Expressive Virtual Characters
for Social Demonstration Games

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Abstract—Virtual characters are an integral part of many game and learning environments and have practical applications as tutors, demonstrators or even representations of the user. However, creating virtual character behaviors can be a time-consuming and complex task requiring substantial technical expertise. To accelerate and better enable the use of virtual characters in social games, we present a virtual character behavior toolkit for the development of expressive virtual characters. It is a middleware toolkit which sits on top of the game engine with a focus on providing high-level character behaviors to quickly create social games. The toolkit can be adapted to a wide range of scenarios related to social interactions with individuals and groups at multiple distances in the virtual environment and supports customization and control of facial expressions, body animations and group formations. We describe the design of the toolkit, providing an examplar of a small game that is being created with it and our intended future work on the system.

I. INTRODUCTION

Social behaviors and interactions are often integral to game-based learning environments, especially those involving social scenarios. A common requirement in such systems is to be able to embody behavior through animated and expressive virtual characters, whether they represent players (i.e. avatars) or non-player characters. These characters are capable of engaging in a wide variety of roles in game-based learning environments, where they may become the focus of the game, for example, in games demonstrating social behaviors. They are suitable for such roles since they are capable of acting in a controllable and repetitive manner.

Two of the main limitations with respect to the use of sophisticated 3D virtual characters in such environments is the level of technical skill required in implementation and the cost involved. These considerations therefore either restrict the possibilities of what can be achieved or redirect the focus of game designers and pedagogists on technologies and away from the issues of creating engaging, educational experiences.

This paper attempts to address these challenges by presenting a toolkit for the development of expressive virtual character behaviors. The toolkit is a middleware work which sits on top of the game engine and provides high-level character behaviors to quickly create social games, i.e. a bridge between the game engine and social games. It enables social interactions for individuals and groups focussed on social game scenarios by controlling their behaviors around the environment. As an accelerator, it allows more time to be devoted towards the design of pedagogical game scenarios and to take the emphasis away from fundamental technical development work involved in programming the animation of expressive virtual characters. As an enabler, our aim is to make the development of social games involving sophisticated 3D virtual characters more accessible to users with varying levels of technical expertise. We believe that the toolkit is a first step in this direction and represents a mid-level interface for controlling virtual characters and enabling the easy creation of social behaviors on top of which simpler end-user scenario creators could be placed.

This paper is divided into the following sections: Section III presents an overview of related work in multimedia and ICT in emotional and social demonstration and skills development with expressive virtual agents and real people. Section IV shows the purpose and role of the toolkit in the creation of social games containing expressive virtual characters. Section V provides technical details concerning the subcomponents of the behavior toolkit which are involved in the creation of
expressive social characters. Section VI presents a concrete exemplar of a small social demonstrator game created using the technical components described in Section V. The conclusion is presented in Section VII.

II. BACKGROUND

While virtual characters feature prominently in a wide range of commercial computer games, they have further potential in serious games aiming to develop the social skills of children.

A. Roles in Social Games

In social games, virtual characters are capable of demonstrating behaviors related to the development of social skills through their full-body motions, facial animations and proxemics. Related with expressions and social cues, the facial expressions and full-body animations represent the emotional states of virtual characters to support social scenarios. Children are asked to re-enact (i.e. role-play) the behavior of the characters as part of a classroom activity or game. For example, they may describe how they feel when role-playing the part of a very high valence/arousal character, versus that of a more subdued one. In addition, aspects of user appearance or behavior are copied in real-time and mapped onto a virtual character (Section V-H).

B. Adaptation and Personalization

In order to maintain engagement, a common requirement in games is that they engage the player by remaining challenging and adapt to the skill level of the player. Virtual characters support variation of challenge that meet both gameplay and learning objectives by allowing the complexity of the appearance and behaviors of characters to be precisely altered in a controllable manner. The variations in complexity and intensity of the appearance and behavior of virtual characters can be combined in order to produce a broad range of difficulty levels that are suitable to a range of skill levels, from beginners and those with difficulties in interpreting emotional expressions [4], right up to complex and difficult to interpret real-world behaviors about which even professional annotators may disagree. The demonstrator shown in Section VI makes use of these types of difficulty levels.

