An extended EBDI Model Applied to Autonomous Digital Actors

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Abstract

This paper defines the requirements for Autonomous Digital Actor's cognitive process, in order to allow them to suggest plans of plausible actions in computer animations. An architecture is proposed, adapted from a traditional EBDI model considering those requirements. This kind of characters are inspired by real human actors and know how to act autonomously following a script, making the creation of animated movies and interactive stories easier. The computational representation of mental processes is an important factor for the credibility of those characters. In this way, it is possible to create more believable agents, presenting better expressivity in their actions.

Keywords:: Artificial Intelligence, Affective Computing, Cognitive Agent, Autonomous Digital Actor

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1 Introduction

Since [Thomas and Johnston 1981] first introduced the principles of animation, there is a constant interest about the creation of more believable virtual characters. The short movie *The Adventures of André and Wally B.*™(from 1984 by *John Lasseter*) was the first fully generated animation and since then, the use of computers has become essential to generate computational models that increase the credibility of those characters.

This technology allows the creation of realistic characters, although humans are still needed to make decisions on how these characters act in a story. Henceforth, the next advance in authoring computer animations could be in the emulation of human behavior, making possible for these characters to act autonomously [da Silva et al. 2010].

Authoring character-based animations is a demanding task, being necessary for skilled animators to specify each action and each emotion being expressed by characters. An alternative to minimize animator's effort is to rely on self animated actors capable of autonomously interpreting the story, choosing which actions they should perform. Virtual characters that know how to act guided by a script, make animations and interactive stories easier to author. In this way, the representation of behaviors and physical models in a computational system is necessary.

The simulation of an actor behavior involves the process of decision making about which actions the actor should take, given a specific dramatic context defined by a script. The study of human cognitive models like emotions and personality and others, gives us an idea about how an autonomous character should behave.

In the context of Dramaturgy, a suitable approach to the implementation of those characters is the *Autonomous Digital Actors* (ADA) [Perlin and Seidman 2008], that are character agents capable of following director's guidelines. To create this kind of agents the *Belief-Desire-Intention* (BDI) approach can be used because it describes a practical process for the human reasoning. A variational approach is the *Emotion-Belief-Desire-Intention* (EBDI) [Jiang et al. 2007] that adds emotions to the original BDI model. While considering emotion as a complement to human reasoning, agents based on EBDI are more expressive.

This paper presents an ongoing research about an architecture that inherits the characteristics of the EBDI model and extends its structure to make possible the designing of virtual actors. This research aims at applying the suggested architecture for the virtual actors being developed by Project D.R.A.M.A. The next sections discuss this project, the original agent models and the preliminary results obtained during the development of the proposed architecture.

2 Project D.R.A.M.A.

Project D.R.A.M.A.[1] (*Developing Rational Agents to Mimic Actors*) is a research project that aims at studying the requirements for the development of an Autonomous Digital Actor (ADA). The behavior of this ADA is inspired on real actors' practice, by means of a computer metaphor.

Although the process for the creation of an ADA remains unknown, some requirements have already been discovered [da Silva et al. 2010]:

1. **Autonomous Script Interpretation:** is the ability of extracting informations regarding what is expected to perform via interpreting the script. This can be divided into two moments: first, the actor reads the script to learn his dialog lines and actions from scene descriptions; secondly, relying on script interpretations techniques he constructs his character by combining these interpretations with previously trained acting knowledge.

2. **Acting Knowledge:** to expressively perform any role, actors need knowledge. They need to understand what it means to act like as some specific character, or what it means to experience some particular situation. For instance acting techniques like emotion and sense memories could be used to represent acting knowledge.

3. **Dramatic Performances:** Analogously to human actors, ADA needs to be able to act expressively. Character animation techniques are used to emulate these skills like facial expressions, body postures and voice intonation.

The Project D.R.A.M.A. architecture assumes that a script is submitted to a group of autonomous digital actors, for them to deliberate by suggesting acting performances. These suggestions are translated into a non-linear timeline for a given animation engine, where the user (animator) can visualize and modify the behavior of the agent.

The main purpose of this article is to present the design and implementation of the *individual actions module* for the Project D.R.A.M.A. architecture. This module represents the decision making process. Using previously interpreted script information, the module suggests plausible actions to be performed by a character.

