
The agent takes the stage

Josephine Anstey*, A. Patrice Seyed,
Sarah Bay-Cheng, Dave Pape,
Stuart C. Shapiro, Jonathan Bona and
Stephen Hibt

Departments of Media Study,
Theater and Dance,
Computer Science and Engineering,
University at Buffalo,
231 CFA,
Buffalo, NY 14260, USA
E-mail: jranstey@buffalo.edu
E-mail: apseyed@buffalo.edu
E-mail: baycheng@buffalo.edu
E-mail: depape@buffalo.edu
E-mail: shapiro@buffalo.edu
E-mail: jpbona@buffalo.edu
E-mail: sdhibit@buffalo.edu
*Corresponding author

Abstract: The deployment of virtual characters in intermedia performance drives divergent agendas of this research group. From the perspective of performance studies, we examine the effect of computer-based characters as actors and believe explorations of mediated agency can open up new forms of engagement for live productions. From the visualisation point of view, we are interested in how abstraction and animation techniques, based on motion tracking and procedural methods, convey character and warp and extend the gestural repertoire of a human actor. In terms of interactive drama, we are working on stream of consciousness characters: algorithmically recombining text to create a psychological entity with an autonomous inner structure. From an artificial intelligence perspective, we investigate how to design and use intelligent agents as actors. These agendas reflect an odd mix of aesthetic and technical concerns, and rightly so, as they are driven by the different goals of our interdisciplinary team.

Keywords: agents; animation; intermedia performance; mixed reality; robots; virtual reality; art and technology.

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Biographical notes: Josephine Anstey is an Associate Professor in the Department of Media Study at the State University of New York at Buffalo. She received her MFA in Electronic Visualisation from the Electronic Visualisation Laboratory, University of Illinois at Chicago. Her creative projects include virtual reality, performance and video, and have shown worldwide. She has art work in the permanent collections of the Museum of

Modern Art in New York and the Ars Electronica Center, Austria. Her research interests include interactive fiction, game studies, intermedia performance and virtual reality. She is a founding member of the Intermedia Performance Studio.

A. Patrice Seyed is a second year PhD student in the Department of Computer Science and Engineering, participating in the PhD Track Program in Cognitive Science at the State University of New York, Buffalo. He received an MA in Psychology and an MS in Computer Science, both from Boston University. He received a BA in Psychology and Minors in Computer Science from N.C. State University. Between undergraduate and graduate degrees, he worked as a Unix Systems Engineer at Intel Corporation specialising in supercomputing. His research interests include knowledge representation and reasoning, emotional intelligence and formal ontology.

Sarah Bay-Cheng is an Associate Professor of Theatre at the State University of New York at Buffalo. She received her PhD in Theatre from the University of Michigan with certification in Film and Video (now Screen Studies). Her publications include the books *Mama Dada: Gertrude Stein's Avant-Garde Theater* (Routledge 2005) and *Poets at Play: An Anthology of Modernist Drama* (Susquehanna UP, forthcoming). Her essays on theatre, theory and digital technology have appeared in *Theatre Journal*, *Theatre Topics* and *Studies in the Humanities*, among others. Her research interests include avant-garde theatre, performance theory, and intermediality in theatre and performance. She is a founding member of the Intermedia Performance Studio.

Dave Pape is an Assistant Professor in the Department of Media Study at the State University of New York at Buffalo. He received a PhD in Computer Science from the Electronic Visualisation Laboratory, University of Illinois at Chicago. He has also worked at the NASA Goddard Space Flight Center, in the Scientific Visualisation Studio and in High Performance Computing & Communications. He works in the creation of interactive virtual environments, as well as the development of tools for computer art and performance. He is a founding member of the IPS.

Stuart C. Shapiro is a Professor of Computer Science and Engineering and Affiliated Professor of Linguistics and of Philosophy at the State University of New York at Buffalo. He received an SB in Mathematics from the Massachusetts Institute of Technology, and an MS and PhD in Computer Sciences from the University of Wisconsin – Madison. His primary research interests are in knowledge representation and reasoning, especially in support of natural language competence and cognitive robotics. He is a Senior Member of the IEEE, an ACM Distinguished Scientist and a Fellow of the AAAI. He is a founding member of the IPS.

Jonathan Bona is a Cognitive Science Track PhD student in the Department of Computer Science and Engineering at the State University of New York at Buffalo. His research interests include artificial intelligence, knowledge representation and reasoning, and cognitive agent architectures.

Stephen Hibit is an Honours undergraduate and dual major in the Departments of Media Study, and Computer Science and Engineering, at the State University of New York, Buffalo. His research interests include performance, robotics and machine vision.

1 Introduction

Three recent productions by the Intermedia Performance Studio (IPS), *365 Days/Plays*, *Office Diva* and *Workers of the World*, have included computer-controlled characters as performers. The IPS is an interdisciplinary research group that fosters experimental intermedia performance using virtual and mixed reality sets, and featuring live, mediated and computer-controlled performers. These productions show the recent trajectory of our experiments with intelligent agents and virtual characters; demonstrate how the diverse agendas of our research team infuse our work; and indicate how work in one production informs and supports later concepts and techniques.

365 Days/Plays was the result of Pulitzer-Prize winning playwright Suzan-Lori Parks' decision to write a play a day for a year. In 2006/2007, cooperating regional and university theatres produced the plays in their originally written order in multiple productions occurring simultaneously across the US. The IPS produced the seven plays written from 23 April to 29 April. In this paper, we focus on two of these plays: *Lights/Rats* that was performed entirely by intelligent agents in a minimalist virtual environment; and *Diva* performed by a live actor and her virtual emanation. *Office Diva* is a performance by and for a computer-controlled character with text by one of the authors. It is a large-scale projection of the character living in a claustrophobic virtual space and compulsively talking, and has been exhibited as a short performance and as an endless installation. *Workers of the World* is an interactive performance for autonomous cleaning robots. The robots speak text taken from plays by Bertolt Brecht, Peter Weiss and Jean Genet, and detect and accost audience members.