Virtual characters are capable of a range of expressive full-body behavior [7] communicating social cues and basic and complex emotion states. Since humanoid virtual characters often share a similar embodiment to humans, studies from domains that deal with human behavior also provide insights towards the creation of behaviors for virtual characters. In both areas, studies generally focus on the facial area; the body (excluding facial expressions [6]); full face and bodily expressions; and higher level expressions potentially associated with impressions of social character [5] e.g. trustworthiness, cooperation. Furthermore, the embodiment and appearance of virtual characters may be changed and their behaviors altered, supporting efforts towards generalization and ensure that they maintain their engagement, while retaining the same core qualities of the motions that relate to behavior.

C. Social Skill Development

The aforementioned capabilities of virtual characters make them suitable for use in Social Skill Development. Social games typically benefit from the ability to convey the internal states of actors in the game via behaviors. For example, games surrounding prosocial behaviors [5], when people act in ways that benefits others, such as cooperation, trust, compassion, fairness and generosity, are ideal candidates for the use of virtual characters that can help to visualise internal states through behavior, represent the behavior of users or allow them to engage in role-play. Virtual characters have good potential for helping to enhance the development of important competencies of self-awareness, self-management, social awareness, relationships, and decision-making 1. It is possible to achieve this due to four important qualities supported by virtual characters: simulation, repetition, control and role-play.

- **Simulation**: It provides learners with the ability to experiment, learn from mistakes and try new strategies without potential repercussions present in the real-world.
- **Repetition**: Virtual characters are capable to repeat the simulation of real behaviors without becoming bored, tired or degrading the quality in an extremely cost effective manner.
- **Control**: Virtual characters are controllable in a very precise manner and provide multiple levels of control to human directors.
- **Role-play**: Virtual characters naturally support role-play opportunities, both as NPCs that are controlled by an AI and also as avatars that represent the user.

III. RELATED WORK

Research and development of core technologies (for example, virtual characters) has been applied to the creation of applications for social skills development for a variety of end users, from children with autism to more general audiences.

A. Character Animation

Social behaviors and emotions can be expressed through different modalities. Facial expressions and full-body animations contribute to the representation of expressive virtual characters through which social cues and emotional information can be conveyed. Building expressive characters requires endowing them with appropriate facial expression and the capability to execute behaviors with different expressivities [11]. [10] shows that both behavior shape and behavior expressivity contribute to the representation of an emotional state. [9] collects the studies of the expressive elements of posture and gesture. It presents the features of postures and body animation that frequently occur depending on the emotional states. Oosterhof et al. [1] identified traits, such as trustworthiness, dominance, which are inferred from emotionally neutral faces. To mirror real-life multiparty conversation settings, [2] presents an algorithm for simulating dynamic movement and positioning of agents in small groups based on observed human behavior. In

1 http://www.casel.org/
order to explore social AI for interactive characters in game environments, [3] developed a software platform (Impulsion) to improve virtual characters by making them more lifelike and realistic in social simulations with a mix of autonomous and scripted behaviors.

B. Games for Skills Development

A number of applications have used character animation capabilities including facial expressions, full-body animations and formations of virtual characters to construct social games. The social games have been applied from people with autism to more general audiences.

The Transporters 2 is a 3D animated series aimed at children with autism spectrum conditions (ASC). Children can either watch the episodes in a fixed order or choose which episodes to view, and can engage in a number of quiz games [12]. An evaluation study [13] concludes that using The Transporters significantly improved emotion recognition in children with ASC. However, anecdotal evidence suggested from the parents of the intervention group says that the children were more willing to discuss emotions and interested in facial expressions.

