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Creative Machine Performance: Computational Creativity and Robotic Art

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Abstract

The invention of machine performers has a long tradition as a method of philosophically probing the nature of creativity. Robotic art practices in the 20th Century have continued in this tradition, playfully engaging the public in questions of autonomy and agency. In this position paper, we explore the potential synergies between robotic art practice and computational creativity research through the development of robotic performances. This interdisciplinary approach permits the development of significantly new modes of interaction for robotic artworks, and potentially opens up computational models of creativity to rich social and cultural environments through interaction with audiences. We present our exploration of this potential with the development of Zwischenräume (In-between Spaces), an artwork that embeds curious robots into the walls of a gallery. The installation extends the traditional relationship between the audience and artwork such that visitors to the space become performers for the machine.

Introduction

This paper looks at potential synergies between the practice of robotic art and the study of computational creativity. Starting from the position that creativity and embodiment are critically linked, we argue that robotic art provides a rich experimental ground for applying models of creative agency within a public forum. From the robotic art perspective, a computational creativity approach expands the performative capacity of a robotic artwork by enhancing its potential to interact with its 'Umwelt' (Von Uexküll 1957).

In the 18th century, the Industrial Age brought with it a fascination with mechanical performers: Jacques de Vaucanson's Flute Player automaton and Baron Wolfgang von Kempelen's infamous chess playing Mechanical Turk clearly demonstrate a desire to create apparently creative automata. Through their work, both Vaucanson and von Kempelen engaged the public in philosophical questions about the nature of creativity, the possibilities of automation and, crucially, perfection.

Moving from mechanical to robotic machine performers, artists have deployed robotics to create apparently living and behaving creatures for over 40 years. The two dominant motivations for this creative practice have been to question "our premises in conceiving, building, and employing these electronic creatures" (Kac 2001), and to develop enhanced forms of interactions between machine actors and humans "via open, non-determined modes" (Reichle 2009).

The pioneering cybernetic work Senster by Edward Ihnatowicz, for example, exhibited life-like movements and was programmed to 'shy away' from loud noises. In contrast to the aforementioned automata, Ihnatowicz did not aim to conceal the Senster's inner workings, and yet "the public's response was to treat it as if it were a wild animal" (Rieser 2002). Norman White's Helpless Robot (1987–96) was a public sculpture, which asked for help to be moved, and when assisted, continued to make demands and increasingly abused its helpers (Kac 1997). Petit Mal by Simon Penny resembled a strange kind of bicycle and reacted to and pursued gallery visitors. With this work Penny aimed to explore the aesthetics of machines and their interactive behaviour in real world settings; Petit Mal was, in Penny's words, "an actor in social space" (Penny 2000). Ken Rinaldo's Autopoesis consisted of 15 robotic sculptures and evolved collective behavior based on their capability to sense each other's and the audience's presence (Huhtamo 2004). The installation Fish-Bird by Mari Velonaki comprised two robotic actors in the form of wheelchairs whose movements and written notes created a sense of persona. The relationship between the robot characters and the audience evolved based on autonomous movement, coordinated by a central controller, and what appeared to be personal, "handwritten" messages, printed by the robots (Rye et al. 2005).

Our fascination with producing artefacts that appear to be creative has created a rich history for researchers of computational creativity to draw upon. What we learn from these interdisciplinary artistic approaches is that, as performers, the artificial agents are embodied and situated in ways that can be socially accessed, shared and experienced by audiences. Likewise, embodied artificial agents gain access to shared social spaces with other creative agents, e.g., audience members.

The ability of robotic performers to interact with the audience not only relies on the robot's behaviours and responsiveness but also the embodiment and enactment of these behaviours. It can be argued that the performer is most successful if both embodiment and enactment reflect its perception of the world, that is, if it is capable of expressing and communicating its disposition. Looking at robotic artworks that explore notions of autonomy and artificial creativity may thus offer starting points for thinking about social settings that involve humans interacting and collaborating with creative agents.

