Article

THE *SNAKE* PROJECT: AN INTERDISCIPLINARY FRAMEWORK OF DISCUSSION

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Figure 1: *Snake* project video demo (screenshot) with animation of the sculpture designed by Chris Forbes and movement by dancer Joanna Geldard.

INTRODUCTION

by Sophia Lycouris

In early 2006, Philip Breedon, myself (Sophia Lycouris) and Jamie Billing, three academic researchers based at the Nottingham Trent University (Nottingham, UK) with backgrounds in the respective areas of control technology, choreography and product design, started a conversation about movement, artificial intelligence and simulation in relation to product design. Tracy Cordingley, a specialist in both product and interior design, joined the original team at the end of 2006, when the conversation had become more specific and funding had been secured to complete the development of a specific project under the title *Snake* by the end of 2007.[1]

The aim of the initial conversation in early 2006 was to develop a common language (and an appropriate methodology) in order to explore the potential of applications/products which have an emphasis on the artistic yet clear potential for subsequent expansion into the commercial sector. During this period, the research process was generative and not driven by any concrete practical problems or issues. Instead, problems or issues arose as part of the research process through discussions about each others' interests and previous work. This process led to the realisation that the team shared interests in issues of space and perception, audience engagement and interactivity. A 'product' emerged through this dialogue, as an example of how the issues identified and explored could be practically addressed in the context of a given artefact. This idea involved the development of an interactive kinetic sculpture (under the working title *Snake Robot*[2]) which could engage viewers in 'dance duets' through reacting to their movements (Figure 1).

After this point, the character of the dialogue between the four members of the collaborative team gradually shifted towards a different direction, since the character of the research process also changed as a result of the decision to focus on the development of an object with tangible form and specified purpose. Clearly the research process was no longer generative but strictly determined by the need to resolve a series of practical problems so that it was possible to build a concrete object. The initial inclination to identify common positions about the themes of space and perception, audience engagement and interactivity on the basis of the three different disciplinary perspectives of control technology, choreography and product design was replaced by the need to establish boundaries and identify differences. The project became a typical case study on interdisciplinary collaboration, through addressing the creation of a common language (or at least a common framework within which all members of the collaborative team could fully understand the principles of the development process) and the undertaking of an on-going negotiation process in relation to how far each one of the participating disciplines could extend their established boundaries, before unacceptable disciplinary compromises were unavoidable.

All four members of the collaborative team have contributed to this article in order to unravel the challenges of the interdisciplinary collaborative working process and introduce thoughts and ideas which emerged as observations about the character of this process. It is important to clarify that, since this article was written when the project was still in development, the observations made and communicated in this text should not be perceived as conclusions. Conclusions will come at a later stage through engagement with appropriate methods of reflection, once the project is completed and tested in the public domain. However, in projects (such as *Snake*) which bring to dialogue academic research and artistic/professional practice, the outcomes of reflection which emerge directly from within the day-to-day developmental processes have a unique value and, therefore, deserve to be shared with an appropriate wider audience for their own sake. Such observations primarily relate to perceptions about the creative process and the experiences of the researchers involved, at a point in time during which these perceptions remain unaffected by the successes and/or failures of the completed project, after this appears in the public domain. There is a clarity and immediacy in these thoughts as they transpire in the on-going debate of the collaborative team or through practical work taking place in studios and workshops, which disappears as time passes. Observations and conclusions which crystallise after the completion of projects tend to become affected by how projects are received by their audiences or users, even if these ideas only relate to the developmental process of this work.

If it was possible to capture the immediacy of a live working process in a written text, this would be the main purpose of this article. Yet I do not think that this can ever fully happen and, as a choreographer who engages with wider issues about the documentation of the live process,[3] I suggest that, instead, this article functions as a written account of crucial decisions which determined the character of the working process, which are specifically presented under the light of the disciplinary contexts informing these decisions. The article includes three parts: on choreography, on product design and on control technology, written respectively by myself (Sophia Lycouris), Jamie Billing with Tracy Cordingley, and Philip Breedon. The structure of each one of these sections reflects the specific structures of thought and decision making protocols which are resonant within the disciplinary boundaries in which the four researchers operated. The sections on choreography and product design both interrogate the character, status and purpose of the interactive sculpture through posing the same set of four questions (what is it? who is it for? what is this experience? what is the rationale of the project?) in order to provide responses from within their different disciplinary perspectives. However, the final section, which focuses on control technology, unfolds as a series of propositions about relevant technical information which indicate some unexpectedly close links between critical approaches to choreography and design and technology-based research.

PART ONE: CHOREOGRAPHIC POSITION

by Sophia Lycouris

The relationship between choreographic practice and interactive technologies is highly complex and multi-faceted and, on one level, depends on the perspectives and politics of choreographers involved, how they use existing techniques, which precise techniques they use, whether they develop anything new and the various implications that all these decisions have for the meaning and purpose of the work and the (power) relationships between artists and audience. In the field of interactivity, technical solutions and how these are implemented and towards which ends, also have repercussions for the relationship between technology and the user. Furthermore, through participating in this dialogue as an equal partner, the practice of design brings its own techniques, practices and political implications of all choices in these fields, to add one more layer to this complex as well as complicated debate. Within this edifice, notions of control cut across the various relationships between people and techniques, artists and audiences, designers and customers, engineers and users. The very idea that a kinetic artefact could be designed and produced to react to the movement of people around it comes with a multiplicity of meanings and effects which emerge from the 'how' and 'why' technological solutions are adopted to support the development of a 'product' in order to fulfil needs identified on the basis of various sets of assumptions about relationships between makers, objects and users/audiences of these objects.

1.1 WHAT IS IT?

There have been various attempts by members of the *Snake* team to describe and name the (artistic) role of the artefact, to say that the outcome of the project would be 'thing a' or 'thing b'. Somehow it seems that the question 'what is it?' can be only replied to by the choreographer, or if any of the other collaborators attempt to provide an answer, this will be an articulation of what they think the choreographer is doing. There is an assumption that the choreographer is leading the project through providing a brief which will determine the contributions of specialists in other areas who will use their expert knowledge to support the materialisation of this brief. So, according to this approach, a choreographer is making a decision to create a 'thing', a technologist is developing an appropriate technology which will support this 'thing' and a product designer is providing a suitable design for the most effective materialisation of this 'thing'. The 'thing' in this project has been described as a *performance robot* by the technologist, as an *interactive piece* by the designers and as an *interactive kinetic sculpture* by the choreographer (myself).

Through providing an alternative concept about what is the 'thing' which is being created and insisting on taking into account this concept, I automatically fulfilled traditional expectations about my role, which is to be *in control* of the 'thing' which is being created. Therefore, as a choreographer, I did not manage to challenge the assumption that I am leading this project and this means that I have a substantial degree of control over certain aspects of the project such as its concept. In actual fact, I more or less accepted the idea that, as a member of the collaborative team, I am responsible to provide a framework of guidance which will allow my collaborators to operate comfortably and use their specialist knowledge in the most beneficial for the project way. This is in line with two main principles of the traditional definition of choreography included in the following excerpt:

> The choreographer is the author of the choreography and arranges material using an individual process to present an end product for performance. Choreographers are responsible for the total visual imagery and expect to negotiate with musicians, costume, set and lighting designers.[4]

So what would a choreographer normally do?

> To choreograph is originally to trace or to note down dance. This is the meaning that Feuillet, the inventor of the word assigns it in 1700…Since Feuillet's time, the acceptation of the term has undergone a singular evolution, and today 'choreography' refers, not to the activity of notation, but rather to the creation of dance, or to 'composition'.[5]

It is interesting that famous choreographers of various periods have not provided definitions of choreography but, instead, have spoken around the term. Here is an example:

> …choreographic movement, used to produce visual sensations, is quite different from the practical movement of everyday life used to execute a task: to walk, to lift an object, to sit down. Choreographic movement is an end in itself, and its only purpose is to create the impression of intensity and beauty. No one intends to produce beautiful movements when rolling barrels or handling trains or elevators. In all these movements, however, there are important visual dynamics if one will look for them.[6]

Situating my work in the choreographic lineage of movement-as-an-end-in-itself (not because I value formalism but because I am fascinated by the physicality of movement and how this is communicated to the viewer as sensation rather than information), I am interested in an approach to choreography which focuses on how elements of time, space and dynamics constitute movement compositions. This is a principle assumed by a number of modern dance choreographers who created abstract (rather than narrative) work and has been succinctly indicated by Lois Ellfeldt as the "use of energy in space and time". [7]

In traditional choreography, whether narrative or abstract, the final result is always the product of the authority of the choreographer and a manifestation of their signature. However, the carefully crafted movement material which is created through processes of traditional choreography cannot exist outside the specificities of the physicality of the bodies of the dancers and their technical abilities, since these dancers provide the vehicles through which the choreographed movement occurs in space and time. This particularity defines the production of movement material as doubly *controlled* by a) the choreographer and b) the performers. It is interesting to notice that these two types of control are closely inter-connected, since the more specific and demanding the choreographer is, the more *controlled* the environment is for the dancers, whereas the more experienced the dancers are, the more they are in *control* of the production of movement material during the performance moment.

