A Conceptual Graph-based Knowledge Representation Model for Virtual Actors

Gabriela Salvador Thumé
Centro de Ciências Tecnológicas - CCT
Universidade do Estado de Santa Catarina
Email: gabithume@gmail.com

Rogério Eduardo da Silva
Centro de Ciências Tecnológicas - CCT
Universidade do Estado de Santa Catarina
Email: rsilva@joinville.udesc.br

***Abstract*—Autonomous Digital Actors (ADA) are self-animated agents specially trained to perform their roles within a story. This paper suggests a fuzzy rules system based on Conceptual Graphs to be used in the cognitive process of an ADA; allowing them to suggest plausible actions for each script unit. An agent architecture adapted from a traditional EBDI model is used. We have managed, using our proposed CG-based formalism, to train an ADA to perform a Comic book story as a testing scenario. Then, we have evaluated if this system was capable of adapting its suggestions to a different untrained story. The results suggest that, even for this unforeseen situation, agents have the ability to suggest plausible actions to a story.**

***Index Terms*—Conceptual graph, Artificial Intelligence, Affective Computing, Cognitive Agent, Autonomous Digital Actor**

I. Introduction

Computer animation refers to the perception of motion created by images using a computer system. The phenomenon when a observer recognizes as a continuous movement a series of quickly shown rendered frames is known as persistence of vision, where eyes retain images briefly beyond the visual stimulus has been removed. These movements can be refereed to a virtual character, humanoid or not, which has the ability to demonstrate behaviors, interact with objects and with other characters within a scenario and story (PARENT, 2007).

An animator uses authoring tools for the creation of such characters. However, to accomplish that, all characters action and emotion expression should be specified previously by the animator. A suggested improvement for animator to analyze the whole story, to decide what actions the character have to perform and to generate these actions, is related to the character knowledge about how to perform a script. Virtual characters whose can act according to a script simplify the creation of animated films and interactive stories. Therefore, the simulation of a real actor is necessary through the representation of their own physical and behavioral model while in a computer system.

Authoring computer-based characters for animations means to describe actions that characters are expected to perform when enacting their roles in a story. This is accomplished relying on specialized software tools designed to support the development of such animations, the faster and easier manner as possible. Modern animation productions have become highly demanding in terms of quality (of graphics) and complexity (of characters' performances), which led to increase the effort and costs of a production. Therefore, novel authoring approaches are being researched to facilitate the animators work.

Autonomous believable characters present themselves as a promising alternative. Autonomous characters are Artificial Intelligence-based self-animated characters endowed with the ability of sensing the situation they are involved, responding appropriately, without (or at least with minimal) human interference. Based on this new technology, several authoring approaches are being proposed. We are interested in studying one of such possibilities: computer-generated actors.

First, it is important to establish a difference between the notion of computer-based characters and computer-generated actors: the prior are digital renditions of human acting performances (captured with special devices); they can only reproduce – while in the virtual world – actions taken by someone else (an actor or animator) in the real world. Computer-generated actors, on the other hand, are computer programs especially designed to emulate very specific aspects of human intelligence to produce self-animated characters capable of autonomously performing their roles according to a script.

The process for the creation of computer-generated 'virtual' actors remains an open question. Our research aims at collaborating with finding an answer for it. This work proposes a knowledge representation formalism, based on conceptual graphs and fuzzy sets rules, that can be used to describe tacit knowledge suitable for autonomous agents. The expectations are that this formalism should allow 'acting teachers' on training autonomous digital actors to perform specific characters within a story.

It is our understanding that performative arts are constantly reinventing itself. It all has started with the first theatrical performance (in ancient Greece), and it was only much later, with the advent of Computer Graphics technology, that a whole new kind of actors emerged; the kind that can now be represented digitally as especial renditions, allowing performances before considered difficult or even impossible to comply. The next step, is to endow digital actors with the ability of 'thinking' autonomously, allowing them to produce autonomous performances from stories.

A. Autonomous Digital Actors

It is important to notice that, despite all breathtaking performances current digital actors can deliver, they are in fact, an illusion, because virtual actors cannot decide for themselves how to perform. They lack *agency*.

Agency means that an artificial character would have the ability of making its own decisions without (or at least with minimal) human intervention. Digital actors endowed with some level of agency are called autonomous characters. Computer games industry has the leadership in using such technology. In games, non-player characters (NPC) are autonomous characters capable of performing specific tasks within game environment. They are common for decades now, and have become very sophisticated in terms of emulating complex behaviors. Players interact with them as if they were any other player. Animation industry, on the other hand, currently mainly relies on autonomous characters as digital extras, that are background characters with no direct relevance for the story being told, like soldiers in the armies of the battle scenes in Peter Jackson's The Lord of the Rings trilogy.

Iurgel and Marcos (Iurgel and Marcos 2007) have been the first to suggest 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 and Seidman 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 (ADA) how to employ various styles of movement, body language, techniques for conveying specific emotions, best acting choices, and other general performance skills*" (Perlin and Seidman 2008).

In this article, the terms virtual actors and autonomous digital actors have been used indistinguishably.

B. Requirements for Autonomous Digital Actors

A suggested list of requirements that any agent should be able to deploy to act as an autonomous digital actor is presented as follows (Silva et al. 2010):

1) **Autonomous Script Interpretation:** is the ability of extracting information 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; second, 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 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, autonomous digital actors need to be able to act expressively. Character animation techniques are used to emulate these skills, like facial expressions, body postures and voice intonation.