Our exploration revolves around the authors' collaboration to develop the robotic artwork Zwischenräume (In-between Spaces), a machine-augmented environment, for which we developed a practice embedding embodied curious agents into the walls of a gallery, turning them into a playground for open-ended exploration and transformation.

Zwischenräume

The installation Zwischenräume embeds autonomous robots into the architectural fabric of a gallery. The machine agents are encapsulated in the wall, sandwiched between the existing wall and a temporary wall that resembles it. At the beginning of an exhibition, the gallery space appears empty, presenting an apparently untouched familiar space. From the start, however, the robots' movements and persistent knockings suggest comprehensive machinery at work inside the wall. Over the course of the exhibition, the wall increasingly breaks open, and configurations of cracks and hole patterns mark the robots' ongoing sculpting activity (Figure 1).

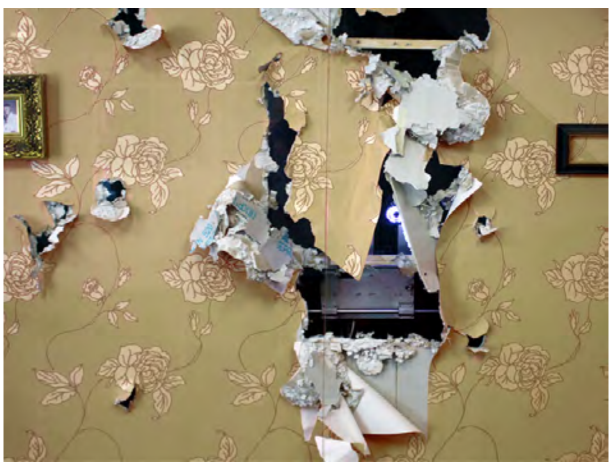

Figure 1: Zwischenräume: curious robots transform our familiar environment.

The work uses robotics as a medium for intervention: it is not the spectacle of the robots that we are interested in, but rather the spectacle of the transformation of their environment. The starting point for this interdisciplinary collaboration was our common interest in the open-ended potential of creative machines to autonomously act within the human environment. From the computational creativity researcher's point of view, the embodied nature of the agents allowed for situating and studying the creative process within a complex material context. For the artist, this collaboration opened up the affective potential to materially intervene into our familiar environment, bringing about a strange force, seemingly with an agenda and beyond our control.

Each machine agent is equipped with a motorised hammer, chisel or punch, and a camera to interact and network with the other machines by re-sculpting its environment (Figure 2). The embodied agents are programmed to be curious, and as such intrinsically motivated to explore the environment. Once they have created large openings in the wall the robots may study the audience members as part of their environment. In the first version of this work, the robots used their hammer to both punch holes and for communicating amongst the collective. In a later version, we experimented with a more formal sculptural approach that used heuristic compositions of graffiti glyphs to perforate walls. Using the more stealthy movements of a chisel, the work responded to the specific urban setting of the gallery by adapting graffiti that covered the exterior of the building to become an inscription, pierced into the pristine interior walls of the gallery space (Figure 3). The final version of Zwischenräume used a punch to combine the force of the hammer and the precision of the chisel.

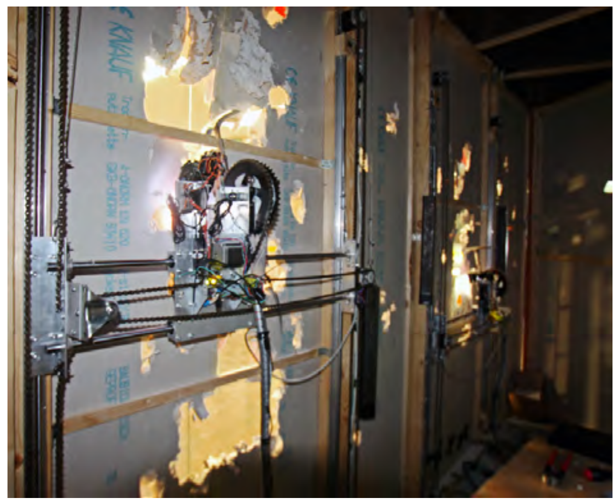

Figure 2: Robot gantries are attached to walls.

