Accomplice: Creative Robotics and Embodied Computational Creativity

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Abstract. The invention of automata has a long tradition as an experimental method for philosophical enquiry into the nature of creativity. Since the 1950s, cybernetic and robotic art practices have continued this tradition, playfully engaging the public in questions of autonomy, agency and creativity. In this paper, we explore the potential of bringing together work in the fields of computational creativity and robotic art. We present our latest exploration of this potential with the development of *Accomplice*, a large-scale, multi-agent, robotic artwork embedded into the walls of a gallery and embodying a computational model of creative exploration. The installation transforms the traditional relationship between the audience and artwork such that visitors to the space become performers for the machine. We argue that both fields can benefit from this alignment; permitting the development of significantly new modes of interaction for robotic artworks, and opening up computational models of creativity to rich social and cultural environments through interaction with audiences.

1 INTRODUCTION

Creativity, whether or not it is computational, doesn't occur in a vacuum, it is a situated activity that is connected with cultural, social, personal and physical contexts that determine the nature of novelty and value against which creativity is assessed. The world offers opportunities, as well as presenting constraints: human creativity has evolved to exploit the former and overcome the latter, and in doing both, the structure of creative processes emerge [21].

Thoughts are shaped, intensified and continuously altered as we interact with our environment [6]. Thus, thought co-evolves with the body that is embodied, situated and contextualised. The emergence and evolution of creativity, likewise, cannot be separated from our embodied, situated, culturally and socially contextualised 'being in the world'.

In the following we explore the potential of robotic performers placed within a gallery context to become a laboratory for developing and experimenting with autonomous creative agency.

1.1 From Creative Automata to Robotic Art

Famous automata from the 18th century include Jacques de Vaucanson's Flute Player and Pierre Jaquet-Droz's Musician, Draghtsman and Writer as well as Baron Wolfgang von Kempelen's infamous chess playing Mechanical Turk [27]. Through their work, Vaucanson, Jaquet-Droz and von Kempelen engaged the public in philosophical questions about the nature of creativity.

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In the past century, artists have developed and deployed cybernetics and robotics to create apparently living and behaving creatures. For example, *The Senster* was a cybernetic artwork developed by Edward Ihnatowicz to explore the relationship between behaviour and appearance. As an example of behaviour-based robotics, which would come to dominate robotics research from the late 1980s, *The Senster* was two decades ahead of its time: it implemented a small set of simple behaviours that combined to produce seemingly more complex ones. The complex behaviour of the audience combined with the acoustic dynamics of the hall made *The Senster*'s behaviour seem more sophisticated than it actually was. Ihnatowicz noted that "[p]eople seemed very willing to imbue it with some form of animal-like intelligence and the general atmosphere around it was very much like that in the zoo" [12, page 6].

More recent robotic artworks have explored a wide range of behaviours that have challenged notions of autonomy and agency. For example, 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 [13]. *Petit Mal* by Simon Penny reacted to and pursued gallery visitors to produce, in Penny's words, "an actor in social space" [18]. Ken Rinaldo's *Autopoesis* consisted of 15 robotic sculptures, constructed of vines, producing collective behaviour based on their ability to sense each other's and the audience's presence [11]. The installation *Fish-Bird* by Mari Velonaki comprised two robotic wheelchairs, equipped with thermal printers, whose movements and 'handwritten' notes created a sense of persona [23].

1.2 Embodied Computational Creativity

As part of the cybernetic and robotic art practices, a series of works have explored the nature of creativity in embodied forms, in ways akin to computational creativity. Gordon Pask's early experiments with electromechanical cybernetic systems provide an interesting historical precedent for the development of computational creativity [9]. MusiColour was constructed by Gordon Pask and Robin McKinnon-Wood in 1953 as one of Pask's "conversational machines", through which he explored the emergence of unique interaction protocols between the machine and musicians. MusiColour was a performance system comprising of coloured lights that illuminated based on audio inputs from a human performer. But it did more than transcode sound into light, it manipulated its lights such that it became a co-performer with the musician, creating a unique (though non-random) output with every iteration [8]. As such, Haque argued that MusiColour acted more like a jazz co-performer might when 'jamming' with other band members [9].

The area of musical improvisation has since provided a number of examples of creative systems that model social interactions within creative activies, e.g., GenJam [2], MahaDeviBot [14]. The recent development of Shimon [10] provides a nice example of the importance of modelling social interactions alongside the musical performance.

