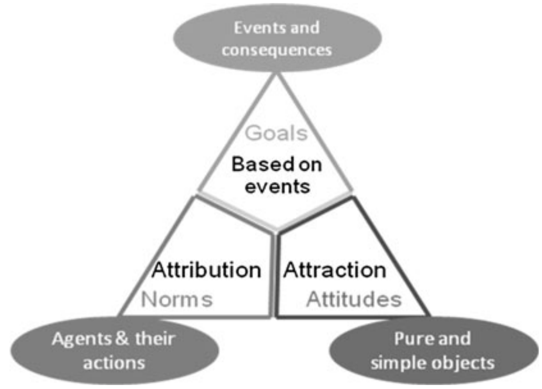


Fig. 1 The OCC model theory

The valuation that a person makes of a situation that induces emotion is based on three variables: desirability, plausibility, and ability to attract, which are applied to event-based emotions, agent-based emotions, and object-based emotions, respectively.

Desirability is evaluated in terms of a complex structure of goals, where there is a focal goal that rules the interpretation of any event. The desirability of the event is assessed based on how it facilitates or hinders the focal goal and the subgoals. Similarly, the plausibility of an agent's actions is evaluated in relation to a hierarchy of norms, and the ability to attract an object is evaluated in relation to the person's attitudes.

There are three kinds of goals: *active* pursuit goals (goals that a person tries to get), goals of *interest* (which habitually are not pursued because people have little control over their realization, for example preserving health), and *filler* goals (which rise and fall like the satisfaction of hunger).

The links between goals can be: *sufficient* (when there are several subgoals, it will suffice for one of them to be fulfilled to achieve the goal with greater hierarchy) or necessary. Links can also be *facilitating or inhibiting*. For more information on this theory, see Ortony et al. (1988). This theory has been used successfully in different works, as in the case of the teaching–learning process. (Mora-Torres et al. 2011; Laureano-Cruces et al. 2010a, b).

Using the ideas outlined above, we designed our virtual pet. In this case, the focal goal of the pet is to *be alive*. To achieve this goal he must satisfy three subgoals: *be healthy*, *be happy*, and *feel loved*.

There are only two options for the focal goal: being satisfied or not being satisfied (because something is either alive or dead). However, the subgoals can take different values, because they can be achieved fully or partially. Accordingly, the focal goal for our virtual pet is associated with a Boolean variable and the subgoals are associated with real variables. We will use fuzzy logic to work with these real variables, and they will have values in the interval [0,1]. Following this logic, these variables will represent how much the pet is *healthy, happy, and loved*, with the value of zero as the worst case and the value of one the best case for each variable.

The measure of how much each of the subgoals is fulfilled will determine the outcome of the game. The player should try to keep the values as high as possible. However, if one of the subgoals falls below threshold the game finishes.

Each of the subgoals listed above has other associated subgoals. For example, the subgoal *be healthy* is associated with the subgoals *eat vegetables* and *be vaccinated*, which facilitate the subgoal *be healthy*. Also, there is a subgoal which inhibits instead of facilitates: *eat candies*.

The full set of goals and subgoals is shown in Fig. 2. Each box represents a goal. In the upper left corner of the boxes there is a letter which indicates the kind of goal: active pursuit goals (A), goals of interest (I), and filler goals (F). The arrows represent the links between goals giving a sense of hierarchy in the structure, and the letters near the arrows indicate if they are sufficient (S), necessary (N), facilitating (F), or inhibiting (I).

And where are emotions? Each time a variable associated with a goal is modified by an action from the user, the pet will register a reaction. For example, if we feed the pet

