A big applause for Cubus: A virtual sandbox to stimulate ideas in children

André Pires[1], Patrícia Alves-Oliveira[2] and Carlos Martinho[3]
[1,2,3] INESC-ID and [1,3] Instituto Superior Técnico, Universidade de Lisboa
Av. Professor Cavaco Silva, 2744-016 Porto Salvo, Portugal
[2]ISCTE-IUL and CIS-IUL, Universidade de Lisboa
Av. das Forças Armadas, 1649-026 Lisboa, Portugal
{[1]andre.b.pires,[3]carlos.martinho}@tecnico.ulisboa.pt
[2]patricia.alves.oliveira@inesc-id.pt

Abstract

Creativity is known as an ability that can be developed and improved. Since creative abilities are desired in most modern societies, it becomes important to develop activities that stimulate creativity at a young age. It seems, however, there is a lack of tools to support creative activities for children. In this paper, we introduce Cubus, which uses autonomous synthetic characters to stimulate idea generation in groups of children during a storytelling activity. With Cubus, children can invent a story and use the stop-motion technique to create a movie of their story. In this paper, we explain the process of Cubus' system design and architecture. Using Cubus, we intend to study the potential of synthetic characters' autonomous behaviors to stimulate idea generation of groups of children during their creative process of storytelling.

Introduction

The role of creativity is paramount in our current day societies. Creativity contributes in a major way to both our professional and personal growth. It is therefore important to encourage the growth of this ability from a very young age (Mellou 1996). Although many schools already feature storytelling activities which help promote the children's creative thinking (Di Blas, Paolini, and Sabiescu 2012), these activities are cumbersome for teachers to prepare and manage, with scarce tools existing to support these activities (Chan and Yuen 2014). Children have been shown to be interested in interacting with electronic devices from a young age (Salonius-Pasternak and Gelfond 2005). With this work, we attempt to leverage this interest for interacting with electronic devices and create a digital tool aimed at enhancing children's creativity, by focusing on the stimulation of idea generation during their creative process. As identified by Torrance (1979), idea generation (also known as *fluency*) is one of the primary aspects of the creative process. Our system, Cubus, consists in a virtual environment that allows groups of children to engage in creative storytelling while interacting with the autonomous synthetic characters that are part of Cubus. In this paper, we focused on the design and implementation details of Cubus. This system was subsequently used in a study where children created stories using Cubus' agents and recorded short movies depicting them. The role of Cubus' agents in this study was to stimulate children's ideas during their storytelling. This study and its subsequent results are covered elsewhere.

Creativity

Creativity is a concept that has no consensual definition, but there is an overall agreement that creativity can be defined as the "interaction among aptitude, process, and environment by which an individual or group produces a perceptible product that is both novel and useful as defined within a social context" (Plucker, Beghetto, and Dow 2004). This work is framed within the field of computational creativity. Before starting the development of the Cubus system it was crucial to understand the different ways that tend to contribute to a creative process. Torrance (1979), cites four fundamental creative abilities in the creative process: *fluency*, *flexibility*, *originality* and *elaboration*. We intend to use Cubus to study stimulating *fluency*, the amount of ideas generated during a creative process. Not only we want to stimulate *fluency* during the creative process, as we are interested in improving this creative ability within a group. In this context, creativity deviates from emerging from an *individual* creative process, to become an ability that is stimulated in a *distributed way within a group* (Sawyer and DeZutter 2009). During the unscripted collaborative efforts that emerge during the creative process, improvisation is key as it involves creating different ideas as well as adapting to concepts introduced by others and building upon them (Sowden et al. 2015).

Creativity Support Tools: Our work contributes toward the enhancement of creativity with the aid of computers, the field of Creativity Support Tools (CSTs) (Shneiderman 2007). We took inspiration from works such as *Dr. Inventor* (Donoghue et al. 2014) and the agent *Sam* which assists children during creative storytelling (Ryokai and Lee 2009). As *motivation* is essential for a successful creative experience (Amabile and Hennessey 1992), we use agents to motivate users in their task. Additionally, the use of synthetic characters does not hinder communication and is able to enhance discussion in a collaborative task with pairs of children (Ryokai, Vaucelle, and Cassell 2003), reinforcing our motivation to include synthetic characters in our work.