All these requirements relate with individual acting performances. Iurgel et al (Iurgel et al. 2010) discuss the requirements regarding the authoring aspects of autonomous digital actors.

In concerning of the construction of the agents, a detailed architecture based on the EBDI (Emotion-Belief-Desire-Intention) approach has been proposed by Project D.R.A.M.A[1] and it is currently been implemented as a proof of concept. This model can describe the deliberation process, by improving the capability of actions expressiveness which results in augmenting agents' credibility.

II. Project D.R.A.M.A

The main goal of this Project is to create an autonomous digital actor capable of deploying acting performances relying on acting techniques inspired on real actors' practice. Current version of the system considers the following steps (Figure 1):

1) First, a script describing the scene to be played, the set, the characters (including their personality traits) and the plot is written by a script writer (possibly the animator itself);
2) Then, the script is submitted to a series of ADA (known as the 'cast') that should interpret it, making individual acting performances suggestions for each script unit, relying on previously trained acting knowledge for that;
3) The third step is the rehearsal. It is when all individual acting performances are combined to produce a suggested time-line for the plot;

[1] http://drama.musa.cc/

4) Finally, the fourth step is to translate the resulting time-line into animation commands for an animation engine of choice, thus, producing an animation film.
5) Eventually, the animator can send criticisms back to the cast, indicating parts of the time-line that are not according to his/her expectations. Agents can learn from these feedbacks, making their suggestions more accurate in the future (current version will only consider reinforcement learning, thus, criticism are of the form like/dislike).

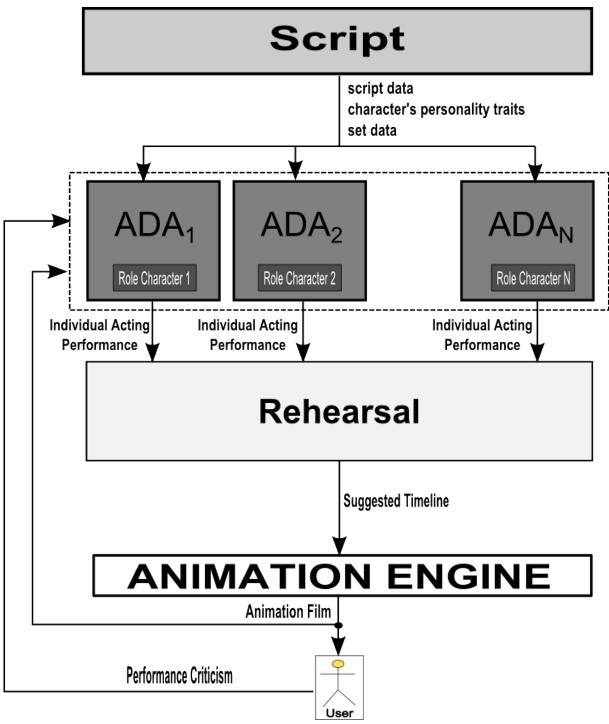

Fig. 1: *General View of Project D.R.A.M.A*

One important aspect for actors when preparing for a role is what is called by acting teachers as 'characterization' (Stanislavski 1950). Characterization is the moment when actors learn their role in the story. In our system, before one could train an ADA to construct its character, some sort of knowledge formalism had to be developed. This study focus on presenting our proposal of a conceptual graph-based knowledge representation language with which one can train an digital actor to act according to its character in different dramatic contexts. Next sections describe this knowledge formalism based on conceptual graphs and later, we describe our test scenario, used for validation of this model.

III. Conceptual Graphs

Conceptual Graph (CG), according to Sowa (Sowa 2008) "*is a graph representation for logic based on the semantic networks of artificial intelligence and the existential graphs of Charles Sanders Peirce*". Several different variants of conceptual graphs can be found in the literature. One of such variants, that seems to be adequate for the purposes of Project D.R.A.M.A is the one proposed by Sowa. He suggested to use CG as a way of mapping natural language into a relational database. To endow autonomous actors with the ability of interpreting formal script descriptions, such ability seems to be a key component for them.

The conceptual graphs representation is composed by concepts, conceptual relations and arcs. *Concepts* can be understood as classes (and associated instances) that are connected by *conceptual relations* via *arcs*. For example, the sentence "`John is going to Boston by bus`" can be represented as the conceptual graph presented in Figure 2, where the squares denote the concepts, the circles denote the conceptual relations and the arcs indicate the order these elements should be interpreted.

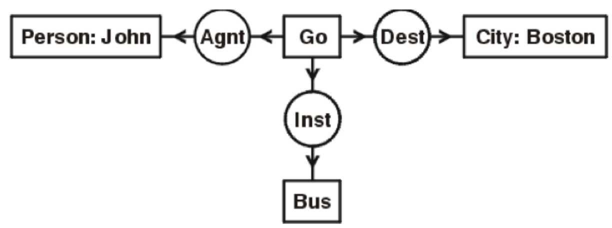

Fig. 2: *Conceptual Graph for sentence "John is going to Boston by bus"*

Source: (Sowa 2008)

It is important to notice that entire graphs can be interpreted as a concept per se, allowing the construction of hierarchical descriptions. This representation enable its transposition to a first order logic representation, which is suitable for inference systems, as illustrated below:

$$(\exists x)(\exists y)(Go(x) \wedge Person(John) \wedge City(Boston) \wedge$$
$$Bus(y) \wedge Agnt(x, John) \wedge Dest(x, Boston) \wedge Inst(x, y))$$

In this research, we are proposing the use of conceptual graphs as a notation to write behavioral fuzzy rules for training EBDI agents as autonomous actors on constructing their characters.