An encyclopedia of emotions, Mind Reading: The Interactive Guide to Emotions 3, primarily aimed at people on the autistic spectrum, who may have difficulty recognizing emotions [17]. In a study evaluating Mind Reading [16], a group of adults diagnosed with high-functioning autism were tested on the recognition of faces and voices at three levels of generalization. The intervention group in both experiments performed significantly better than the control group on close generalization tasks, although there were no significant differences between the control and invention groups for distant generalization tasks.

The SARA project [14] is based on an open-source platform for rapidly creating and prototyping animated virtual characters. Automatic speech recognition and synthesis capabilities are provided by third-party software integrated in the framework. A notable study conducted using this framework include DECT, the Dynamic Emotion Categorization Test reported in [15], which was an experiment using human participants and virtual agents to examine the ability of emotion recognition with dynamic physical stimuli in children with autism.

An evaluation study involving Peppy Pals 4 [18] indicated that children really enjoyed playing the game and were able to clearly articulate the emotions of the animals and understood the emotions in the context of the scenarios. However, the study reports that they did not have to actively use emotions in order to play the game and often tried a trial and error approach to playing the game.

Ho and Dautenhahn [19] extend previous work [20] towards the development of a virtual learning environment and intelligent virtual agents for facilitating and better understanding the development of social relationships between children. Interactions take place in a playground and canteen scenario and allow the investigation of the social structures that emerge from play, especially with respect to group formations e.g. formations [21] and social distance [22].

IV. THE VIRTUAL CHARACTER BEHAVIOR TOOLKIT

The toolkit that we introduce is designed for the development of virtual character behaviors aimed specifically towards social game scenarios. It is not to provide a single game scenario or set of characters, but rather a development kit for creating a wide range of scenarios surrounding social behaviors and interactions that support a large variety of character appearances. Two general examples of the types of scenarios that can be created are shown in Figure 2.

![Image](https://via.placeholder.com/150)

Fig. 2: Example of game scenarios: The cold shoulder (left). The character in dark clothes orients their back towards the other in a display of impoliteness. Maintaining social distance (right). The character in dark clothes moves backwards in order to maintain a comfortable social distance with respect to the other character.

Operationally, the behavior toolkit (Figure 3) manages the control of the face, full-body and formation behaviors [8] of individuals and groups of virtual characters. It is especially focussed towards behaviors relating to social scenarios. The toolkit also supports a number of peripheral features required for working with virtual characters, such as camera, player and navigation control, and a number of special features, such as the copy controller, which enables and determines how sets of human facial expressions are to be mapped onto the faces of virtual characters in real-time.

A number of existing virtual characters are supported in the toolkit combined with existing predefined behavior labels (See Section V-I). Since the style and needs of each game differ, the expectation is that game designers will eventually design, rig and create predefined animations for their own characters that they will associate with existing predefined labels in the toolkit. The process for doing this involves binding the facial expressions and full body animations of the new characters. This process is described in each of the related subsections for the face and body. A further subsection details the process for the use of 2D sprites. And subsections on formations and copy controller follow afterwards.

The behavior toolkit consists of the following components:

- **Player and Camera Controllers**: These enable the agent to be controlled by mouse and keyboard, also the selection of views in the game and methods for the player to shift between them.

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2http://www.thetransporters.com
3http://www.jkp.com/mindreading
4http://peppypals.com/
Fig. 3: Overview of components related to the behavior toolkit.

- **Face Controller**: Play face related expressions or movements based on the mesh-based blendshapes through predefined face labels and facial expressions database.
- **Body Controller**: Play 3D body animations using Unity animator component through predefined body labels.
- **2D Sprites Controller**: Play 2D Sprite animations using the Unity animator component through predefined 2D sprites labels.
- **Behavior Controller**: This is a combination of both the face controller and body controller. It invokes the corresponding controllers based on the requirements of the developer as specified in a behavior profile database.
- **Formation Controller**: The formation controller initiates the positions of each virtual character in groups and alters their positions based on different behavior states.
- **Conversation Controller**: This consists of an automatic conversation model in which speakers and listeners use a Finite State Machine (FSM) to simulate the transaction between seven conversational states.
- **Relationship Manager**: Defines agents relationships which affect their interactions, for example, their behaviors when they join a group.
- **Copy controller**: Defines support for and mapping between the facial expressions of humans in real-time and the faces of virtual characters.

