Building Characters: Lessons Drawn from Virtual Environments

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Abstract

There are a number of common research problems encountered in building applications which involve the usage of virtual characters or sociable robots, especially when the application demands the facilitation of social interaction and communication with users (Breazeal, 2002; Kidd, 2003; Schroeder, 2002). One of these challenges is in modelling characters of high visual fidelity and behavioural authenticity (Slater et al., 2000; Goetz et al., 2003). This paper gives a review of studies that offer evidence to support the importance of developing characters with plausible and consistent behavioural models.

Introduction

Evaluative studies within virtual environments, have suggested that in scenarios requiring social interaction, feedback and communication the more visually realistic the representation gets, the more naturalistic users expect the virtual character to act (Garau et al., 2003; Tromp et al., 1998). This argument for consistency and a balanced tradeoff between visual and behavioural realism in virtual characters is shared by many researchers. It is reminiscent of Masahiro Mori's hypothesis which contends that user responses to various levels of non-realistic to realistic portrayals of a humanoid is not linear (Fong et al., 2003; Minato et al., 2004; Mori, 1970). Mori predicted that near the higher end of the realism spectrum, there is a dip (an 'uncanny valley') in user responses to the character as subtle imperfections in the character becomes disturbing.

This paper aims to present a review of ongoing studies with regards to the appearance-behaviour problem encountered in modelling virtual characters. Studies have shown that simply increasing the anthropomorphic or photorealistic quality of virtual characters is not sufficient to enhance their overall fidelity (Garau et al., 2003; Vinayagamoorthy et al., 2004b). The underlying premise of the studies presented in this paper is that if virtual characters with an acceptable level of visual fidelity displayed subtle behaviours typical of a certain mental state, users interacting with the virtual character in the virtual environment will respond in a manner consistent with those of the physical world (Pertaub et al., 2002). The effect of incorporating these behaviours in virtual characters has been studied by conducting controlled experiments designed to observe social interactions between subjects and a virtual character. This paper proposes that some of the methods used to enhance the effectiveness of virtual characters can be drawn upon and utilised in the field of android science.

Social characters and robots

Virtual characters and sociable robots are used in a variety of overlapping applications requiring communication and social skills including:

- Games and entertainment (Arts, 2005; Bartneck and Okada, 2001)
- Educational aids in training environments (Fong et al., 2002; Gratch and Marsella, 2001)
- Virtual therapy (Freeman et al., 2003; Goetz et al., 2003; Dautenhahn, 2003; Pertaub et al., 2002)
- Conversational representatives (Fong et al., 2003; Pertaub et al., 2002)
- Expressive conversational interactive agents (Breazeal, 2002; Cassell et al., 1999)

Communication within most of these social contexts is based on expressive feedback and requires a certain degree of proximal interaction. In the physical world, when individuals need to get spatially close for specific interaction purposes or otherwise, they subconsciously draw impressions about the mood and psychological state of the other from behavioural cues displayed during the interaction (Argyle, 1969). This places demands on the virtual character or sociable robot to be behaviourally responsive to users in a manner that is both expressive and coherent.

There is some evidence that virtual characters and/or social robots can elicit subconscious responses from individuals (Freeman et al., 2003; Goetz et al., 2003; Pertaub et al., 2002). Goetz et al. (2003) argue that humanoid robots convey certain cues that evoke automatic perceptions of life in the robot and lead individuals to attribute personalities to it. The tension between subconscious user responses and the self-rationalisation that virtual characters and sociable robots are not real has been addressed by a number of researchers. Studies into the embodiment of users in a collaborative setting suggest that users in virtual environments respond strongly to humanoid representations of other users in the environment (Benford et al., 1995; Nowak and Biocca, 2003).

Slater and Steed (2002) reported a set of three studies in a shared virtual environment in which subjects were represented by simple characters with limited movement and no capability for emotional expression. Groups of three subjects meet for the first time in a virtual environment. Their representative characters were labelled: Red, Green and Blue. In the studies, the green character was made visually more realistic than the other two. The subjects' collaborative task was to solve a series of puzzles in a virtual room together. Post-experimental discussions revealed that the differences in the green characters' representation had an effect on the relationship formed during the collaboration even though the subject being represented by the green character was unaware of this. The discussions indicated that virtual characters with no associated behaviours were perceived to be 'cold' (Tromp et al., 1998; Slater et al., 2000), which greatly deteriorates the experience of the social interaction (Schroeder, 2002). The degree of realism of the green character raised the other subjects' expectation about its' capabilities (Slater and Steed, 2002; Tromp et al., 1998).