Similar to Jean Tinguely's kinetic sculptures (Hultén 1975), Zwischenräume's performance and what it produces may easily evoke a sense of dysfunctionality. As the machines' adaptive capability is driven by seemingly non-rational intentions rather than optimisation, the work, in some sense, subverts standard objectives for machine intelligence and notions of machine agency. Rather, it opens up the potential for imagining a machine that is 'free', a machine that is creative, see (Hultén 1987).

Machine Creativity

This section focuses on the development of the first version of Zwischenräume as depicted in Figures 1 and 2. Each robotic unit consisted of a carriage, mounted on a vertical gantry, equipped with a camera mounted on an articulated arm, a motorised hammer, and a contact microphone. The control system for the robots combined machine vision to detect features from the camera with audio processing to detect the knocking of other robots and computational models of intrinsic motivation based on unsupervised and reinforce-

Figure 3: Inscription of adapted graffiti glyphs.

ment machine learning to produce an adaptive, autonomous and self-directed agency.

The robot's vision system was developed to construct multiple models of the scene in front of the camera; using colour histograms to differentiate contexts, blob detection to detect individual shapes, and frame differencing to detect motion. Motion detection was only used to direct the attention of the vision system towards areas of possible interest within the field of view. Face detection is also used to recognise the presence of people to direct the attention of the robots towards visitors. While limited, these perceptual abilities provide sufficient richness for the learning algorithms to build models of the environment to determine what is different enough to be interesting.

Movements, shapes, sounds and colours are processed, learned and memorised, allowing each robotic agent to develop expectations of events in their surrounds. The machine learning techniques used in Zwischenräume combine unsupervised and reinforcement learning techniques (Russell and Norvig 2003): a self-organizing map (Kohonen 1984) is used to determine the similarity between images captured by the camera; Q-learning (Watkins 1989) is used to allow the robots to discover strategies for moving about the wall, using the hammer and positioning the camera.

Separate models are constructed for colours and shapes in images. To determine the novelty of a context, sparse histograms are constructed from captured images based on only 32 colour bins with a high threshold, so only the most significant colours are represented and compared using a self-organising map. Blob detection in low-resolution (32x32 pixel) images, relative to a typical model image of the wall, is used to discover novel shapes and encoded in a self-organising map as a binary vector. In both cases, the difference between known prototypes in the self-organising map provide a measure of novelty (Saunders 2001).

Reinforcement learning is used to learn the consequences of movements within the visual field of the camera. Error in prediction between learned models of consequences and observed results is used as a measure of surprise. As a result system that is able to learn a small repertoire of skills and appreciate the novelty of their results, e.g., knocking on wood does not produce dents. This ability is limited to immediate consequences of actions and does not current extend to sequences of actions.

The goal of the learning system is to maximise an internally generated reward for capturing 'interesting' images and to develop a policy for generating rewards through action. Interest is calculated based on a computational model that captures intuitive notions of novelty and surprise (Saunders 2001): 'novelty' is defined as a difference between an image and all previous images taken by the robot, e.g., the discovery of significant new colours or shapes; and, 'surprise' is defined as the unexpectedness of an image within a known situation, e.g., relative to a learned landmark or after having taken an action within an expected outcome (Berlyne 1960). Learning plays a critical role in both the assessment of novelty and surprise. In novelty, the robots have to learn suitably general prototypes for the different types of images that they encounter. In surprise, the 'situation' against which images are judged includes a learned model of the consequences of actions (Clancey 1997).