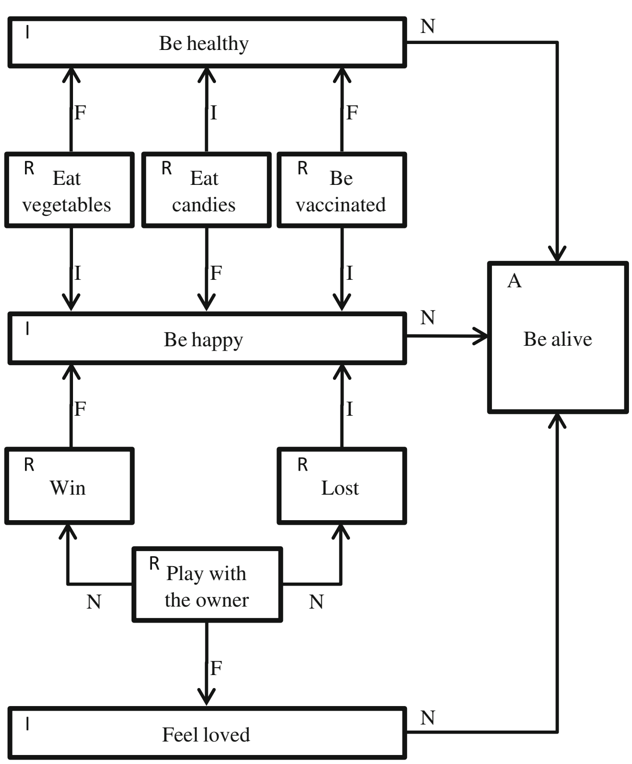


Fig. 2 Goal macrostructure of PUMAGOTCHI

vegetables, its sub-goal *be healthy* will be modified positively, but its subgoal *be happy* will be modified negatively. In this case, the pet will be temporarily *angry* with the user.

5 Integrating synthetic emotions in the virtual pet

Emotions and feelings are basic regulators of human activity. They are the basis of our interaction with the world: through *pleasure, pain, hunger, or fear* we create intentional dispositions, acting like homeostatic controls over our actions (Vallverdu and Casacuberta 2008). To imbue machines with emotions is a colossal task for the future on the research agenda. However, an initial approach has been made: synthetic emotions. (Picard 1997).

A synthetic emotion is an independently embedded (or hardwired) self-regulating system that reacts to the diverse inputs the system can collect (internal or external). So we consider an emotion:

a) a signal, which is generated after evaluations of surroundings and which produces automatic responses.
b) a regulating system with valence (+ or −) (Vallverdu and Casacuberta 2008).

In this sense, we consider that our virtual pet has synthetic emotions, because it can be in emotional states (angry, happy, scared) as a result of a signal generated after evaluating the state of the system, including external signals, which are provided by the human–computer interaction when the user feeds, vaccinates, or plays with the virtual pet, or internal signals (for example, when the system checks in its memory which activities were done the previous day and shows the user its sadness as a result of poor care). In addition, there is homeostasis in the system, because it can give the player alerts through the synthetic emotions, *expressing* to him its needs (it can show sadness if it didn't receive enough care the day before) and lightly coercing the user's actions. We can see this as a survival mechanism for the pet, appealing to the owner's feeling for it. According to the OCC theory, the description of emotions is based on classes instead of specific words because in ordinary language there are several words that refer to different aspects of the same kind of underlying emotion, like the different levels of intensity of fear. On the other hand, we need to consider the cognitive aspect, for example: an emotion like grief is a reaction to an undesirable event; the event itself has to be interpreted as undesirable, and since interpreting the world is a cognitive process, the conditions that trigger emotions, incorporating cognitive representations of such interpretations (Ortony et al. 1988). Table 1 offer a global structure of the kind of emotions considered in the study case.

Table 1 The OCC model (*Ibidem*), described using a format similar to the one showed in Nishida (2010)

1	[+]				Pleased
	[−]				Displeased
	Focus on consequences for others		[+]	Desirable for other	"Happy-for"
				Undesirable for other	Gloating
			[−]	Desirable for other	Resentment
				Undesirable for other	Pity
	Focus on consequences for self	[+]	Prospects relevant		Hope
				Confirmed	Satisfaction
				Disconfirmed	Disappointment
			Prospects irrelevant		Joy
				Attributed to self (agent)	Gratification
				Attributed to other agent	Gratitude
		[−]	Prospects relevant		Fear
				Confirmed	Fears-confirmed
				Disconfirmed	Relief
			Prospects irrelevant		Distress
				Attributed to self (agent)	Remorse
				Attributed to other agent	Anger
2	[+]				Approving
	[−]				Disapproving
	Focus on self-agent			[+]	Pride
				[−]	Shame
	Focus on other agent			[+]	Admiration
				[−]	Reproach
3	[+]				Liking
	[−]				Disliking
	Attraction			[+]	Love
				[−]	Hate