But how would this be outside the context of traditional choreography? And, furthermore, how does the element of interactivity impact on these definitions and techniques? If it is possible to argue that the interactive artefact operates as an artificial dancer, the outcome depends on the sophistication and accuracy of the interactive system and the accompanying computer programming. There is a distinct element of control here: the more accurate the system is, the more *controlled* the outcome (product or behaviour of the product) is. But who controls this outcome? A second manifestation of a double control system becomes apparent. There is one type of control which relates to the production of the artefact and this lies with the control of the makers and most importantly, the programmers of the interactive mechanism. At the same time, there is another kind of control which relates to the function of the artefact: the audience or users are the ones who exert this type of control.

To compensate for the fact that I accepted to play a leading role in the development of the concept of the *Snake* project, I attempted to challenge assumptions about what it means to be a choreographer and what kind of elements are acceptable within the practice of choreography, through introducing expanded notions of choreography. This is in line with the development of my practice in recent years and, most importantly, the last six years during which I explored the potential of *interdisciplinary choreography* in the double sense of: a) borrowing lenses and techniques from other art forms (as well as disciplines more widely) in order to develop movement-based artistic work with dancers and b) applying choreographic principles on materials other than the dancing body.

Approaching the *Snake* project from the perspective of interdisciplinary choreography, I came to the decision that the most useful framework of guidance was to think of the artefact as a *sculpture* and, more specifically, an *interactive kinetic sculpture.* Through bringing the term *kinetic* into the project I also wanted to share my fascination for the long tradition of kinetic sculpture which celebrates the phenomenon of movement beyond the human body, for patterns and qualities of pure movement without purpose other than the celebration of movement for its own sake, as this emerges from carefully designed *kinetic* systems. Guy Brett suggests that, in kinetic art, "the visual is immersed in the phenomenon of energy".[8] Similarly, in the *Snake* project I focus on the dynamic aspects of the situation which are communicated kinaesthetically to the viewer rather than information about meanings which is communicated through (dance) movement.

1.2 WHO IS IT FOR?

To address this point, I am going to ask a different question first: 'but why is it a *sculpture*?' The main element behind my suggestion to conceptualise this artefact as a *sculpture* is my interest in the understanding of choreography as a dynamic process which affects the viewers'/users' perceptual access to space, and colours how they experience the presence of objects in this space. Through adopting this perspective, a shift of priority and focus takes place and the element of 'performance', which was traditionally associated with the physical manifestation of the choreographic outcome, loses its primary significance. This approach challenges the traditional assumption that choreography is only an artistic technique through which intricate movement material is created to be 'performed' by human bodies (or any elements that can replace them, such as robots). I suggest a shift towards the conceptualisation of choreography as dynamic process in order to redirect the research focus towards the exploration of relationships in choreographic processes instead of the study of elements through which choreographic manifestations take material form.

This approach becomes increasingly relevant as choreographers become increasingly interested in creating work outside traditional theatre spaces. In non-theatre environments, the space of the performance event can expand and physically include its audience so that 'performance' can manifest itself everywhere in the physical (and sometimes virtual) space shared by performers and audience. In non-theatre environments, performance does not only happen on the 'other side'. Traditionally this 'other side' of the space is the theatre stage, an area inaccessible to the audience, in which dynamic changes take place, manifested as movement events which are 'performed' by performance agents, such as human bodies. Through challenging the traditional spatial divide between audience and performance event, *control* becomes diffused between the makers of the artefact (as a past activity and precondition of the situation) and the performance of the technology in dialogue with the physical involvement of the viewers who trigger the interactive mechanism (in the 'present' moment of the performance event as this unfolds in space and time).

Through undertaking previous research, I introduced the notion of *choreographic environments* to emphasise that it is possible to use a shared space within which the choreographic action and its audience can co-exist. This work presented the idea that choreography can focus on the function of dynamic changes within spaces (rather than movement sources, such as the human body) through contributing to the construction of dynamic environments. However, in the *Snake* project, the role of the dynamic environment is secondary, as there is a clear emphasis on the very source of the movement event (rather than how this contributes to the creation of a dynamic environment and how this is perceived or experienced by viewers/users), yet this element is an artefact instead of a human body. The idea of *sculpture* accommodates better the challenges of this paradox in which there is a focus on a single physical element in the space, which is however not placed in a dedicated area of the space inaccessible to the viewers. It can be argued that the spatial role of a sculpture, at least in its traditional sense, is to be part of an environment, and that a sculpture of this type is not usually created for spaces inaccessible to the viewers. It is the idea of sculpture as a physical element which has been created to be part of the public space, which is implied here. The combination of the terms *interactive* and *sculpture* provide appropriate means so that the diffusion of control between makers, artefact and viewers/users is located within an appropriate conceptual framework.

The *Snake* sculpture will be situated in a room, not necessarily in the centre of this room, but in such a way that viewers can have physical access to it from all directions. Sensors built in the body of the sculpture will be recording the movements of the viewers in order to pass information which will trigger 'appropriate' movement responses in the sculpture. It is anticipated that the viewers/users will be motivated to respond through movement. This form of exchange between viewer and artefact will constitute a 'duet' relationship between the two. The core of the future research will concentrate on the study of the conditions of movement exchange between artefact and user. Experiments will be conducted on how specific movements of the sculpture can motivate the viewer to respond with one quality of movement instead of another. There will be a focus on how the movement of the sculpture affects the user 'corporeally', and therefore what kind of movements are being generated by the users as a result of them experiencing a specific movement quality generated by the sculpture; furthermore, how the movement of the users 'affects' the movement of the sculpture, how this movement is being recorded by the sensors of the sculpture, and finally how the information recorded feeds into the interactive mechanism so that the exchange can continue through new movement produced by the sculpture which will affect the viewer accordingly and so on and so forth. During this stage, there will be opportunity to explore relationships between the viewer and the artefact and how these two elements share control over the emergence of the 'dance duet' as an event unfolding in space and time. At a later stage of the project, it will be explored if the sculpture can be developed as a commercial project, which will be used as a training tool for children with disabilities who will benefit from developing their movement skills. This phase of the project will introduce further controversies in relation to where control is located within the project and how it is distributed between those who designed the artefact and those who use it.

1. 3 WHAT IS THE EXPERIENCE?

In the discussions with the research team about the character of the movement of the sculpture, I emphasised the importance of avoiding an anthropomorphic approach: the sculpture should not look like a human being, or remind one in any way. My assumption was that, the less unidentifiable this artefact is, the more its movement is expected to contribute to the development of an 'atmosphere' or 'mood' which should affect the viewers' perception at a corporeal, perhaps visceral, level instead of only engaging their intellect. The purpose of this work is to stimulate the viewers to express themselves in movement through responding to the movement of the sculpture. The specific aim of this 'dance duet' is to provide an appropriate physical and emotional setting so that a dialogue about feelings can emerge through the medium of bodily movement.

A necessary step in the development of the project was to provide information about possible movement qualities that would characterise the sculpture so that the designing process could start and technical solutions could be explored which would support effectively the purposes set for this artefact. In order to avoid that audience members attribute anthropomorphic or other roles to the sculpture (since this would prevent them from engaging with it at the basic experiential level required), I tried to approach this task in the most abstract way. With the awareness that this is a practically impossible instruction (which would however work if it was used as a direction towards which the project should develop rather than as a strict rule), I suggested that the movement of the sculpture should be subtle and curvilinear, "as if a line was moving in the space, leaving a delicate 'trace' behind." This instruction still remains a considerable challenge for the other members of the team and has stimulated a number of interesting responses which have provided starting points for the development of appropriate technology and product design solutions.

The control technology specialist translated the visual brief of a "line which moves in a subtle and curvilinear way, leaving a trace behind" into the idea of undulating movement, and concluded that, if the artefact was structured as a series of vertebrae connected together into a kind of 'spine', this was a good basis for the development of efficient design solutions. It was then useful for him to introduce the metaphor of a 'snake' which was accepted by the team, and became part of the title of the project, which, as mentioned earlier, was initially called *Snake Robot*. It is interesting to observe that the word 'snake' does not offer an accurate description of the visual impression that the sculpture is expected to provide. The artefact will not look like a snake but will be developed on the basis of a principle of movement which underlines the movement of snakes. However, the concept of 'snake' was particularly helpful at the early stage of development because it offered a common ground for the communication of ideas between the members of the research team.