Human-Agent Interaction

The Cubus system includes synthetic characters whose design inspiration includes previous works in the area of Human-Agent Interaction (HAI). Cubus offers a similarly structured environment as presented in the Oz Project, designed for the creation and presentation of dramas in a virtual setting (Kelso, Weyhrauch, and Bates 1993). Cubus uses non-humanoid characters to allow children's imagination to direct the characters' narratives freely. The use of simple shapes as been shown to allow the creation of rich narratives in similar contexts (Gordon and Roemmele 2014). To address emotional expression when designing these characters, we followed a survey carried out by Bethel and Murphy (2008) in which different means of expression are analyzed, such as movement (Wallbott 1998), color (Argyle 1973), sound and how we distance ourselves from each other during our interactions (proxemics) (Friedman, Steed, and Slater 2007). We incorporated several of these means and guidelines while designing how our synthetic characters should interact with the user and with each other to increase their chances of expressing themselves successfully.

Cubus System

Our work features a virtual environment which contains a small set of world building tools and synthetic characters (Figure 2). The system was tailored to fit the target audience of children between the ages of 7 and 9 years old. Our main concern during the development of Cubus was to keep it accessible for children and open-ended to leave space for creation, allowing the creative storytelling process to unfold. Cubus can be divided into two primary components:

- **Synthetic characters:** Our characters will be featured in the children's story as their *actors*;
- **Virtual environment:** The environment is responsible for supporting the world building features and recording the story that children create.

The development of this work was carried out with the Unity™ game engine (version 5.3.5f1) and our testing environment consists in a Samsung™ Galaxy Tab Pro 10.1 tablet through the use of its touch interface (Android™ 5.1.1).

Synthetic Characters

The *synthetic characters* are the most innovative part of this work as they were designed to be non-humanoid and rely on the emergent interaction between them for emotional expression. For brevity, "synthetic characters" will be addressed as "agents" for the remainder of this paper.

Agents' Implementation: Each agent corresponds to one of five specific emotions (anger, happiness, fear, sadness, disgust), displaying behaviors that attempt to be consistent with that emotion. There is no limit to how many agents of a given emotion can be present in our environment at a given time. To add more depth to the agents' emotional displays, two types of behaviors were created for each emotion: a *standard behavior* and an *intense behavior*, the latter being perceived as a stronger display of that emotion.

Additionally, each agent has two drives: one that triggers *standard behavior* and another that triggers *intense behavior*. These drives vary between 0 and 90. The **standard drive** starts at a random value between 0 and 35 and increases with the passing of time (1-second intervals). When

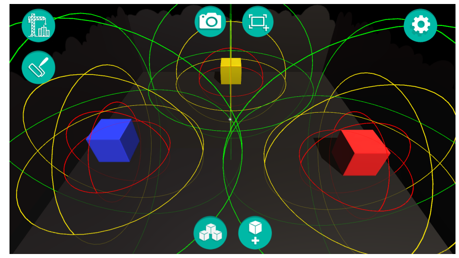

Figure 1: Proxemic distances that weigh the agents' interaction.

this drive reaches 90, it triggers the standard behavior and resets its value to 0. Additionally, this timed increase "step" is affected by a multiplier, within the range of 1 to 1.5 for the standard drive and 1 to 1.3 for the intense drive. These multipliers are set randomly within these ranges at the moment of the agent's creation. Both elements of randomness introduce diversity to the different agents' behaviors, reducing their predictability and making their interaction appear more natural. The same drive also increases when other agents display any behavior within a certain radius of the agent. The **intense drive** starts at 0 and only increases with time until 65, after this point only increases when stimuli from other agents' behaviors (which share the same emotion) are received. When this drive reaches 90 the corresponding behavior is triggered and both drives are reset. It should be noted that while a behavior is occurring, no stimulus is received from other agents. These agents interact with each other by broadcasting stimuli to the surrounding agents when they display a behavior. The intensity of these stimuli differs taking into account the distance at which the other agents are (closer agents provide stronger stimuli). These distances are fixed for every agent and divided into three intervals as evidenced in Figure 1. The contributions from the stimuli vary from 25 to 45 when contributing toward the standard drive and between 35 and 60 for the excited drive.