Group 1 corresponds to consequences of events, group 2 to actions of agents, and group 3 to aspects of objects

Using this framework, we will define the synthetic emotions of the virtual pet as follows (see Table 1 for the corresponding group of emotions):

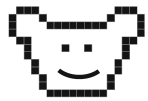
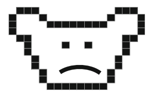
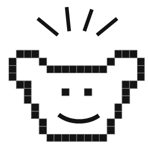
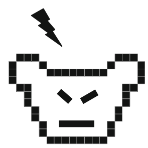
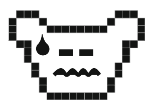
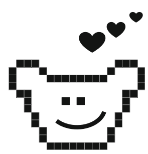
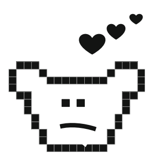
(1) Pleased: is the result of positive events, particularly being fully attended to by the user.
(2) Displeased: is the result of negative events, particularly being poorly attended to by the user (when the owner forgets to feed, vaccinate, or play with the pet).
(3) Joy: appears when the user gives the pet candies.
(4) Anger: appears when the user feeds the pet vegetables.
(5) Fears-confirmed: results from vaccinating the pet, because it doesn′t want to be hurt again.
(6) Pride: occurs when the pet wins the game.
(7) Shame: occurs when the pet loses the game.
(8) Love (of the owner) appears when the owner plays with the virtual pet for a while.

The interface shows the user the pet's emotional state in two ways: first, showing a small text indicating what the pet feels as a result of the owner's actions. It is written as if there were a third person in the game (a kind of omnipresent narrator). For example, when the pet receives vegetables, the narrator shows the message: *PUMAGOTCHI is angry because it hates vegetables. But they are very good for its health*. This message works as a mechanism to explain to the user the results of his actions, which will affect the pet's level of health, happiness, and love. In addition, there is a graphic representation of the pet's emotional state. This is shown in Table 2.

6 Getting the virtual pet's mental model

At this point we have modeled the basic ideas of our virtual pet. However, we are far from a computational implementation of it. The next step will consist of modeling the pet's behavior. We will use a methodology proposed by Laureano-Cruces et al. (2001). Some of the ideas are summarized below. This methodology is explained in Laureano-Cruces and De Arriaga, (2000) and Laureano-Cruces et al. (2001).

Table 2 Graphic representation of PUMAGOTCHI's emotional states

Emotional state	Graphic representation
Pleased	
Displeased	
Joy	
Anger	
Fears-confirmed	
Pride & Love	
Shame & Love	

This methodology proposes a procedure to develop a cognitive model. Cognitive models have been used successfully in many applications, including modeling reactive conduct or as part of a comprehensive model which, in addition to learning cognitive abilities, includes affective, motivational, and social skills. The methodology starts developing a *Behavior Cognitive Task Analysis* (BCTA) to elucidate the components necessary to simulate behaviors. This is a recursive analysis which consists of analyzing the behavioral process and taking abilities into consideration. For example, we start with the principal mental model for PUMAGOTCHI (see Fig. 3). Then, the behavior is recursively divided into increasingly specific sub-behaviors, allowing us to identify its component elements. Each sub-behavior is related to its underlying mental model. (Figs. 4, 5, 6, and 7). These mental models include norms of a healthy diet and also the feelings of a pet. With this in mind it is possible to relate the different elements that constitute behavior.

```
START
        REPEAT
                Waiting in the egg
        UNTIL (egg is broken by the user)
        Born
        WHILE (alive)
                WHILE (daytime)
                        Check if owner feeds pet
                        Check if owner vaccinates pet
                        Check if owner wants to play
                END WHILE
                WHILE (night time)
                        Sleep
                END WHILE
                Check status
        END WHILE
END
```

Fig. 3 Primary mental model of PUMAGOTCHI's behavior

With the mental models of behaviors and goals macrostructure we can correlate *interest and active goals* with emotions, focusing on the three general classes: reactions to events, reactions to agents, and reactions to objects (see Figs. 1, 2; Tables 1, and 2).