IV. Proposed EBDI Knowledge Formalism

EBDI agents (Jiang and Vidal 2006) are a type of deliberative agents that relies their deliberation process on four main mental states: emotions (E), beliefs (B), desires (D) and intentions (I).

A. Emotions

Emotions are special inner states, maintained by agents, that reflect their cognitive interpretation of the current dramatic situation being played. These states can be used by other parts of the system to more accurately deliberate proper acting performances. Despite the fact that, in theory, any emotion model can be used for this emotional inference, we are considering the model proposed by Ortony, Clore and Collins called OCC model (Ortony et al. 1988).

In this model, emotions are the result of cognitive appraisal of the situation in terms of agents, events and objects (Bartneck 2002). Also, an emotion can be modeled as the tuple `[label, intensity, valence]`, where:

- `label` denotes the name of the emotion. In our system, the supported values are (according to the OCC model): happy_for, gloating, hope, satisfaction, fear, joy, pride, admiration, gratification, gratitude, love, resentment, pity, relief, fear_confirmed, disappointment, distress, shame, reproach, remorse, anger and hate;
- `intensity` denotes the 'amount' of emotion been experienced (ranging from 0.0 to 1.0);
- `valence` indicates the pleasantness of the emotion; supported values are -1 (unpleasant) or 1 (pleasant).

We are proposing a simplified conceptual graph structure to represent emotions as

emotion(LABEL, INTENSITY, VALENCE**)**

For instance, the description **emotion(love, 0.5, 1.0)** represents the emotion named love with 50% of intensity.

B. Beliefs

Whenever agents sense their surrounding environment (e.g., the scenario in which the virtual actor is performing a scene), a series of new beliefs are produced to improve agent's comprehension of its dramatic context. A belief is a special state that reflects the agent's understanding of a particular aspect of the environment or the story. In our model, three kinds of beliefs storage (memories) are proposed: semantic memory, episodic memory and procedural memory.

1) Semantic Memory: is the part of the memory responsible for storing agent's knowledge about the world. The general rule to describe one semantic entry is

belief(semantic, DATA**,** VALUE**)**

where *Data* represents one of three possible aspects:

- agent(LABEL, ATTRIBUTE, VALUE)
- object(LABEL, ATTRIBUTE, VALUE)
- event($\text{LABEL}_{AGT|EVT|OBJ}$, NAME, $\text{LABEL}_{AGT|EVT|OBJ}$)

2) Episodic Memory: stores all episodes experienced by the agent. An episode is a conceptual graph that describes a particular event defined according to the following syntax:

belief(episodic, DEPENDENCY(DATA)**,** VALUE**)**

as it would be too complex trying to represent every possible dependency for every possible concept, thus a conceptual dependency simplification is necessary as shown in Figure 3. Each *dependency* is described based on its own list of attributes (*Data*). Additionally, to each belief is associated a degree of confidence (*value*).

PTRANS: The transfer of location of an object
ATRANS: The transfer of ownership, possession, or control of an object
MTRANS: The transfer of mental information between agents
MBUILD: The construction of a thought or of new information by an agent
ATTEND: The act of focusing attention of a sense organ toward an object
GRASP: The grasping of an object by an actor so that it may be manipulated
PROPEL: The application of a physical force to an object
MOVE: The movement of a bodypart of an agent by that agent
INGEST: The taking in of an object (food, air, water, etc.) by an animal
EXPEL: The expulsion of an object by an animal
SPEAK: The act of producing sound, including non-communicative sounds

Fig. 3: *Conceptual Dependencies Primitives*
Source: (Lytinen 1992)

3) Procedural Memory: all knowledge relatively to ADA's motor skills is called its 'repertoire', which represents a series of predefined animations for actions it is able to perform when enacting a story. In terms of conceptual graphs, it is described as

belief(procedural, proc(AGENT**,** ACTION**,** TARGET**,** ANIMATION**),** VALUE**)**

where *agent* represents the name of the actor performing an *action* towards another *target* agent by executing a predefined *Animation*.

C. Desires

Desires represent the goals of which agents 'want' to pursue in order to respond to a given enactment request (defined in the script). Setting goals help agents to direct their decisions towards more expressive acting performances. The list of supported desires shall vary according to the script being performed. However, one non-exhaustive list suggested by Reiss (Reiss 2008) includes the following goals: avoid_criticism, sustenance, moral_behavior, self_reliance, muscle_movement, sex, peer_companionship, safety, thinking, raise_children, better_world, structure, influence, collection, social_standing and get_even.

Similarly to the syntax used to describe emotions, desires are described as

desire(LABEL**,** VALUE**)**

D. Intentions

Intentions are commitments to perform actions, which means that the agent had already selected the most suitable rule to perform, regarding current dramatic situation. To do that, our agents rely on fuzzy rules in the traditional condition-action fashion, but considering each of this components as conceptual graphs (as detailed later in this paper). Figure 4 shows one example rule including the associated fuzzy values for each CG clause in it.

