

Cover Page

Title of submission: *SpiderCrab* and the Emergent Object: Designing for the Twenty -first Century

Category of submission: Design Research Study

Name and full contact address (surface, fax, email) of the individual responsible for submitting and receiving inquiries about the submission: Professor Mick Wallis, School of Performance & Cultural Industries, University of Leeds, Leeds, LS2 9JT, United Kingdom, +44 (0)113 343 8711, pcumw@leeds.ac.uk

SpiderCrab and the Emergent Object: Designing for the Twenty-first Century

Mick Wallis

pcumw@leeds.ac.uk

Sita Popat

s.popat@leeds.ac.uk

Alice Bayliss

a.bayliss@leeds.ac.uk

Joslin McKinney

j.e.mckinney@leeds.ac.uk

School of Performance & Cultural Industries
University of Leeds
Leeds LS2 9JT
United Kingdom

John Bryden

johnb@comp.leeds.ac.uk

David Hogg

d.c.hogg@leeds.ac.uk

School of Computing
University of Leeds

Leeds LS2 9JT
United Kingdom

Matthew Godden

mg@shadowrobot.com

Rich Walker

rw@shadowrobot.com
Shadow Robot Company Ltd.
251 Liverpool Road
London N1 1LX
United Kingdom

Abstract

This paper presents the development of the robotic prototype *SpiderCrab* in the context of Emergent Objects 2 (EO2), a portfolio of sub-projects funded by the EPSRC/AHRC 'Designing for the Twenty-first Century' initiative. We report first on explorations across EO2 into how performance knowledge and practice can help to understand and facilitate emergence in the context of the design process, including its outcomes.

Turning to *SpiderCrab*, conceived of as a mediation between dancing partner and architectural environment, we report on the performance-led process undertaken by an interdisciplinary team in pursuit of *performative merging* between the robot and its human partner. We conclude by reflecting on the relationships between expressive and responsive modes in the conduct of design for user experience.

Keywords

Interaction Design, Interdisciplinary Design, Live Performance, Responsive Environments, Product Design, Robots, User Experience, Human-Centered Design, Visual Systems

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Copyright © 2007 AIGA | The professional association for design.

Problematizing Design

How might we find new ways of design thinking that will meet the challenges for designers in the 21st Century?

This was one of the questions posed in 2004 by Designing for the 21st Century (D4C21), a joint initiative of two of the UK government's Research Councils, the Arts and Humanities Research Council and Engineering and Physical Sciences Research Council. In making this joint approach, the two disparate Councils state that they are signaling three things:

- the ubiquity of design: from engineering to fashion;
- the need to build shared understanding of theories, cultures, languages and methods between different design communities;
- the need to find new ways of design thinking that will meet the challenges of designing for 21st Century society.

And the last emphatically includes user experience.

The School of Performance and Cultural Industries (PCI) at the University of Leeds, UK answered with the proposition that performance theory and practice would provide a productive point of dialogue with current design practices and understandings. This would not presume to aspire to the precipitation of a paradigm shift. But it would aim to participate in that emergence of new and various ways of doing things already in train in the design field – as *dux* amply demonstrates. We aim to *play* with the nature and possibilities of the design process. We also use performance to *defamiliarise* the design process, to make it strange and

thus open to fresh understanding. As Bertolt Brecht, the German playwright once remarked, when glossing the *Verfremdungseffekt* ('estrangement device') that lay at the heart of his dramaturgy, and silently taking Hamlet as his example: a young man will find that his widowed mother is readily defamiliarised when she marries another man.

In 2005, funded by Phase 1 of D4C21, PCI hosted Emergent Objects 1, a research cluster embracing PCI academic and industrial collaborators from digital media, computer games, urban planning, disability arts, culture-led urban regeneration and robotics to scope possibilities for dialogue between performance and design, both theoretical and practical.

For the calendar year 2007, PCI is leading Emergent Objects 2 (EO2), a portfolio of projects conducted by a consortium of three universities (Leeds, Huddersfield and Nottingham Trent) and the Shadow Robot Company, London, and funded at £301k by Phase 2 of the initiative. EO2 involves artists, designers, choreographers, performance academics, computer specialists and roboticists from the academy and the professional sphere.

Research Questions

Design thinking and performance knowledge intersect particularly when considering the potential for an expressive and affective interaction between the designed object and the human subject, and this is the terrain that Emergent Objects 2 (EO2) explores – with particular respect to the design of interfaces between people and their technologies. The portfolio is driven by two fundamental and overlapping research questions:

1. How does performance knowledge help us to understand and facilitate emergence in the context of design processes?

- How do performance processes facilitate interdisciplinary communication and collaboration in a design context and what new insights does this bring to design thinking?
- How can practice-based methodologies which are used in performance practice and research be usefully applied to the design process?
- In more participatory and open-ended contexts, when does the design process finish?

2. How can we design intimate interfaces between humans and technological objects by engaging with embodied experience rather than cognitive understanding?