This behavior proved adequate and sufficient to elicit new ideas from children and to maintain a suspension of disbelief regarding the agents' perceived intelligence. Developing a more complex system was not guaranteed to produce any added value to our particular scenario, as interpreting these more complex behaviors could prove difficult given our agents' restricted interfaces (Wardrip-fruin 2007).

Appearance: We opted for selecting a neutral appearance for the agents' design to provide the possibility for children to project any desired character. This helps avoiding bias in the types of characters children create for their stories. We selected the geometric shape of a *cube*, inspired by LEGO™ bricks. Since emotions seem to enhance creativity in video games (Hutton and Sundar 2010) it was important to establish which emotions we were attempting to model and represent. We considered Ekman's (1972) model of six emotions to be apt for our context, omitting the surprise emotion given that there is no consensus regarding its inclusion as an emotion.

Expression: We focused on two primary means of communication for the agents: color and body movements/posturing. To combine these means appropriately and make them be perceived as natural during the agents' animations, we studied Disney™'s twelve principles of animation (Thomas, Johnston, and Thomas 1995). These principles attempt to address the human need for more pronounced cues in order to correctly perceive actions or displays of affection by synthetic characters. The principles that were most relevant in our design were: squash and stretch, anticipation, follow-through and staging.

Color: In order to create an identity for our emotions some emotion-color associations were selected, the inspiration for these was drawn from Disney™'s movie *Inside Out*. Ekman was one of the scientific consultants for this movie and the emotions present in the movie feature one predominant color. As such, we considered that the unique colors associated with each emotion would create distinguishable agents. Additionally, in an effort to direct the users' attention to the agents' behaviors we added a blinking effect triggered in the beginning of the agents' behaviors. This blinking remains within the hue of each agent's base color and depending on the valence of its emotion the blink varies, being brighter when the valence is positive (*e.g.*, happiness) or darker for a negative valence (*e.g.*, anger). This blinking effect also varies according to the arousal of each emotion, *e.g.*, happy and angry emotions have a high arousal, therefore the blinking will have a higher frequency than, for instance, when sadness is being displayed. These blinking frequencies were tuned to ensure they were distinguishable and represented the different arousals levels.

Body Movement and Posture: In addition to detailed animation principles, we explored character deformation in our animations to create simple but organic movements for the agents. This step toward deformable characters enabled a more appropriate representation of simple actions (*i.e.*, jumps, nods, squats, etc). Some of the aforementioned animation principles such as squash and stretch or follow-through, helped convey the physical impact actions have on a character's body. To convey our particular set of emotions through animation, we looked toward Wallbott's (1998) work, which summarizes some of Darwin's observations regarding movement and posture in emotional expression. These observations provided enough insight to create the desired set of emotions for our agents, as well as their arousal state. For example, stretching the body and mimicking an inflated chest while leaning forward conveys anger, while squashing and tilting down while staying motionless conveys sadness. When combined and properly timed, these cues produced the final version of our animations for the agents' expression. In an effort to increase our agents' expressiveness, two animations were designed and created for each emotion. Each agent exhibits two different intensity levels for every emotion: standard and intense. This allows the agent to express the heightened emotional intensity of agents with the same emotion interacting.

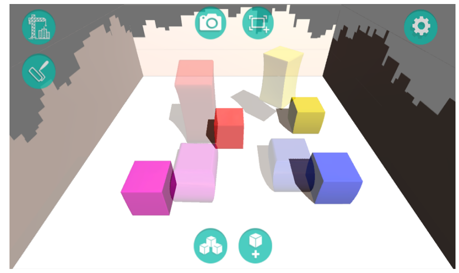

Figure 2: Virtual environment.