While it is hard to avoid some compromising of categories, this paper is divided into four sections corresponding to four different aspects of our research. Section 2 is a discussion of virtual characters in performance, using as examples the productions of *Lights/Rats* and *Diva*. Section 3 focuses on animation and virtual bodies in *Diva* and *Office Diva*, extending a body of work exploring movement and abstraction in virtual characters. Section 4 deals with our inquiry into stream of consciousness characters (SoC), initiated in *Office Diva* and continued in *Workers of the World*. Section 5 focuses on the intelligent agents used in *Lights/Rats* and *Workers of the World*, a continuation of our research into an architecture for actor-agents.

2 Virtual characters in performance

Theoretically, our work with virtual characters in performance has been informed by Philip Auslander's consideration of the meaning of 'live' amid new advances in computer and recording technologies. Within his brief historical review of the live and recorded, Auslander inserted the question of the 'bot', a piece of software that autonomously responds to various kinds of input and attempts to communicate, sometimes using techniques designed to disguise the bot's non-human identity. For Auslander, the chatterbot is most interesting for its challenge to the concept of live performance, reframing his discussion "as a discussion of the ontology of the performer rather than that of the performance" (Auslander, 2002, p.70). In short, if the bot talks like a human, moves in real time like a human and disappears at the end of performance like a human, does the category of live actor still have weight in time-based performance? Ruminating on such questions, our performances include live and virtual characters, address the role

of 'live' in mediated performance contexts, and serve as the means to explore the confusions over mediated, augmented, artificial and post humans.

As practitioners, we have an equally complex, although very different, relationship with the notion of 'live'. In attempting to programmatically construct virtual characters, we ask ourselves what should they look like, how should they behave, how should they be structured internally, how should they signify agency? In effect, we are trying to determine what 'liveness' consists of, how 'liveness' can be represented, what aspects of 'liveness' are sufficient and necessary for our characters to be useful and effective. We note that Auslander mentions walking and talking – which presupposes mind as well as a body, mental as well as physical behaviour – and we are interested in both. Conceptually and technically, we link this 'liveness' not to a super-realistic simulation of life but to the more elusive sense of an entity 'being there' – and we also draw on the VR concept of presence. Mel Slater was the first to theorise this concept; his subsequent experiments strove to identify the elements that make a human treat a virtual environment and characters as if they are real; he has linked his concept of presence to an actor's stage presence (Slater and Wilbur, 1997). Presence has become its own field and at a workshop on presence at ICT in Fall 06, researchers from many disciplines seemed to converge on the notion that presence is a default state: instead of suspending disbelief to experience the virtual, the human has to make an effort to treat the virtual differently from the real. Where does this non-intuitive insight lead us in our development and use of virtual characters?

There is not enough space here for an extended discussion of the links between these two complex concepts; however, these are the questions that engage us as we proceed.

2.1 *Lights/Rats*

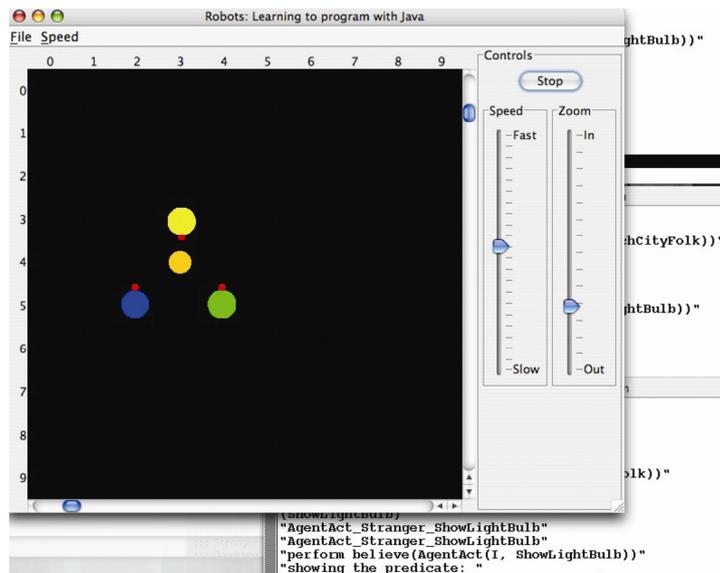
In November 2002, American playwright Suzan-Lori Parks began a self-imposed project of writing one play every day for a year – 365 plays in 365 days. According to Parks, "It became a daily meditation, a daily prayer celebrating the rich and strange process of a writing life" (Parks, 2006). Contextualising contemporary performance around the world, but particularly in New York, London, and major venues in Italy, France, Germany and Japan, theatre researcher Hans-Thies Lehmann argues that theatre has entered an era in which new forms increasingly reject the paradigm of dramatic theatre – a theatre "subordinated to the primacy of the text" (Lehmann, 1999, p.21) – and embrace new dynamics of performance predicated on image, media and a reconceptualisation of the performing body. Similarly, Jennifer Parker-Starbuck has argued that "There is no future but the cyborg theatre," a theatre that troubles the shifting relations among bodies, technologies and, perhaps, intelligent agents (Parker-Starbuck, 2006, p.39). What would it mean, then, to integrate drama, that is, at least in part about the process of writing, into such a mediated dynamic? What is the role of a playwright's text when performed by virtual performers in a nevertheless live theatre context? As an approach to this problem and the question of live performance and the role of the non-live actor, the IPS produced Parks' short play, *Lights/Rats* with autonomous agents.

Many of the 365 plays in Parks' year-long project reflect on technology and popular culture. Indeed, technology often represents thwarted and frustrated attempts at human communication for Parks. In American culture, we may attempt to connect through media, but such attempts often alienate us even more. *Lights/Rats* creates an elegant context for this critique. Our performance took place on a large screen, in one window

was a very simple geometric 2D world – a top-down view of a dark room – other windows contained real time print outputs of the workings of the agents' minds (Figure 1 shows a testing configuration of the setup). The agents appeared as brightly coloured balls with clown-like red noses, which indicated which direction each of them was facing. The agents could turn to change the direction they were facing, could move around within the room, and also enter or exit the room. When an agent spoke, the agent's avatar flashed to indicate that it was speaking, and the utterance was spoken out loud in a synthesised voice. Each of the agents had a distinct voice. The lightbulb – the only prop in the performance – appeared as a small yellow ball (details of the agent architecture in Section 5). The play is very short. Two characters – city folk – stand in the dark. A third enters with a lightbulb. The first two characters exclaim over the lightbulb, plug it in, and discover that it does not work. 'Rats'.