Now we can easily transform these mental models into a computational implementation, taking advantage of their procedural notation. In addition, we can find details which are not in the emotional Macrostructure (Fig. 2).

7 Improving the virtual pet with fuzzy cognitive maps

In the field of artificial intelligence, cognitive maps encode knowledge relating to causal events and how it is activated. Modeling cognitive maps using fuzzy logic seems natural,

```
START
        IF (Owner wants to feed pet)
                IF (Owner gives vegetables)
                        Get Angry
                        Gain health
                        Lose happiness
                ELSIF (Owner gives candies)
                        Get joyful
                        Gain happiness
                        Lose health
                ELSIF (Owner gets distracted)
                        Steal and eat candies
                        Get joyful
                        Gain happiness
                        Lose health
                END IF
        END IF
END
```

Fig. 4 Mental model for checking if owner will feed pet

```
START
    IF (Owner wants to vaccinated pet)
        Be vaccinated
        Confirm fears
        Gain health
        Lose happiness
    END IF
END
```

Fig. 5 Mental model for checking if owner will vaccinate pet

```
START
    IF (Owner wants to play)
        Play
        IF (pet wins)
            Get proud
            Gain happiness
        ELSE
            Get ashamed
            Lose happiness
        END IF
        Feel loved
        Gain love
    END IF
END
```

Fig. 6 Mental model for checking if owner will play with pet

```
START
    IF (not healthy OR not happy OR not
    feeling loved)
        Be dead
        Be buried
    ELSE
        Live another day
    END IF
    IF (pet wasn't fed OR pet wasn't vaccinated
    OR pet didn't play with the owner)
        Be displeased
        Lose health, happiness, and love
    ELSE
        Be pleased
    END IF
END
```

Fig. 7 Mental model for checking pet's status

due to the inherent uncertainty found in real world data and knowledge bases.

FCMs are a recent approach to the modeling of behavior and the operation of complex systems. They were introduced by Bart Kosko in 1986 to describe the behavior of a system in terms of concepts and causal relations among such concepts (Kosko 1986; Pelaez and Bowles 1995).

FCMs originate in an informal cognitive model of a process. The word cognitive is related to mental activities that deal with: (1) abstract information proceeding from the real world; (2) its representation; (3) the way in which we access this information from memory. The model becomes a formal cognitive model when it provides a framework that relates the disjecta membra of our fragments of knowledge, forming a coherent unit and representing the causal system of relations among the components of the process.

Thus, the objective of a FCM is to enable instructional designers to develop an effective simulation of the problem-solving methodology in a given domain. In this technique knowledge is divided into components that are isomorphic to the way in which humans classify and use them (Miao and Liu 2000; Pelaez and Bowles 1995).

FCMs are represented by a digraph (Fig. 8) in which the nodes are concepts that describe the main process characteristics and the edges between nodes establish causal relationships (positive or negative) between concepts.

This graphic representation illustrates the influence that each concept has on the rest. The concepts in an FCM are events whose values change over time and are originated in the system starting from initial values.

Kosko (1986) introduced the Fuzzy Cognitive Maps (FCM) as a way to model the behavior of complex systems. FCMs are represented by a digraph in which the nodes represent concepts and the edges establish causal relationships between concepts. These have been used successfully to model the behavior of expert systems in different fields, Laureano-Cruces et al. (2006), Mora-Torres et al. (2009) and Laureano-Cruces et al. (2010a).