Interactive Virtual Environment

The virtual environment sustains both the interaction between children and our agents, as well as the children's storytelling process (Figure 2). This environment allows the recording of the children's story, managing and directing the agents and customizing virtual scenarios. For the design of the system, we followed a modular approach with four major components: screen recorder, world building tool set, agents, and user interface (UI) manager. The screen recorder module is responsible for the capture of objects within the scene that are 3D while excluding, any screen overlays or UI elements. The world building tools control and carry out children's inputs when managing their story's scenes. This ranges from changing the scenario to creating and deleting agents. A UI manager module serves as the interface between the children's inputs and both the agents and tool set.

Stop-motion: To allow the recording of the stop-motion story, children can perform screen captures when creating scenes they want to feature in their movie. These screen captures omit the application's UI elements and record only the actors and scenario. The images resulting from the screen captures are stored within the device and, at a later stage, imported into an application that supports the creation of a stop-motion movie. Two features were added to help children understand how to use the system: an effect mimicking a camera flash each time a screen capture is performed, helping reaffirm the action; and an overlay with small opacity covering the entire screen of the previous screen capture (visible in Figure 2). This last feature was useful, as children had difficulties recalling their last recorded moment in the story if they *e.g.*, changed the story scene. It is also possible to create intertitle screens (as seen in silent movies). These allow children to record a screen with a written message, enabling them to explore and explain more drastic changes within their story.

World: The virtual environment gives children enough degrees of customization to personalize their story. Several scenarios were available in our environment, these are very distinguishable from each other and allow for different uses. For instance, the scenarios' walls can be curvilinear, rectilinear, with sharp angles or straight. To point out an example, our sharp angled scenario was seen as pine trees, mountains or traps by children (*e.g.*, rectilinear walls can be seen in Figure 2). To provide children more creative freedom, a color selection screen was added, enabling children to select a color for the scenario and another for the skybox that envelops it.

Interacting with the actors: The building tools allow children to create and manage their actors. To this end, children are able to select which type of agent (or actor) they wish to feature in their story. Additionally, children can access a list of all their actors, through which they can hide or reveal actors or delete them. The ability to toggle an actor's visibility is useful for actors that are not in every scene of the story, allowing children the creative freedom to experiment with more complex storytelling narratives. To control the actors, children can perform dragging (press on the agent with their finger and drag it from one point to another) and rotation movements (press on the agent with one finger to select it and use another finger to slide up or down, to rotate forward or backward) of their actors. These movements allow children to represent characters walking around or facing an important object or character in any given scene.

Using Cubus

Having covered how our system works it is also important to understand how it will be used to stimulate creativity. Children will create and place our agents (their actors) and personalize the available virtual scenarios to match their stories. When children are happy with their setup for a scene they should perform a screen capture, thus capturing it. This process should be repeated until their story is fully recorded. In the end, these images can be imported into a stop-motion editing application to create the final movie and add the children's voice-over (*e.g.*, a narration, dialogue, etc.). Our agents' affective expressions should contribute to the children's creative process, eliciting new ideas during their storytelling.

Conclusion

The innovative component of Cubus concerns the autonomous agents whose behaviors were designed to stimulate children's creativity, specifically, idea generation. Cubus is a pioneering effort in the study of group creativity with the aid of autonomous embodied agents. With Cubus we contribute to the computational creativity field as well as toward the development of CSTs.

Acknowledgments

This work was supported by national funds through Fundação para a Ciência e a Tecnologia (FCT) with reference UID/CEC/50021/2013 and through project AMIGOS (PTDC/EEISII/7174/2014). We would also like to thank the school São Francisco de Assis for their support.

References

Amabile, T. M., and Hennessey, B. A. 1992. The motivation for creativity in children. *Achievement and motivation: A social-developmental perspective* 54–74.

Argyle, M. 1973. The Syntaxes of Bodily Communication. *Linguistics* 11(112):71.