Though simple, the exchange recollects images of light, the enlightenment and human failures. Perhaps responding to Gertrude Stein's adaptation of the Faust myth in her *Doctor Faustus Lights the Lights* (1938), Parks situates her characters as believing that the lightbulb can deliver them from darkness – a literal possibility and an historical and philosophical problem of faith, technology and knowledge. For our purposes, the question was how to best articulate the significance of the lightbulb in ways that neither diminish the philosophical context nor make the short play a limited reflection on technology. Our answer was to create characters for whom the lightbulb could represent a compelling, even spiritual force. This play was performed by artificial computer characters; agents who were taught to act, directed, and then released into a live performance context. Thus, the lightbulb takes on the role of creator and even progenitor, and the futility of connection is displaced from humans in a critical, even humorous way. How ironic, then, that the little agents would experience for themselves the frustration of technological failures. In a larger context, however, their experience of technological failure takes on a great ontological significance, since their very existence depends on technology. To be truly in the dark, for these little guys at least, is to cease to exist.

Figure 1 Lights/Rats, 365 Days/Plays (see online version for colours)



2.2 *Diva*

The virtual characters and 2D world of *Lights/Rats* were simplified and abstracted – their empty world, blank selves and computer voices, reflected their alienated condition. They were minimally alive. By contrast, the only character in Parks’ short play, *Diva*, longs to be hugely alive – an aliveness that only comes from mediation and performance. Our staging of this play was based on a very different reconceptualisation of the performing body. Here, the virtual character augments a live performer – supporting her, redefining her, becoming more than her – and serves as a projection of a huge ego and signifier of a fabulous body.

In *Diva*, an aging actress reflects on her memory of past performances and the applause that greeted her on stage. “They would applaud,” she remembers, “until their hands bled. And the house manager would bring their blood-stained handkerchiefs to my dressing room as testaments” (Parks, 2006, p.193). Our approach in this short play was to make the *Diva*’s projection of self as vivid as the image of an audience clapping until their hands bled. To accomplish this, we connected a live actress to a tracking system that would turn her gestures – her memories – into fantastic projections; to overwhelm the live audience visually with the force of her phantasmagoric memory (details of the visualisation work in Section 3). The excessive memories without clear context cast doubt upon the *Diva*’s veracity. Like much of her work on history and memory (e.g. *The America Play* [1990-93] and *Venus* [1998]), Parks’ *Diva* exposes a character in a moment of memory conflated and indistinguishable from fantasy. The fact that this fantasy of her own success is vividly portrayed in the blood of others suggests the heightened stakes for live performance, even if only imagined.

These two productions engage with Auslander’s ponderings about where the liveness of performance is now situated, and rehearse some confusions about the ontological status of artificial and augmented entities. *Lights/Rats* and *Diva* speak about issues of liveness and lack. Robots and other technological entities are stereotypically portrayed as lacking some aspects of humanity, of ‘life’, and longing for it. However, humans now experience that their own aliveness is confirmed by seeing themselves reproduced by media. We are set up to long for a life augmented by technology, where we are bigger, super-real and super-alive.

3 Virtual characters and visualisation

In previous virtual reality work, we have experimented with the visualisation of entities so that they feel present and alive. We have used VR tracking systems to animate avatars of networked participants and intelligent agents (Dolinsky et al., 2005). A typical tracking system consists of a sensor on the head and on one or two hands. This simple system is immensely effective in imparting an uncanny sense of ‘life’ to the avatar as it captures small and natural movements: a turning head indicates the direction of a person’s gaze and attention; a tilted head can signify inquiry or confusion; hand gestures underline or undermine conversation. We have seen and used a large variety of avatars, from simple models to elaborate representations of humans, and have concluded that a more abstract avatar, coupled with natural body language, reads as a living entity better than a photo-realistic (but never really human) humanoid. We used this insight as the basis for the animation of virtual characters in *Diva* and *Office Diva*. In this section, we

discuss the visualisation and animation of *Diva*, followed by a description of our subsequent virtual character in *Office Diva*. The SoC aspects of *Office Diva* are explored in Section 4.

3.1 *Diva*

In our production of *Diva*, an avatar augments a human actor in a mixed reality space rather than representing the human in virtual space. The audience sees a live actress wearing tracking sensors who is shadowed by a virtual emanation of her ego projected on a very large screen. Using a virtual character allowed us to extend the human actor: effectively to double her. The projection is as an exteriorised part of the body – the same, because it moves in real time as the live performer moves – but also different. The projection defies age and loss. It is a fantastical self with a mask for a face, connoting the tragedy/comedy masks; an elaborate headdress and banners drawn from Chinese opera; a body represented only by ephemeral streamers agitated by the movement of the actor's arms. It sits in total darkness.

The *Diva* character is animated with a combination of motion capture and real-time procedural methods. The technology is derived from that of projection-based virtual reality (Cruz-Neira et al., 1993), using large-scale projection and an electromagnetic tracking system. The performer wears one tracking sensor on her head and holds the other sensors in her hands, with motion data passed via Ethernet to the real-time OpenGL program animating the *Diva* (Figure 2). The *Diva*'s face is surrounded by her headdress, banners attached to her shoulders and streamers in her (invisible) hands. These are all simulated cloth objects, using the constraints given by the tracked motion data with a mass-spring simulation (Witkin, 1995). Their motion is also affected by wind forces generated with a turbulence function, to add further life and unpredictability to the animation. The human actor playing the *Diva* character rehearsed her gestures while she and the director watched the virtual *Diva* and refined a series of gestures that worked for both human and virtual bodies. At show time, both human and virtual actors faced the audience. The effect is alluring, distant and powerful – for the *Diva* as well as the audience.