- How can performance knowledge of embodiment and kinaesthetics inform the design of such interfaces?
- How is that space between humans and technological objects negotiated/managed/left open/evaluated?
- How do we design interfaces that are fluid, malleable and emerging, to promote human engagement with technological objects as an expressive, communicative and creative act?

The portfolio name plays with the concepts of emergence and objectile. Emergence addresses three areas:

- self-evolving *performances* engendered by complex products and systems such as gaming;
- productive complexity in *design processes*;

- the complex and shifting *context* of design practice itself.

Jan Overfield, a participant in the Emergent Objects 1 research cluster, was at that time working as Strategic Arts Officer in the local government of a market town in the English Midlands. As well as commissioning performances to animate the town, she also used it to engage the general population in questions about Hinckley's urban development. Furthermore, she used techniques derived from Augusto Boal to engage planners in a critical appraisal of their own practices, and as a means of public advocacy to politicians and civil servants. Impressed by her capacity, the chief executive put her in charge of public consultation around the town's Master Plan for development. Engaged thus in a deep praxis folding together design and performance, she conceived of and promoted a disused factory building as a Deleuzian 'objectile' [1] – constantly transformed through the use of the community in their rehearsals and modelling of their material environment.

Taking our cue from Jan, we consider the designed object as an 'objectile', a continuous variation of matter and development of form: the object becomes an event, always in the process of becoming through interaction. Such a perspective doubles as an impetus to the development of new design thinking and practices.

In Emergent Objects 2, the notion of a singular designer is displaced by the notion of a *collaborative design process*, whereby any participant is an active *design agent*, partaking in *design functions*. Even where one person may be ultimately responsible for the

design outcome of a particular aspect of a project, the *permeability* of their own design activity is an important principle and indeed object of research. Wherever possible and appropriate, active collaboration on the setting and conduct of design tasks is sought.

This contrasts with the currently dominant conception of the designer and their place in the design process. The *Cox Review* [2], commissioned by the UK government, provides a linear sequence of three defined terms. It neatly maps traditionally good business practice:

- creativity - 'is the generation of new ideas'
- design - 'shapes ideas to become attractive propositions for users or customers'
- innovation - 'is the successful exploitation of new ideas'

But we suggest that, in order better to understand the actual and possible place and nature of design, we might play with these definitions and the relation of terms. Rather than think of 'Design' as 'creativity deployed to a specific end' [3], we might ask:

Is there any line to be drawn between creativity and design?

Are perhaps creative play and working towards specific ends both parts of the design process? If so, are they sequential? dialectically related? cyclical? Or is the situation 'fractal' – design having its own sequence or cycles of creativity-design-innovation?

How can we define and map the three terms – creativity / design / innovation – in relation to the functioning of our proposed objectiles?

The design process in EO2 is eccentric in conventional terms. Not only is the design function spread across a number of agents, few of whom are professional designers; the team members are also typically institutionally and geographically distant. EO2 set up its design process as a complex system for three reasons: to examine how such a system encourages emergent behaviour in the design process, and emergent design solutions; to play towards the emergence of a new, complex, sustainable design process; and to ask what conditions might encourage the design of such new processes themselves to be emergent, evolving.

Emergent Objects 2: Project Structure

There are three sub-projects within Emergent Objects: *Snake*, *SpiderCrab* and *Hoverflies*. By design, they are at different stages of development; this enables us to consider the role of performance as practice and as optic at different phases of the design process.

Snake (Nottingham Trent University) is the most developed sub-project and the installation is due for gallery exhibition in December 2007. *Snake* principally investigates the performed engagement between an interactive sculpture and human agent. The key objective is to design an interface to facilitate a direct responsiveness that is conducive to a corporeal, tacit engagement. The sculpture will engage the viewer in a 'dance duet' through use of sensors, both responding to existing mood and suggesting/creating alternative mood. The design of the moment of engagement between duet partners takes account of its

emergent nature, arising from a real-time encounter where the partners have equal influence. (Fig. 1)



Figure 1. Snake robot. Copyright: Chris Forbes, NTU

Hoverflies (Universities of Huddersfield and Leeds) is at the earliest design stage, where the object is in its most fluid state of emergence. The aim set in January 2007 was to design and build an interactive object which entices performative interaction and play. Using accelerometers as the mediating technology and the performing body in flight, the work investigates how motion, gravitational pull and velocity might be projected into a variety of digital outputs. The guiding principle is to investigate hyper-physical interfaces where the traditional notion of 'user' is supplanted by 'participant-performer'. Paradigms from HCI, scenography, architecture and performance inform both process and outcome. The use of accelerometers develops earlier work by Bayliss and Sheridan, *iPoi*, which used poi implanted with accelerometers to generate signal for projection through light and sound into dance club environments. Ordinary club-goers get to change the aesthetic of their architectural environment through immediate bodily expression. Within the space of play that this designed encounter

provides, people become dynamic composers – working in a small and shifting community. [4]

