Fuzzy Micro-Agents for Interactive Narrative

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Abstract

This paper describes our current approach in implementing computational improvisational *micro-agents*. This approach is intended to foster bottom-up research to better understand how to build more complex agent behaviors in a theatrical improvisational setting. Micro-agent designs are based on our current findings in a multi-year study focused on studying real life theatrical improvisers with an aim towards better understanding the cognition employed in improvisation at the individual and group level. It also introduces a key architectural component from the domain of fuzzy logic that enables us to clearly represent some of our current findings.

Introduction

Improvisational agents have been of interest to the interactive narrative community off and on for decades (Hayes-Roth and Van Gent 1996; Hayes-Roth et al. 1994; Perlin and Goldberg 1996; Swartjes and Theune 2009; Bruce et al. 1999). These approaches have typically been influenced by improvisational practices or writings on improvisation. However, they have neither attempted a large scale study of improv to inform their formalism of the practice nor engaged in an effort to encapsulate all of the main individual and group processes involved in improvisation, instead focusing on some small subset of performance.

Though there have been arguments against strongly autonomous agents (e.g., they are difficult to coordinate to serve story goals instead of individual goals (Mateas and Stern 2002)), there are multiple conditions when an interactive agent may require improvisational behavior:

Story space breached by user: The user has executed a series of actions that has led to a world state not covered by authored story content (Magerko 2007). This could mean anything from physically altering the environment or a character (e.g., the canonical example of shooting an important character) to being in an unexpected social situation or conversation.

Story space breached by environment: Some series of events in a dynamic environment has led to a world state not covered by authored content (Young et al. 2004).

Story generation recovery: An interactive story that has been generated (e.g., by a planner) cannot currently replan given a story state breach. An improv agent could keep the story goals in mind while improvising and keep a story going, even if not the one explicitly pre-authored. In the case of an educational application, an improv agent may be able to keep pedagogical goals in mind while improvising, even though the dramatic goals can no longer be fulfilled.

Improvisational theatre: If authors want to create a computational improvisational theatre experience (e.g., (Bruce et al. 1999)) the creation of improvisational agents for the performance seems wholly necessary.

It is with these situations in mind that we have sought to better understand human improvisation with the goal of creating improvisational agents. This paper presents our current work in the computational modeling of improvisation, which seeks to understand individual aspects of improvisation through the creation of *micro-agents* that represent those singular aspects. The intention behind this methodology is that by developing simple agents in different environments we can reach a better understanding of the issues involved in building a more complex improvisational agent, as well as the issues involved in embodying and interacting with them.

Cognition and Improvisation

While there has been work on understanding the role of improvisation and/or story management within the context of interactive drama (Kelso, Weyhrauch, and Bates 1993; M. O Riedl 2010; Swartjes and Theune 2009) and more ethnographic studies of improv theatre (Sawyer 2003), there have been only a handful of studies that have taken a serious look at the cognitive processes involved in human improvisational performance within artistic domains. In designing our study in the specific domain of improvisational actors, we looked to this existing body of research (Mendonça and Wallace 2004; Pressing 1998; Seddon 2005; Gabrielsson 2003). Computational approaches to the subject include Johnson-Laird's proposal of a principle of algorithmic demands to govern improvisation, examining the role of working memory in the task (Johnson-Laird 2002). Other work has focused on the role of knowledge and experience, such as how improvisers draw upon motifs during performance and how skill develops with practice (Pressing 1998). Ramalho et. al's AI model of an intelligent jazz performer draws from these ideas in focusing upon two specific aspects of musical improvisation: creating a "musical memory" of previous played melodic fragments, and reusing those during live performances (Ramalho, Rolland, and Ganascia 1999). However, our research is the first large-scale effort to study human cognition within the domain of theatrical improvisation.

Overview of Empirical Study

Theatrical improvisation is of particular interest since improvisation in acting has been used as the motivation for research on believable agents (Hayes-Roth and Van Gent 1996; Harger 2010; Perlin and Goldberg 1996). This work has been based on specific improvisation teachings or concepts (such as character "status" in a scene) without a more granular understanding of what the actors attend to on stage. Therefore, it does not take into account—as it was unknown at the time of the work—the knowledge that goes into improvisers making decisions, how they communicate their decisions to other actors, and how that communication is, in turn, received by others. Our work focuses on building the understanding and knowledge base needed to create robust and useful improvisational agents for use in computer game and interactive narrative worlds. We have designed and conducted an extensive study of human improvisers (see (Magerko et al. 2009)) and analyzed a large corpus of performance, retrospective protocol, and interview data. This analysis has led to a better understanding of narrative development in agents (Baumer and Magerko 2009) and the process of cognitive convergence (Fuller and Magerko 2010).