Figure 2 *Diva*, 365 Days/Plays (see online version for colours)



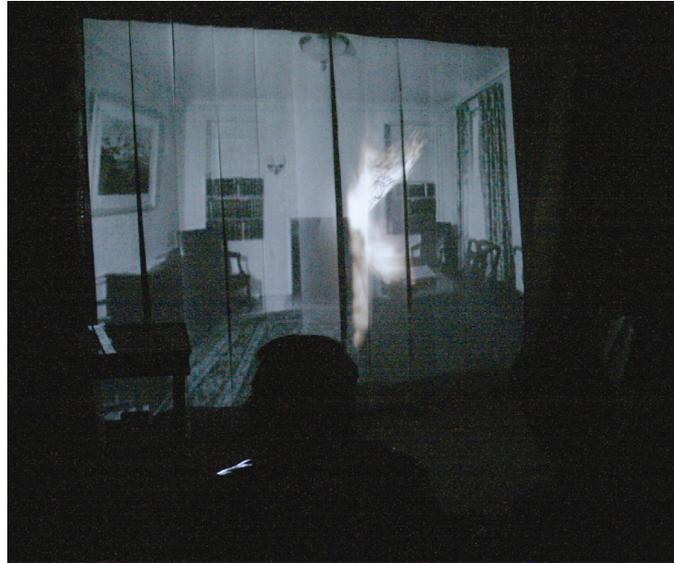
This visualisation work exemplifies how we use abstraction and animation techniques to convey character. The abstraction here was to focus on the head area and to suggest that it is the face that drives this Diva's fantasies. Like the ubiquitous close up or the old time movie star, it is all about the face; however, it is an enhanced face, surrounded by a living headdress that underlines the tropes of untouchable beauty and swoon-worthy magnificence. Finally, the animation gives it the quality of a living presence – but again the animation based on information from the tracking sensors is augmented by a second procedural animation. The secondary motion gives a medusa-like liveness to the streamers and banners that surround the face – and again we borrow from an organic model, this time a model of the wind. These visualisation techniques are in service of the ideas that we are addressing in the play – they evoke the projecting work of an actor, the cult of personality, the pressure to be a success and to create a huge presence, and the current role of media in producing that presence. The visible wires of the tracking system are the mechanism for signifying this particular brand of the post-human, the entanglement of personality and technology.

3.2 *Office Diva*

Office Diva is a large-scale projection of a computer-controlled character living in a claustrophobic virtual space and compulsively talking (Figure 3). This project reuses the Diva idea of a virtual character as psychic emanation and uses related animation techniques. However, in this case the virtual character is autonomous and not attached to a live performer. The *Office Diva* character simulates the mind of a woman struggling with manic-depression. Her disturbed consciousness is focused inwards trapped by its own solipsistic and unreal processing of daily events. *Office Diva* enters the arena of the post-human by playing with the ways in which mad and machinic behaviour can appear to manifest in similar ways (Sengers, 1998). The Office Diva installation comprises computer, projector, screen and speakers and has been shown as a short performance and as an endless installation. The recombinant SoC text is spoken by a Macintosh text-to-speech tool. The SoC aspects of *Office Diva* are explored in Section 4.1.

For *Office Diva*, we used the same animation technology as for the *365 Days Diva*, except that we recorded a library of motion captured fragments in place of live performance by an actor – in effect we retained the ghost of the performance. The face is again a mask – but now reduced to the merest suggestion of features. The motion capture data create an animated skeleton for the body, attached to this skeleton is a set of particle systems simulating fire, spreading along the arms, torso and head of the character (Reeves, 1983). The result is a dimly human shape: a flaming archetype. This strangely foetus-like representation of the character's ego drifts in a subdued and utterly mundane office and swirls chaotically in response to the internal narratives she retells so intently. This setting connotes her work place, the site of her obsessions and serves as a gentle reminder of the real world that she so desperately and inadequately parses. When this project was shown at the 2007 'Artists and Models: Unhinged' event at Buffalo's historic, abandoned Central Terminal, we were able to take advantage of site-specific features: the piece was displayed surrounded by rusty metal office furniture in one of the old offices of this beautiful, but disintegrating railway terminal. We created a projection screen of streamers of obsolete line printer paper, which were agitated by breezes in the large, draughty location: a perfect setting for the disintegrating psyche of the *Office Diva*.

Figure 3 Office Diva installation at Artists and Models: Unhinged (see online version for colours)



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and 5.

For this project, our visualisation used abstraction and animation techniques to convey the interior rather than exterior of the character. The flaming abstract body clearly connotes the spirit. However, this spirit is writhingly tethered to the social, physical self evoked by the spoken text and represented by the motion capture skeleton. Again this piece speaks to the confusion of categories that the juxtaposition of liveness and technology evokes. Machines have long served as a metaphor for living creatures and computers now serve as a metaphor for our understanding of human cognition. Yet at the same time, we juggle concepts suggesting a similarity between a damaged human and a machinic mind: we note a lack of proper affect; inexplicable non-sequiturs; difficulty processing context. This suggests that we consider that a badly functioning human mind is lacking essential humanity, lacking recognisable and reciprocal aliveness.

4 Stream of consciousness characters

One aspect of our work with virtual characters is research into autonomous actor-agents who can support interactive performance. As well as being part of larger mixed media and mixed reality productions, such social actor-agents would facilitate interactive fiction and games. In previous projects, we have experimented with actor-agents whose job is to engage an audience member in a participatory VR drama (Anstey et al., 2007, 2004), and Section 5 details our continuing AI research. However, there are a plethora of difficult issues to deal with in building VR actor-agents: from their ability to move intelligently and with some emotional motivation; to their ability to sense the environment and the user; to their ability to represent and reason about the story and their part in it. On top of this an ideal actor-agent would understand and generate language in ways that fit a dramatic context. Our work with SoC characters addresses a small part of the overall

problem. Here, we are simply interested in language generation: in implementing a believable and compelling stream of thought, and in exploring the necessary text manipulations for creating this stream.