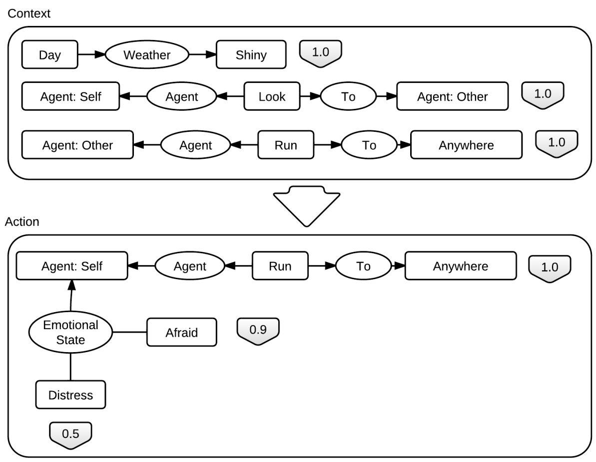

Fig. 4: *Fuzzy Rule with a Conceptual Graph Example*

E. Fuzzy Evaluation

Fuzzy logic theory is based on the theory of fuzzy sets, which allows the representation of inaccurate concepts (Zadeh 1965). These fuzzy sets group elements do not have well-defined group boundaries, they have degrees of relevance to the group instead.

The EBDI model is related to an algorithm where states are defined as sets of emotion, beliefs, desires and intentions elements specified as rules following a condition-action form. The classical set theory adopts a boolean assessment (true or false) to rule conditions, called perfect matching. To determine that a sentence can only assume these two states is not suitable for real systems, because it is commonly necessary to define rules for the whole world. The matching of dramatic context with conditional rules may be imperfect, then the rule is not fully matched with the context and even then it must be decided which is the best rule to be applied. Henceforth, fuzzy logic is used to represent the uncertainty of rules, with a "fuzzy weight" associated with each one of them. For the inference of rules and their respective weights – which comprise the EBDI state of each agent during the performance – it is suggested the use of fuzzy evaluation.

The proposed rules were inspired by a Case Based Reasoning (CBR) model: the cases represent specific knowledge. From a previously experienced situation, the solution is adjusted to new similar situations. It is based on the principle that solving a problem a second time is easier than the first because the agent will know whether to run same action again or to avoid it (Poch et al. 2004). In this way, the rules for training EBDI agents as autonomous actors can be described as follows:

if DRAMATIC CONTEXT **then** INTENTION

The dramatic context is given through the formal description of a situation that may occur during a performance, represented by a sequence of descriptions of currents emotions, beliefs, desires and intentions elements. An action intention is chosen in function of its similarity with the found context. To determine the context that agent is related, we used a fuzzy rules system based on similarity principles, ensuring that only a subset of all possible contexts should be defined to represent a system within a certain domain. In other words, choosing the most similar rule to the current context is sufficient to represent the whole system.

V. EXPERIMENTATION AND RESULTS

We conducted an experiment to assure the efficacy of the proposed system. We have selected two strips from a Brazilian comic book called "Monica's Gang", to be our training and testing sets. Working as an acting teacher, we have manually transcript the training story to CG fuzzy rules in terms of all EBDI mental states.

The same fuzzy rules set used during the training phase (see Section V-A) was later used to assess the system efficacy for a different story, during the acting phase (as presented in Section V-B). The comic strip used in the training phase and its deliberation results can be found at Appendix A. This experiment showed us that besides having different contexts and mental states, a fuzzy rules set can be built to contemplate all the character knowledge.

The next sections illustrate this process for a selected frame of each story: the training (Figure 5) and acting phases (Figure 6).

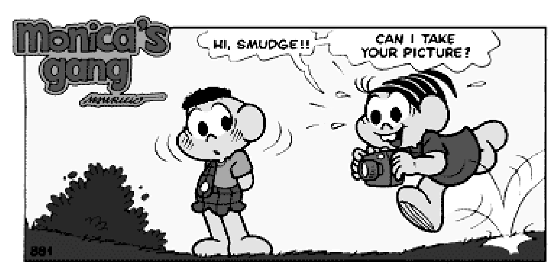

Fig. 5: *Excerpt from the comic strip used for training ADA*

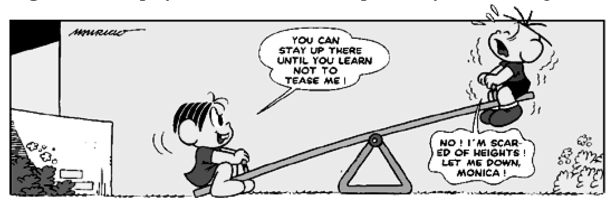

Fig. 6: *Excerpt from the story used during acting phase*

A. Training Phase

The purpose of this phase is to train an ADA regarding how to enact. Our approach is based on training stories being transcript into acting rules for characters. The expectation is that once trained it would be possible to apply this virtual actor to a variety of different scripts, without the need for re-training. Although, the more training it gets, the more 'general purpose' it becomes.