An animation has been created of the final artefact which is currently used in exhibitions and presentations about the project (Figure 1). In a recent presentation,[9] audience members suggested that the artefact and the way it moves in the animation reminds them of a plant which is moved by the wind. This idea prompted another member of the audience[10] to think of the potential of this artefact as a source of alternative energy. The basic idea was that people could have such sculptures in their gardens and 'dance' with them on a regular basis to generate energy for their houses! This suggestion was welcomed by the collaborative team, as worthwhile to pursue during later phases of the project. Thus elements of control were also introduced into the process of the long-term development of the project through the team's engagement with feedback provided by audiences/users and peers.

1.4 WHAT IS THE RATIONALE OF THE PROJECT?

One of the main aims of my interdisciplinary agenda in this project has been to encourage the collaborative team to find appropriate ways to foreground ideas about what they think this project is (or can be) from within their own perspectives of technology and design rather than on the basis of what they assume choreographers do traditionally. This is a delicate area, as a number of heterogeneous factors co-exist within a web of highly complex relationships between practicalities, concepts, techniques and approaches defined by widely existing disciplinary boundaries and professional fields, as well as separate elements beyond these fields. For example, there has been extensive discussion about whether the artefact should be standing on the floor or hanging from the ceiling. The latter was particularly convenient for technical purposes. However, this suggestion was not matched with an appropriate concept and, therefore, did not appear suitable for the project.

It is possible to notice that the very notion of 'concept' (which seems to be the validating factor for any 'good' decision in this situation) originates in very specific disciplinary contexts, perhaps the contexts of artistic practice (choreographic practice in this case) and design. It is clear that a certain type of disciplinary practice has determined crucial developments in the project situation which affects/controls the outcome distinctively. It becomes challenging to examine the conditions under which the idea that 'all disciplines involved in this project should be encouraged to foreground their perspectives on equal terms' is operational in this project. And indeed is it possible for such an idea to operate unconditionally? How can disciplinary control be eliminated in these complex negotiations between conceptual and practical aspects of a project, and is this ultimately possible? The following section explores the complexity of this issue from the perspective of product design.

PART TWO: PRODUCT DESIGN PERSPECTIVES

by Jamie Billing and Tracy Cordingley

Traditionally, within the context of product design, the final 'outcome' of a project is *generally* referred to as an 'object' or 'product'. The object itself is developed against a pre-determined set of 'design criteria' (or brief), and is designed for a particular purpose - whether that be practical, aesthetic, symbolic or the more recent hypothetical and critical designs[11]. Regardless of the intended role of the object, the product itself would have a clearly defined purpose and its nature, meaning and identity would all be intrinsic to this function.

It became apparent, however, when attempting to provide a 'label' or definition for the final outcome of the *Snake* project, that there were a number of issues raised relating to the interdisciplinary nature of the project and the three different contextual frameworks from which it was being conceived.

It was always taken for granted and celebrated that the three disciplines involved with the conception of the final outcome would have their own perspective of what the final outcome should exist as – governed by the knowledge framework of their own discipline. However, when it becomes necessary to establish a common ground, and in this case, make decisions about the actual role and purpose of the outcome, definitions and meanings can quite easily be seen as conflicting.

Regardless of whether a firm definition is established, and a common language/label agreed (hence, there would be nothing to prevent the final outcome, due to its multidisciplinary development, having a multitude of different meanings and values), it is imperative that each discipline engage in their own debate and discussion regarding the object's meaning.

Therefore, from a product design perspective, how do we define the 'object' within the contextual framework of the *Snake* project? What is its nature, spirit, meaning and identity? What are we trying to communicate through this product? These are all important questions which, from a design perspective, need both discussion and clarification. Only when these ideas are sufficiently formulated and externalised can the design of the object be successfully conceived.

2.1 WHAT IS IT?

the technological object

In contemporary society, recent technological developments are rapidly redefining existing models and definitions of 'the object' or 'product'. As these new technologies continue to emerge, traditional conceptions of the product as a solely 'physical' entity can no longer be sustained. Today we live our lives through an increasing array of technological products that have become mediators of a variety of new virtual spaces and experiences. These products often extend into complex information systems, as well as our own physical architectural environments. But how do we define such complex multifaceted technological objects?

It is now taken for granted within the design profession, (and in some ways has become somewhat outdated), that products no longer exist as definitive, static 'three-dimensional objects'. As early as the 1990s the new design concept 'four-dimensional design' entered the foreground of academic debate, opening up the doors for product design to now exist as a much more multi-disciplinary practice. According to John Thackara[12], just as the 2D was concerned with graphic communication, the 3D with craft and industrial artefacts, 4D design was all about electronic interactivity[13]. In Thackara's opinion 4D design was "the biggest challenge to face the design profession since the Industrial Revolution"[14]. So what is it, beyond the electronic interactive nature of these products that determines them 'four-dimensional', and more importantly within the context of this particular discussion – can the *Snake* be defined as a four-dimensional object?

Although there have been a variety of definitions provided for four-dimensional objects, the one provided by Alec Robertson, one of the original conceivers of this new design paradigm, appears most relevant to this discussion. According to Robertson, 4D design is a "dynamic form resulting from the design of the behaviour of artefacts and people in relation to each other and their environment"[15]. Hence, the complex and non-material form of these new consumer products opens up more multifaceted functional and kinaesthetic relationships and movements between objects, people and their environment. It is such possibilities that extend 4D design beyond the traditional boundaries of digital interactive technologies and introduce it to the physical world of human 'performance-based' practices such as choreography.[16]

Whilst it becomes immediately evident that cross-disciplinary collaboration, (particularly within a number of specific disciplines), would become increasingly necessary to the development of these new four-dimensional objects, traditional educational structures within product design do not always appear to accommodate this[17]. The interesting aspect of this project, however, is the richness of its cross-disciplinary development and also the nature of the particular three disciplines involved. Hence, from the perspective of four-dimensional design, bringing together the disciplines of choreography, control technology and product design could be seen as an exemplary working model. It is within this context, that the final outcome of the *Snake* project could be considered a four-dimensional object; a product which is less defined by its three-dimensional enclosure, and more by the dynamic relationships and activities that it both enables and encapsulates.

(new) product design [18]

As the boundary between what we understand as 'product' becomes blurred, the role of the product designer and the nature of the profession itself needs to be continually renegotiated. Whilst the traditional knowledge/skills framework of the discipline may still have an important role, the fundamental shift of products from the 'hard' and 'static', to the 'soft' and 'dynamic', catapults the profession into a new interdisciplinary arena. The 'interactive architect' Usmen Haque[19], suggests that such a transition, (within the context of his own profession), has redefined meanings and roles. According to Haque, as "pervasive computing encourages users to configure their own space [and] people become architects of their own spaces (through their use), the word architecture ceases to be a noun, and becomes a verb."[20]

Within the context of product design, it is now taken for granted that a variety of new skills and abilities are essential to the practice. Product Designers today come equipped with a vast array of new, so called 'interactive' skills and abilities; crossing the boundaries of graphic/web/multimedia and system design. Whilst these new skills and abilities may enable the (New) Product Designer to engage and practice within these new disciplines, there is an overriding lack of understanding and consideration for the 'non-material' kinaesthetic behaviours and relationships of these new four-dimensional objects – with the main focus for development of most technological products being on their efficiency and 'ease of use'.

In order to develop products which provide meaning and value to our new technologically mediated lives, the discipline of product design must now develop new types of interdisciplinary relationships and a more contemporary knowledge framework. From a (New) Product Design perspective, the *Snake* project is an encouraging example of a project which attempts to harness such new working practices, engaging in the much needed cross-disciplinary discussion and development process.

2.2 WHO IS IT FOR?

to brief or not to brief?

Within the profession of product design defining the 'end user' of the product is an important part of the design process. This would be something that is initially specified in the design brief [21] and later further developed by the designer. Within the commercial context that product design commonly sits, the end 'user' of the product is normally classified in terms of 'a market' or 'consumer group'. Hence, the target market would be something that the designer (as an integral part of the design process) would attempt to 'profile' and define as accurately as possible in order to provide a detailed insight into the values and aspirations of their potential customers.[22]

Whilst the practice of product design may not always exist within such a consumer-driven framework, the establishment of a clear picture of 'who' the design is intended for remains integral to the design process.[23] The 'who' or more commonly referred to 'end user' of the product plays an important role in defining both the aesthetics and functional elements of the product – and generally exists beyond, and in many cases in spite of, the personal values and aspirations of the designer.[24] It is this objective, customer/user-driven aspect of design that, it could be argued, differentiates it from general arts practice – where the motivation for projects and pieces of work may be driven more by personal interests/aspirations.[25]

Within the context of the *Snake* project, during initial development discussions, it became immediately apparent however, that the 'who' part of the project had not yet been established. Whilst there was a clear understanding and knowledge framework of what the *Snake* was going to be designed 'to do', and the subsequent nature and meaning of the exchange and interaction between the object and the user – the users themselves and their demographic had not yet been considered. It also became apparent in these early discussions that the object-to-user interaction and experience was to be largely dictated by the choreographer (the originator and leader of the project) and would be driven by personal research expertise and interests.