If *Snake* focuses on the sensual dialogue between a gallery-goer and an installed object, *Hoverflies* explores the expressive relationship between those club-goers and their immersive environment. This is perhaps an experiment in liquid architecture, but one in which the human/technological interface is emphatically and directly physical. The club-goer fluidly shifts between witnessing, communal play, performance and immersive reverie. But *Hoverflies* will not be confined to clubs; it will be installed in a number of different social contexts (e.g. playground, festival, shopping mall) to investigate how positioning and spatiality impact on people's willingness to participate. (Fig. 2)



Figure 2. Hoverflies. Copyright: Alice Bayliss

SpiderCrab (University of Leeds and Shadow Robot Company) is the 'middle' sub-project in terms of development. It is a robotic agent conceived of as a multi-sensorial mediation between architectural environment and dancing partner. As with *Snake*, *performative merging* is a key concern. The fully-realized 6-limbed, 3.3 metre high, robot will have pseudo-human characteristics including precoil and recoil in gesture, learning, aesthetic choice, redundant movement, mood and physical temperament. As objectile, it will set continuing evolutionary challenges to software design, robot engineering, performance specialists and human agents. Work began in January 2007 with a CAD drawing (Fig. 3), some guiding principles – and the knowledge that we had the peculiarly fluid air muscle technology of Shadow Robots, London to hand. In this 12-month phase of the planned work, we aim to complete one limb for real and the 6-legged whole in virtual space. We write more extensively about *SpiderCrab* below.

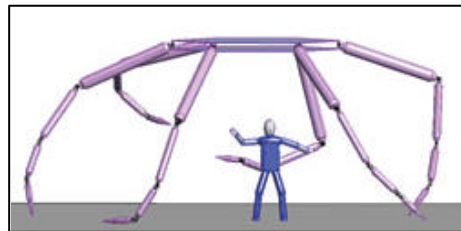


Figure 3. CAD drawing of SpiderCrab from January 2007.
Copyright: Matthew Godden

While all three sub-projects are based in performance understood in the artistic sense (extending to participatory arts and social dance), this aspect is in a way bolted on to our fundamental concern, which is with the design process itself. The development of new

performance opportunities, meanwhile, will constitute a considerable bonus. That said, we need not rehearse too much the turn to the *performative* in design as much as other spheres in aesthetics, culture and politics since the 1970s. In EO2, we use our performance praxis to play-through the performativity of design and its products.

There is a fourth element to the project structure, the Meta Project, managed by PCI.

Meta Project

The sub-projects inform each other through regular joint meetings. Simultaneously the Meta Project team charts the interpenetration of the sub-projects for theorization. The Meta Project informs the sub-projects by mapping design- and performance-related models and paradigms for application and reflection. The models cluster under three areas: Play, Embodiment and Composition. Meta Project Briefings on these models have been given to all project members to inform their design practice and to provide frames for *post-hoc* analysis.*

A. Play

Play theory has regained importance in performance studies through its appropriation for instance by games design and theory. EO2 makes its own strategic appropriations. Huizinga [5], Caillois [6] and others conceive of play as a framed activity, where the frame both defines a space of freedom and provides a productive restraint. Csikszentmihalyi [7] associates play with the condition of 'flow' – the absorbed concentration, non-contradiction of goals, and immediate feedback essential to creativity.

* The Meta Project Briefings are available online, via <http://www.emergentobjects.co.uk/> following links to Events and thereby June Colloquium.

For a conventional designer, the non-contradiction of goals necessary to a creative design solution often equates to a clear design brief. Such has been the habitual expectation of software designer John Bryden from the *SpiderCrab* team, for example. But EO2 works to deny such teleological prompts, by opening out a complex space of play from the outset. At the same time, it offers easily graspable models for self-management of the newly-opened space. In particular, the Meta Project Briefing provides Caillois' two key mappings of play for reflection and experimentation: first, the four categories agon/competition; alea/chance; mimicry/illusion; and illinx/vertigo; and second the continuum between paidia/sheer playfulness and ludus/rule-bound play. The first question for an EO2 designer, then, is 'Am I playing, and how?'



Figure 4. John Bryden experimenting with the SpiderCrab limb. Copyright: University of Leeds

Contributing to the Meta Project, Bryden reports that such tools have provided him with what might itself be identified as a frame of play – the license and the

protection within which to play. That he began with an inclination to experiment outside his 'safety zone' was of course crucial. (Fig. 4)

Caillois' categories of play have been directly exploited early in the *Hoverflies* process, with each member of the design team in turn leading the others in a play-based activity prompted by their initial self-briefing. Playing between the striations of play categories and the smoothness of open experiment [8], the team thereby generated a complex system of prompts for their design process through inductive experiment. The intention is to allow the nature of the process itself to project into the designed object which, in turn, will encourage playful shifts between roles of performer, participant and observer - as defined in the model of tripartite interaction. [9]

Schechner [10] adapted the notion of the frame of play to consider what might otherwise be called determinations on the performer's playful creativity in a staged drama: it happens within concentric frames of play, rather like Russian dolls, from the logic of the part as written in the script through the director's desires, to the prevailing performance conventions. While ambiguous – which is the most potent frame, the nearest or all-encompassing? – Schechner's model provides a useful tool for the negotiation of internal and external determinations on process, including we suggest design. In other words, it provides a metaphorical space in which a complexity of determinations – the contradictions of interdisciplinary praxis; funding imperatives; scheduling, etcetera – can be managed by the group as a group.