The training story focuses on two characters (Monica and Smudge). We present here the process for one frame where Monica is approaching Smudge, smiling and holding a camera. Then, she asks him "`Hi, Smudge!! Can I take your picture?`". In order to the acting teacher to transcript this frame into fuzzy rules, to consider all four aspects of the agent architecture (emotions, beliefs, desires and intentions) is required:

1) Defining Emotions: Every character is able to 'feel' a series of emotions each time (called an emotional state). The OCC model suggests 22 emotions, that can all be expressed in our model. For the training frame (Figure 5), the following emotional states have been proposed:

Monica:

{emotion(happy_for):70.0, emotion(joy):100.0, emotion(hope):60.0}

Smudge:

{emotion(hope): 20.0, emotion(fear): 80.0}

No effective method to define intensities for each individual emotion have been studied yet. So, the values proposed here for the intensity the characters are feeling these emotions are arbitrary. Because the purpose of this experiment was to assess the efficacy of the model, these values came from the trainer's impressions of the study of the story and from his own experience.

2) Defining Desires: To define the desires a character should pursue, comes from a deep understand of the character being played; which means having to know their personalities and roles in the story. Once more, relying on the previous experiences of the trainer, the following list of desires have been suggested for our experiment:

Monica:

{desire(avoid_criticism): 50.0, desire(thinking): 50.0,
desire(sustenance): 80.0, desire(muscle_movement): 20.0,
desire(peer_companionship): 100.0, desire(safety): 10.0}

Smudge:

{desire(avoid_criticism): 20.0, desire(thinking): 60.0,
desire(sustenance): 60.0, desire(muscle_movement): 80.0,
desire(peer_companionship): 80.0, desire(safety): 100.0,
desire(collection): 80.0}

3) Defining Beliefs: The beliefs set that every character has regarding the world (the common sense knowledge) and regarding individual beliefs (personal experience).

Common Sense Knowledge: in terms of semantic memory it describes the objects belonging to the scene (in the example: the camera) and the operations associated to them. The episodic memory stores the experienced episodes, so is related to knowledge of theme, place and time of the current story (script analysis). And in procedural memory, the character stores its enacting skills.

1) {belief(semantic, object(obj_camera, name, obj_toycamera)): 100.0}
2) {belief(semantic, object(obj_toycamera, type, fake)): 100.0}
3) {belief(semantic, object(obj_realcamera, type, real)):100.0}
4) {belief(semantic,event(obj_toycamera,push_button,evt_squirtwater)):100.0}
5) {belief(semantic,event(obj_realcamera,push_button,evt_takepicture)):100.0}
6) {belief(semantic, event(evt_squirtwater, wet, agt_self)):100.0}
7) {belief(episodic, mbuild(theme, type, conversation)): 100.0}
8) {belief(episodic, mbuild(place, type, open_space)): 100.0}
9) {belief(episodic, mbuild(time, type, present)): 100.0}
10) {belief(procedural,proc(agt_self,look,agent, animation_look)):100.0}
11) {belief(procedural,proc(agt_self,point,agent,animation_point)):100.0}
12) {belief(procedural,proc(agt_self,fight,agent, animation_fight)):100.0}

Personal Experience: comprises the experiences (belief set) that characters possess before the story takes place.

Monica's Knowledge: The individual belief set created for the character Monica, in this context, is related to her name and age, the name of the other agent in the scene, the notion that getting Smudge wet cleans him, that she wants to wet Smudge and that she is holding a camera.

1) {belief(semantic, agent(agt_self, name, agt_monica)): 100.0}
2) {belief(semantic, agent(other, name, agt_smudge)): 100.0}
3) {belief(semantic, agent(agt_self, age, 9)): 100.0}
4) {belief(episodic, propel(wet, clean, agt_smudge)):100.0}
5) {belief(episodic, mbuild(agt_self, want, event(agt_self, wet, agt_smudge))):90.0}
6) {belief(episodic, grasp(agt_self, hold, obj_toycamera)): 100.0}

Smudge's Knowledge: The belief set created for Smudge is related to his notion that getting wet hurts him among other beliefs.

1) {belief(semantic, agent(agt_self, name, agt_smudge)): 100.0}
2) {belief(semantic, agent(other, name, agt_monica)): 100.0}
3) {belief(semantic, agent(agt_self, age, 10)): 100.0}
4) {belief(episodic, propel(wet, hurt, agt_self)):100.0}
5) {belief(episodic, grasp(agt_monica, hold, obj_toycamera)): 100.0}

4) Deliberation: Considering current mental states of both agents Monica and Smudge, their beliefs are updated by the *beliefs revision functions* of our architecture. The resulting beliefs are presented below.

Monica showing that she is happy, is holding a 'fake' camera and wants to squirt water on Smudge:

{belief(episodic, mbuild(agt_self, emotion, happy_for)): 100.0, belief(episodic, mbuild(obj_toycamera, type, fake)): 100.0, belief(episodic, mbuild(agt_self, want, event(agt_self, wet, agt_smudge))):100.00}

Smudge sees Monica's display of happiness, so he infers the camera she is holding might be fake and that she wants to wet him:

{belief(episodic, attend(agt_monica, emotion, happy_for)): 100.0, belief(episodic, mbuild(obj_toycamera, type, fake)): 20.0, belief(episodic, mbuild(agt_monica, want, event(agt_monica, wet, agt_self))): 80.0}

Regarding this dramatic context, the deliberation process selects the intentions, by matching current emotions, beliefs, desires and intentions with the fuzzy rules data set, determining the most pertinent one. Two defined fuzzy rules for the character deliberation process are shown at Figure 7. Another rules were inserted to allow variability in choice of intentions. Is presented on Table I the resulting intentions and their associated pertinence to the context.