This SoC work also addresses the question of ‘liveness’ from the standpoint of production. What heuristics can we employ to fragment, categorise and reassemble text so that the generated speech connotes a live mind at work? Once the text is in pieces, how can we control and recreate the kind of narrative linkages that make for a satisfying chain of signification? In these early tests, our first choice was to deal with chunks of text rather than parts of sentences. The programs that we have written to reassemble the text can order the fragments episodically, thematically and with linked keywords. These different orderings relate to different modes of reassembly, for example: episodic fragments can be reassembled with narrative structure; fragments can be tagged with multiple themes so that the consciousness after harping on one theme for a while can move over to a related theme. The details of the projects below show how these mechanisms worked in practice. In the case of the Office Diva, any roughness in the reassembly of meaning could be attributed to the character’s madness.

Office Diva is our first SoC character – the recombinant generated text defines a personality in a particular context. *Workers of the World* extends this work, fuses it with our AI investigations and takes the first steps in making the characters interactive. In this section, we will discuss the concept and implementation of the SoC character in Office Diva, and then we will give a brief overview of the *Workers of the World* project and discuss it in relationship to the SoC idea.

4.1 *Office Diva*

As described above, the *Office Diva* project is a simulation of an entity with a disturbed mind – the SoC text spoken by a text-to-speech tool represents her thoughts. The SoC is generated by the assembly of text fragments that were originally written by one of the authors. We were not too worried about smoothly recombining the fragments, assuming that repetitions, lack of affect, inappropriate juxtapositions, and non-sequiturs can read as signs of disturbed people as well as machines. However, we also wanted to be careful that our ‘mad’ consciousness was not so badly fragmented and fractured as to be indecipherable to a human audience.

In the case of *Office Diva*, the recombinant text has to simulate the thoughts of a woman obsessing over the events that led to her being fired from her job as a receptionist in a small therapy centre, revealing in the process her progressively insane relationship to her job and coworkers. To simulate the increasing madness, we wanted a SoC with several modes – the basic mode to be a dramatic monolog with a discernable if fractured narrative; a second madder mode to more radically disrupt the text; and the third maddest mode to degenerate into broken phrases and repetitions.

To achieve this, the original text was divided into five episodic and sequential sections labelled start, observations, actions, results and end. The sections each have multiple short paragraphs that can be selected. They also have a place in the narrative arc: start and end are self-explanatory; the observation section has text describing the character noticing things that are wrong in her office; the action section has text describing the actions she takes to fix the problems; the results section has the reactions of her co-workers. Specific story-lines carry through the observation, action and result sections – for example, the Office Diva observes that the waiting room is uncomfortable

and unfriendly; she acts by coming in when the centre is shut and reorganises it; the result is that the therapists complain.

In one run-through of the basic mode, the program selects 1 paragraph from the start section, 3 or 4 paragraphs each from the middle three sections and 1 end paragraph. The virtual character speaks the text. There is no guarantee that a complete story-line will be heard, but the audience starts to build up a picture of the character and her world. In subsequent runs of this basic mode, more events and stories are revealed and can be pieced together by the audience. For the madder mode keywords were identified, the program selects a keyword and then selects paragraphs from the middle three sections that contain that word. The keyword may change if a text contains multiple keywords and definitely changes when there are no more available texts with that word. For the maddest mode the keywords are used again, but instead of selecting complete paragraphs, the program grabs small fragments of text beginning with that keyword. Over about 40 min, the program cycles through basic mode, madder mode, maddest mode, and then starts again.

4.2 *Workers of the World*

Workers of the World is a performance for three cleaning robots – we used iRobot Creates that look like Roombas (Figure 4). The robots wander about the performance space and speak a SoC text drawn from three 20th century plays with strong revolutionary themes. When they detect humans, they address remarks to them. If a robot encounters another robot, their SoC texts are influenced. We discuss the work with concept and text here, and the details of the implementation are in Section 5.

Figure 4 Workers of the World (see online version for colours)



The SoC elements for this project were drawn from *The Decision* by Bertolt Brecht (1930), *The Balcony* by Jean Genet (1957) and *Marat/Sade* by Peter Weiss (1964). In different ways, the plays are about people who are outside societal rules and norms and therefore have a stake in changing them: revolutionaries, sex radicals and mad people. The SoC of each robot is designed to define one of these outsider personalities, and is drawn from just one play. The revolutionary robot takes text from *The Decision*: a play in which revolutionaries act out the circumstances that led them to execute a comrade so that an entity called the Control Chorus can judge them. The sex radical takes text from *The Balcony*: which is set in a brothel and in the middle of a revolution. In the brothel, clients and workers play out sexual fantasies of power imbalance; in the streets, the revolutionaries need fantasy to sustain their effort. The mad robot takes text from *Marat/Sade*: the conceit of this play is that while the Marquis de Sade was incarcerated in a lunatic asylum he created a play about the French Revolution that was performed by the inmates for the asylum director.

About 50 short (i.e. 1–3 line), pieces of text were selected from each play. Computer voices were chosen from the selection created by ATT Natural Voices and the lines were recorded. In a very few cases, the text was slightly altered either because the computer voice had trouble saying it, or to support the idea that each robot was speaking from its own personality. The implementation of the SoC allowed each individual robot to traverse all the text in its library thematically (details in Section 5). The robots speak these streams of consciousness while they wander around the performance space. The SoC is perturbed if a robot wanders close to another robot or detects a human. If two robots are in close proximity, they stop, spin in place, compare themes and then interchange remarks using a common theme, before resuming their wandering. If the robots detect a human, they stop and address her. We wrote an additional text for each robot’s personality to use when it accosts a human being. The revolutionary tries to encourage the human to join the revolution; the sex radical is provocative; the mad robot is enigmatic and paranoid. The robots are both workers and entertainers. They are small, weak and powerless. They push the audience into the role of oppressors. They are the ultimate outsiders.