The Meta Project Briefing appropriates Schön's [11] analysis of professional practice: 'reflection-in-action'; 'tacit understanding' and '*post hoc* reflection', to engender a five-phase feedback cycle around the concept of play in design practice:

(1) <i>post hoc</i> reflection on existing practice	- have I been playing; and how?
(2) conscious framing	- I am consciously using a frame of play to guide or inform my design process
(3) reflection-in-action	- I am aware that I am playing, and how, but my principal focus is the process
(4) tacit understanding	- I am fully immersed in the process; I am playing but am unconscious of this
(5) <i>post hoc</i> reflection on developed practice	- have I been playing; and how? is there a qualitative difference from (1)?

Rich Walker from Shadow Robot said that "the briefing notes were useful in opening up a different grid to read the project process". Conscious reflection on "play" during the project produces a more elegant solution to technical problems – "because we want to background the technology and foreground the play."

B. Embodied knowing

Recourse to Schechner's frames of play for the understanding of complexity mediates between the modes of knowledge and knowing. On the one hand, a reified map of determinations begins to precipitate out; on the other, the ambiguity and mobility of the model tends to dissolve precise boundaries. Our formulation here draws on Williams' notion of a 'structure of feeling' [12]: while we may feel able to objectify historical data into clear structures, our grasp of the present necessarily remains fluid, more a matter of feeling. Structure remains emergent.

Such knowing requires an open body, and the Meta Project Briefing foregrounds the role of the designer's own body as much as it asks what kind of embodied relations we want our designed objectiles to draw their human co-agents into. The *SpiderCrab* team have reflected, for instance, on the *habitus* – defined by Bourdieu as 'the deeply-installed set of cultural frames within which our physical improvisations can occur' [13] – that we bring to the designing process. Allowing, as many do, *habitus* to include intellectual and emotional as well as physical dispositions, we might suggest that two vectors of Bryden's habitus at the start were his openness to experiment and his discomfort at the lack of a clear brief. Physical games in particular assisted him in his desire to experiment outside his 'safety zone'. Professor David Hogg, also from the Leeds School of Computing, described the early initiation into physical play as at first 'terrifying' and then liberating: the *habitus* frame was recalibrated within the frame of EO2.

Popat and Palmer [14] report on a mask exercise by Popat and Wallis in experiments with Shadow Robots in

late 2003. Dancers contemplated a robot so as to identify fully with it, to embody it. Drawing on regular mask technique, the exercise proved to have significant value in the context of technological design. The performer contemplates the mask so deeply that it can 'possess' - fully inhabit or in-form - their body when worn. In 2003, this embodied performance of the robot by the dancer (Liz), one instance of knowing, served also as a second. Designers and mechanics from Shadow in turn had the sensation of haptic, kinaesthetic, encounter with the dancer-as-robot. Their knowledge of their robot (Zephyrus) was for a time supplanted by a more immediate knowing. New perspectives on the robot, its design and potential, emerged with a palpably exciting rapidity. *SpiderCrab* adopted the mask exercise as a foundation.

The protocol of knowing aligns broadly with Heidegger's *techne* [15], a kind of relationship with the world, its objects and processes, that works through an attitude of in-dwelling. Truth is not extracted; rather, space is made for the essence to make itself manifest. And when complexity theory identifies or conceives of self-developing closed systems, it suggests essences. Idhe [16], like others, has celebrated the power of Heidegger's intervention in the 'Technology' essay, while resisting his romanticism and recourse to foundationalism. Wallis [17] subjects the essay to a rhetorical critique to much the same ends, while proposing the theatrical apparatus as a collective subject of *techne*. One thread that runs through the EO2 Meta Project is a similar conception of the individual design process as a creative iteration of objectifications and phenomenal encounters, simultaneously drawing on and contributing to the human-crafted environment.

C. Composition – and Projection

In arts practice, the two terms 'creativity' and 'composition' easily slide into one another. And as Derrida reminds us, there is no thought, no gesture that is not already a citation. To create is to compose. In residual but still potent conceptions of design, the idea of composing a solution to a design problem still perhaps commands precedence over any creative imperative. How much is this tied up with the long and shifting historical differentiations in the West between art, science and craft? And what might a shared and playful reflection on this do to the *habitus* we bring to the design process?

Taking the cue from Csikszentmihalyi, the Meta Project Briefing also asks *inter alia* how we might playfully re-order what persists as a dominant *linear* model for the process of creativity: *preparation / incubation / insight / evaluation / elaboration* in our actual creative design processes?