Consequently, intrinsic motivation to learn directs both the robot's gaze and its actions, resulting in a feedback process that increases the complexity of the environment – through the robot's knocking – relative to the perceptual abilities of the agent. Sequences of knocking actions are developed, such that the robots develop a repertoire of actions that produce significant perceived changes in terms of colour, shapes and motion. In this way, the robots explore their creative potential in re-sculpting their environment. Figure 4 presents a collage of images taken by a single robot when it discovered something 'interesting', illustrating how the evaluation of 'interesting' evolved for this robot; it shows how the agent's interest is affected by: (a) positioning of the camera, e.g., the discovery of lettering on the plasterboard wall; (b) use of the hammer, e.g., the production of dents and holes; and, (c) interaction of visitors.

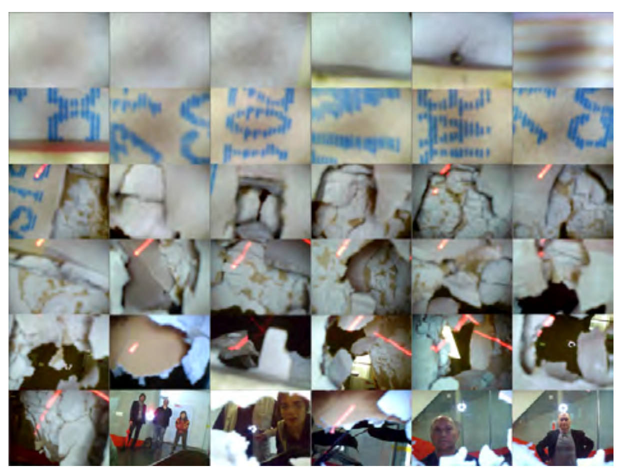

Figure 4: Robot captures, showing the evolution of interesting changes in the environment.

Discussion

The robots' creative process turns the wall into a playful environment for learning, similar to a sandpit; while from the audiences' point of view, the wall is turned into a performance stage. This opens up a scenario of encounter for studying the potential of computational creativity and the role of embodiment. Following Pickering (2005), we argue that creativity cannot be properly understood, or modelled, without an account of how it emerges from the encounter between the world and intrinsically active, exploratory and productively playful agents.

Embodiment and Creativity

The agents' embodiment provides opportunities to expand their behavioural range by taking advantage of properties of the physical environment that would be difficult or impossible to simulate computationally (Brooks 1990). In Zwischenräume the machines' creative agency is not predetermined but evolves based on what happens in the environment they examine and manipulate. As the agents' embodiment evolves based on its interaction with the environment, the robots' creative agency affects processes out of which it itself is emergent.

This resonates with Barad's argument that 'agency is a matter of intra-acting: it is an enactment, not something that someone or something has' (Barad 2007). It also evokes Maturana and Varela's notion of enaction, where the act of bringing about a world occurs through the 'structural coupling' between the dynamical environment and the autonomous agents (Maturana and Varela 1987). While the machines perturb and eventually threaten the wall's structural integrity, they adapt to their changing environment, the destruction of the wall and how it changes their perception of the world outside.

The connection to creativity is two-fold: Firstly, the robots' intrinsic motivation to explore, discover and constantly produce novel changes to their environment demonstrates a simplistic level of a creative process itself, akin to the act of doodling, where the motivation is a reflective exploration of possibilities rather than purposeful communication with others. Secondly, the audiences interpret the machines' interactions based on their own context, producing a number of possible meaningful relations and associations. The agents' embodiment and situatedness becomes a portal for entering the human world, creating meaning. The agents' enacted perception also provides a window on the agents' viewpoint, thus possibly changing the perspective of the audience.

Furthermore, an enactive approach (Barad 2003; Clark 1998; Thompson 2005) opens up alternative ways of thinking about creative human-machine collaborations. It makes possible a re-thinking of human-machine creativity beyond the polarisation of human and non-human, one that promotes shared or distributed agency within the creative act.