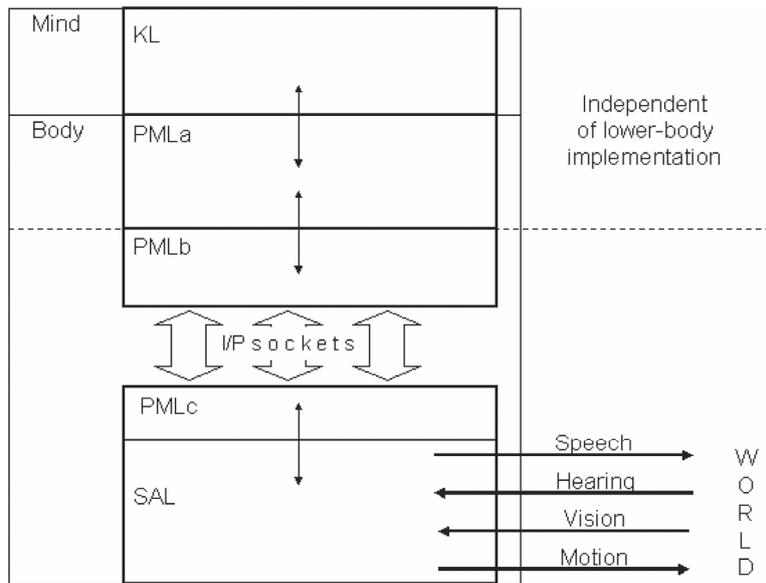
It is interesting to consider the virtual characters in *Office Diva* and *Workers of the World* in the light of Auslander’s suggestion that such performers challenge the category of live actor. In the case of *Office Diva*, a viewer who paid fleeting attention might assume that it was entirely pre-recorded. Only those with a longer attention span would come away with a sense of the persistent, real time and procedural nature of the work. We suggest that only for the latter audience does a haunting sense of a live entity emerge. In the case of *Workers of the World*, the presence of the robots was much greater; they inhabited the same space as the humans, banged up against them and addressed them. The fact that they could be responsive seemed to make them appear much more ‘live’, whereas a real, live actor would not have to interact directly with an audience to be experienced as alive.

5 Actor-agents architecture

Our research group is interested in developing an architecture for actor-agents who will be able to deliver scripted lines, interact with other actors (agent or human), improvise material in response to audience participation, and be deployed in virtual and mixed

reality settings. We have been working with the SNePS AI system and Grounded Layered Architecture for Integrated Reasoning (GLAIR), a three-level architecture for cognitive robots and intelligent autonomous agents (Figure 5). Our first actor-agents and multi-actor-agent systems were developed for two VR projects, *The Trial The Trail* (Anstey et al., 2004) and *Human Trials* (Anstey et al., 2007). We continued this work in *Lights/Rats* performed by three intelligent agents in a 2D world, and *Workers of the World* a performance for three cognitive robots in the real world.

Figure 5 The GLAIR Architecture. ©2007



Source: Shapiro et al. (2007).

5.1 GLAIR, SNePS and the repeater

The design of our actor-agents is based on the grounded layered architecture for integrated reasoning (GLAIR) (Hexmoor et al., 1993). GLAIR is organised as three layers: the sensori-actuator layer (SAL), the perceptuo-motor layer (PML) and the knowledge layer (KL). In the SAL are the controllers of the sensors and effectors of the hardware robot or software avatar. The PML is divided into three sublayers. The PMLc directly abstracts the sensors and effectors into the basic behavioural repertoire of the robot or avatar. The PMLc is implemented in Java or whatever programming language is native to the robot or graphics software in which the avatar is implemented. The PMLb, along with the higher layers, usually runs on a different computer from the PMLc and SAL, is implemented in Common Lisp, and communicates with the PMLc via TCP/IP sockets. The PMLa contains the Common Lisp implementation of the conceptually primitive sensor and effector actions of the KL, and translates between those high-level actions and the lower-level behaviours of the PMLb/c. The KL and PMLa are independent of the particular implementation of the robot or avatar body, and so can be developed independently of the choice of that body.

The KL constitutes the ‘mind’ of the actor-agent, and contains its script or behavioural rules, in a language understandable to the human director of the performance in which the actor-agent is performing. The KL is implemented in the SNePS Knowledge Representation, Reasoning and Acting system (Kumar and Shapiro, 1994; Shapiro and The SNePS Implementation Group, 2007). The actor-agent’s actions depend on its beliefs about the world of the performance, about the actions of the other actors and about its own previous actions. These beliefs are formed as the actor-agent processes perceptual information that originates in the SAL, passes through the PML and makes its way to the KL. For instance, an actor-agent does not know that another actor (human or agent) has spoken a particular line until it is perceived, communicated to the KL via the agent’s hearing modality and believed.

A Java-based central ‘repeater’ server was written to serve as the PMLc to provide message passing between the KL and SAL of all agents (i.e. their minds and bodies). The agents’ PMLb layers are TCP/IP clients that connect to the repeater, and pass messages to and receive messages from it. The repeater opens a TCP/IP listener for the agents’ PMLb or SAL client. When a connection is initiated, the repeater negotiates with the client to establish separate one-way sockets for each of the perceptual and efferent modalities used. Once an agent is connected, it has a socket for each modality that includes hearing, vision, speaking and navigation. Implementation of the SAL is responsible for receiving such messages, determining how they affect the world, producing/simulating any changes in the state of the world, and reporting the resulting state(s) back to the repeater. These messages are propagated from the repeater to all agent connections. Each agent’s PMLb layer receives these messages and passes them up the GLAIR stack. These percepts are expressed as propositional content about the state of the world, and are represented at the agent’s KL.