In a workshop for the Embracing Complexity in Design research cluster within D4C21 in June 2007, Mick Wallis combined play, embodiment and composition under the rubric of *projection*. [18] The work synthesises methods derived from Boal's Image Theatre [19] with the cross-arts praxis pioneered by Isabel Jones of the UK arts charity Salamanda Tandem (<http://www.salamanda-tandem.org/>). First, in the Boalian phase, a personal verbal account of the design problem, figured as a blockage, is shared with a partner. Then both teller and told sculpt the other bodies in the room in their separate representations of what has been told. The only rule with respect to mimesis versus abstraction is to ignore that boundary. The bodies can be either and both. Then, in the Jones

phase, those images are translated or projected by the group or its sub-divisions (the order is decided spontaneously according to the state of the players) into words or phrases; and these into movement; and these into drawings; and these into sounds; and any circulation of projection combined with the *composition* of the projected materials into something like an installation. The outcomes are almost universally liberating and astonishing for new participants – if somewhat predictable but nevertheless pleasing for old hands at this kind of stuff. The point is the *lateral* movement between concrete manifestations of concepts, images and gestures, the insistent and localised (re)embodiment of the imagination. We plan to conduct a similar exercise at the December 2007 Colloquium, as prelude to our jointly addressing a real-world design challenge.

SpiderCrab

SpiderCrab mediates between dancing partner and architectural environment. The dancer – either a professional on a stage or anyone involved in a participatory arts context – interacts with individual limbs as well as the robot as a whole. And the whole simultaneously acts as an environment for the interaction. It is a kind of ‘double immersion’. (Fig. 5)

There is a long tradition in robotics of building legged robots. Most if not all to date have been what we might call ‘hard’ robots. For example, Ghengis [20] is designed to demonstrate AI technologies; the GE Quadruped or Walking Truck built by Ralph Moshier in 1968 is a hulking machine designed to carry 750lbs; and currently Boston Dynamics is developing a series of large 4-legged robots for combat support [21]. Los Alamos has produced a series of legged robots

designed for warfare. The Stelarc Hexapod robot [22] combined such machismo with a heroic cyborgian gesture, the performer situated inside or on top of the hardware, like the driver of an intimate tank. We wanted to explore the other end of this territory - a legged robot that was designed for up-close and personal interaction with the performer as a separate entity; one that was fun, able to embrace and enfold and play - subverting the traditional way legged robots are seen.



Figure 5. SpiderCrab limb and dancer (foreground). Lower sections of full-scale mock-up of 6-limbed robot (background). Copyright: University of Leeds

SpiderCrab came to the imagination as a result of those earlier experiments with *Shadow*, at the back of which was a question set us by a colleague in Robotics at Leeds, who keeps abreast with European Community research imperatives: *How can we design robots that are aesthetically and socially acceptable to people?* Our broad response had been (a) to focus principally on the phenomenological dimension – what is it *like* to hang out with the robot? – rather than communication; (b) to design-in redundant movement rather than primarily

seek efficiency; (c) to engage in an iterative and distributed design process.

SpiderCrab is being designed as a dancing partner. Success in the Turing Test for AI requires that the human agent be unable to tell whether the partner with which they are conversing is human or artificial. We propose our own version, an Embodiment Test, where success will be measured by whether or not the human dancer feels that he/she is dancing with a true partner. This for us defines the 'performative merging' between dancer and robot. And while the dancer already has her own embodiment, which both allows and constrains or gives bias to her dancing, *SpiderCrab's* fundamental embodiment remains emergent until the moment that the Test is passed. And of course that fundamental embodiment is then subject to further emergence; passing the Test is not an objectified moment, but a continuous process of becoming.

For this year's phase of the work, we are confining ourselves to one element of *SpiderCrab's* sensorium: vision. Leeds has significant activity and expertise in Computer Vision, with a long record of innovation in motion tracking and analysis.

When it comes to computer science and dance, work has already been done on physical posture analysis, concerned to identify 'key aesthetic poses' – like the *plié* in classical dance [23]. The model this suggests is of successive *poses* and the *transitions* between them. We explored this approach for a short period. But much modern and almost all postmodern dance barely consists of poses. It is fluid, constantly emergent. And it is based on bodily *impulses*. So what might have been thought of as 'transitions' in a previous model

come to the foreground as impulses in ours, and with that the focus is perforce on the *quality* of movement realized by the impulse. It is here that Rudolf Laban's system for movement analysis comes to the fore. A reduction of Laban's 'Effort/Shape' provides us with four binaries that constitute a simple framework to enable dialogue between dance and computing – *light/strong, free/bound, direct/indirect and sudden/sustained*. The framework provides a matrix from which a wide and expressive range of movement qualities can be both analyzed and synthesized: gliding, dabbing, floating, and so on. [24]

The whole *SpiderCrab* team - engineers, performance academics, computer scientists, dancers - engaged in body-sculpting and other embodiment exercises from the beginning. For one thing, we wanted to work physically on *habitus*, as discussed above. Just as different bodies dance differently, so too do different bodies think, imagine and make different things – and differently.