V. CORE SYSTEM COMPONENTS

A. **Player and Camera Controllers**

The player controller specifies the control of the agent through the mouse and keyboard. The camera controller allows the player to shift among different views in the game. There are four views in the game as shown in Figure 4.

B. **Face Controller**

The 3D animated facial expressions of virtual characters are controlled by mesh-based blendshapes. In order to add facial expressions that can be played on 3D characters, it is necessary to complete a binding process, which maps the facial expressions defined for a specific character to a set of predefined facial expression labels. A lookup table (PSL_FaceExpressionLookupTable) contains the mappings between predefined facial expression labels and user defined facial expressions. The values of blendshapes of face expression are stored in a database (PSL_FaceExpressionDataBase). When presenting a expression is required, the actual facial expression is mapped from related label and triggered.

C. **Body Controller**

The body animations of virtual characters are controlled by the Unity animator through the body controller. As it is similar to the Face Controller, the main part of the process involves binding the animations that are specific to the virtual characters into the system through the body labels. All the animations should be attached to the animation controller of the character beforehand.

D. **2D Sprite Controller**

2D animated sprites are also supported by the system. The use of such sprites will enhance the performance of the character animation system, especially on platforms that do not...
have substantial graphics capabilities. Although the flexibility of such systems is more limited, in many cases, the use of 2D sprites will provide a comparative level of visual quality to their 3D counterparts, which improve the performance of the virtual characters in tablets, mobile phones, etc.

E. Behavior Controller

The Behavior Controller manages the control of the face and body of virtual characters. It plays a crucial role in the interactions within groups. A behavior profile defines the behaviors (i.e., animations) that virtual characters perform in different situations, thus allowing different characters to have different reactions to similar events. It defines the related animation labels (and thus, animations) that will be called in specific interaction situations, phases, relationships, and states.

Each virtual character is assigned a single behavior profile. Profiles are stored in the Behavior Profile Database. The user can customize and add their own profiles to the database according to the pre-defined rules in the system. An example of parts of the behavior profile in the joining phase of a social interaction (i.e., when a character joins a group of characters) is shown in Figure 6. While default behavior profiles exist for the characters in the system, new profiles may be created and it is expected that the game developer will tailor the behavior profiles according to the needs of their specific scenario.

F. Formation Controller

The formation controller consists of a group generator and an interaction controller: The group generator manages aspects of the group such as the formation type and range at which a player is considered to join the group; The interaction controller manages the processes relating to the joining, leaving, and maintaining interaction with a group of virtual characters.

1) Group Generator: The initial positions of each agent in the group are determined by evaluating the similarity between randomly positions (with constraint) and real data corpus [24]. The positions are generated repeatedly until the similarity is below threshold.

2) Interaction Controller: There are three main states in the interaction between new coming agent and the group: join, leave, and maintain. The interaction controller takes control of the new coming agent (if it is previously controlled by the player). The transition between each state is accomplished by choosing different options in the pop-up dialogue and buttons.

G. Conversation Controller

The conversation controller manages the turn-taking behaviors of virtual characters that are engaged in a group conversation. It offers two options of control: automatic and user defined.

1) Automatic Control: This is applied when a player is not actively engaged in interaction with a group of characters (when they are animated in the background for example). In this case the conversation of the group is managed automatically. The type of behaviors each character makes, order in which each takes its turn to speak, duration for which it speaks, and so on, are determined by a turn-taking conversation model based on the work of Ravenet et al. [23]. This model is a joint of speakers and listeners using Finite State Machine (FSM) to simulate transitions among seven conversational states. These states and transitions between them depend on the attitudes between each agent and the rest of the group. Attitude is depicted on a two-axis space: status and affiliation. The status axis ranges from submissive attitude to dominant attitude, while the affiliation axis ranges from hostile to friendly. The attitude of each agent triggers the transitions between the

Fig. 6: Example of the Join Group behavior definition for an agent (left) and corresponding animation (right) of a high intensity happy face animation and arm wave if the agent has a positive relationship with the others.