3 Autonomous Digital Actor

Iurgel & Marcos [Iurgel and Marcos 2007] have suggested the term 'virtual actor' as "*an analogy to a real actor, which autonomously, and by its independent interpretation of the situation, can perform its role according to a given script, as part of a story*".

Later, Perlin & Seidman [Perlin and Seidman 2008] have foreseen that "*3D animation and gaming industry will soon be shifting to a new way to create and animate 3D characters, and that rather than being required to animate a character separately for each motion sequence, animators will be able to interact with software authoring tools that will let them train an Autonomous Digital Actor how to employ various styles of movement, body language, techniques for conveying specific emotions, best acting choices, and other general performance skills*".

[1] `http://www2.joinville.udesc.br/~coca/drama/`

To accomplish that, an ADA needs agency, that is the ability of acting autonomously. It seems a reasonable approach to get inspiration from traditional acting techniques, applying them on computer animation. These actors differ from other types of agents because they have the ability to enact a script based on a holistic reasoning instead of simply reactive actions. Virtual actors should enact the script in an individual way, because similar behaviors can affect the realism of the scene [Perlin and Seidman 2008].

We believe that authoring process with ADA can represent a new approach to the authorship of characters in film production, because the animator assumes explicitly the role of the director [Perlin and Seidman 2008].

A key issue in simulation of virtual humans is believability. Believable characters must convince the audience to believe that they are coherent, which does not necessarily means realistic. It means that they have capabilities like perception, emotion, goal-oriented behavior, reactivity to the environment, memory, inference, personality and social interactions [Magnenat-Thalmann and Thalmann 2005]. Analogously, the appearance of an ADA does not have to remember humans (e.g. cartoon characters). Their movements can be more theatrical and exaggerated.

Agency is another important goal for ADA and means that characters have the ability of making their own decisions without (or at least with minimal) human intervention. Some characteristics are essential to accomplish agency: the perception of environment, adaptation, reasoning, memory, emotion, personality and others [Magnenat-Thalmann and Thalmann 2005].

This article focus mainly in reasoning. Next sections present our proposed solution.

3.1 Requirements

The process for implementations of an Autonomous Digital Actors still remains in open question in literature. However, we are proposing some requirements for this implementation:

Mental states: Represent the internal states of emotions, beliefs, desires and intentions for the agent, which resembles the human cognitive process:

Emotions are collections of physiological changes induced by nerve cell terminals controlled by the human brain, that is responding to the stimulus of thoughts relating to an entity or event. Because they influence the decision making process, an affective agent tends to be more believable.

Beliefs are the conviction that certain proposition is true, even while does not having concrete evidences [Jiang et al. 2007], for instance, "`it's raining`".

Desires are the agent goals (preferable states). They are determined based on its beliefs and intentions, and drive the agent to satisfy a necessity.

Intentions represent the focus (goals that the agent is committed to accomplish) and are affected by agent's emotional state, desires and previous intentions. Its main characteristic is persistence, that means that once committed to an intention, an agent will act determined to satisfy it, until he is done or believes that the intention became unfeasible [Jiang et al. 2007].

Perception and action: one of the main characteristics of an agent is being modeled with perceptions, through sensors (to sense objects or other agents), and action, through actuators. In this project, actuators means a repertoire of predefined animations.

Agency: endowing the agent with ability to govern itself is essential. In this way, the animator does not need to specify each step of character actuation.

Learning: the agent should include some mechanism of learning to make decisions based on a prior performance. This indicates that the deliberation process does not need to be used only to enact, but also to provide the possibility of improvement in future performances. It is the result of interaction between the agent and the world, and the observation by the agent of their own decision making processes [Russell and Norvig 2003].

Memory: is necessary to make possible the storage of information about prior situations for future reference.

Decision making process: it is the process of choosing actions for an actuation based on inference rules obtained from a knowledge base. Can be defined by: the stimuli processing, the reasoning about the current dramatic situation, how to reach certain goals, how to maintain a knowledge base and how to generate a significant response.

Planning: in order to satisfy certain intentions by reaching specific goals, it is necessary to make plans as sequences of future actions.