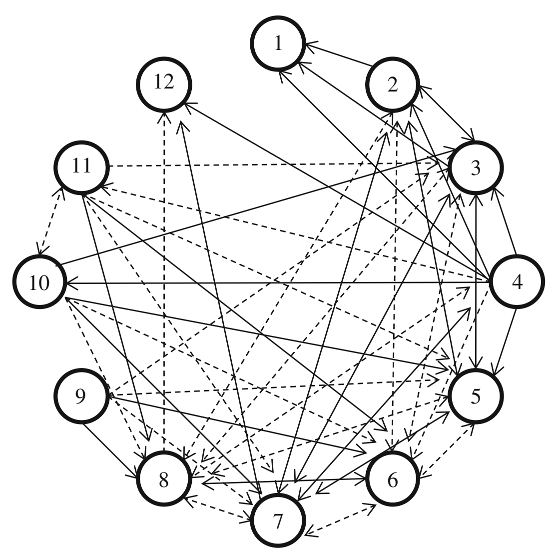


Fig. 8 Causal graph of emotional model of PUMAGOTCHI

Table 3 Causal matrix of PUMAGOTCHI's elements

	1	2	3	4	5	6	7	8	9	10	11	12
1	0	0	0	0	0	0	0	0	0	0	0	0
2	+	0	+	0	+	−	+	−	0	0	0	0
3	+	+	0	0	+	−	+	−	0	0	0	0
4	+	+	+	0	+	−	+	−	0	+	−	+
5	0	+	+	0	0	−	+	−	0	0	0	0
6	0	−	−	0	−	0	−	+	0	0	0	0
7	0	+	+	+	+	−	0	−	0	0	0	+
8	0	−	−	−	−	+	−	0	0	0	0	−
9	0	0	−	0	−	+	−	+	0	0	0	0
10	0	0	+	0	+	−	+	−	0	0	−	0
11	0	0	−	0	−	+	−	+	0	−	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0

(+) represents a positive causality, (−) represents a negative causality, and (0) represents null causality

A concept in a FCM describes one of the process characteristics. The concepts are events whose values change over time, taking values in the interval [0,1].

Causal relationships between concepts can be positive or negative, taking values in the interval [−1,1]. Letting i and j be events of a FCM, and p_{ij} the causal relationship between i and j, then:

1) If $p_{ij} = 0$ then there is no relationship between i and j.
2) If $p_{ij} > 0$ then there is a positive causality (an increase in i results in an increase in j and a decrease in i results in a decrease in j).
3) If $p_{ij} < 0$ then there is a negative causality (an increase in i results in a decrease in j and a decrease in i results in an increase in j).

Using a FCM for the virtual pet allows a better representation of the interaction between the elements of the emotional model; it is interesting to see how the different actions taken depending on the different elements that make up a given behavior are formed by a network of causalities among themselves. Figure 8 shows the digraph for our virtual pet and Table 3 its respective matrix. The solid arrows represent positive relationships and the dotted arrows represent negative relationships. The concepts we are considering part of the process are: (1) Be alive, (2) Health, (3) Happiness, (4) Feel loved, (5) Pleased, (6) Displeased, (7) Joy, (8) Anger, (9) Fears-confirmed, (10) Pride, (11) Shame, and (12) Love of the owner. The last are based on the Goals Macrostructure shown in Fig. 2 and the emotions considered and summarized in Table 3. In this case the main objective is to relate the active and interest goals with the emotions present in the behavior.

Let P be the adjacency matrix that contains the relationships between the concepts of our FCM and $Vs(t) = \{c_1, c_2, \ldots, c_{12}\}$ the vector which contains the value of the concepts at instant t.

The value of each of the concepts at time $t + 1$ is determined by the present value of the concept and matrix P. In this application, we quantify each node's effect on the other elements as follows.

Let Δc_i be the change in the value of the concept i produced as a result of the interaction between the user and the virtual pet. Then:

$$Vs_j(t+1) = \mathrm{f}\left(Vs_j(t) + \left(P_{ij} \times \Delta c_i\right)\right) \quad (1)$$

where:

$$\Delta c_i = c_i(t+1) - c_i(t) \quad (2)$$

And f(x) is a unitary ramp function defined as:

$$\mathrm{f}(x) = 0 \quad \text{if } x \leq 0$$
$$\mathrm{f}(x) = x \text{ if } x > 0 \text{ and } x < 1$$
$$\mathrm{f}(x) = 1 \text{ if } x \geq 1 \quad (3)$$

The FCM improved the performance of our virtual pet, because when one of the concepts of the system is increased or decreased as result of the owner's decisions in the game, the values of the other concepts are modified based on the causal relationships. The direct effect on the pet's owner is a feeling of greater complexity in the pet's reactions.