Curious Whispers (v2.0) was developed to explore user interactions with an embodied creative system, composed of a small group of mobile robots equipped with speakers, microphones and a movable plastic hood [25]. Each robot is capable of generating simple songs, evaluating the novelty and value of a song, and performing those songs that they determine to be 'interesting' to other members of the society – including human participants. Each robot listens to the performances of others and if it values a song attempts to compose a variation. Closing their plastic hood, allows a robot to rehearse songs using the same hardware and software that they use to analyse the songs of other robots, removing the need for simulation. A simple 3-button synthesiser allows participants to play songs that the robots can recognise and if a robot considers a participants songs to be interesting it will adopt them. Using this simple interface, humans are free to introduce domain knowledge, e.g., fragments of well-known songs, into the collective memory of the robot society. For more information on the technical details of the implementation see [5]. Unlike traditional interactive systems that react to human participants [7], the individual agents within this artificial creative systems are continuously engaged in social interactions: the robots would continue to interact and share songs without the intervention of the participants.

In the following sections we explore the experimental potential of bringing robotic art practices and computational creativity research closer together. For computational creativity embodiment provides access to a rich social and cultural context beyond the confines of the computational elements through interaction with audiences. In addition, embodiment also provides opportunities for embodied agents to reduce the need for complex computations by taking advantage of aspects of their morphology or environment. Our exploration revolves around the authors' robotic installation *Accomplice*; a machine-augmented environment for which we developed a robotic practice that structurally couples curious robots with an architectural environment to establish an ever-shifting playground for open-ended exploration, negotiation, and performance.

2 ACCOMPLICE

The robotic installation *Accomplice* embeds a group of autonomous robots into the architectural fabric of a gallery, see Figure 1. The robots appear to inhabit the wall, sandwiched between the existing wall and a temporary wall that resembles it. Each robotic agent consists of a carriage mounted on 2 meter vertical slide and a 7-8 meter horizontal rail, allowing each robot to cover a large wall area. Each robot carriage is equipped with a motorised punch, an array of sensors, and a camera, which they use to interact with their surrounds. To enable the robots to communicate, each is equipped with a microphone so that they can hear knocks against the wall. Two robots can share a single wall such that their areas of operation overlap—allowing each robot to make changes in the 'territory' of the other.

The robots are programmed to be curious and, as such, are intrinsically motivated to explore, experiment and discover through interaction with their environment, i.e., the wall. Using their punch, each robot is able to affect their environment in ways they can sense, using their camera, and hence experiment with different ways of using it to affect their environment. Movements, shapes and colours are processed, learned and memorised, allowing each robotic agent to develop expectations of events in their surrounds, based on a two dimensional map of the wall. While limited, these perceptual abilities provide sufficient richness for the learning algorithms to build complex models of the environment and for the model of intrinsic motivation to determine what is different enough to be interesting. This adaptive model of their 'world' allows the robotic agents to expect learned behaviours and proactively intervene. Consequently each robot is able to affect change in their world and create new experiences whenever the environment becomes too predictable.

Figure 1. *Accomplice*: robots equipped with punches and cameras are embedded into the walls of the gallery.

The robot's vision system has been developed using the OpenCV library [3] 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. The machine learning techniques used in *Accomplice* combine unsupervised and reinforcement learning techniques [22]: a self-organising map [15] is used to determine the similarity between images captured by the camera; Q-learning [26] is used to allow the robots to discover strategies for moving about the wall, using the hammer and positioning the camera. 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 [24]: novelty is defined as a difference between an image and all previous images, e.g., the discovery of 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 a specific action [1]. 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 relative to the perceptual abilities of the robot.

As a result of their ongoing piercing, sculpting and knocking activity, the wall increasingly breaks open, and configurations of cracks and hole patterns appear that mark the machines' presence and traces their autonomous agency. While the audience's presence and actions matter, the individual robots in *Accomplice* do not rely on input from its visitors to interact with each other, allowing the work to evolve autonomously. The audience plays a part in the work's wider ecology but *Accomplice* doesnt necessarily respond to or perform for them. This is a conception of interaction that, in Simon Penny's words, "has been expanded beyond user-machine, to larger ideas of behaviour be-

Figure 2. *Accomplice*: each robot is intrinsically motivated to explore their environment and equipped with a motorised punch and camera.

tween machines and machine systems, and between machine systems and the world" [19, page 100].

Producing cracks, holes and loud knocking sounds, *Accomplice* turns architecture into a milieu, a dynamic, operative medium. The robotic agents physically inscribe their computational processes into our built environment by turning the wall into a playful stage for creating and learning. Such an autonomous, proactive machine performance challenges common interaction paradigms of primarily reacting to what is sensed.