From a product design perspective, the notion of working without any specified external user/scenario/context, i.e., someone or something tangible that could be worked towards, was seen as a very difficult task. Hence, after much discussion between the *Snake* team a decision was made to develop a 'brief' to identify a basic set of criteria for the object to be designed against. Whilst the debate regarding the content of the brief was long and challenging, a relatively detailed brief was eventually developed for the *Snake* project – formulated by the designers. Included in the brief are some general guidelines for the aesthetic/functional elements of the object, possible aesthetic influences/inspirations for the design and a time-frame for the project. The 'Target Users/Viewers' section of the brief however, (which identifies the 'who' part of the project), is still rather vague and has been defined at this point of the project as: "a broad demographic, not restricted by any factors other than the locality of the physical gallery space and the range of visitors it receives".

Although the market, from a design perspective, is still largely undefined, it became evident through discussion within the *Snake* team, that the final 'public' context and delivery of this project, i.e., an exhibit at a variety of local and national public gallery settings, prevented any further user definitions being made. It was agreed, however, that the traditional product design methods of obtaining 'user feedback' through testing the product on a selection of its 'intended audience' would be a worthwhile exercise. Hence, a general audience demographic for a number of possible gallery spaces is currently being sought – with a view to establishing an external user feedback forum at key points in the product's development.

The question as to whether this project benefited from developing a predefined brief and undertaking user-feedback/audience validation can only really be answered at the end of the project. Such exercises, however, could be viewed from the onset (particularly within the artistic context), as being somewhat restrictive – providing an unnecessary framework to a project which is predominately about identifying new, previously undefined models. Furthermore, it could also be argued that the exercise of developing a brief and the overriding need by the designers to identify a firm set of guidelines from the beginning, was in fact a response to designers' own needs to remain within the 'comfort zone' of their own knowledge framework/discipline. The interesting aspect regarding the final brief, however, was that whilst it seemed to provide a basic platform from which to start the project, it still appeared to leave sufficient space for the required level of exploration to take place. It is believed that this was achieved through sensitive dialogue and debate within the interdisciplinary *Snake* team during its development process.

design ethics?

Whilst it is acknowledged that there are many advantages of exploring and developing new types of behaviours/interactions between people and technological objects outside of any socio-cultural constraints, the issue of the 'design ethics' of the final 'outcomes' of the project also needs to be considered. The need to address such an issue, from a product design perspective, is further heightened by the fact that the context of the 'who' for this project could not be clearly established from the onset. Hence, whilst the project is centred, (for exploratory reasons), on the relationship between people and the way they interact with a technological object, it is important to establish how any newly defined 'models of experience' between 'humans' and 'machines' could eventually affect sociological relationships and of course culture. The main questions that need to be addressed through this project, therefore, are what are the potential threats/opportunities of any new models of experience identified/developed within the socio-cultural framework and how could/might this affect, for example, the value/nature/role of future 'popular' technological products?

2.3 WHAT IS THE EXPERIENCE?

experience of visual aesthetics

An important element, from a product design perspective, that also needed some form of definition through the design brief was the aesthetic requirements of the object. Whilst it was fully acknowledged by the designers that the physical representation of the *Snake* would be largely dictated by the technological decisions made prior to the development of the brief, the designers felt it necessary to develop a set of principles for the physical manifestation of the *Snake* itself – in an attempt to provide some form of experience through the object's visual aesthetics and form.

aesthetic influence/inspiration

In order to provide something tangible to work from, beyond the technological function and experience of the object, the designers identified a number of possible visual influences for the design of the object's aesthetics. These were generally defined as: Traditional Eastern Dance Culture/Aesthetics; Middle Eastern Architecture/Detailing and Islamic Art/Sculpture/Textile Design. A number of 'mood' boards were subsequently developed to provide visual referencing material to aid the design process. These particular sources of inspiration were selected based on their cultural relationship to the possible context of 'snake charming'. It was acknowledged, however, that any referencing to these concepts in the physical design would need to be approached very sensitively, allowing the *Snake* to nurture its own aesthetic qualities.

the 3D form

As pointed out the physical, three-dimensional form of the *Snake* was largely dictated, prior to establishing the brief, by technological decisions and limitations. Hence, it was already established that the *Snake* would be constructed from a series of disc-based 'vertebrae', each containing three pneumatic actuators. In the early prototype however (as shown in Figure 2), the discs themselves had been made from acrylic and were circular in form – each one being identical in size. Based on the inspiration material developed, the decision was made by the designers to change the basic shape and size of the discs. The existing identical circular discs of the object, the designers felt, limited the potential aesthetic qualities of the object and made it appear somewhat sterile and standardised. A number of full-scale models were consequently developed to test a variety of possible shapes and sizes for the basic 3D object (see Figure 3).

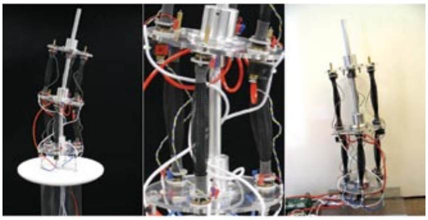

Figure 2

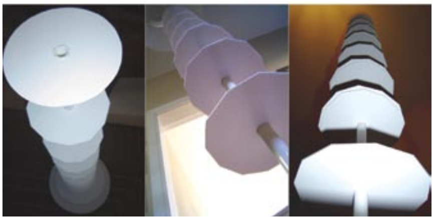

Figure 3

After discussions within the *Snake* team regarding these early prototypes, a number of decisions were made relating to the 3D form of the *Snake.* Firstly, due to anthropometric data and transportation restrictions, the robot would now only have 9 'vertebrae' and not 10 – making the total height of the object now approximately 1.8 metres. At this slightly smaller height, the object could be accommodated in a variety of different spaces, and would not (it was hoped), intimidate or overpower its audience/user through its scale.

The second major decision that was made regarding the object's form was to increase the size quite significantly of the lower discs (the bottom now being as big as 440mm in diameter) and to graduate the discs smaller towards the top of the object – to reach the much smaller size of 160mm disc diameter at the top. This, it was felt, would give the 3D object a richer, more fluid and sculptural quality, which may compliment its interactive kinetic nature (see Figure 3). Furthermore, it was also identified in the brief that "the overall aesthetic and experiential qualities of the outcome should (as far as we could define this within such a project), be 'delicate' and 'sensitive' with a certain level of 'finesse'." The team also felt that this new form helped to create such a 'visual aesthetic'.

Alongside this change in size, two other major decisions were made by the team regarding the basic 3D form – in an attempt to create the desired aesthetic qualities in the object. The first one was that the bottom disc was now to be a 'dodecahedron' shape rather than a circle, and the graduation from the bottom up would also be in form and size. Hence, the discs would now morph in shape from a full dodecahedron at the bottom to a full circle at the top. Again, the aim here is to create a form with movement, and dynamics within the 3D object itself, which would compliment its experiential qualities. It has also been decided, in an attempt to further enhance the aesthetic qualities of the object, to look into the potential of sandblasting the acrylic discs, again following similar gradient/morphing principles employed within the form.

In light of the above, the intent is to give as much consideration as possible to the technological/mechanical detailing of the object and to consider the possibility of detailing or 'hand crafting' any physical engineering components or 'finishing parts'. Hence, it is acknowledged that the final outcome may be one of deliberate 'over-design/over-detailing' to possibly 'charm the *Snake'.*

sustainability of use

The final issue that was identified by the designers as something that, at the very least, should be considered in the design of the *Snake*, was the question of the object's 'lifespan' or 'lifecycle'. Within the context of product design, the issue of sustainability is now an integral part of the design process – particularly within the context of technological products.[26] Hence, when viewed from a product design perspective, there are a number of important questions that could be raised regarding this issue. Firstly, what happens to the object over time, could it age gracefully for example? Secondly, and perhaps of most relevance – how is the object to be disposed of after use – could it have an afterlife?

Although it is fully acknowledged by the designers that these issues aren't necessarily integral to the successful development of the *Snake* and its aesthetic/experiential qualities, it was felt that this could, (if integrated sensitively within the design), provide another 'meaningful layer' to the object. Hence, after discussion regarding these issues the following concept was developed regarding the *Snake* and its 'sustainability of use': throughout the process of the development of the final object, the *Snake* team would attempt to retain any components of the final design whose use had 'expired' during the development process. Each component would then be clearly labelled with their expiry date and reason for failure, with the final intention of providing a secondary sculpture (made from these components) alongside the 'live exhibit'.