Now two possible scenarios are presented: Scenario A: this input vector is an almost perfect state: $Vs(t) = \{0.91, 0.91, 0.91, 0.97, 0.91, 0.09, 0.91, 0.09, 0.00, 0.97, 0.03, 0.97\}$ and the owner gives the pet candies; the output vector is $Vs(t+1) = \{0.91, 0.94, 0.94, 0.94, 0.94, 0.06, 0.94, 0.06, 0.00, 0.97, 0.03, 0.97\}$. The outcome can be explained as *an increase* in the health, happiness, feeling of being loved, pleasure, and joy of the pet and *a decrease* of its displeasure and anger.

Scenario B: is where the user feeds the pet vegetables. In this case the input vector (Vs(t)) is the same as in scenario

Fig. 9 PUMAGOTCHI waiting for the owner's decision. Depending on the decision there are two possible output scenarios (A or B)

Table 4 PUMAGOTCHI's system of rules to help owners with advice

Rule	Condition	Advice
1	Health <0.4	Its health is poor. You should vaccinate it and feed it vegetables
2	Happiness <0.4	It seems to be unhappy. You should give it candies sometimes and let it win when you play together
3	Feel loved <0.4	It thinks you don't love it enough. You should play together more often

A, and the resulting output vector is $Vs(t + 1) = \{0.91, 0.88, 0.88, 0.94, 0.88, 0.12, 0.88, 0.12, 0.00, 0.97, 0.03, 0.94\}$; with this outcome the action implies *an increase* in displeasure and anger, and *a decrease* in the health, happiness, feeling of being loved, pleasure, and joy Fig. 9.

We include a system of rules in Table 4, to *verify Vs* and *give* owners *advice* about how they can improve the pet's status.

We are convinced that one of the most interesting things about human relationships is the fact that we don't know exactly how someone else will react when we do something. Likewise, the behavior of the virtual pet with the FCM gives the player a measure of uncertainty, making the game more interesting. For more information on the use of FCMs, see Kosko (1986), Laureano-Cruces et al. (2006); Mora-Torres et al. (2009); and Laureano-Cruces et al. (2010a).

8 Evaluation

To evaluate our digital pet we use *in-depth interviews* as our *methodology*. In-depth interviewing is a qualitative research technique that involves conducting intensive individual interviews with a small number of respondents to explore their views on a particular idea, program, or situation. In-depth interviews are useful when you want detailed information about a person's thoughts and behaviors or want to explore new issues in depth. The primary advantage of in-depth interviews is that they provide much more detailed information than what is available through other data collection methods, such as surveys. They also may provide a more relaxed atmosphere in which to collect information (Boyce and Neale 2006). The in-depth interview is discursive and allows the researcher and respondent latitude to explore an issue within the framework of a guided conversation (Prairie Research Associates, Inc. 2001). We experimented with ten children and the procedure for each of them was as follows:

1) The child is interviewed before using the virtual pet. We asked questions like *Do you like eating vegetables? Do you enjoy eating candies? If you can choose between vegetables or candies, which do you prefer? Do you cry when you are vaccinated?*
2) The child plays with PUMAGOTCHI. We closely observed the reactions of the child throughout the game and asked questions about the state of the pet. For example: *Do you think it is angry? Why do you think it is angry? What do you think PUMAGOTCHI is feeling?*
3) After the game we conducted a third in-depth interview with the child. We asked similar questions to the first interview, but when we detected a change in the child's response in relation to the answers given previously we added a question inquiring about the reasons for the change.