Audience Participation

Autonomous, creative machine performances challenge the most common interaction paradigm of primarily reacting to what is sensed, often according to a pre-mapped narrative. Zwischenräume's curious agents proactively seek interaction, rather than purely responding to changes in the surrounds. Once the robots have opened up the wall, the appearance and behaviours of audience members are perceived by the system as changes in their environment and become an integral part of the agents' intrinsic motivation system.

The agents' behaviours adapt based on their perception and evaluation of their environment, including the audience, as either interesting or boring. A curious machine performer whose behaviors are motivated by what it perceives and expects can be thought of as an audience to the audiences performance. Thus, in Zwischenräume it is not only the robots that perform, but also the audience that provokes, entertains and rewards the machines' curiosity. This notion of audience participation expands common interaction paradigms in interactive art and media environments (Paul 2003). The robots don't only respond or adapt to the audience's presence and behaviours, but also have the capacity to perceive the audience with a curious disposition.

By turning around the traditional relationship between audiences and machinic performers, the use of curious robotic performers permits a re-examination of the machine spectacle. Lazardig (2008) argues that spectacle, as "a performance aimed at an audience," was central to the conception of the machine in the 17th century as a means of projecting a perception of utility; allowing the machine to become "an object of admiration and therefore guaranteed to 'function"'. Kinetic sculptures and robotic artworks exploit and promote the power of the spectacle in their relationship with the audience. This is also the case in Zwischenräume however, it is not only the machines that are the spectacle for the audience but also the audience that becomes an 'object of curiosity' for the machines (Figure 5). Thus the relationship with a curious robot extends the notion of the spectacle, and, in a way, brings it full circle.

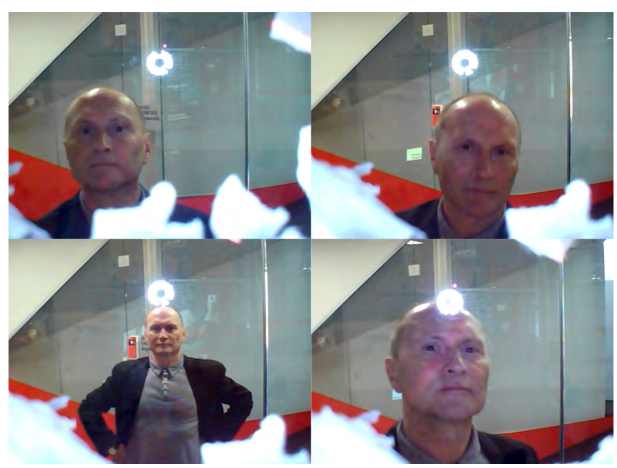

Figure 5: Gallery visitor captured by one of the robots' cameras as he performs for the robotic wall.

Concluding Remarks

A significant aspect of Zwischenräume's specific embodiment is that it embeds the creative agents in our familiar (human) environment. This allowed us to direct both our, and the audience's, attention to the autonomous process and creative agency, rather than the spectacle of the machine. The integration of computational models of creativity into this artwork extended the range of open-ended, non-determined modes of interaction with the existing environment, as well as between the artwork and the audience.

We argue that it is both, the embodied nature of the agents and their autonomous creative capacity that allows for novel meaningful interactions and relationships between the artwork and the audience. The importance of embodiment for computational creativity can also be seen in the improvising robotic marimba player Shimon, which uses a physical gesture framework to enhance synchronised musical improvisation between human and nonhuman musicians (Hoffmann and Weinberg 2011). The robot player's movements not only produce sounds but also play a significant role in performing visually and communicatively with the other (human) band members as well as the audience.

Embodying creative agents and embedding them in our everyday or public environment is often messier and more ambiguous than purely computational simulation. What we gain, however, is not only a new shared embodied space for audience experience but also a new experimentation space for shared (human and non-human) creativity.

Acknowledgements

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