At the time of writing this paper, a full-scale prototype of the basic 3D form is under construction. However, it is acknowledged that the physical manifestation of the object at this stage, may once again, initiate further changes to its design. The design and development process of this object to date, however, has revealed a number of interesting points, particularly regarding working methods/roles and responsibilities assumed within the project.

From a (New) Product Design perspective working within the 4D design framework, such high focus of attention on the development of the physical 3D 'static form' against a predefined 'design criteria', could be seen as the designers simply working within their traditional practice models. Hence, despite working within an interdisciplinary team, the question as to whether the product designers here have simply done what they always did, i.e., specify and design a static object in response to the client's needs (whom in this case can be said to be the choreographer/leader of the project), does need to be raised. However, this notion is challenged if we look at the deliberate 'open-ended' nature of the brief itself that was developed by the *Snake* team and the acknowledgement that this was only a preliminary 'working document' to 'kickstart' the project. Furthermore, the development of a physical prototype of the 3D form, to be used by the interdisciplinary team to externalise/ visualise and to a certain degree 'test' some of its 'four-dimensional elements' within a selection of its intended audience/users, further extends existing working boundaries. Hence, from this perspective, it could be argued that a new model of product design may be starting to evolve here – one which enables design to operate more as a 'facilitator' of a 'continuous process', rather than simply as a definitive manufacturing process.

the aesthetics of technological exchange

At this stage in the project, there has been limited development regarding the nature of technological exchange between the technological object that is the *Snake* and the user. Largely, this part of the project will be influenced by the choreographer, the control technologist and the company supplying the technology; since the development of the software programming used to control the *Snake*, the types of human presence that the *Snake* detects, and the way that it interprets this presence is specific to those disciplines.

However, whilst the previously outlined process may not require direct design scrutiny, there are certainly parts of this development where it will be imperative that design consultation and consideration takes place; in order for the technological object to successfully embody the design rationale. This is predominantly concerned with providing technological design interventions that prevent transparent or simulated experiences. In his book, *The Transparency of Evil,* Jean Baudrillard describes these types of experiences by questioning the relationships between man and machine. He writes:

> Am I man or machine? There is no ambiguity in the traditional relationship between man and machine: the worker is always, in a way, a stranger to the machine he operates, and alienated by it. But at least he retains the precious status of alienated man. These new technologies, with their new machines, new images and interactive screens do not alienate me. Rather they form an integrated circuit with me.[27]

Here, Baudrillard refers to new types of digital interaction as a diminished experience of reality, where our relationship with technology may be one of seduction. He further illustrates how such technologies conceal processes and often make decisions on our behalf. In this example, according to Baudrillard, we may well become 'part of the interaction', but we certainly do not 'interact'.

One of the challenges of the *Snake* project is, however, to attempt to provide a design language that does not conceal the technology (and the subsequent knowledge associated with this understanding) to a degree where it cannot be easily accessed by the user, while at the same time enabling the robotic structure to function effectively. For example, some of the technological considerations regarding the types of interaction and levels of 'exposing' those interactions as well as the physical positioning of the technological components, wiring, electronics, etc. will need to be considered in order to fulfil that rationale. The level of balance and any compromise required in design interventions between these components and the object's aesthetic presence is at this stage unknown and will need to be established through the process.

2.4 What is the Rationale of the Project?

critical design

As discussed in the previous section, when trying to describe some of the desired experiences, there are varied aesthetic design factors that also support the rationale and development of the project. However, many of these experiences (such as the decision to 'decorate' the physical nuts and bolts of the *Snake* object with pattern) are in fact already limited by the overriding practical requirements imposed on the project (such as the necessity to have nuts and bolts in order to hold the *Snake* object together). Whilst these design decisions are often a direct result of the emerging physical realisation of the *Snake* object and the restrictions that the technicality and physicality of the object impose, they are also determined by the previously defined design approach that seeks to underpin all design decisions during the course of the project.

The approach explores the boundaries and potential of a new design language associated with the development of work involving the inter-relationship of people, objects, information and space (technological objects). The aim is to provide evidence of research that might support a future for alternative forms of 'interface' (new design language) for technological objects.

Most designs for complex technological objects are typically driven by the desire to make the technology understandable/saleable - which is essentially a 'styling' job for the designer; more often than not resulting in the physical manifestation of a case, body or shell that hides the technology (circuits, networks, electronics, etc.) in order to create a product that is useable, appealing and profitable. Whilst we may accept that it is the role of commercial design to generate capital in this way, we must also understand that perhaps design research should question the role that these products play in our lives. This too includes the need to explore the way that the complex (and popular) language of products may be mediating our experience of the world.[28] While there is some very good design research concerned with the exploration of new types of interfaces which explore the potential to achieve a level of design language that does not simply 'wrap up' beautiful and complicated technology, so people cannot interact with it and learn from it[29] – there are few examples of such product design research resulting in practical or commercial solutions that go beyond that of mere hypothetical suggestion.

One such example of Product Design research that does go beyond mere hypothetical suggestion is Daniel Weil's *Radio in a Bag* produced at the RCA in 1983. At this time, designs for radios were commonly plastic cases that housed (covered up) radio technology (circuits, electronic components, etc.). With *Radio in a Bag,* Weil actually succeeds in exposing the electronic components of a basic AM radio by simply placing them in a transparent bag. The radio still functions as a radio, but because it does not conceal the technology – it also enables increased access to the potential knowledge associated with the new understanding of how the radio functions. On a very basic level, this visual exposing of the technology enables the user to at least observe the technology, perhaps even make judgements about it/react to it, before actually using it.

However, while *Radio in a Bag* is one example of a commercial product that exposes its technology by presenting its electronic components – it does only manage to expose the 'physicality' of radio technology and does not provide any further understanding of the part of the electromagnetic spectrum in which radio-wave technology exists. Radio is part of the electromagnetic spectrum which is out of the white light frequency and therefore, out of human sight. Consequently, this design does not offer any new design tools that may provide access to potential knowledge and understanding of how the 'invisible' radio technology functions.

Furthermore, since this type of basic AM Radio was produced twenty-four years ago (and at that time required a limited number of technological components to function), the task of exposing those components in such a way is much simpler than that of the more complex, (often networked) technological objects of today. As electronic technologies continue to emerge at an increased rate, so does the existing gap between the design tools/languages we develop and the potential of those tools/languages to prevent transparent experiences and interactions.

passive interaction

With the increased use of electronic technology, objects, systems and operations now frequently cross between the physical and virtual. The rapid miniaturisation of technology has not only catapulted tiny (often invisible) computers into almost every object, but perhaps, and more importantly, computing and telecommunications has also given rise to a new breed of 'intelligent' and often incomprehensible, multi-faceted 'social organisational mechanisms'.[30]

The emergence of these technologies bring with them the promise of increased experiences, and more free time thanks to a new type of 'interaction' with technology that is much quicker, easier and efficient than previous methods involving communicating with people. The reality, unfortunately, is often quite different and any cynic who has recently tried to contact their utility company or speak to their bank will probably have experienced the mundane and bureaucratic experience that is the result of our fantastic new technology. The irony is that this exclusion made possible by 'user-friendly' design methods may be encouraging a type of 'passive interaction' alienating people from their environment.

Paul Virilio, in his book *The Art of the Motor* (1995) describes this type of passive interaction between human and 'intelligent' technology as an unbalanced relationship, where the human is always a slave to the technology. He writes:

> [the] so-called 'interactive user-friendliness'…is just a metaphor for the subtle enslavement of the human being to 'intelligent' machines; a programmed symbiosis of man and computer in which assistance and the much trumpeted 'dialogue between man and machine' scarcely conceal the premises:…the total, unavowed disqualification of the human in favour of the definitive instrumental conditioning of the individual.[31]

Current forms of user-friendly design methodologies for human and technological interactivity often exclude the potential of human and technological engagement by reducing it to that of mere function. Unfortunately, because this type of approach taken by the design community is so popular, it is difficult to find good examples of design-related work that challenge the user-friendly design methodology. There is little consideration given to the wider issues regarding the potential socio-cultural effects of such interaction methods by designers and sadly still too much of this endeavour is left to sociologists, anthropologists and cultural theorists.

There are various good examples[32] of practical design work which offer contemplations for products that are located in a cultural context and there are also some rare theoretical perspectives evident in Thackara's recent books *Design After Modernism*[33] and *In the Bubble.*[34]However, to understand the more complicated cultural significance of such practice, the work of cultural theorists/thinkers proves more revealing than that of much design-related work.