2.1 Audience

As the agents are intrinsically motivated to explore their environment, the audience comes into play once they have created sufficiently large openings in the wall for them to detect and study the audience members as part of their environment. The appearance and behaviours of audience members are perceived by the system as changes in their environment. In line with the work's coupling with the built environment, the way in which it involves the audience pursues an expanded, ecological perspective. Thus, it is not only the robots that 'perform' for the audience, but also the audience that provokes, entertains and rewards the machines' curiosity.

Rather than being invited to control the course of events, the audience is implicated in the material interventions of *Accomplice*, becoming accomplices in the works ongoing transformations. Initially, it is the physical impact of the work, the loud banging, expelled bits of wall, and dust accumulating on the floor, that draws them in. As soon as they realise that there are robots embedded into the gallery wall, they get closer, moving along the wall slowly and peeking into the holes to catch a glimpse of the strange machines. It is interesting to observe how keen visitors are to be 'seen' by the robots, for them to acknowledge their presence. Yet the machines soon lose interest and move on to continue making a new hole or piercing along the raggedy edges of an existing one. Similar to Ihnatowicz's observation, the encounter between human and non-human agents in *Accomplice* is reminiscent of those we have in the zoo.

Further studies are required to gain a better understanding of the interactions between the audience and *Accomplice*. Two such studies will be conducted in the coming year as part of installations in galleries in the UK and China, allowing for the first time the actions of the robots and the movements of audience members to be correlated.

3 DISCUSSION

In *Accomplice* 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, 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 [21]. In addition, computational models of creativity, cybernetic and robotic systems like *Accomplice* offer new opportunities and challenges due to their embodied nature.

The robots' intrinsic motivation to explore, discover and constantly produce novel changes to their environment demonstrates a simplistic level of a creative process itself where the motivation is a reflective exploration of possibilities rather than purposeful communication with others. The agents' embodiment, however, provides opportunities to expand their behavioural range by taking advantage of properties of the physical environment, e.g., the material dynamics of a wall, that would be prohibitively expensive to simulate computationally [4].

It is the ability of the robots to learn how to manipulate the plasterboard that provides the strongest claim for embodiment in *Accomplice*, as it is only through the careful coupling of actions, e.g., small movements between punches, that allow the robot to effectively work with the material of the wall to produce intended outcomes. In this way, the robots achieve a combination of *historical embodiment* and *physical embodiment* [28], based on their ability to learn from experiences with their physical environment through experimental actions and continuous sensing.

In *Accomplice*, the machines' creative agency evolves based on the contingencies of its actions in relation to 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. 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. Consequently, the creative agency of the robots emerges as part of a 'structural coupling' between the dynamical environment and the autonomous agents [17].

The robots in *Curious Whispers* demonstrate an alternative way for embodiment may relieve the computational requirements of a creative agent. The use of a hood allow the robots to rehearse 'songs' without the need for additional computational facilities to allow simulation of how they might sound. Instead, the simple robots in this artificial creative system can, through use of the hood, make efficient use of the dedicated hardware already used to perceive tones captured by the microphones. Consequently, these simple robots display a form of morphological computation suitable for computational creativity, i.e., the reduction of computing needs by taking advantage of physical characteristics; as approach most often found in robotics, e.g., in the use of 'compliant joints' in articulated limbs [20].

In addition to providing an engaging environment for testing computational creativity, by turning around the traditional relationship between audiences and machinic performers, the use of curious agents permits a re-examination of the machine spectacle in robotic art. A significant aspect of *Accomplice*'s specific embodiment is that it embeds the creative agents in our familiar environment. Hidden from direct view, this arrangement allows the audience's attention to be directed to the autonomous process and creative agency, rather than the spectacle of the machine. Lazardig [16] argues that spectacle, defined 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 *Accomplice*, 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. Thus the relationship with a curious robot extends the notion of the spectacle, and, in a way, brings it full circle.

4 CONCLUSION

The integration of computational models of creativity into this artwork extends the range of open-ended modes of interaction with the existing environment, as well as between the artwork and the audience. The embodied nature of the agents and their autonomous creative capacity allow for novel meaningful interactions and relationships between the artwork and the audience. Embodying creative agents and embedding them in our everyday or public environment is often messier and more ambiguous than purely computational simulation. Embodied creative systems, however, like the one presented here offer a relatively unexplored but potentially fruitful area for computational creativity research.

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