The final phase of our research is the creation of synthetic characters that computationally represent our findings. By formally representing these findings, we are forced to be exact in terms of our formalisms, a process that has led us to reconsider how we interpret our data. However, immediately jumping into building such a complex agent design without a full understanding of the domain, how to computationally represent that domain, or even the implementation issues involved (e.g., how the agents interact with each other), is premature. We instead have opted for an initial bottom-up approach to creating improv AI, "micro-agents," which focuses on creating agents that represent singular aspects of our findings to help better understand how to formalize such findings and build future, more complex improvisational agents.

Improv Micro-Agents

We have constructed two micro-agents (i.e., computational agents that display a non-trivial but small behavior) as the beginning of an exploration into how to formally represent our findings on improvisation. These agents have focused on: (1) how to create a character, (2) how improvisers get "on the same page," and (3) how conflict can be introduced into a narrative. These agents are not to be considered final representations of robust improvisational agents, but rather as formalisms of particular aspects of our data on human performers.

Party Quirks

Party Quirks is a common improvisational game that involves knowledge disparity—i.e., improvisers having differing amounts of information. During the game, one improviser takes on the role of a party "host" and the remaining improvisers are party "guests." The guests are assigned quirky behaviors that they must portray, and the host must guess these quirks over the course of the scene. We chose to implement this game as a micro-agent because it incorporates two important aspects of improvisation: character generation and cognitive convergence.

Character Generation How to portray a character is one of the most important decisions that an improviser must make when beginning a scene. Although improvisers are often provided with basic information about their characters in a scene (e.g., improvisers are often given content constraints related to character to begin a scene, such as a character's occupation or relationship to another character on stage), they still must choose which trait and behaviors associated with that character to communicate. For example, during a game of *Party Quirks*, one of our participants who was given the quirk of a "video game addict" reported his decision to act like a "ridiculous caricature" of that character type based on what he knew to be a stereotype of antisocial, obsessive behavior. He used his own internal "video game addict" schema (i.e., a mental structure that represents an aspect of the world) to pull out the most typical features, essentially creating a prototype (the average values inside a schema) in order to clearly communicate this character type to the other actors and the audience. Another participant, when given the trait that he could fly, also considered his schema for a person who can fly, determined the most typical values, and then intentionally took an atypical twist on them, portraying his character as someone who could fly but uncontrollably so. He later reported that he thought it would be more "interesting" than the "Superman" stereotype of flying.

These two examples illustrate a phenomenon that we saw frequently from improvisers in their character choices. Based on their schema for a character, they would stick close to the prototype (often to be more obvious for the other actors) or take a significant step away from it (i.e., giving it a "twist") in order to make the performance more interesting or humorous. One troupe even trains actors to build a typical schema for a character and then add a "twist" to make it more interesting.

We see several ways that improvisers tend to construct these "twists":