For example, here are fragments of the interviews with Ivan (age ten), one of the children in the experiment:

FIRST INTERVIEW (BEFORE THE GAME)

…

Interviewer	*Do you like eating vegetables?*
Ivan	*No, I hate them. They're disgusting*
Interviewer	*Do you like candies?*
Ivan	*Yes*
Interviewer	*If you can choose between vegetables or candies, what do you prefer?*
Ivan	*Candies*

…

SECOND INTERVIEW (DURING THE GAME)

…

Interviewer	*You need to choose between vegetables or candies to feed your pet. Which will you select?*
Ivan	*Candies!*
Interviewer	*Why?*
Ivan	*Because they are delicious. I hate vegetables (Child gives the pet candies)*
Interviewer	*What happened to PUMAGOTCHI?*
Ivan	*He's happy because I gave him candies*
Interviewer	*But look at his health. What happened?*
Ivan	*Oh yes, it went down. Well, my mom says that candies are bad for health*

…

THIRD INTERVIEW (AFTER THE GAME)

…

Interviewer	*Now that you have played with PUMAGOTCHI, do you like to eat vegetables?*
Ivan	*No, I think they are disgusting. But I think they are good for health*
Interviewer	*Why?*
Ivan	*I think PUMAGOTCHI died because I gave him only candies*
Interviewer	*Do you like candies?*
Ivan	*Yes, but I promise to eat more vegetables*
Interviewer	*If you could choose between vegetables and candies, which do you prefer?*
Ivan	*Half and half*

…

After experimenting with the group of children, we detected that seven of them could correctly detect most of the pet's emotional states with only the graphical representation and nine of them could detect all its emotional states after reading the narrator's messages.

Eight of the children felt comfortable using it and enjoyed the game, and in minutes they developed an emotional tie with the pet, which was reflected in empathy. For example, when they vaccinated the pet and saw its facial expression, they said things like: *ouch, that hurts it*. Actually, three of the children intentionally lost when they play the mini-game included (where the child plays versus the pet) to avoid causing the pet to feel ashamed. When we asked them *why do you think PUMAGOTCHI is angry/happy/etc.?*, nine of the children answered referring to the virtual pet as *if it were alive*, attributing properties of living beings to the virtual pet. Only one child consistently stated that PUMAGOTCHI couldn't feel anything because it was a toy. Four of the children showed positive changes in their way of thinking after playing with PUMAGOTCHI, especially in the issues related to vegetables and candies.

9 Conclusions

The digital pet described in this paper is an interesting educational tool. The children didn't notice the underlying educational purpose and they consider this software a game, so the system could be a powerful and amusing way to transmit educational content. One of the goals of artificial intelligence is to emulate human behaviors. The greater the fidelity achieved the better, because the behaviors would then be more realistic. In our work we propose behavioral matrices as a tool to model the behavior of a pet that is very similar to the behavior of the children who are going to learn from it, *the art of eating healthily*.

In a future investigation, we will incorporate more educational activities in the system, for example integration of multimedia elements in the activities (one of the activities could be *watch TV* and when it happens the interface will display a video with educational content). The game can be found at the following site: http://ce.azc.uam.mx/profesores/clc/ (software section).

Knowledge representations of the kind FCMs make are considered suitable tools for modeling the behavioral process, because they have the ability to represent distributed and collaborative reasoning.

Acknowledgments This work is part of the Soft Computing and Applications research within the Emotions research section, funded by the Universidad Autónoma Metropolitana; the authors also want to acknowledge the enthusiasm of Arturo Rodriguez-Garcia (CVU: 330563); a student in the Universidad Nacional Autonóma de México Postgraduate Program in Computer Science and Engineering and supported by the National Counsel for Science and Technology-MEXICO.

References

Boyce C, Neale P (2006) Conducting in-depth interviews: a guide for designing and conducting in-depth interviews for evaluation input. Pathfinder International. Available at http://www.pathfind.org/site/PageServer?pagename=Pubs_MandE_Guides

Fogg BJ (2003) Persuasive technology: using computers to change what we think and do. Elsevier, USA

Klopfer E (2008) Augmented learning: research and design of mobile educational games. MIT Press, USA

Kosko B (1986) Fuzzy cognitive maps. Int J Man-Machine Stud 24:65–75

Laureano-Cruces A, De Arriaga F (2000) Reactive agent design for intelligent tutoring systems. Cybern Syst (Int J) 31:1–47