We also wanted to develop that practice that Popat and Wallis had explored with Shadow in exploratory workshops in late 2003. The embodied mode of knowing through the mask exercise has continued to inform this project. It is deeply processual and allows productively lateral extensions and drifts in understanding. The dialectic between 'cognitive' and 'precognitive' is stimulated. A processing space that feels at once deeply metaphorical and thoroughly concrete opens up like a bubble of steam.

We found that we were able to use the performers' embodiment of the robot to explore the space of possible robot systems "around" the robot that had

actually been built. Later, we used the same techniques to explore the space of possible physical and sensorial designs for *SpiderCrab* with a group of dancers embodying a series of tentative *SpiderCrab* limbs and a "naive" dancer interacting with this ensemble. (Fig. 6)



Figure 6. Four dancers embodying *SpiderCrab* limbs. Dancer on left is dancing with this distributed robot. Centre: John Bryden (Leeds Computing) and Rich Walker (Shadow). Copyright: University of Leeds

SpiderCrab is designed to fill a stage space, whilst still interacting in an intimate way with the performers. There are big structures, there are intimate structures, and there are moving structures. But there are very few big, intimate, moving structures – and that is what Shadow set out to produce. Normally robots are separated from people with safety curtains. This robot is designed to be able to embrace the person. So the movements need to be elastic, the body needs to be soft and light, and all corners need to be padded. The required fluidity of movements is provided by Shadow's patent air muscles.

The material finish to *SpiderCrab* is left very simple. This is not in pursuit of a Modernist statement of efficiency. Rather, it allows the robot to be 'dressed' for performance – from electrophorescent material to fur, or plain pipe lagging. In demonstrations, people have found exposure of its simple mechanics intriguing, and this can be exploited whenever appropriate. Indeed, the *Snake* team observes an ethical imperative to lay bare as much as possible of its technology as possible, since concealment denies knowledge and thereby power.

SpiderCrab's limb segments are proportioned according to the classical aesthetic principle of the Golden Ratio. Also known mathematically as the Fibonacci Series (1, 1, 2, 3, 5, 8, 13...), it corresponds to the natural order. The air muscles are powered by a low-noise compressor. The switching of valves produces a soundscape that emanates from the robot's body. We regard this as something like *SpiderCrab*'s 'breath' and plan if anything to augment (perhaps process) rather than conceal it.

Given a physical structure designed to embody dancer-like qualities (softness, elasticity, lightness, fluidity) the aim of the software project was to bring the structure to life as a fully embodied robotic dance partner. As such, it should operate within the realm of aesthetic movement - not only producing aesthetic movements, but interpreting aesthetic qualities of its partner's movements.

Since the aim was to achieve a true improvisational dialogue between dancer and robot, Laban Movement Analysis was positioned to provide an *interlingua* between dancer and robot. It provided their common

aesthetic vocabulary. The software implementation used a vision system to capture and analyze the dancer's movement – tracked for the present by detection of a coloured armband - into Laban-style metrics. These then formed the basis for the generation of the robot's own movement. Laban Movement Analysis has been used in computer characterization and graphical generation of human gestures [25], but it has not previously been employed as a mode of extracting purely movement quality and effort from human movement for computer processing.

Now, a closed loop of robot-copying-dancer would destroy any sense of improvisational dialogue. The robot's movements are therefore generated on a *random* basis. Yet a robot moving on a random basis simply moves chaotically. There is no 'offer' to the dancer. So how might a robot generating its own random movement be experienced as dancing? We determined that, if the robot's movements gain some degree of consistent *quality* to them within a given time frame, the dancer can start to make an aesthetic interpretation and engage accordingly.

To generate an interesting repertoire of movements, then, it was only necessary to introduce *bias*.^{*} In the *SpiderCrab* prototype, muscle impulses are therefore biased toward either strong or light impulses (representing the Laban weight category). And a bias towards low frequency of change in direction gives direct movements, while a bias towards high frequency gives indirect movements (representing the Laban space category). The control software chooses which biases are appropriate based on the movement of the dancer and its own internal '*mode*'. 'Mode' designates the computational space in which the robot makes

absolute choices or defines its *disposition*. It might, for instance, be disposed to repetitious behaviour, or to alternate between choices within absolute modes with a particular frequency and/or bias of choice.

The absolute mode we have begun with follows the basic choices dancers make when improvising together: to *copy*, *oppose* or *innovate*. We found that, when in 'copy' mode, the robot's responsiveness to the quality of movement of the dancer gave the dancer a sense of interaction on an aesthetic level. The robot's imitation of the strength and directness of the dancer's movement gave it a friendly, attentive, character. However, the dancer is not left with a feeling of being in total control. The dancer must respond to the random movements of the robot which makes for an exciting, rich, improvisation experience. When we changed the mode of the robot to 'oppose' (where it contrasts its quality of movement to the dancer's) the character of the robot became more aggressive – strong movements were needed from the dancer to pacify it. This felt less interactive, so the best setup was therefore a robot which copied the dancer *most* of the time.