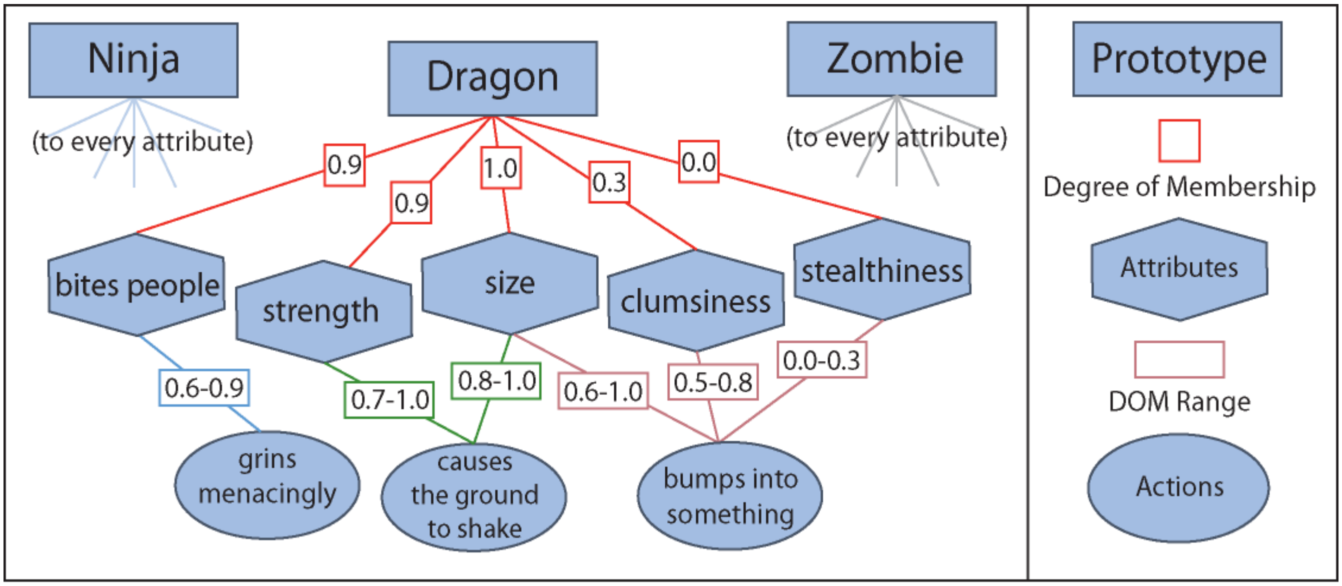

Figure 1. Diagram of character prototypes, their degree of membership (DOM) in attributes, and the translation of DOM values in an attribute to an action for an agent to execute.

Opposing. Like the man who flies uncontrollably, an improviser might take a typical behavior for a schema and replace it with an opposing idea. A prototype for flying is the Superman-style character who is in control of his actions; the improviser here instead chose an "out-of-control" character who was scared of his own abilities.

Caricaturization. Another technique an improviser might use, as with the video game addict, is to portray a caricature of a prototype. Though perhaps less of a "twist" than choosing opposing characteristics, it may also be an interesting character choice to go for exaggeration. The portrayal of a "video game addict" mentioned earlier is an example of this, where the improviser picked the most salient features for portrayal and exaggerated them.

Reverse scaffolding. An alternate take on displaying character attributes is what we call *reverse scaffolding*: improvisers initially portray more esoteric aspects of a character prototype and slowly offer more exoteric attributes as a scene goes on. This technique is most common in what we call *knowledge disparity games*, which involve some improvisers on the stage having information about the scene that one or more other improvisers do not have (e.g., *Party Quirks*). An improviser typically applies reverse scaffolding when another improviser is trying to guess the specifics of some scene element (e.g., what characters are on stage, the setting, etc.) and the improviser providing clues does not wish to start off heavy-handed (i.e., big clues early on may lead to a premature scene ending).

Blending. This type of twist does not involve tweaking a behavior within a prototype, but rather combining elements from multiple schemata. In this way, the improvisers can construct more complex characters rather than relying solely on stereotypes. For example, a popular improvisation TV show often has characters that are blended prototypes, such as "mosquito" and "gets drunk off of blood" (de Moraes and Forrest 2001). Blending often occurs when an actor is initially imbued with a combination of concepts. How to computationally blend prototypes is an open research question and has yet to be implemented in our work.

By using one of these techniques, an improviser can therefore make a character more interesting based upon a schema (or multiple schemata) as a starting point. This is an important aspect of improv, one that relates to both basic cognitive concepts such as knowledge representation and concepts of character development in narrative. We have applied our micro-agent technique to focus on this essential component of character development.

We have developed a micro-agent that employs the first three of these behaviors for portraying a character (opposing, caricaturization, and reverse scaffolding) in the game *Party Quirks*. Guests at the "party" share a common knowledge base centered on character schemata. One common organizational scheme for knowledge about characters is for categories of knowledge to be organized around prototypes, the focal members that are defined by people's judgments of "goodness" of category membership (Rosch 1999). Therefore, when considering a "bird," one tends to think "has wings," "has beak," "can fly," etc.—so that the image that comes to mind more closely resembles a robin than an ostrich. Rather than asking if something *is* a bird, where the determination is a binary true or false, we can recognize the "fuzzy boundaries" of categories and instead ask how similar a particular instantiation of a bird is to our ideal model (Bruckman 2006).