TABLE I: *Pertinence values for the Deliberated Intentions*

I	Intention	Monica	Smudge
1	intention(sex)	0.000	0.000
2	intention(moral_behavior)	0.255	0.473
3	intention(social_standing)	0.250	0.297
4	intention(get_even)	0.438	0.000
5	intention(raise_children)	0.000	0.000
6	intention(avoid_criticism)	0.250	0.000
7	intention(peer_companionship)	0.312	0.062
8	intention(collection)	0.000	0.000
9	intention(influence)	1.000	0.062
10	intention(sustenance)	0.000	0.000
11	intention(muscle_movement)	0.000	0.000
12	intention(structure)	0.000	0.000
13	intention(thinking)	0.027	0.332
14	intention(self_reliance)	0.062	0.062
15	intention(better_world)	0.000	0.000
16	intention(safety)	0.262	0.812

Monica chooses one from those intentions with the greatest pertinence value (*influence* in this case). This choice is justified by her intention of demonstrating power over Smudge as she is planning to gets him wet against his will.

Smudge, on the other hand, demonstrates fear due to the selection of the intention of *safety*. This is because Monica is running towards him holding a camera that can be fake. Smudge hates getting wet and believes that the camera might squirt water.

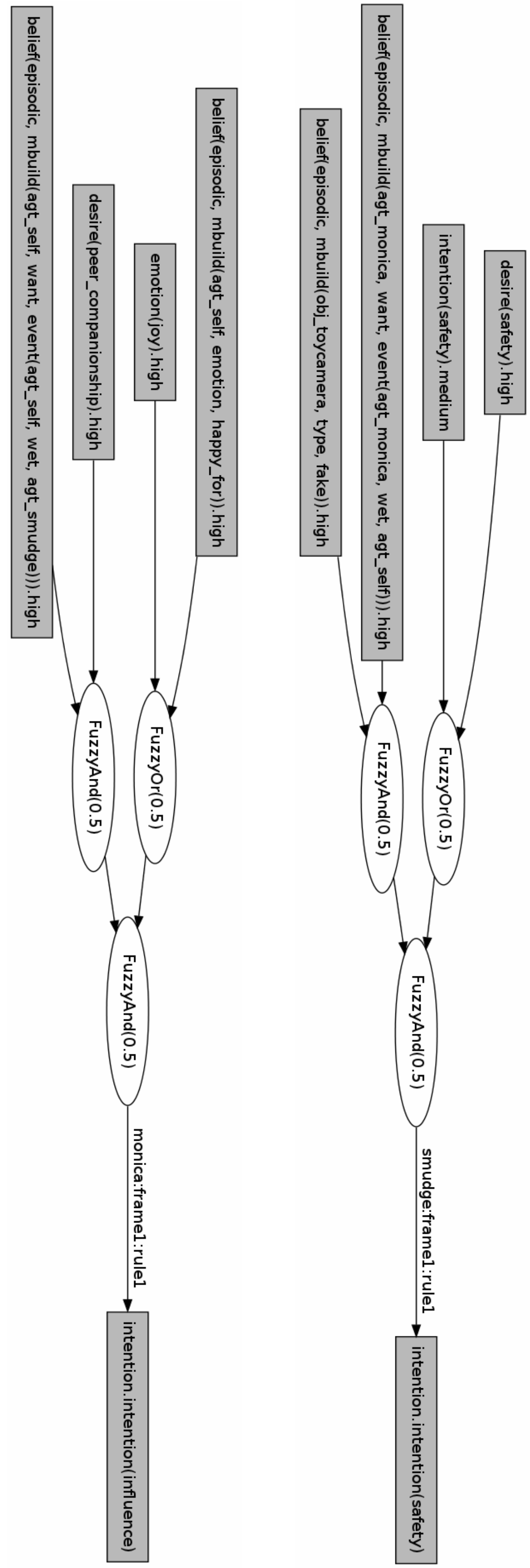

Fig. 7: *Character rules for training frame*

B. Acting Phase

In this phase, in order to assess if this model can be applicable for unknown situations (as it would be expected with fuzzy rules), we used a different story of the one used for training. In this story, the objects, the facts and even a new character 'Jimmy Five' (thus, a new personality) were added. The first frame of this story was previously presented in Figure 6.

1) Defining Emotions: Monica wants revenge against Jimmy Five, because he is always teasing her, so she did not let him down, what scares him. The initial emotional states obtained from analyzing this frame are:

Monica's Emotions:

{emotion(happy_for): 70.0, emotion(satisfaction): 100.0, emotion(pride): 60.0}

Jimmy Five's Emotions:

{emotion(hope): 20.0, emotion(remorse): 80.0, emotion(fear): 100.0, emotion(fear_confirmed): 80.0, emotion(disappointment): 90.0, emotion(distress): 90.0}

2) Defining Desires: Monica's desires list is the same of the training phase, but Jimmy Five's ones can be represented as the follow set:

{desire(avoid_criticism): 50.0, desire(thinking): 100.0, desire(sustenance): 50.0, desire(muscle_movement): 90.0, desire(peer_companionship): 100.0, desire(safety): 80.0, desire(collection): 100.0}

3) Defining Beliefs: Some of the initial character's beliefs are shared between they:

1) {belief(procedural, proc(agt_self, jump, agent, animation_jump)): 100.0}
2) {belief(episodic, mbuild(theme, type, conversation)): 100.0}
3) {belief(episodic, mbuild(place, type, open_space)): 100.0}
4) {belief(episodic, mbuild(time, type, present)): 100.0}

By being different characters with distinct personality, Monica and Jimmy had their own set of beliefs which differ one from another, guarantying their different view of the world:

Monica's individual beliefs:

1) {belief(semantic, agent(agt_self, name, agt_monica)): 100.0}
2) {belief(semantic, agent(other, name, agt_jimmy_five)): 100.0}
3) {belief(semantic, agent(agt_self, age, 9)): 100.0}
4) {belief(episodic, mbuild(agt_self, like, event(agt_jimmy_five, tease, agt_self))): 100.0}
5) {belief(episodic, mbuild(agt_jimmy_five, hate, event(agt_self, suspended, agt_jimmy_five))): 90.0}
6) {belief(episodic, mbuild(agt_jimmy_five, emotion, emotion(fear_confirmed)))): 85.0}
7) {belief(episodic,mbuild(agt_self,emotion,emotion(joy))): 90.00}

Jimmy Five's individual beliefs:

1) {belief(semantic, agent(agt_self, name, agt_jimmy_five)): 100.0}
2) {belief(semantic, agent(other, name, agt_monica)): 100.0}
3) {belief(semantic, agent(agt_self, age, 10)): 100.0}
4) {belief(episodic, mbuild(agt_self, like, event(agt_self, tease, agt_monica))): 100.0}
5) {belief(episodic, mbuild(agt_self, hate, event(agt_monica, suspended, agt_self))): 90.0}
6) {belief(episodic, mbuild(agt_self, emotion, emotion(fear_confirmed)))): 85.0}
7) {belief(episodic, mbuild(agt_monica,emotion, emotion(joy))): 90.00}

4) Deliberation: Resulting intentions was obtained for this story, and they values are presented in Table II. This time, Monica selects `intention(get_even)`, while Jimmy Five choose `intention(moral_behavior)` as the more important intention, which is a plausible result considering the dramatic context of the analyzed frame.

TABLE II: *Intention Selection Results*

I	Intention	Monica	Jimmy Five
1	intention(sex)	0.000	0.000
2	intention(moral_behavior)	0.251	0.251
3	intention(social_standing)	0.250	0.016
4	intention(get_even)	0.375	0.250
5	intention(raise_children)	0.000	0.000
6	intention(avoid_criticism)	0.250	0.000
7	intention(peer_companionship)	0.312	0.062
8	intention(collection)	0.000	0.000
9	intention(influence)	0.062	0.062
10	intention(sustenance)	0.000	0.000
11	intention(muscle_movement)	0.000	0.250
12	intention(structure)	0.000	0.000
13	intention(thinking)	0.001	0.004
14	intention(self_reliance)	0.016	0.062
15	intention(better_world)	0.000	0.000
16	intention(safety)	0.250	0.250

It is noteworthy that Jimmy have another three intentions with its respective value near to the most valuable one, which are: `intention(get_even)`, `intention(muscle_movement)` and `intention(safety)`. This occurred because more than just one rule matched to the context given, and it is plausible for Jimmy "feels" this others intentions in the current context.

Results of deliberation process shown that the fuzzy rules system works satisfactorily, even if the story has different characters. This experiment has provided evidence that the proposed representation can be generalized to contemplate different types of acting knowledge for virtual actors.

VI. Conclusions

Autonomous Digital Actors are believable self-animated characters capable of suggesting animations relying on specialized knowledge for that. These characters are inspired on human actors practice.

Computer-generated actors are capable of autonomously perform a script by emulating acting skills to expressively perform roles. The proposed knowledge representation based on conceptual graphs allows autonomous actors to interpret formal script descriptions.

A formalism based on EBDI agents was proposed. This model relies on mental states of emotions, beliefs, desires and intentions. The validation of the efficacy of this model has been accomplished in two phases: the training phase and the acting phase. In the first one, tacit knowledge of performance skills were translated into CG fuzzy rules for decision-making of plausible actions.

Then, during the acting phase, we used a different story from the one used for training. However, the same conceptual graphs fuzzy set rules were used, to ensure reliability. The results of the deliberation process showed us some evidence about its applicability to different contexts.

This research is part of Project D.R.A.M.A, which aims at studying the requirements for the development of an ADA, inspired by real actors' practice. Following steps involve extending this model to allow characterization of actors based on the Field Theory of Kurt Lewin.

Appendix
Deliberation result of training phase

At Section related to training phase (V-A) it was presented the deliberation process for the first strip of Figure 8. Considering the same process, all this story was used with the purpose of training the ADA. In Tables III e IV are presented the resulting intentions for the last dramatic unit of each frame. The characters are shown as

<M (Monica)| S (Smudge)> <frame number>

and the relation between intentions and numbers of for the column named I is listed in Tables I andII.