5.2 *Actor-agents for Lights/Rats*

To interact with each other and be available for observation by audiences, the actor-agents needed a common world in which to perform. In *Lights/Rats*, we created a simulated 2D world using the ‘Karel the Robot’ software (Becker, 2006; Bergin et al., 2005), a Java-based system that facilitates rapid development of simple simulated robots in a 2D environment. The virtual world and the simulated bodies inhabiting it occupy the SAL of GLAIR. The agents’ bodies are implemented as Java classes that extend the Robot class in the Karel World system. They have methods for navigation, which trigger the appropriate animation in the simulated world (turning and other movement). They also have methods to initiate speech, which take the sentence to be spoken as an argument and play back the corresponding synthesised speech, while making the agent’s avatar flash to indicate that it is speaking. The agents’ KLs are written in SNePSLOG, the logic-language interface to SNePS (Shapiro and The SNePS Implementation Group, 2007), and the PML sublayers *a* and *b* are implemented directly in Lisp. The simulated 2D world and bodies and the speech/hearing system occupy the SAL. These are written in Java and Microsoft’s .NET, respectively.

Each of the characters speaks and performs non-verbal acts, such as gesturing, turning away from or towards another actor, moving from one location to another, and entering or exiting the stage. Each agent is aware of its own lines, knows the cues that signal speaking of its lines, and perceives what is happening as the other actor-agents perform. The agents use the speech recognition functionality of the Speech API of .NET to listen

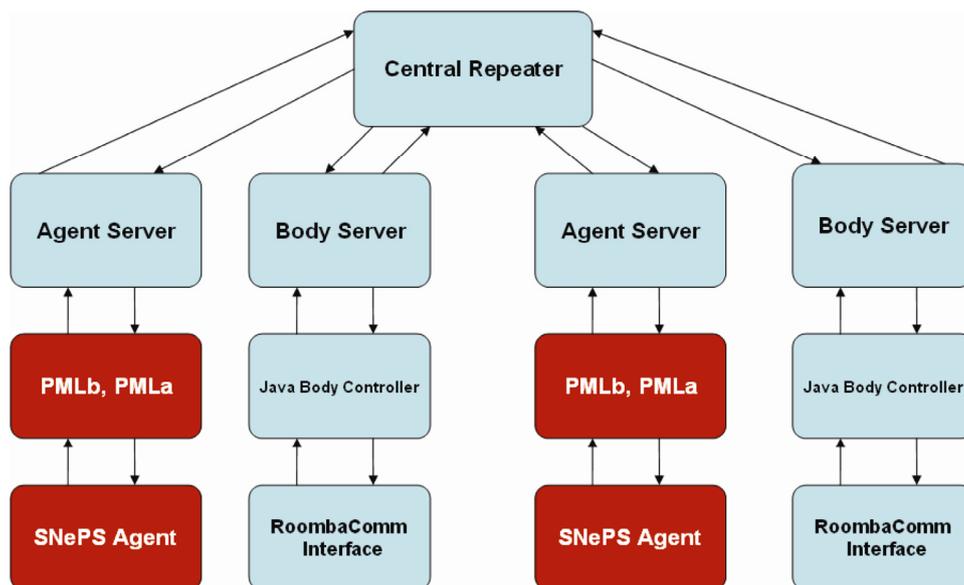
to each other speaking. A laptop with a microphone and speech recognition software is placed next to a speaker during the performance. The sound signal from the microphone is processed in real-time. The speech recognition software is connected to the repeater as the ‘Karel the World’ software does via TCP/IP sockets. When the system recognises a sentence, a message is sent to the repeater and then forwarded to the agents through those sockets that correspond to the agents’ hearing modalities. As a result, the agents come to believe that the sentence has been spoken (having heard it), and are able to reply with their own lines or initiate actions when appropriate.

5.3 Actor-agents for Workers of the World

Each of three robots of the *Workers of the World* project is physically composed of an iRobot Create robot with an Eee PC laptop, an iPod-style speaker, and a web camera mounted on top. A wireless router is employed for communication of the GLAIR components. The body software runs on each of the laptops running Microsoft Windows XP that is connected to its respective Create robot over a serial port. The robot minds, implemented in SNePS, all execute on a separate laptop running Ubuntu Linux along with the repeater.

The repeater employed for *Workers* differs from *Lights/Rats* in that it accepts communication from multiple SALs. In *Lights/Rats*, the SAL was the simulated 2D world; all agent bodies are controlled through the ‘Karel the Robot’ software. In *Workers*, as the concept of world is the actual physical world instead of a virtual one, messages concerning sensory messages of each robot, such as vision and hearing, are sent through a process of the SAL for each robot body. Figure 6 shows the updated architecture. The TCP/IP listeners spawned by the repeater are labelled *Agent Server* and *Body Server* for connection by the agents’ PMLb and SAL, respectively. The nodes labelled *Java Body Controller* and *RoombaComm Interface* are specific to the SAL (discussed below).

Figure 6 GLAIR architecture for Workers of the World (see online version for colours)



The persistent functionality of the robots consists of movement that corresponds to their personality and speech from SoC texts (see Section 4.2). Interrupt-driven functionality includes detecting human faces and other robots. When a human face is detected, the robot speaks to the human, and when a robot detects another robot, one of the robots changes its speaking part ‘theme’ to correspond to the other’s.

Each robot speaks from its SoC using sequences of selected text from its designated play. Each speaking part is tagged with one or more themes, including: revolution, strategy, fantasy and madness. Each robot mind randomly selects one of its themes and then randomly selects a speaking part from the theme until each one is spoken once. After all speaking parts are spoken from the theme, the robot mind randomly selects another of its themes not previously selected, and repeats the process of selecting speaking parts. Once all the speaking parts from all the themes have been spoken, the robot mind will consider all themes again in its random selection. To enhance the SoC effect, whenever a selected speaking part is tagged with more than one theme, the robot mind switches to the other theme or one of the other themes, as the case may be, and selects a speaking part from it to speak from next.

The robots change their SoC’s current theme when in close proximity with another robot. We assigned dominant-submissive pairs for each of the three robots. *Robot 1* is dominant to *Robot 2*, *Robot 2* is dominant to *Robot 3* and *Robot 3* is dominant to *Robot 1*. The robot-to-robot detection is currently being simulated by buttons on the StageManager GUI (Figure 7). Once a dominant robot detects its respective submissive robot, it initiates a communication sequence in which it retrieves the current theme of that robot. The initial message asserting one robot that is in close proximity of another is sent by the StageManager GUI. The dominant robot sends a message through the repeater requesting its submissive robot’s theme. The submissive replies with its theme, and then the dominant enters a decision procedure to determine which of the two should change themes.