Kidd (2003) reported a study to explore the differences and similarities within a limited range of subjective user responses to robots and virtual characters. Perceptions of the character's reliability, credibility, as well as a measure of how enjoyable the interaction were compared between a robot and a virtual character. Differences were found in user responses mainly due to the physical presence of the robot and these differences depended on the level of interactivity required in the task. Results in the study carried out by Kidd (2003) also highlighted the importance of behaviour modelling in order to enable a more naturalistic interaction. This is in keeping with results from studies with virtual characters which suggest that social interactions are often inhibited by a lack of emotional expressiveness and gesture content in the representations (Slater and Steed, 2002; Tromp et al., 1998).

The challenging aspect in creating a convincing character is that of representing plausible behavioural cues to depict a perceived psychological state. However, human behaviour in terms of social interaction and communication is a very intricate phenomenon dependent on many factors in the physical world, and extremely difficult to replicate in either a virtual character or a sociable robot.

Measuring success in virtual environments

The success of a virtual environment (and character) is often measured in terms of the extent to which sensory data projected within a virtual environment replaces the sensory data from the physical world. This success is conventionally quantified by rating the subjects' sense of presence and/or copresence during the experience. Presence, within the context of virtual environments, is the sense of '*being there* in the place' portrayed by the virtual environment while copresence refers to the subjects' sense of being in the company of others (Schroeder, 2002; Nowak and Biocca, 2003). An increase in subjective presence or an appropriate objective (physiological or behavioural) user response relates to an enhanced experience in terms of communication, realism, and so on. In most of the research presented in this paper, a higher self-rated presence/copresence response is experienced when users interact with characters with higher perceived behaviour fidelity.

Inducing user responses to characters

Disney and other cartoonists have maintained that emotional expressions are necessary substrates for producing plausible characters (Thomas and Johnson, 1981). Some have argued that incorporating emotions in characters is essential to creating intelligence and reasoning (Minsky, 1988; Picard, 1997). For instance, Minsky (1988) maintains that it is impossible to implement intelligence without emotions. Picard (1997) has argued that the inclusion of emotions and affective behaviours may contribute to a richer interaction and impact on the users' ability to interact in an intelligent manner. The perception of innate emotions and personalities in a character is important to impart a sense of unique characteristic and genuine responsiveness to it. In some cases, the appropriate behaviour of characters is more critical than a visual likeness to the human form, in order to evoke an emotional response in subjects immersed in virtual environments (Nowak and Biocca, 2003; Blascovich et al., 2002).

In an attempt to reduce the monotonous and repetitive behaviours of agents, work has gone into producing more varied, expressive and natural-looking behaviours from a smaller set of available behaviours for instance adding a *jitter* quality through stochastic noise (Perlin and Goldberg, 1996), modifying shape and effort parameters to change the qualitative aspects of motion (Chi et al., 2000), adding secondary movements to existing animations based on personality and mood (Morawetz and Calvert, 1990) or emotional transforms (Amaya et al., 1996). However evaluative studies have shown that the mere addition of movement or random behaviours to enhance *liveliness* in characters is not sufficient. The behaviours have to be both naturalistic and bear relation to the context within which the virtual character is being used.

Natural responses to different events and stimuli in the physical world is as varied as the events themselves. This is partially the problem in trying to build a consistent and realistic behavioural model for virtual characters and robots. Researchers have always assumed that it would be possible to construct a dictionary to translate emotions and personality into the appropriate behavioural cues. A survey of literature and daily observations suggests that different individuals respond to different levels of behavioural cues (Argyle, 1969). The same state is expressed differently by different individuals at different times; however in the physical world, people are able to use even minimalistic cues to correctly perceive the internal emotional state of others and get an impression of their personality trait. There are two main issues to resolve in the design of studies aimed at this problem. The first revolves around the question of the existence

of a set of distinct behaviours for a psychological state caused by a specific stimuli. The other issue involves mapping the commonalities within attributes presented in behaviours used in conjunction with a particular psychological state caused by *different* stimuli.