The fuzzy rules system generated for this story has enabled the acting phase (Section V-B) of choosing consistent behaviors for the ADA. The demonstrative figure of this rules is available at *http://tecendobits.cc/tcc/sistema.png*

I	M1	S1	M2	S2	M3	S3	M4	S4
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.255	0.473	0.251	0.438	0.264	1.000	0.901	0.262
3	0.250	0.297	0.250	0.250	0.250	0.273	0.391	0.625
4	0.438	0.000	0.188	0.125	0.188	0.344	0.188	0.031
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.250	0.000	0.438	0.000	0.250	0.000	0.438	0.000
7	0.312	0.062	0.438	0.004	0.062	0.004	0.062	0.219
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	1.000	0.062	0.250	0.062	0.250	0.062	0.250	0.062
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.125	0.000	0.250	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	0.027	0.332	0.004	0.297	0.004	0.314	0.016	0.789
14	0.062	0.062	0.016	0.062	0.215	0.086	0.895	0.062
15	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16	0.262	0.812	0.250	0.438	0.262	1.000	0.297	0.375

TABLE III: *Resulting intentions for first part of the story*

I	M5	S5	M6	S6	M7	S7	M8	S8
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	1.000	0.253	0.438	0.306	0.255	0.253	0.255	0.309
3	0.297	0.578	0.297	0.578	0.438	0.297	0.250	0.297
4	0.438	0.000	0.438	0.000	0.188	0.000	0.188	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.438	0.000	0.250	1.000	0.250	0.000	0.250	0.000
7	0.062	1.000	0.062	0.000	1.000	0.505	0.145	0.473
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	0.250	0.062	0.250	0.375	1.000	0.438	1.000	0.375
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	1.000	0.000	1.000	0.000	0.000	0.250	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	0.027	0.262	0.027	0.262	0.027	0.262	0.027	0.332
14	1.000	0.062	0.438	0.000	0.062	0.000	0.062	0.062
15	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16	0.262	0.250	0.262	1.000	0.262	0.262	0.262	0.684

TABLE IV: *Resulting intentions for first part of the story*

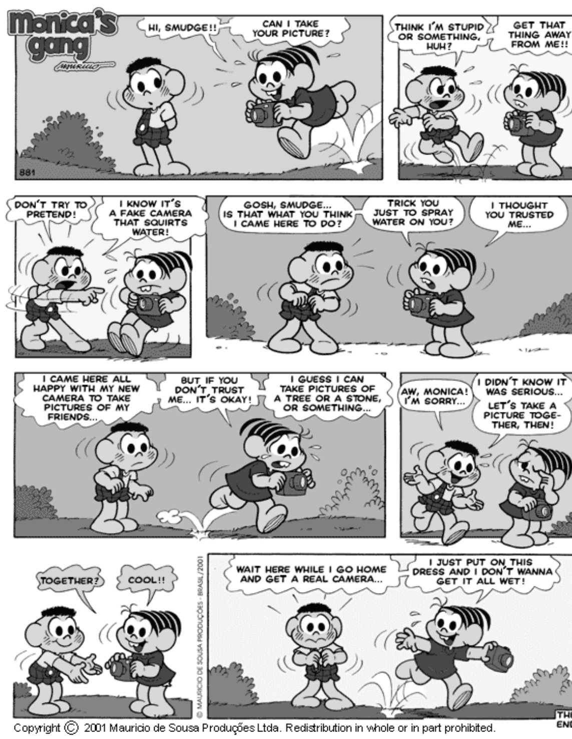

Fig. 8: *Comic strip used for training ADA*

References

Bartneck, C. 2002. Integrating the OCC model of emotions in embodied characters. In *Proceedings of the Workshop on Virtual Conversational Characters: Applications, Methods, and Research Challenges*.

IURGEL, I. A., AND MARCOS, A. F. 2007. Employing personality-rich virtual persons–new tools required. *Computers & Graphics 31*, 6 (Dec.), 827–836.

IURGEL, I. A., SILVA, R. E. D., AND SANTOS, M. F. D. 2010. Towards virtual actors for acting out stories. In *Proceedings of the 5th International Conference on E-learning and Game (Edutainment)*, Springer Verlag, Changchun, China.

JIANG, H., AND VIDAL, J. M. 2006. From rational to emotional agents. In *Proceedings of the AAAI Workshop on Cognitive Modeling and Agent-based Social Simulation*, IEEE Computer Society.

LYTINEN, S. 1992. Conceptual dependency and its descendants. *Computers & Mathematics with Applications 23*, 2, 51–73.

ORTONY, A., CLORE, G. L., AND COLLINS, A. 1988. *The Cognitive Structure of Emotions*. Cambridge University Press.

PERLIN, K., AND SEIDMAN, G. 2008. Autonomous digital actors. In *Motion in Games*, vol. 5277/2008 of *Lecture Notes in Computer Science*. Springer Verlag, 246–255.

POCH, M., COMAS, J., RODRIGUEZ-RODA, I., SANCHEZ-MARRE, M., AND CORTÉS, U. 2004. Designing and building real environmental decision support systems. *Environmental Modelling & Software 19*, 9, 857–873.

REISS, S. 2008. *The Normal Personality*. Cambridge University Press.

SILVA, R. E. D., IURGEL, I. A., SANTOS, M. F. D., BRANCO, P., AND ZAGALO, N. 2010. Understanding virtual actors. In *2010 Brazilian Symposium on Games and Digital Entertainment (SBGAMES)*, IEEE, 220–229.

SOWA, J. F. 2008. Conceptual graphs. In *Handbook of Knowledge Representation*, F. v. Harmelen, V. Lifschitz, and B. Porter, Eds. Elsevier, 213–237.

STANISLAVSKI, C. 1950. *Building A Character*. Methuen Drama.

ZADEH, L. 1965. Fuzzy sets. *Information and control 8*, 3, 338–353.