To add a further interactive dimension, we have programmed the software to calculate the 3-dimensional location of the armband. While allowing for a safe mode when humans are in close proximity to the robot, this also allows the robot to make pointing gestures by rotating some of its joints towards the dancer. This means that, rather than just pointing at the dancer, the robot continues to move while it points. An 'offer' is therefore still being made to which the dancer can make an aesthetic response. Plans for future developments include touch-sensitive elements

* At first we had conceived of 'constraints' on the random movement. This rhymed nicely with the notion of changing frames of play. The Meta Project Briefing suggested that the concept of 'vector' might usefully be crossed with frame of play adequately to model determinations on otherwise free play. 'Vector' seems roughly aligned with 'bias'. Such fluid movement between quite simple models and metaphors helps sustain that 'third space' necessary for the sort of collaborative design experiments we are engaged in.

so that the robot will respond to the dancer's physical contact with it, and auditory sensors so that the robot can pick up musical rhythms. Software learning mechanisms may also be introduced so that the limb can begin to learn individual dancers' or choreographers' aesthetic preferences and movement habits. Advanced control software to respond to the pressure in the muscles will aid in generating more graceful movements.

Alongside the single robotic limb is the 3-dimensional computer graphical prototype of the full 6-limbed *SpiderCrab*. This includes extra features such as independently moving limbs, copying each other, moving symmetrically, or engaging in other gestalt movement actions. We predict that a dialectical tension between symmetry and asymmetry will enhance the 'offer'. This virtual *SpiderCrab* functions as an addition to the experience of dancing with a single limb and also as a simulator for exploring the design of the fully realized robot.

Conclusions, questions and dialectics

Delegates to its June 2007 Colloquium commended EO2 for innovative investigation and development of design processes through performance theory and practice. (www.emergentobjects.co.uk) This is encouraging in advance of the evaluations each sub-project will undertake up to and including the final dissemination of this phase of the research in the December 2007 Colloquium. We conclude here by identifying two apparent dialectics revealed in the course of our process.

The first concerns our foundational shift from key aesthetic poses to impulses in the *SpiderCrab* sub-

project. In the exercise described above, where dancers simulated robot limbs driven by impulse, most sense of 'offer' was in fact annihilated. We have described how 'bias' comes to correct this in the prototype, and this is in particular we think due to the complexity generated by a simple palimpsest of bias and mode. Meanwhile, while our dancers are trained to explore all modes and possibilities of their body (and Liz as Zephyrus found new possibilities), at some level there will be that fundamental *aspect of habitus* that holds them in the world - generated by a double accretion of cultural and personal history. This deep *body-hold* was evident even beneath the ostensibly chaotic movements of the dancers in the exercise. It is not possible to wipe the slate completely clean. *SpiderCrab* achieves a basic body through a combination of its physical composition and the pressure of air in its muscles. Something like a borrowed *habitus* derives from the stochastic/bias /mode basis of the present prototype, as we project our own cultural biases into the software. If we do come to experiment with layering learning protocols onto this, then *SpiderCrab* will have its own modest history – or set of histories. And it is here that the principle of gestalt might make its return. Might the passing of the Embodiment Test ultimately depend on a sense at least of 'deep' aesthetic choices of the kind that corresponds to a human dancer's fundamental body-hold? Of an 'aesthetic directionality' to those random impulses? This is to suggest, perhaps, that we might ultimately be concerned with a *dialectic* between impulse and gestalt.

The second concerns the bounds of designing for user experience. One of the international delegates to our June 2007 Colloquium, distinguished in the field of experience design, expressed satisfaction with the *SpiderCrab* process. If we understood right, their

opinion was that we had addressed the needs of the user at all levels. Now, while we have not consulted with a field of users, we have worked closely with student dancers in the development of the robot. And we shall be making evaluations with a different group of users – young people with learning disabilities – as well as with the December 2007 delegates, before the year end. Yet there remains something *expressive* about the project. It did not begin with a design brief, but with a creative act of imagination. We might here recall Cox. But a further comment from the same delegate suggests more, much on the lines of our critique of Cox. The delegate, we understood, had found *Snake* to be a splendid work of art, but was less convinced of it as a piece of design. It seemed to offer itself up to view rather than respond to an identified need. Nestling in the middle here is perhaps the *Hoverflies* project which, as stated above, investigates hyper-physical interfaces “where the traditional notion of ‘user’ is supplanted by ‘participant-performer’”. The participation is engaged, free and creative – but ultimately comes *after* the ‘offer’ made by the designed object. And *SpiderCrab* appeared, as it were intuitively, in one of our minds, in the light of our experimentation with *Shadow* – and as a result of our thinking about theatres, performance and the human-crafted environment. Is it possible – ethical – to propose an *expressive*, as opposed to responsive, frame or vector to designing for user experience? In other words, design that sets a new (negotiable choice of) frame for self-realisation. Even – and some have argued especially [25] – in a ‘postmodern’ context, the figure of the artist as imperious agent survives the supposed demise of Modernism. Experience design offers to negotiate a closer cont(r)act. But might perhaps one way of working through the aporia constructed by the

sort of maps that Cox makes be precisely and fully to admit expressivity into design? That is, in dialectical tension with an imperative to serve understood and expressed need? Echoing Heidegger, might the design process regain or renew the function of *poesis*?