Figure 7 displays the Stage Manager GUI that provides high level control of the robots. The *Begin start* button initialises the robots, and the *Begin wander* button begins them wandering in a manner based on their personality and speaking as described above. The *Begin stopMove*, *Begin stopAudio* and *Begin stopAll* buttons stop all robot bodies from moving, talking or both, respectively, and are used to end the play or for testing. The *Cease robotn stopMove*, *Cease robotn stopAudio*, *Cease robotn stopAll* and *near robotn boundry* buttons, where n is the robot identifier, are for testing only. The *near_robotn_robotm* buttons, where n is the dominant and m is the submissive robot identifier for a dominant-submissive pair, are used to alert the dominant to begin the SoC changing sequence described above. Future work places the robot-to-robot detection at the SAL.

The implementation at the SAL that connects to the Roomba Create is the *JavaBody Controller* (see Figure 6); it is written in Java and uses the RoombaComm library. It controls robotic movement given its personality based on its play, as well as performing audio and web camera video processing. The program connects to its respective Body Server; messages received from the repeater are translated to speaking and movements tasks. An audio component of the program parses what file to play at what volume level, and handles speech interruption. A video component handles automatic face recognition; once communicated to the KL the robots speak to humans. A movement component uses Roomba-Comm to read sensors and perform movements.

Figure 7 StageManager GUI (see online version for colours)

6 Conclusions and future work

The IPS is committed to interdisciplinary research and the production of innovative performances using virtual characters and virtual reality technology. Our work is designed both to explicate dramatic texts and to appeal to younger, diverse populations. The productions described in this paper are both performances and experiments that enlarge our repertoire of techniques and tools.

A major theme of our productions is an engagement with current questions about cyborg, artificial and posthuman entities. We are able to explore the strained and changing relationships between technology and identity by our choice of live, mediated or virtual performers. The productions discussed in this paper demonstrate possible confluences of technological and human consciousnesses and bodies in ways that are by turns exhilarating, demoralising and enlightening. We believe that the integration of virtual and robot performers that have internal integrity and are not just sham mock-ups deepens the experience and intensifies a sense of unheimlich processes at work.

Our animation work has influenced and been influenced by these confusions about ourselves as mediated-, augmented-, artificial-, post-humans. Animation techniques based on motion-capture were already an essential part of our toolkit, and we were already committed to visualisation of our virtual entities based on techniques of abstraction that avoid generic photorealistic representation. In these productions, we focused on visualisations that convey character metaphorically according to the dictates of a specific concept, while preserving the key idea that the characters must present as live, real-time beings. Because we are interesting in straddling the line between human and machine (and not reserving liveness as a quality of only one of these), we also developed and implemented procedural animation techniques to warp and extend captured motion.

Our productions also engage with current performance theory about the challenge by computer-controlled entities to the category of live actor. Although it is easy to experience the power and intensity of a live performer – and indeed to judge one performer as having much more stage presence than another – it is not easy to identify the work the performer is doing, let alone to represent and implement that in a virtual actor.

One observation from this body of work is that a virtual actor might have to prove that it is capable of responding to the audience in order for the audience to accord it the same status as a live performer. An additional complication is that the techniques a virtual (or even an augmented) actor might use to command stage presence may be different, media-infused set of techniques, from those used by traditional actors. At this point, we are still at an *ad-hoc* experimental stage, trying to increase the effectiveness of virtual actors, by manipulating vectors that connote powerful and lively presence: responsiveness, physicality, movement, speech, and spectacle.

Clearly, the nexus of live performance is the space between the performers and audience – this is where intensity and meaning are made. In our SoC work, we also depend on the active involvement of the audience to fill in gaps in the text and to infer a live, working, mind. In this work, we attempt to reproduce mental processes. Again the specific nature of a particular project, rather than an abstract model of the mind, dictates our process. Currently, we are focusing on ways that we can divide text into chunks and reassemble it procedurally and endlessly. One major aspect of the work is to divide and reassemble text episodically, counting on the audience to gather and order episodes into a coherent whole, much in the same way that audiences assemble linear narratives when watching episodic TV shows out of order.

Finally, our work with intelligent agents has led to an agent architecture divided both vertically and horizontally. Vertically, a system of layers handles various tasks: at the top is the KL that deals with representing, reasoning and planning; at the bottom is the SAL, the virtual or real body that performs and perceives; between these two is the PML that translates the plans into commands, which can be passed to the body, and the perceptions into propositions that can be understood by the mind. Horizontally, we divide the agent into modalities that can all process in parallel: in the same way that a person can walk and talk and listen all at the same time. The use of this architecture and related software discussed above facilitates the development of actor-agents independently of a particular embodiment. It provides a standard, cognitively plausible way of connecting agents' minds to their bodies, and is being used to develop additional actor-agents for current and upcoming projects.

We have continued all aspects of our work with virtual characters, live actors, mixed reality sets, and artificial intelligence in our current work *WoyUbu*, which premiered in March 2009. This collaboration with a satirical theatre group is a mashup of Georg Buechner's prescient drama, *Woyzeck* and Alfred Jarry's *Ubu Roi*. In our production, *Woyzeck*'s endless struggle to work hard enough to survive in a dystopian and exploitative worlds is hindered by the eruption of the Ubu pastiche of Shakespeares royal plays. The scenes from *Woyzeck* are played by two live actors in a set, which is physically minimal but features large projections on two walls. The interrupting scenes from Ubu are multi-media explosions of film, TV, puppetry, virtual reality, mixed reality, computer games and robots. The Ubu scenes are projected onto the *Woyzeck* walls. Audience members can choose to watch the *Woyzeck* play, or to take part in a live mixing of multimedia scenes in the Ubu space.

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