4 Agent Models

Intelligent agents are computational systems with characteristics like autonomous actuation, perception of the environment, adaptation for changing and ability to pursue their own goals (proactivity). Thus, tasks normally performed by humans can be assigned to agents [Russell and Norvig 2003].

A person can be defined by hers cognitive processes — which is the innate ability that complex organisms have to navigate and interact with their environment — along with thoughts, perceptions and actions resulted from those processes. Therefore, an ADA needs to be implemented as an agent with (at least some level of) a cognitive process.

The main feature of an agent is its autonomous actuation, that occurs when its behavior is determined by its own experience and not only by knowledge about the environment. Thereby, the program that controls an agent can be characterized by a function that implements the mapping of percepts into actions and updates its internal states [Russell and Norvig 2003].

Agent architectures are software models used to represent theoretical characteristics of agents. They specify which are the components and how works the interaction among them. Doing so, it is possible to specify how to map environment perceptions into actions. And according to its architecture, agents can be classified in reactive and deliberative (or hybrid).

- **Reactive Agents**: are characterized by a function that directly maps perceptions into actions [Russell and Norvig 2003].
- **Deliberative Agents**: (or cognitive) agents implement decision making for actions without a direct stimulus-response map (like reactive agents). This architecture considers *practical reasoning* — the process of deciding, at each moment, what is the best future action to achieve a specific goal [Russell and Norvig 2003].

BDI and EBDI models are examples of this kind of architecture. These models implement the deliberation process and are discussed below.

4.1 BDI

BDI (Belief-Desire-Intention) model finds its origin on the theory of human practical reasoning, developed by [Bratman et al. 1988]. Agents based on this model depend on the manipulation of data structures that represent their beliefs, desires and intentions. It is considered an interesting model, because all human beings recognize which is the process of deciding what to do and how to do it, and also understand the concepts of beliefs, desires and intentions. The main problem while implementing this model is how to implement it in a efficiently way [Weiss 1999].

For example, when a person graduates at school, she has to decide what to do for living. The decision begins realizing the current situation (deciding which career she wants to work on), then inferring about this situation and generating all plausible options. At the same time, she also should examine what options are available, like a post-graduation program or a job. After generating all these options, it is necessary to choose and commit to one of them. Therefore, they become intentions. These intentions are used to determine what are the future agent actions, because after it is committed to a goal, the agent should devote time and effort to accomplish it. A suggested implementation is presented at [Rao and Georgeff 1995].

4.2 EBDI

An improvement for the BDI model consists of adding primary and secondary emotions in its original architecture. This model of emotional agents is known as EBDI (Emotion-Belief-Desire-Intention) and was proposed by [Jiang et al. 2007]. The primary emotions act as "filters", adjusting the priority of beliefs, allowing agents to accelerate the decision making process. Secondary emotions are used to refine this decision, when time permits.

The components E (emotion), B (belief), D (desire) and I (intention) summarize the whole agent state at any given time. The architecture connecting all these components with environment perceptions and action decisions, including planning, can be implemented according to the algorithm in Listing 1 [Jiang et al. 2007].

Listing 1: *EBDI algorithm*

```
E ← E0;              (E0 are initial emotions)
B ← B0;              (B0 are initial beliefs)
I ← I0;              (I0 are initial intentions)
while true do:
        Bp ← brf−see(Env);
        Bm ← brf−msg(Cont);
        E ← euf1(E, I, Bp ∪ Bm );
        B ← brf−in(E, I, B ∪ Bp ∪ Bm );
        D ← options(B, I);
        I ← filter(E, B, D, I);
        E' ← E;
        E ← euf2(E, I, B);
        if time permits and E ≠ E' then:
                B ← brf−in(E, I, B);
                D ← options(B, I);
                I ← filter (E, B, D, I);
        π ← plan(I, Ac);
        execute(π)
```

Beliefs can be acquired through perception, communication and contemplation. The *brf-see* procedure maps the environment perception (*env*) into possible beliefs: $Bp \leftarrow brf - see(Env)$.

The *brf-msg* procedure maps the content of communication messages (*Cont*) into possible beliefs: $Bm \leftarrow brf - msg(Cont)$.