References

- [1] Deleuze, G. *The Fold: Leibniz and the Baroque*. trans. Tom Conley, Minneapolis: University of Minnesota Press, 1993.
- [2] Cox, G. *Cox Review of Creativity in Business: building on the UK's strengths*. London: HMSO, 2005.
- [3] *ibid*.
- [4] Bayliss, K.A., Sheridan J.G. & Villar, N. New shapes on the dance floor: influencing ambient sound and vision with computationally augmented poi. *International Journal of Performance Arts and Digital Media*, 1(1), 2005, 67-82.
- [5] Huizinga, J. *Homo Ludens: A Study of the Play-Element in Culture*. London: Routledge & Kegan Paul, 1949.
- [6] Caillois, R. *Man, Play and Games*, trans Meyer Barash. University of Illinois Press, 1958, 2001.
- [7] Csikszentmihalyi, M. *Creativity, Flow and the Psychology of Discovery and Invention*. New York: HarperCollins, 1996.
- [8] Deleuze, G & Guattari F. *A Thousand Plateaus. Capitalism and Schizophrenia*, trans Brian Massumi. London: Continuum, 1980, 1987.
- [9] Bayliss, K.A., Lock, S. & Sheridan, J.G. Understanding interaction in ubiquitous guerilla performances in playful arenas. *People and Computers XVIII - Design for Life: Proceedings of HCI 2004*, Springer-Verlag, 2004, 3-18.

- [10] Schechner, R. Performance Theory. London: Routledge, 1988.
- [11] Schön, D, A. The Reflective Practitioner: How professionals think in action. NY: Basic Books, 1983.
- [12] Williams, R. Drama from Ibsen to Brecht. Harmondsworth: Penguin, 1973.
- [13] Bourdieu, P. Outline of a Theory of Practice. Cambridge: Cambridge University Press, 1998.
- [14] Popat, S & Palmer, S. Creating Common Ground: Dialogues between performance and digital technologies. International Journal of Performance Arts & Digital Media 1(1), 2005, 47-65.
- [15] Heidegger, M. The question concerning technology. The Question Concerning Technology, and other essays, trans William Lovitt. New York, London: Harper and Row, 1949, 1977.
- [16] Idhe, D. Postphenomenology. Essays in the postmodern context, Evanston III: Northwestern University Press, 1993.
- [17] Wallis, M. Thinking through *techné*. Performance Research 10(4), 2005, pp.1-8
- [18] Puglisi, L. P. Hyper Architecture: Spaces in the Electronic Age. trans. Lucinda Byatt. Basel, Boston and Berlin: Birkhäuser, 1999.
- [19] Boal, A. Games for Actors and Non-actors, trans Adrian Jackson, 2nd edn. London: Routledge, 2002.
- [20] Brooks, Rodney A. "[A Robot That Walks: Emergent Behaviors from a Carefully Evolved Network.](#)", MIT AI Lab Memo 1091, February 1989.
- [21] <http://www.bdi.com/content/sec.php?section=BigDog>
- [22] <http://www.stelarc.va.com.au/hexapod/hexapod1.htm>
- [23] Neagle, R. J., Ng, K. & Ruddle, R. A. Developing a Virtual Ballet Dancer to Visualise Choreography. Proceedings of the AISB, 2004.
- [24] Laban, R. The Mastery of Movement. Plays Inc, 1971
- [25] Chi, D., Costa, M., Zhao, L. & Badler, N. The EMOTE Model for Effort and Shape. Proceedings of the 27th Annual Conference on Computer Graphics and Interactive Techniques, ACM, 2000, 173-182.
- [25] Merquior, J.G. Spider and bee: towards a critique of the postmodern ideology. L. Appignansi ed, Postmodernism. ICA Documents. London: Free Association Books, 1989, pp. 41-48

Acknowledgements

We gratefully acknowledge funding from the EPSRC/AHRC Designing for the Twenty-first Century initiative, directed by Tom Inns.

Parts A and B of the Meta Project section previously appeared in A. Bayliss, J. McKinney, S. Popat & M. Wallis (2007) Emergent Objects: Designing through Performance, International Journal of Performance Arts & Digital Media 3.2. We are grateful to the editors for permission to include this material.

Dancers for *SpiderCrab* are Laura Blazy, Lucy Foster-Perkins, Kathryn Jarvis, Natalie Orr, Deborah Waldie.

Other members of the Emergent Objects team are Sophia Lycouris (Edinburgh College of Art), Jamie Billing, Philip Breedon, Tracy Cordingley (Nottingham Trent University), Christopher Baugh, Scott Palmer (University of Leeds), Derek Hales (University of Huddersfield), Jennifer Sheridan (BigDog Interactive), Alec Robertson (De Montfort University).