We have therefore adapted this concept as well as the non-Boolean concept of fuzzy values from fuzzy logic to represent character prototypes as having varying degrees of membership (DOM) within each attribute set. Our reliance on this theory is based upon the idea that schema values may not be black or white but shades of gray, and that being able to represent more nuanced degrees of membership for character traits rather than "on" or "off" will provide us with a richer knowledge base. In fact, it has been argued that a major distinction between human and machine intelligence is that humans have a greater ability to manipulate fuzzy concepts (Bellman and Zadeh 1970). Therefore, just as in the real world classes of objects do not have precisely defined memberships (such as the ostrich that cannot fly but is still a bird), our character types are represented as fuzzy sets, or classes with continuum grades of membership. As such, there is a relationship between prototype effects and conceptual structures with gradations of category membership (Lakoff 1987).

Our *Party Quirk* agent's knowledge is represented as a grid of character classes and attributes (traits or behaviors) with non-Boolean (between 0 and 1) values that represent the DOM for that character in that attribute (see Figure 1). The process of determining these grades of membership is called *fuzzification* and for the purposes of our micro-agents, we are authoring these values ourselves (future work will involve surveying people or web mining for "better" values). For example, a King has a value of 1 for "wears crown" but only .1 for "cackles" whereas a Witch has a value of .9 for "cackles."

DOM values alone do not describe how important or iconic a particular attribute value is. Any value, not just a high one, has the potential for being representative for a particular prototype (e.g., a monk would possibly have a low value for "speaks" but that low value would be very iconic). We compute the *ambiguity value* for each prototype/attribute pair, which is currently a function of the number of prototypes that share the DOM value (within 0.1) and how far away this value is from the median value. In other words, the more prototypes that have this DOM value for the given attribute, the less unique the DOM value is for the given prototype/attribute pair.

This representation allows us to create characters that employ these different techniques for starting from a character schema and then portraying them in an "interesting" way by possibly changing DOM values and reasoning about how to portray them. For this micro-agent, an agent employing *caricaturization* will select the least ambiguous attributes (top 30% most unique) to portray and will pick the least ambiguous action (described below) for each of those attributes to try to make it as obvious as possible. An agent using *opposing* with prototype *p* will take a unique (top 30%) attribute *a*, replace its DOM value with the inverse (1-DOM), and, as with *caricaturization*, pick one of the least ambiguous actions for that attribute to try to make what they are doing more clear.

Once an agent has a set of candidate attributes to portray, it proposes the set of *actions* associated with those attributes (with the given DOM value for each), as shown in Figure 1. Each attribute is associated with a set of pre-defined *actions* that can be executed. Actions may include preconditions (what must be true in the world) and effects (how the world changes) and are limited for selection based on what attributes they are associated with.

In summary, agents are defined by the prototypes they are given or selected. They choose to portray their prototype with one of the techniques listed here, which involves communicating an attribute of that character based on the prototype's DOM and ambiguity values for attributes. The portrayal of that character is visualized through the selection of an action associated with an attribute that has an appropriate DOM for the current character portrayal technique. These micro-agents therefore demonstrate the capacity of improv actors to make creative choices within the common constraint of being given a particular type of character to portray.

Cognitive Convergence When an improviser does not know what another is thinking when working within a scene, *cognitive divergence* occurs (Mohammed and Ringseis 2001; Salas and Orasanu 1993; Fuller and Magerko 2010). If an improviser attempts to correct the divergence, they engage in the process of *cognitive convergence*. Cognitive convergence is a multi-step process of attempting to reconcile the two mental states in question (i.e., the mental states of the improvisers or even an improviser and the audience). The process of cognitive convergence takes place in three phases: *observation* (recognition by one agent that a divergence exists), *repair* (that agent trying to change the mental state of themselves or another agent), and *acceptance* (resolution with the repair either succeeding or failing) (Clark and Schaefer 1989; Traum 1999). When the two agents appear to understand each other (i.e., when they are "on the same page"), *cognitive consensus* has been achieved.

As a knowledge disparity game*, Party* Quirks directly involves the process of cognitive convergence; the crux of this class of games is that some actors have information about the scene that is unknown to other actors in the scene. They therefore tend to focus explicitly on the process of actors achieving cognitive consensus.

Our *Party Quirks* implementation focuses specifically on the process of one agent guessing at another agent's quirk, given clues that are ambiguous in nature. The character portrayal techniques we explore above are created with the intention of communicating the mental model of the party guests to the party host. The future intention is the development of a larger system that will enable a user (the host) to interact with multiple agents at a virtual party and engage in the process of going from cognitive divergence (i.e. the guest quirks are unknown) to convergence through a sequence of repair and acceptance actions. The details of the kinds of techniques used by improvisers is detailed in (Fuller and Magerko 2010).