Fig. 7: Virtual characters in a group welcome and make space for the player (left). A character in the group is introducing the player to the rest (right).

The interaction controller acts not only as a trigger for the behavior controller, but also handles the dynamics with the groups. For example, in the join state, if the agent tries to join a position in the group formation in which there is not enough space, the agents in the group will move aside to make space. After the agent leaves the group, other agents in the group will move back to the previous positions.

In the maintain state, the developer can set behaviors of each agent through the behavior controller. In the default case, the introduction behavior is played in which a character in the group introduces the newcomer. In this mode, the user is prompted to select two characters in the group who will engage in the introducing behavior: the first selected character introduces the second one. By default, two close-ups of the faces of each character are displayed on the screen in order to clearly show the facial expressions being made during the introduction process. Both face and body animations also play in the main scene window.
different states. A schematic and in-game view of the turn-taking FSM transaction framework is shown in Figure 8.

Fig. 8: Schematic of the conversational turn-taking FSM model from [23] (left) and an image of the model in operating within a small group. The automatic model is employed for fully automated groups of virtual characters, such as those in the periphery or background of an ongoing game scenario.

2) Manual Control: Once the player joins a group of characters, the automatic turn-taking model is switched off and a user defined conversation is activated. The behaviors, order to speak, speech content and so on are based on pre-defined data from the behavior controller.

H. Copy Controller

The copy controller manages the translation of human motion from an input data source and analysis module to the realization of a similar or alternative behavior on the virtual character in real-time. For example, the face motions of the virtual character may be driven from high-level emotion labels derived from analyzing the face of the user through a webcam. Examples of a direct mapping of labels are shown in Figure 9, in which expressions of happiness and anger on a user face are mapped to predefined animations of happiness and anger on the face of the virtual agent, both in the close-up view and in the situated 3D environment. The copy controller does not define a specific module for user behavior analysis, but rather it is chosen and added to the system by the developer as third-party software. Example of tracker that has been used with the system is Affdex SDK, which uses basic free license.

In order to support a variety of possible game scenarios, a Behavior Mapping Table defines the mappings from input emotion labels to the behaviors that are realized by the character. Thus, it is possible for the developer to define mappings that vary the input and output modalities, for example, to render the users facial expression as a body motion with a corresponding emotion by the virtual character. Other possibilities include mapping multiple input user expressions onto fewer or more intense/subtle emotional expressions and to map user facial expressions to alternative emotions expressed by the character (e.g. an angry facial expression made by the user becomes a happy expression made by the character).

I. Assets

Our toolkit supports various types of virtual characters. Support is provided already for the MCS Female character as an example embodiment to demonstrate various possibilities of the system. This model was chosen since it has a good degree of visual realism, has detailed 3D face and body animation capabilities and is also available in a free version. Support is also provided for other third-party software or SDK, such as LipSync Lite, Affdex SDK, etc.

VI. EMOTIONS WITH FRIENDS

A prototype game, Emotions with Friends (Figure 10), concerns the recognition of social cues and emotions. A first prototype has been created, featuring two levels of difficulty and facial and full-body behaviors for two virtual characters. The characters have two embodiments that differ in terms of realism. The first is a simplified manga-type cartoon character while the second is a more realistic and detailed human male. Additional characters may be added in a straightforward manner to the game. The same sets of behaviors, i.e. the same basic motions, are played across different characters. The initial pedagogical aim of the demonstrator has been to raise awareness and discussion possibilities with students about face and body expressions and to enrich their emotional vocabulary i.e. through the use of a range of emotion labels. However, the longer term goal within the project is to investigate the potentials of the game for actively developing the emotion and social recognition skills of students.