Inducing *realistic* responses from users

Perceiving the psychological state of others depends on a number of factors including personal variables, characteristic traits and anxiety threshold. For instance, there is empirical evidence that individuals who are prone to harbouring feelings of interpersonal vulnerability and anxiety in the physical world are more likely to get anxious in response to essentially neutral contexts in a virtual environment (Slater et al., 2004). In a preliminary step towards studying human-robot social relationship, Walters et al. (2005) have reported that subjects prefer approach distances to a robot that were compatible with those expected under normal social situations and suggested that these distances were dependent on the personality trait of the subject. The ability to induce realistic responses in individuals could be an astute measure of the plausibility of a social character or robot (Minato et al., 2004).

Pertaub et al. (2002) conducted a pilot study based on public speaking, in which subjects were asked to give five minute presentations to a virtual audience of eight male characters dressed in formal wear and of varying behaviours. The aim of the study was to investigate whether the type of virtual audience (hostile, friendly, or neutral) would affect the emotional response of the subject. The characters were continuously animated to display behaviours based on data gathered from social psychology literature. The characters also responded to the subject with either facial expressions, shifts in body postures or short animations and appropriate verbal feedback. Each subject was asked to give their presentation thrice, each time to a differently inclined virtual audience. Independent of time, subjects' self-rated performance was positively correlated with the perceived *good* mood of the agents. Recently Slater et al. (2004) reported another study designed to extend the research on public speaking to include effects of virtual audiences on subjects who had a phobia against public speaking in the physical world. The characters appearances and behaviours were changed to make them more subtle based on observations of face-to-face meetings in the physical world. The goal of the study this time was to create a virtual audience that would not affect confident speakers but would arouse similar anxiety levels in phobic subjects (Slater et al., 2004). The results of the studies confirmed Slater and colleagues' hypothesis and demonstrated that minimal behavioural cues can have a profound effect on subjects.

Nowak and Biocca (2003) conducted a study to examine the influence of anthropomorphism and perceived agency on the subjective responses of subjects (see Table 1). Subjects were required to take part in a very limited interaction with a representation of another subject on a screen. The perceived agency of the representation was induced by telling subjects that the controller behind the virtual character was either another subject or purely scripted depending on the condition. The anthropomorphism factor of the representation was varied by using either a humanoid face, an abstract representation (only mouth and eyes) or no representation at all. Their results indicated that subjects responded socially to the virtual character regardless of agency. However more interestingly, subjects in the study reported a higher sense of copresence while interacting with a less humanoid representation. Nowak and Biocca (2003) argue that this is inline with the speculation that users interacting with a highly anthropomorphic character had higher expectations with regards to the ability of the character which were not met in the study.

Table 1: Conditions and user response score from Nowak and Biocca (2003)

Anthropomorphism	Perceived as a controlled character	Perceived as autonomous character
High	low	low
Low	high	high
None (*control*)	low	low

In other works, it has been demonstrated that a virtual character with limited behavioural complexity coupled with the right perceived context can induce the appropriate social or emotional response from users. Garau et al. (2004) conducted a study designed to investigate the spatial and temporal variations of users' subjective responses to a virtual bar containing five virtual characters. An in-depth semi-structured interview was conducted with the subjects at the end of their exposure to the virtual bar. Their qualitative findings indicate that subjects responded to the characters and recalled memories of their experience as if they were in a real social situation in spite of the characters displaying limited behaviours. For instance, a perceived sense of mutual gaze, combined with ad-hoc animation, produced in some subjects a sense of postural congruence, and made them feel 'watched' by a character playing the part of a bartender. Similar results were obtained in studies conducted by Freeman et al. (2003) in which the extent to which virtual reality can be used to instigate persecutory ideation was explored.

Freeman et al. (2003) ran a gender-balanced study in which subjects were instructed to explore a virtual library for five minutes and form impressions of the characters in it Freeman et al. (2003). Three male and two female characters were animated to display various behaviours including smiling, looking at the individual and talking to each other (Figure 1). Findings from the study indicated that subjects attributed sentience and a mental state to the characters. Subjects in the study typically ascribed benevolent intentions to the characters, but some subjects had thoughts of a persecutory nature about the characters, although the behaviours modelled

Figure 1: Characters in a virtual library from the social anxiety studies

in the characters were of a neutral nature. Subjects who had persecutory thoughts about the virtual characters had significantly higher levels of interpersonal sensitivity and anxiety Freeman et al. (2003).