The primary emotions — reactive emotional responses to a situation — appear before the conscious thought and are instinctive responses from human brain: $E \leftarrow euf1(E, I, Bp \cup Bm)$.

Through contemplation, the *brf-in* function considers intentions and emotions to review current agent beliefs: $B \leftarrow brf - in(E, I, B \cup Bp \cup Bm)$. The procedure that generates options of desires relating beliefs and intentions is: $D \leftarrow options(B, I)$. Using a filter procedure it is possible to infer new intentions from current states: $I \leftarrow filter(E, B, D, I)$.

The secondary emotions are results of deliberation and may replace the primary emotions. They are used by the *euf2* procedure to refine decision making, if time permits: $E \leftarrow euf2(E, I, B)$. So, if secondary emotions differ from the primary ones, some updates are executed.

Based on the resulting intentions of an agent (I), and the set of possible actions that this agent can perform (Ac), the *plan* procedure decides which plan (or plans) is the best one to follow. A plan (π) is a sequence of actions produced by this procedure: $\pi \leftarrow plan(I, Ac)$. The procedure $execute(\pi)$ receives the plan π and performs it. If π is empty, the current intention has already been successful or it will be impossible to carry it out (e.g. by contradiction with another intention) and the procedure will be finished.

5 Results and discussion

Due to EBDI is accepted as an improvement for BDI model that considers emotions on it, our proposed solution is an architecture that extends the original EBDI model. This architecture is discussed in the next section.

5.1 Proposed extended EBDI architecture

As an important factor for believability of agents, the implementation of some human reasoning functions allows modeling of an affective agent. In this way, the problem that this research aims to solve is to design an architecture for the deliberation process of an ADA. Figure 1 illustrates the proposed architecture for the reasoning process.

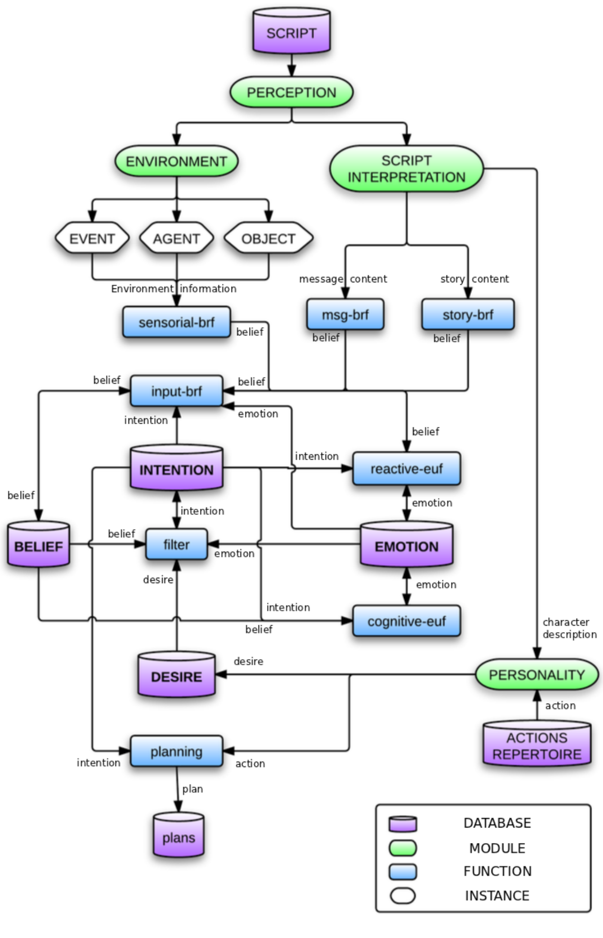

Figure 1: *Suggested deliberation model for Project D.R.A.M.A.*

This architecture starts with a *script* interpretation and ends by suggesting plausible *plans of actions*. It has been integrated with EBDI modules that implement a personality model (which is not the focus of this paper).

The *perception* module, receives as input the *script*, and is divided into two sub-modules: environment and script interpretation. The *environment* perception processes data about events, agents and objects to the *sensorial-brf* procedure. This procedure extends *brf-see* from the original model, by extending the agent's sensorial abilities, considering all five senses (sight, hearing, touch, smell and taste). The *script interpretation* module processes messages, like speech content, to the *msg-brf* procedure and also *script analysis* data — like theme, time, place — to a new procedure called *story-brf*.