The manifesto for the 'user-friendly' design approach (led by the Human Factors community[35]) is that the implementation of 'invisible' or 'transparent' interfaces should make for an easier user experience of (complex) technological exchange. However, this process, driven by profit, is often carried out in relatively short time frames and in isolation of any contemporary cultural framework.[36] Products are developed according to whether or not they meet practical or financial ends and therefore little consideration is given to whether those ends are culturally desirable. There is a danger that the nature of this approach does not enable sufficient dialogue with any potential consequences of those ends, nor does it provide examples of design solutions or possible scenarios for alternative futures and experiences. Ultimately, it is of concern that this approach may result in a diminished experience of reality, since the aim here is not to 'explore' the potential of both human and technology, but to 'harness' it.[37]

The *Snake* project, being outside of 'commercial design' constraints, provides an opportunity to explore the potential for an advanced dialogue between people and technology, encouraging a type of 'active interaction' that may enable individual expression and subsequently enrich the human experience. This involves the exploration of new types of interfaces for technological objects that could expose the complexity and potential of the technology, and in turn, heighten awareness of this technology. This may require the need to implement 'clever' design (that prevents transparent use) by 'alienating' people from the product in such a way that they 'observe' it as a product from which they can learn, as well as using it?

PART THREE: CONTROL SYSTEM DESIGN: A PROBLEM OF CONTROL
by Philip Breedon

As explained in Part Two, the *Snake* project has been a considerable challenge for typical Product Design working methods, yet its open-ended character also stimulated ideas that could lead to new ways of thinking about Product Design in general. Given the importance of precision, accuracy and relevance of detail to the development of 'efficient' technological products, the open-ended character of the *Snake*'s research process has challenged even more deeply how technological issues were identified, defined and approached. However, it is important to emphasise that this challenge did not concern or affect the technical procedures or techniques regularly employed in the area of control technology. Rather it opened up numerous possibilities to reflect upon assumed relationships between principles which currently underline typical working methods in this area. The project gave the team (and the technologist in particular) the opportunity to see and conceptualise new relationships between these principles, directions, priorities and ultimately meanings as these crystallised around the emerging object during the research. Following a highly complex interdisciplinary process, this conceptual shift eventually reinforced a more 'efficient' use of control technology in this project, which was consistent with its crucially open-ended character and successfully captured in its brief.

At this juncture, it is important to clarify that some of the questions asked by the choreographer and the product designers, such as 'What is the experience?' are meaningless for the particulars of technological research, whereas others such as 'What is it?' or 'Who is it for?' have no effect on the principles which support the technological mechanism. Replies to such questions only refer to the specifics of the materialisation of an underlying technological concept rather than the very nature of the concept itself. When these questions kept being asked by the choreographer and the product designers during the development of the *Snake*, the technologist was not expected to reconsider the protocols of his working methods and techniques. His main challenge was to remain committed to these practices whilst revisiting previously unquestioned assumptions about the principles behind them. Part Three introduces a series of points about this delicate aspect of the project and explains how existing working methods in control technology were revisited in ways which encourage the development of technological objects with open-ended character and exploratory purposes as opposed to those which fulfil pre-determined purposes and precisely specified criteria.

3.1 PRECISION AND COMPLEXITY

Day to day problems faced by the human race can potentially be both complex and ambiguous; individuals face and address these everyday problems subconsciously in a complex real world. Humans have the ability to apply approximate reasoning to complex issues, allowing them to gain an understanding of a real problem whereas at present computers are not capable of addressing these complex and ambiguous problems.

Lotfi Zadeh's principle of incompatibility reads as follows:

> As the complexity of a system increases, our ability to make precise and yet significant statements about its behaviour diminishes until a threshold is reached beyond which precision and significance (or relevance) become almost mutually exclusive characteristics.[38]

Ross provides a simple graph relating system complexity and model precision.[39] (See Figure 4.)

Figure 4 shows that for systems with little complexity mathematical expressions can provide a precise system description. For systems that have significant amounts of data but are more complex, model free methods may be

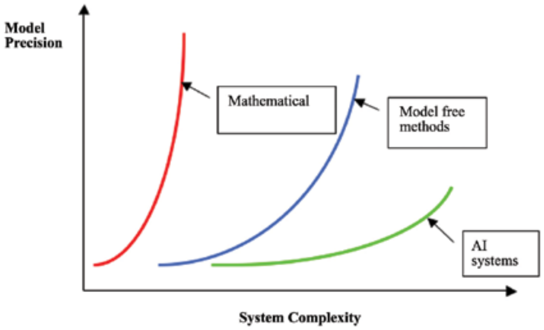

Figure 4: System complexity versus model precision.

employed, ANN (Artificial Neural Networks) being a good example. This type of system reduces uncertainty via learning based on data patterns. For complex systems where numerical data may be sparse and only imprecise information may be available 'fuzzy reasoning' can provide a solution to system behaviour based on the correlation between system inputs and outputs.

A human operator responsible for a defined process is able to cope and adjust to non-linearity that may be present within a system, resolving conflicts and allowing for slow variants in order to satisfy performance criteria. Problems arise, as the actions of the human operator are difficult to model due to variances. These variances may be fatigue, inconsistency, reliability and other errors. 'Intelligent' control could provide the positive attributes provided by the human operator whilst at the same time removing the factors that are detrimental to the control process.

3.2 ROBOTIC SYSTEMS

Robot control systems can be considered complex systems and the design of the controller involves determining the dynamic model for the system. This in itself can be a complicated task due to non-linearity, multiple axes or degrees of freedom control, and the constantly changing working environment.

Problems arise when the theoretical model produced for such a system does not exactly match the actual working environment of the system under control. When developing a controller using conventional techniques a design scheme has to be produced, usually based on a model of the system. In addition, kinematics equations must be derived to represent both the environmental and physical boundaries of the system. Original point-to-point robotic systems rely on a closed loop feedback system using both velocity and position information.

One of the main problems with conventional control lies in the inability to correlate the inputs and outputs of the system using mathematical modelling techniques, which may be either too complex or too large to compute in real time.

3.3 CONVENTIONAL CONTROL METHODOLOGIES

Two basic control system structures exist for the control of dynamic systems:

- open loop control
- feedback control (closed loop control)

The main difference between these two structures is that feedback control has a sensor monitoring the output variable as part of the feedback loop, see Figures 5 and 6.

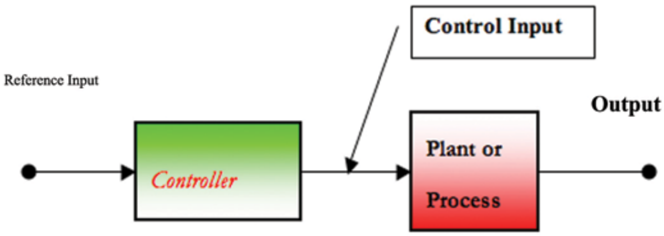

Figure 5: Open loop control system.

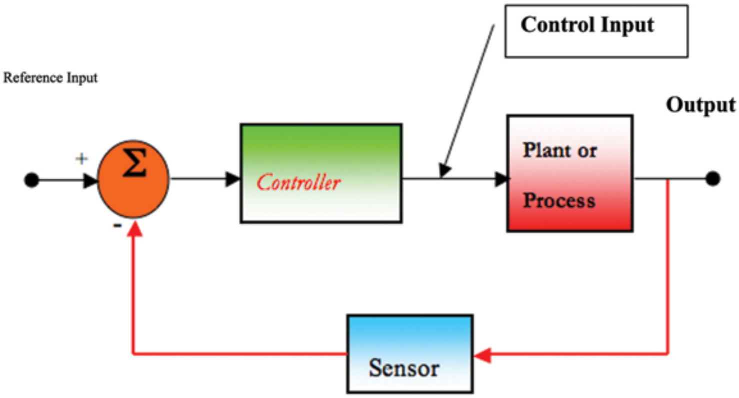

Figure 6: Feedback control system (closed loop).

3.4 CLASSICAL THREE-TERM CONTROL

The classical three-term Proportional Integral Derivative (PID) controller is by far the most commonly used control algorithm. According to Åström and Hägglund (1996), PID is widely used for industrial control applications with 90 – 95% of all control problems being solved by this type of control.[40]

The PID control action is generated as a sum of three terms, the control law being described as:

$$u(t)= u_p(t) + u_I(t) + u_D(t)$$

where u_p uI uD are the proportional, integral and derivative elements respectively.

The first of the three elements of this classical controller on its own, i.e. proportional feedback control, may allow a non-zero steady state error, but can reduce error responses due to changes in the system environment. Proportional feedback can also increase response times but results in an increase in transient overshoot. The inclusion of a term proportional to the integral of error will eliminate the steady state error but will have a direct contribution to the deterioration of the dynamic response of the system. Finally, the inclusion of the final element expressed as a proportional to derivative term can have the effect of damping the system dynamic response.[41]

Multi axis systems are generally controlled using proportional-integral-derivative (PID) algorithms; problems arise, however, as many practical systems are mathematically complex and very difficult to model.