Bethel, C., and Murphy, R. 2008. Survey of Non-facial/Non-verbal Affective Expressions for Appearance-Constrained Robots. *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)* 38(1):83–92.

Chan, S., and Yuen, M. 2014. Personal and environmental factors affecting teachers' creativity-fostering practices in Hong Kong. *Thinking Skills and Creativity* 12(1):69–77.

Di Blas, N.; Paolini, P.; and Sabiescu, A. G. 2012. Collective digital storytelling at school: a whole-class interaction. *International Journal of Arts and Technology* 5(2-4):271–292.

Donoghue, D. P. O.; Saggion, H.; Dong, F.; Hurley, D.; Abgaz, Y.; Zheng, X.; Corcho, O.; Zhang, J. J.; Careil, J.-M.; Mahdian, B.; and Zhao, X. 2014. Towards Dr Inventor: A Tool for Promoting Scientific Creativity. *Proc. 5th International Conference on Computational Creativity (ICCC)* (October):268–271.

Friedman, D.; Steed, A.; and Slater, M. 2007. Spatial Social Behavior in Second Life. *Intelligent Virtual Agents* 4722:252–263.

Gordon, A. S., and Roemmele, M. 2014. An Authoring Tool for Movies in the Style of Heider and Simmel. *The Seventh International Conference on Interactive Digital Storytelling (ICIDS 2014)* 1–12.

Hutton, E., and Sundar, S. S. 2010. Can video games enhance creativity? effects of emotion generated by dance dance revolution. *Creativity Research Journal* 22(3):294–303.

Kelso, M. M.; Weyhrauch, P.; and Bates, J. 1993. Dramatic presence. *Presence: The Journal of Teleoperators and Virtual* 2(1):1–15.

Mellou, E. 1996. Can Creativity be Nurtured in Young Children? *Early Child Development and Care* 119(1):119–130.

Paul, E.; Wallace, V. F.; and Phoebe, E. 1972. *Emotion in the Human Face*. Fairview Park, Elmsford, New York: Pergamon Press Inc., 1st edition.

Plucker, J. A.; Beghetto, R. A.; and Dow, G. T. 2004. Why Isn't Creativity More Important to Educational Psychologists? Potentials, Pitfalls, and Future Directions in Creativity Research. *Educational Psychologist* 39(2):83–96.

Ryokai, K., and Lee, M. 2009. Children's storytelling and programming with robotic characters. *C&C '09 Proceedings of the seventh ACM conference on Creativity and cognition* 19–28.

Ryokai, K.; Vaucelle, C.; and Cassell, J. 2003. Virtual peers as partners in storytelling and literacy learning. *Journal of Computer Assisted Learning* 19(January):195–208.

Salonius-Pasternak, D. E., and Gelfond, H. S. 2005. The Next Level of Research on Electronic Play : Potential Benefits and Contextual Influences for Children and Adolescents. *Health San Francisco* 1(April):5–22.

Sawyer, R. K., and DeZutter, S. 2009. Distributed creativity: How collective creations emerge from collaboration. *Psychology of Aesthetics, Creativity, and the Arts* 3(2):81–92.

Shneiderman, B. 2007. Creativity support tools: accelerating discovery and innovation. *Communications of the ACM* 50(12):20–32.

Sowden, P. T.; Clements, L.; Redlich, C.; and Lewis, C. 2015. Improvisation Facilitates Divergent Thinking and Creativity: Realizing a Benefit of Primary School Arts Education. *Psychology of Aesthetics, Creativity, and the Arts* 9(2):128–138.

Thomas, F.; Johnston, O.; and Thomas, F. 1995. *The illusion of life: Disney animation*. New York, United States: Hyperion Books, revised edition.

Torrance, E. P. 1979. *The Search for Satori and Creativity*. Buffalo, New York: Creative Education Foundation, 1st edition.

Wallbott, H. G. 1998. Bodily Expression of Emotion. *European Journal of Social Psychology* 28(6):879–896.

Wardrip-fruin, N. 2007. Three Play Effects : Eliza , Tale-Spin and SimCity. *Digital Humanities* 1–2.