Following the perception, the *reactive-euf* procedure updates the emotional state according to agent's beliefs and intentions. The perceived beliefs, along with previous beliefs, the new emotional state and intentions are sent to the *input-brf* procedure, which updates the *beliefs* state.

The *personality* module gets actor's personality traits and establishes its desires. As the original model do not consider personality traits, we are proposing to replace the *options* procedure for this new personality model. After that, the *filter* receives current sets of emotions, beliefs, desires and intentions to infer the new appropriate intention (or intentions) regarding the current situation.

The second update for the emotional state is performed at the *cognitive-euf* procedure. Considering previous reactive emotions, the revised beliefs and intentions, this procedure updates actor's emotional state. If this condition differs from that found by *reactive-euf*, the procedures *input-brf* and *filter* are executed again.

The *action repertoire* database stores a series of predefined animations. The *personality* module classifies each action according to its chance of being performed, regarding to the actor's personality. The *planning* procedure receives intentions and prioritized behaviors, and decides the possible plans that lead the agent's current state to the state related with an expected goal.

5.2 Practical example

This section shows how the architecture works for an action unit, based on a popular brazilian comics book named Monica's Gang[2]. A character named Smudge is in the scenario and a character Monica is running in his direction holding a camera. Smudge decision making process is described below.

First, the initial states of emotions, beliefs, desires and intentions are instantiated. *Emotions* represented a set of different emotions, *beliefs* are the set of procedural, semantic and episodic beliefs and *desires* are related to actor's personality, coming from *personality module*. This story starts in an open space scenario and the initial *intention* of Smudge was to walk towards it.

The environment perception module gets informations about the existence of a bush and a camera objects and also that the other agent (Monica) is running in his direction. The script interpretation will analyze that the scenario is an open space, the theme is conversation, the time is day-present. Considering these perceptions, the *belief* set is update by the *sensorial-brf*, *msg-brf* and *story-brf* procedures.

The emotions are updated by *reactive-euf*. For example: if there is a rule that says "if other agent is running in your direction, increase fear in 0.1 and decrease happy in 0.1", the reactive emotions response will be the previous emotions state updated accordingly.

After that, *input-brf* updates the beliefs set. This update may add an episodic belief, using all current informations regarding the episode. Then, *filter* updates intentions, according to current EBDI states. One example of a filtering rule is (the result is a intention of thinking with a weight of 0.4):

$$agent(other, running) \wedge theme(day, present) \wedge \\ desire(thinking) > 0.2 \rightarrow intention(update(thinking, +0.4))$$

Due to simplification, *cognitive-euf* considers emotions as the same as reactives.

Next, *planning* suggests a series of actions towards an expected goal. The *personality* module has already labelled each action, according to its chance of being performed. This helps *planning* to define a most adequate plan. For instance, is suggested that Monica look at Smudge with an emotion state of happy_for(0.4), fear(0.1) and hope(0.2).

This whole process is repeated for all script units. These actions being labels, they are not the actual character movements. These labels will later be translated into animation commands during character's performance.

[2]http://www.monica.com.br/ingles/comics/

6 Conclusion

Autonomous Digital Actors are believable characters inspired by the human actors practice. These characters are suitable for the simulation of virtual actors while acting out a script.

For the development of an ADA, deliberative agents are being studied as an appropriate solution. For authoring these agents, the EBDI architecture provides an adequate model to describe human cognitive process, simulating the processes of perception, internal states, planning, decision making and other fundamental features that we believe necessary for ADA expressivity.

The proposed architecture suggests some extensions to the original EBDI model, as follows:

- The desires are now considered as initial inputs, resulting from the personality module.
- The *options* procedure was replaced by the personality module, that is responsible for inferring desires and possible actions according to character's traits.
- The *brf-see* procedure was replaced by *sensorial-brf*, to consider all five human senses.
- The *story-brf* procedure was incorporated to identify elements from the script analysis, like theme, time and place.

The next steps are the implementation and validation of the architecture.

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