Figure 2: Higher level semi-photorealistic characters in the virtual street

Elsewhere Vinayagamoorthy et al. (2004a) reported a study designed to investigate the users' response to variations of visual realism in the scene. Users who were asked to explore a virtual street, which had virtual characters walking through it (Figure 2). Two factors were varied - texture quality of the visual scene and the characters' visual realism (Figure 3). They concluded that the highest significant subjective measure was the users' *perceived* sense of realism with respect to the behaviour of the characters. The more users *perceived* the agents's behaviour to be realistic, the higher their reported sense of presence.

These studies reinforce results obtained by (Slater et al., 2004) which suggest that increasing expressivity

Figure 3: Characters of varying visual realism used in the virtual street. Lower level cartoon form characters and higher level semi-photorealistic characters

and responsiveness in characters of relatively simplistic appearance even on a simple level can have a significant impact on users.

Contexts requiring social communication

The simulation of inferred or affective behaviours in a character can go further in improving a users' experience especially in virtual environments requiring social interaction and interpersonal communication (Pertaub et al., 2002; Garau et al., 2003; Schroeder, 2002).

Garau et al. (2001) conducted a study focusing on assessing the impact of behaviour fidelity, specifically gaze behaviour on dyads between individuals using a variety of communication media. Subjects were recruited to carry out a negotiation task under four conditions: audio only (no gaze feedback), random (random gaze and random head animation), inferred (inferred gaze and tracked head animation), and video tunnel[1]. The first and last conditions were implemented to act as controls. In the other two conditions, the subjects in the dyad were represented to each other by identical gender-matched characters on a screen. The random gaze behaviour was based on a pseudo-random number generator. The inferred gaze behaviour was implemented based on previous work reported by Argyle and Cook (1976). Unsurprisingly, the video tunnel was the most favoured medium for communication. The random gaze condition was the least favoured. The most encouraging results were that on two counts of the response variables measures, the inferred condition was not significantly different to the video condition.

Garau et al. (2003) conducted a further study designed to test the impact of varying levels of character *visual*

[1]Video mediated communication

and *behavioural* realism on user responses in an immersive virtual environment. The two levels of visual realism utilised in the study is depicted in figure 4. Whereas the study conducted by Nowak and Biocca (2003) focused on the anthropomorphic dimension of visual realism, this study placed more focus on the photorealism dimension. Like the previous studies conducted by Garau et al. (2001), the behaviour focused on was eye gaze in a dyad under a negotiation context.

Figure 4: Lower visual realism genderless, higher realism male, higher realism female character from the study on character realism

The nature of the task encouraged the subjects to particularly focus on the nonverbal aspects of the communication as well as the verbal content. Two levels of gaze behaviour was simulated for the study based on works done by Lee et al. (2002) and Argyle and Cook (1976). The first level of behaviours were designed as a control and included a random eye gaze model with accompanying subject-controlled arm, legs and head animation. The more realistic set of behaviours included the same body animations as well as a more complex eye gaze behaviour model (Vinayagamoorthy et al., 2004b). The results once again supported the hypothesis that a more visually realistic character is expected to behave in a more human-like manner especially given that the differences in the behaviour models used were very subtle and indistinguishable to the naked eye (Vinayagamoorthy et al., 2004b). This is in keeping with theories presented by Goetz et al. (2003) which state that a robot's appearance and behaviour provide cues to the robot's abilities and propensities. In addition to subjective responses, there was anecdotal evidence to suggest that the subjects were responding to the virtual characters in a manner consistent with interactions in the physical world.

> *... I was surprised at how much I felt accountable to my partner's avatar (character), I was unable to fully take the aggressive alternative ...*
>
> *I wonder whether the other person could realise that i could not stop smiling at his ridiculous claims and comments!*
>
> *Towards the end of the conversation my partner was looking around the room and the ceiling which gave me the impression she was not concentrating, the response I had to this was very realistic, as if a real person was not concentrating on what I had to say.*
>
> *- Quotes from the study on character realism*

Most interestingly an interaction effect was observed within the factors tested in the study on character realism 2. It suggested that in the case of a lower visually realistic character, the inferred gaze model had a *negative* effect on user response (Garau et al., 2003; Vinayagamoorthy et al., 2004b).