Laureano-Cruces A, De Arriaga F, Garcia-Alegre M (2001) Cognitive task analysis: a proposal to model reactive behaviors. J Exp Theor Artif Intell 13:227–239

Laureano-Cruces A, Ramirez-Rodriguez J, Mora-Torres M, Espinosa-Paredes G (2006) Modeling a decision making process in a risk

scenario: LOCA in a nucleoelectric plant using fuzzy cognitive maps. Res Comput Sci 26:3–13
Laureano-Cruces A, Ramirez-Rodriguez J, Mora-Torres M, De Arriaga F, Escarela-Perez R (2010a) Cognitive-operative model of intelligent learning system behavior. Interact Learn Environ 18–1:11–38
Laureano-Cruces A, Mora Torres M, Ramirez Rodriguez J, Gamboa-Rodriguez F (2010b) Implementation of an affective-motivational architecture tied to a teaching-learning process. In: Proceedings de E-Learn 2010 World conference on E-learning in corporate government, healthcare, & higher education, pp 1930–1938. ISBN: 1-880094-53-5. Orlando, USA, October 18–22
Levy D (2010) Falling in love with a Companion. In: Wilks Y (ed) Close engagements with artificial companions, key social psychological, ethical and design issues. John Benjamins Publishing Company, The Netherlands, pp 89–94
Loewenstein G, Lerner JS (2003) The role of affect in decision making. In: Davidson RJ, Scherer KR, Goldsmith HH (eds) Handbook of affective sciences. Oxford University Press, Oxford, pp 619–642
Melson GF, Kahn PH Jr, Beck A, Friedman B (2009) Robotics pets in human lives: implications for the human-animal bond and for human relationships with personified technologies. In: Knight S, Herzog H (eds) New perspectives on human–animal interactions: theory policy and research. Wiley, New York, pp 545–568
Miao Y, Liu ZQ (2000) On causal inference in fuzzy cognitive maps. IEEE Trans Fuzzy Syst 8(1):107–119
Mora-Torres M, Laureano-Cruces A, Ramirez-Rodriguez J, Espinosa-Paredes G (2009) Analysis and design of the representation of the knowledge for the implementation of a distributed reasoning. En Revista de Matematica: Teoria y Aplicaciones 16(2): 267–281. Universidad de Costa Rica. Zentralblatt MAT. ISSN: 1409–2433, Latindex: 1409–2433
Mora-Torres M, Laureano-Cruces AL, Velasco-Santos P (2011) Estructura de las Emociones dentro de un Proceso de Enseñanza-Aprendizaje. Revista Perfiles Educativos-UNAM, XXXIII(131): 64–79, January–March 2011. ISSN: 0185-2698. http://www.iisue.unam.mx/seccion/perfiles/
Nishida T (2010) Modeling machine emotions for realizing intelligence—an introduction. In: Nishida T, Jain LC, Faucher C (eds) Modeling machine emotions for realizing intelligence: foundations and applications. Springer, Berlin, pp 15–34
Ortony A, Clore GL, Collins A (1988) The cognitive structure of emotions. Cambridge University Press, Cambridge
Oxoby M (2003) The 1990s American popular culture through history. Greenwood Publishing Group, United States of America
Pelaez CE, Bowles JB (1995) Applying fuzzy cognitive maps knowledge-representation to failure modes effects analysis. In: IEEE proceedings of the annual reliability and maintainability symposium. IEEE Publishing, Piscataway, NJ, pp 450–456
Picard RW (1997) Affective computing. MIT Press, Cambridge
Prairie Research Associates, Inc. (2001). The in-depth interview. Prairie Research Associates, Inc. (TechNotes), Winnipeg. Available at http://www.pra.ca/resources/pages/files/technotes/indepth_e.pdf
Stern A (2002) Creating emotional relationships with virtual characters. In: Trappl R, Petta P, Payr S (eds) Emotions in humans and artifacts. MIT Press, Cambrige, pp 333–362
Vallverdu J, Casacuberta D (2008) The panic room: on synthetic emotions. In: Briggle A, Waelbers K, Brey P (eds) Current issues in computing and philosophy. IOS Press, Netherlands, pp 103–115