Continued development of the game has focused on optimizing its performance. This has been accomplished especially through the use of 2D Sprite animation control (see Section V-D) instead of real-time 3D characters. A number of other improvements have been made, such as allowing developers and users to customize their own scenarios and adding more possibilities in relation to automatic difficulty adjustment as a basis for personalized adaptation.

5http://developer.affectiva.com/v2_3/unity/

6https://www.morph3d.com/

7https://www.assetstore.unity3d.com/en/#!/content/61886
difficulty level of the game can be altered include the number of emotion labels to choose between and their relationship with the animation being made.

### TABLE I: Animation Factors Linked to Difficulty

<table>
<thead>
<tr>
<th>Factor</th>
<th>Description</th>
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<tbody>
<tr>
<td>Embodiment</td>
<td>Cartoon-like versus realistic faces and bodies.</td>
</tr>
<tr>
<td>Variety</td>
<td>The number of faces and bodies of the same embodiment type used for playback.</td>
</tr>
<tr>
<td>Complexity</td>
<td>Basic versus complex emotional expressions.</td>
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<tr>
<td>Intensity</td>
<td>Subtle versus exaggerated expressions.</td>
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<tr>
<td>Speed</td>
<td>Real-time versus slow motion playback of expressions.</td>
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D. Additional Uses of the Demonstrator

The demonstrator has additionally been used to investigate the viability of social games that use virtual characters for emotion and social cues recognition with teachers and children. Especially, to investigate what aspects of a lesson should be encapsulated in the game itself and which should be external to the computer e.g. as part of a larger classroom activity taking place away from the computer. It also allows us to investigate the challenges involved in creating a credible pedagogical tool that is also viable in its own right as a game. More specifically, implement and obtain feedback on some of the different issues surrounding skills development in the classroom, such as repetition, reward and generalization.

E. Future Work

An updated version of the game is currently in development, it will include more detailed scenarios with a progressive story and context. To approach the real-life situation the scenes in the scenario will only be shown for a limited amount of time, this will be adaptable based on the difficulty settings of the player. A scenario can be augmented by written or recorded dialogue and an adjustable background for a more realistic context. The scenario creator will also be extended to allow users to create new scenarios with a graphical interface. The existing ranking database will be used to grant players a score on their performance, additional score can be achieved by finishing a scenario, to reward players even if they do not get many right answers. The score can be used to unlock new characters for the scenario, this will act as an incentive. Several other improvements have been made such as adding more possibilities in relation to automatic difficulty adjustment as a basis for personalized adaptation.

The game built on the toolkit is being evaluated in schools. While the current version of the toolkit is quite general in terms of its range of capabilities, more detailed components are planned for future versions. For example, the camera controller can be developed to animate automatically in complex and changing environment and support interactive narratives [25]. The conversation controller can be integrated with the IrisTK [26] dialogue system to develop multi-modal interactions. Moreover, the copy controller can be extended to recognize body movement and gestures [27].
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tails concerning the application of expressive virtual characters
towards their realization. A work-in-progress behavior toolkit has been shown for the development of virtual character behaviors. An example demonstrator has been detailed which shows how a small social game featuring expressive virtual characters can be built using the toolkit described here. This game is currently being evaluated in schools.

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REFERENCES


Fig. 11: A work in progress scenario in which the player must choose the nearest matching emotion word from a selection of labels surrounding the character in a limited amount of time. The number and content of labels can be customized in order to create more difficult games.

VII. CONCLUSION

This paper has presented the background and technical details concerning the application of expressive virtual characters to social game scenarios. It builds upon a previous description of the roles and potentials of virtual characters in social skills development through games to detail the technical components towards their realization. A work-in-progress behavior toolkit has been shown for the development of virtual character behaviors. An example demonstrator has been detailed which shows how a small social game featuring expressive virtual characters can be built using the toolkit described here. This game is currently being evaluated in schools.