Table 2: Conditions and response scores from the study on character realism

	Low visual realism	Higher visual realism
Random gaze	High	Low
Inferred gaze	Low	High

In a sense the non-realistic random gaze model was more dynamic and visually stimulating than the subtler eye movements of the realistic behaviour model. Perhaps following in the Disney tradition (Thomas and Johnson, 1981), users in a shared virtual environment need to be *made* to believe that a visually simplistic virtual human is 'alive' or expressive in order to feel a higher sense of presence when interacting with it (Garau et al., 2003; Vinayagamoorthy et al., 2004b). A final observation that resulted from the studies by Garau et al. (2001, 2003) was that other than the issue of consistency, evidence suggest that the importance lies not only in implementing behaviours but that the behaviours have some relation to the context of the interaction.

It cannot be assumed that the results found in the studies conducted by Garau et al. (2001, 2003) will hold when applied to other forms of human behaviours. The behaviour model used in both studies was lacking in other non-verbal behavioural factors such as posture, gait, gesture and other facial cues (smiling, lip synching). However, it does open an exploratory question into other non-verbal behaviours and offers empirical evidence towards the theory that there needs to be a consistent correlation between visual and behaviour realism.

Conclusion

Observations from the studies reviewed in this paper have highlighted three main issues in the modelling of convincing virtual characters:

- Increasing either the visual realism or the behavioural complexity of characters is not sufficient to enhance user responses.
- It is important to maintain consistent levels of behavioural fidelity with increasing levels of visual realism. There is empirical evidence to suggest that increasing behavioural realism for characters of low visual quality might lead to a *degradation* of user responses.
- The behavioural expressivity of a character must be modelled in correlation to the context within which the character is placed. The right level of subtle cues can perform surprisingly well in achieving the desired effect.

Studies into the impact of implementing emotional and personality models coupled with appropriate behavioural cues in sociable robots is not a new arena. Breazeal (2002) have produced sociable robots like Kismet which engage people in a natural and expressive face-to-face interaction. The robots perceive a variety of natural social cues using visual and auditory channels, and respond with social signals through gaze direction, facial expression, body posture, and vocal babbles. In most circumstances the addition of an emotional dimension to an embodied character or sociable robot has had a significant positive effect on the interaction.

However this effect is dependent on other factors, most importantly context and the needs of the application. Goetz et al. (2003) reported that the robot's appearance and behaviour influenced the users' perception of the robots characteristics like it's personality and intelligence. Users expect a robot to look and act in accordance to the task it is meant to be performing. This result has been found in the usage of virtual characters as well. Thórisson and Cassell (1999) reported in a study that envelope feedback[2] is more important than emotional feedback in terms of creating a conversational agent such as Rea (Cassell et al., 1999). In general this is a prematurely drawn conclusion against emotional expressions, however it does drawn attention to the importance of implementing context-appropriate behaviours. Psychological studies have shown that even mildly positive affective states in an individual profoundly affects the flexibility and efficiency of thinking and problem solving (Isen et al., 1978). Cognition and emotion play inter-related roles in intelligent decision-making, planning, learning, attention, communication, social interaction and memory (Breazeal, 2002). The effectiveness with which an individual expresses and understands psychological states, and the interpersonal communication of these states is fundamental to both daily and clinical interaction. It is a culturally-patterned process to which all users in an interaction constantly contribute using messages of varying overlapping length along multi-sensory channels. This makes behaviour modelling one of the more challenging aspects in the development of convincing characters.

Despite the complexities involved, virtual characters present promising avenues for research into social behaviour because they enable the controlled manipulation of specific visual and behavioural variables. Prior sections have attempted to illustrate the complexities involved in trying to build an accurate portrait of the interrelationships between visual and behaviour fidelity with regards to building a virtual character. Add emotions, moods, context, interpersonal relationships, personalities, communicative intentions and related factors to the behaviour model and the challenge of building plausible characters becomes even more intricate especially due to contextual differences and the discrepancies in the underlying theories of emotions and personalities. Another problem is the lack of methodological research into exploring the exact means by which to enhance user responses to a particular sociable character within a given context. Further work is required in order to focus future research into producing effective behaviour models for both virtual characters and social robots.

[2]Feedback related to the process of the conversation

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