3.5 ADAPTIVE CONTROL

Conventional control techniques often fail when an appropriate model is difficult to obtain due to the sheer complexity or unpredictable variances within a system. With adaptive control, compensation is made for parameter variations by continually monitoring and adjusting the appropriate parameters in order to satisfy the system performance criteria. Adaptive control algorithms can provide a solution to non-linear control but can soon become mathematically complex as system variables increase. In addition, these algorithms are not always suitable for real time systems.

To understand some of the basics surrounding control and feedback systems we must briefly revisit some of the basic elements of control system design, as the robot *Snake* may be considered to be a complex system. Ross[42] described the seven basic steps in designing a controller for a complex system:

- Large-scale systems are decentralised and decomposed into a collection of de-coupled subsystems.
- Variations in plant dynamics are assumed to vary at a slow rate.
- Non-linear plant dynamics are linearised locally about a set of operating points.
- Sets of state and control variables or output features are available.
- Simple P, PD, PID or state feedback controller is designed per subsystem.
- Controller design should be designed optimally, based on the control engineer's knowledge.
- Introduction of a supervisory control system provides additional benefits in allowing for effects of variations caused by unmodelled dynamics.

In addition, a number of assumptions should be made when the appropriate control system is to be considered for a solution:

- A control solution exists.
- 'Plant' is observable and controllable.
- A solution may be acceptable but not necessarily an optimum solution.

3.6 ROBOT *SNAKE* – MUSCLES, CONTROL AND SENSOR SYSTEMS

Interactive sculpture movements will be closed loop (feedback) controlled and will use a form of rectilinear motion, but instead of the 'typical' snake-like comparable horizontal motion, this motion will be relative to the vertical plane. The two stage model has been built to examine the feasibility of the design. Initially three pneumatic muscles have been fixed centrically between discs to create the individual vertebrae. Simple control of individual muscles provide the appropriate 'tilt angle' for each individual vertebra.

Originally it was considered that the pneumatic muscles that would be utilised within the design would all be of uniform diameter. A large bending force on the lower 'vertebrae' would be created when the sculpture effectively 'forms' more 'severe' positions. Therefore the probability will be that the lower muscles will be of an increased diameter in the lower sections of the sculpture. This provides the required support; in addition the muscles also provide the extra energy required to move the upper sections when more 'load demanding positions' are introduced as dictated by the overall position of the interactive sculpture.

Ten individual vertebrae will be linked vertically to form the final interactive sculpture. Pneumatic muscle and hence individual vertebrae pitch and roll control is achieved via a dedicated PC interface and the respective control software. The pneumatic muscles that will be used for the sculpture are shown in Figures 7 and 8.[43]

Ultimately a series of ultrasonic proximity sensors will be utilised to provide the appropriate control feedback and hence movement of the sculpture. Ultrasonic sensors will be investigated as a method to feed back to the control

Figure 7: Pneumatic muscle 'activated'.

Figure 8: Pneumatic muscle 'deactivated'.

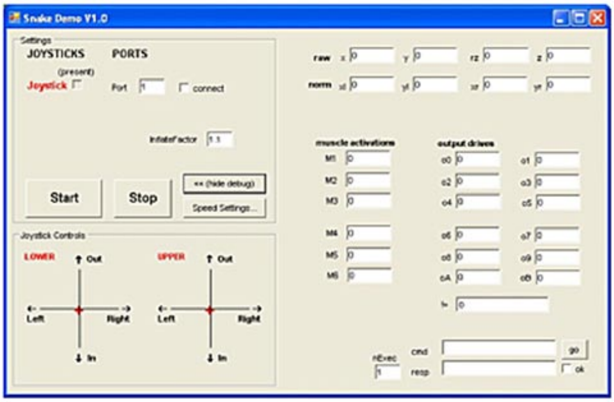

Figure 9: Simple user interface - parameter set up and debugging.

system providing proximity information in relation to anyone 'approaching' the sculpture. The sensors will supply a proportional linear voltage to the input of the control interface, and hence the voltage level being dependant upon the proximity of an object/person relative to the sculpture.

A simple user interface will be utilised to 'explore' the movement of each individual vertebra. This will enable speed, motion and range of movement to be examined for the whole sculpture. This interface also provides a useful tool for development of the relative programme subroutines which will ultimately control the robot. The simple user interface for manual control is shown in Figure 9.

3.7 WHAT IS A ROBOT?

There has been much discussion recently in terms of the use of the word 'robot' and the very interaction of these 'machines' with humans. Bill Gates in his recent article in *Scientific American* writes:

> Although a few of the robots of tomorrow may resemble the anthropomorphic devices seen in Star Wars, most will look nothing like the humanoid C-3PO. In fact, as mobile peripheral devices become more and more common, it may be increasingly difficult to say exactly what a robot is. Because the new machines will be so specialized and ubiquitous – and look so little like the two-legged automatons of science fiction – we probably will not even call them robots.[44]

C Evans-Pughe[45] examines current robotic research work and questions robot bodies being self aware, suggesting that robots tell us more about humans; and C Biever informs us that "robots are gaining the ability to encourage us emotionally, giving them a much broader range of uses".[46]

3.8 A TECHNOLOGICAL 'ROBOT'?

A control system can monitor and affect the operational conditions of a *system* by adjusting the *input* variables and consequently directly affecting the output variables of the system.

Biomimicry or biomimetics is a scientific and technical discipline finding inspiration from biological systems to define new engineering solutions and allows us to extend the concept of controllers to more *complex systems*. Correlation can be made with the natural world where individual organisms appear to be equipped with controllers that adjust their internal environment to maintain a stable, constant condition, by means of numerous adjustments and controlled by interconnected regulation mechanisms.

Both manufactured and natural systems demonstrate collective behaviour amongst individuals in which the control systems seek some form of stability. Stability in relation to control systems is extremely important, and is often associated not just with control but also system safety.

The stability of a system relates to its response to an input(s) or disturbance. A system which remains in a constant state unless affected by an external action and which returns to a constant state when the external action is removed can be considered to be stable (see Figure 10). System stability can be defined in terms of its response to external inputs.

- The system stability can also be defined in terms of bounded or limited inputs.
- A system is stable if its stimulus response approaches zero as time approaches infinity.
- A system is stable if every bounded input produces a bounded output.

With a closed loop system the output is continually monitored, usually to ensure that the 'desired response' is achieved. It will be critical to produce a 'bounded' system for *Snake* robot control, however programming alone will not finally define movement patterns. 'Ultimate' control will be based on multi sensor input, the 'desired response will be affected' by other control and input parameters.

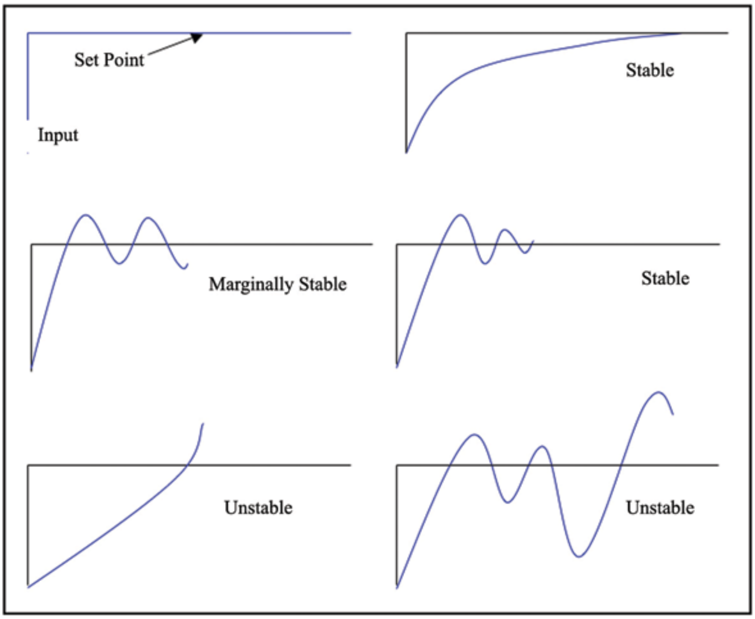

Figure 10: System stability.

3.9 THE DESIRED RESPONSE?

The 'interesting unknown' in trying to create the 'desired response' is, does such a response exist? When a programmed output based on sensor feedback moves the robot stages to a particular position an additional element and input to the feedback loop will be from the monitored stress induced in each lower muscle. If system parameters deem this to be too great a stress the command will be automatically modified to keep the movement bounded and prevent damage to the robot. This provides an element of the unknown.

Ultimately each movement of the robot will have a dedicated programmed subroutine to control an individual movement based on sensory input, but control and ultimate overall movement will be overridden by the safety control of the system within selected muscles. A combination of inputs from the ultrasonic sensor array combined with the pre programmed safety system input parameters will dictate that ultimate robot 'reaction' and movement. This movement cannot be predicted.