Interesting Conflicts and Reincorporation

The ultimate goal of this micro-agent is to develop a partial-order planning system that employs an "interestingness" adversarial search. The micro-agents can use objects while attempting to accomplish various goals. In a traditional adversarial search planning method one agent would oppose the other and attempt to prevent the other from achieving its goal. Roberts, Riedl, and Isbell (2009) proposed a narrative model in which each agent would encounter problems in accomplishing their goals. Those problems do not necessarily foil their goals, but instead produce a result/interaction other than what they intended. This would "maximize interestingness" and help to develop a satisfying narrative. Interestingness can be viewed as an agent's schema of appropriate actions (or plans) being dynamically violated in such a fashion that it contextually makes sense to the narrative and can raise an appropriate emotional response (in the user/audience) to the scene.

Our system is based on three narrative methods improvisers used in our data. They are *offers, yes, and…*, and *reincorporation*. *Offers* are the basic building blocks of improv (Baumer and Magerko 2009). They introduce an element (or elements) to the narrative onstage that can potentially be used to help the scene progress (e.g., asking another improviser if they remembered to bring some important object). *Yes, and…* is a method of taking an offer and constructively building off of it—continuing the example, an improviser answering, "Yes" (acceptance) "I brought the antique vase" (addition). *Reincorporation* is when an improviser refers to some element from earlier in the scene and introduces it to the scene again (e.g. the antique vase from earlier in the scene was cursed).

We saw these phenomena consistently in our experimental data. An example of an offer (and its acceptance) began with D1 and D2 (names are removed for anonymity) discussing the free trade muffins they were eating and how good it felt to be doing the "right thing." D3 entered the scene with a pantomimed tray of muffins and her head down. D1 rolled his eyes as D3 said, "Mr. Coffeeman, I have more muffins for you from homeland." D3 explained in her retrospective that she wanted to establish the muffins as "anything but fair trade" and introduced herself as a "low-status" character. D1 picked up on this offer and in his interview explained, "D3 comes in with this great offer to me that we're ostensibly caring and politically aware, but actually in truth we're subjugating people still." He accepted her offer by rolling his eyes and treating her like an inferior (or low-status character). He further built upon her offer (i.e., *yes, and…*) by describing her as "annoying" to D2 and then actively ignoring her. However, in the climax of the scene, it was revealed that D3 had been putting drugs in the muffins so that she could steal company secrets. At the outset of the scene, D1 had pantomimed raking leaves, which was quickly abandoned in deference to other plot events. After hearing what D3 had done, D1 exclaimed, "No wonder I was raking leaves in the break room!" reincorporating that idea from earlier.

In order to model this kind of behavior, we began with agents who contain a library of plans to achieve certain goals. For example: A cat is in a tree and two agents want to get that cat out of the tree. Working towards the final goal, one of the agents might work backwards from the final goal of "Get Cat out of Tree." Before this can be accomplished, the agent has to grab the cat. Before that action can be performed, the agent has to be at the same height as the cat. A plan for the agents would be ("-->" means a transition to the next item in the sequence):

Action: Be at same height as Cat -->
Action: Grab Cat -->
Goal: Get Cat out of Tree.

The interestingness adversarial search allows difficulties to be generated for interrupting this flow (which should induce the audience with a sense of anxiety due to identifying with the agents' difficulties encountered). In the scene mentioned earlier, the introduction of a low-status character that overturns the supposed morality of the other characters does not end the scene, but it does introduce conflict. An example of completing the first step of being at the same height would be:

Action: Get Object -->
Action: Use Object to attain height -->
Goal: Be at same height as Cat

The interestingness adversarial search creates disruptions in the plan to introduce conflict into the narrative. An object (such as a ladder) might be too short or broken. In a traditional adversarial search, this foil would try to defeat an opponent, preventing it from achieving a goal. In our situation it presents a surmountable difficulty to generate a conflict-oriented narrative. The other agent would then offer a solution to the immediate problem. This could be fixing a broken object or suggesting a different methodology (e.g., trying to lure the cat down). If no method succeeds after a certain number of iterations, the agents' plans will come to fruition in order to end the scene. Future work will allow for a higher chance of previously used items or actions to be reincorporated as the scene progresses (e.g., a broken ladder being used to get a fish as food to lure the cat). This would allow elements introduced earlier in the narrative to be linked to later elements, creating a cohesive whole. Therefore, if story space were breached by a user or environment, the agents could reincorporate elements from earlier in the scene to resolve current narrative goals.

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