CONCLUSION

by Sophia Lycouris

Object, technology or movement? The interactive sculpture *Snake* is a complex combination of all three, and the result of an interdisciplinary research project which explores the limits of three different disciplines: choreography, product design and control technology. An expanded notion of choreography, which foregrounds the use of energy in dance and is primarily concerned with the communication of kinaesthetic experiences outside traditional theatre spaces, offers multiple possibilities for audiences to engage in 'active' viewing and become physically/bodily involved with the work. From the perspective of design, the element of movement changes the traditional character of the object (sculpture) as static and re-invents it as a dynamic four-dimensional entity, which manifests itself both in space and through time and develops evolving relationships with its users. The *Snake* wants to be playful, have initiative and surprise the viewer, thus generating a number of interesting challenges in relation to the development of appropriate supportive technology. But as Philip Breedon explains in the third part of this article, technology has not managed yet to discover how to reproduce human qualities. So the *Snake* cannot be programmed to have initiative in an 'accurate' manner, yet it can remain playful through constantly negotiating the instructions of its interactive mechanism with the limitations of its robotic structure. This could be perceived as a technological failure, however in an interdisciplinary context the freedom to push the boundaries of traditional disciplinary assumptions opens up unexpected possibilities for the creation of both new 'objects' and underlying concepts; indicating in this way that the participating disciplines can serve purposes beyond their recognised limits.

1 *Snake* became part of *Emergent Objects,* a portfolio of projects led by Professor Mick Wallis at the University of Leeds (UK) which aimed to explore design processes through the lens of performance during 2007 (http://www.emergentobjects.co.uk). *Emergent Objects* received funding by the UK's Engineering and Physical Sciences Research Council (EPSRC) and the Arts and Humanities Research Council (AHRC), as part of their joint initiative 'Designing for the 21st Century' (http://www.design21.dundee.ac.uk/).

2 The name *Snake Robot* was reduced to *Snake* when the project was invited to be part of the *Emergent Objects* project.

3 For a detailed account of this debate please see Lycouris, S (2000) "The documentation of practice: framing trace". *Working Papers in Art and Design 1*, http://www.herts.ac.uk/artdes/research/papers/wpades/vol1/lycouris2.html (last accessed on 27 May 2007).

4 Liz Aggiss in Alan Bullock & Oliver Stallybrass (eds), *The Fontana Dictionary of Modern Thought* (London: Fontana Press, 1977), 124.

5 Laurence Louppe in Laurence Louppe et al.., *Traces of Dance,* trans. by Brian Holmes (Paris: Editions du Voir, 1994).

6 George Balanchine in Anatole Chujoy & P W Manchester (New York: Simon & Schuster, 1967), 202.

7 Lois Ellfeldt, *A primer for choreographers* (London: Dancebooks, 1974).

8 Guy Brett, *Force Fields: phases of the kinetic* (London, Hayward Gallery, 2000), 2.

9 Please see sci/art symposium at http://www.primitivestreak.org.uk/

10 Poet Dave Wood is based in the area of Derbyshire (UK).

11 Over the past decade there has been an increasing trend towards the development of products based on more hypothetical design criteria. Such work is generally constructed within a future context and framed within a particular scenario. The main purpose and role of such designs is to act as a critical tool for debate and discussion regarding particular future social issues of concern and to identify potential threats or opportunities of new technological developments. For a leading example, please see www.dunneandraby.co.uk (last accessed on 20 October 2007).

12 John Thackara is a leading design theorist and academic and founder of the international, highly regarded design conference, "Doors of Perception". Thackara's selected works include the classic design critique, *Design after Modernism*, and his more recent publication, *In the Bubble*.

13 See J Myerson, "Crucial Timing". Available at: http://nelly.dmu.ac.uk/4dd//ct.html (last accessed on 15 May 2007).

14 Ibid.

15 A Robertson, "4D Design Futures: Some Concepts and Complexities". Available at: http://nelly.dmu.ac.uk/4dd//guest-ar.html (last accessed on 15 May 2007).

16 For further reading on '4D Dynamics' please see ibid.

17 Unfortunately, traditional educational structures have always been forced to 'pigeonhole' specific design disciplines (essentially for marketing purposes) within particular subject areas and schools. Whilst Product Design's historical links to the engineering/manufacturing fields is now starting to be renegotiated, its link to the 'built environment', appears to remain integral and somewhat overriding. Whilst there are many interdisciplinary links that can be made between architecture and product design, the absence of more fundamental working relationships between the fields of information design, choreography and the more 'interactive/performance-based' practices (the disciplines that the field of (New) Product Design should now harness), is having a profound effect on the richness of the experiences of new products developed and the progression of the (New) Product Design discipline itself.

18 Throughout this paper the term '(New) Product Design' is used to draw attention to the fact that the role and meaning of the product design discipline is currently in transition, with any 'New' models of practice identified not yet firmly established.

19 Usmen Hague is an architect specialising in the design and research of interactive architectural systems. Haque has undertaken an extensive number of projects exploring the territory of architecture as a "dynamic, responsive and conversant" event. See www.haque.co.uk for further information on his projects.

20 U Haque, "The choreography of sensations: Three case studies of responsive environment interfaces". Available at: http://www.haque.co.uk/papers/choreography-of-sensations.pdf (last accessed on 18 May 2007).

21 By the client or person delivering the project.

22 Traditionally markets were classified in terms of their socio-economic groups or personality types. More recently, however, groups of consumers are increasingly identified according to their particular lifestyle affiliations. This is a model which exists outside of constraints dictated by socio-economic 'class' and personality type – and one based on lifestyle affiliated groups and patterns of consumption.

23 Even in the more critical, hypothetical design projects that exist outside the commercial constraints (again see www.dunneandraby.co.uk for a leading example of this type of design) the development of a tangible future 'user-based' scenario is an integral part of the design project – providing essential criteria for the development and manifestation of the final products.

24 Particularly within the commercial framework, where the designer's primary role is to develop products which are 'consumerable', despite any ethical or socio-political issues that may prevail through such activity.

25 Although it is fully acknowledged that it is impossible to draw a line between the boundaries of art and design practice, and there are many designers (particularly those who practice within the more conceptual design context) whose work sits very comfortably within the artistic framework. See www.studioball.co.uk for an exemplary example of this.

26 From July 1st 2007 in the UK any business that manufactures, brands or imports electronic products are responsible for the cost of collection, treatment and recycling of obligated Waste Electrical and Electronic Equipment (WEEE). See www.weeecare.com for more information on this compliance scheme. Such directives are long overdue, when we observe established models of electronic waste recycling schemes like those in Japan; in which the cost of recycling goods must by law be incorporated into the retail price.

27 Jean Baudrillard, *The Transparency of Evil* (Paris: Verso, 2002), 58.

28 For an accessible discussion on some potential types of mediation, see A Dunne, *Hertzian Tales* (London: RCA, 1999). This book includes many examples of how this mediation may occur and is a unique and challenging insight; exploring a potential for product design to assume a critical and cultural position.

29 Ibid.

30 See Jamie Billing & Tracy Cordingley, "Some Kind of Analogtivity: anti-simulation through design", *Personal and Ubiquitous Computing*, 1(2), January 2006, 101-105.

31 Paul Virilio, *The Art of the Motor* (Minneapolis: Minnesota University Press, 1995).

32 In particular, the work carried out by students and staff working within the Interaction Design and Design Products departments at The Royal College of Art. Available at: http://www.designproducts.rca.ac.uk (last accessed on 15 May 2007) & http://www.interaction.rca.ac.uk (last accessed on 15 May 2007).

33 John Thackara, *Design After Modernism* (London: Thames and Hudson, 1998).

34 John Thackara, *In the Bubble* (Cambridge, MA: MIT, 2005).

35 The Human Factors community consists mainly of Engineers and Scientists. For further reading, please see cognitive psychologist, D Norman, *The Psychology of Everyday Things* (New York: Basic Books, 1998).

36 Cultural framework here referring to the complex and intertwined sociological relationships between people, objects, technology and the way this affects culture. Not simply the relationship between people and the way they interact with or consume technology, etc.

37 However, it seems that the UK government is becoming aware of this. Through its Office of Science and Innovation, in particular the "Horizon Scanning Centre" (www.foresight.gov.uk/horizonscanning), as part of "Sigma Scan" and "Delta Scan", it commissions a huge amount of pioneering research regarding current emerging technologies; resulting in the publication of approx 360 'scans' of possible future scenarios since 1995 (see www.sigmascan.org and www.deltascan.org). Also a recent initiative (Science Horizons), aims to engage the public regarding the possibilities of new science and technology futures, through various forms of dialogue and discussion. See www.sciencehorizons.org.uk for more information.

38 Lotfi Zadeh, "Outline of a New Approach to the Analysis of Complex Systems and Decision Processes", *IEEE Transactions Syst., Man. and Cybernetics,* Volume SMC 3, 1973, 28.

39 TJ Ross, *Fuzzy Logic with Engineering Applications* (Columbus, OH: McGraw- Hill, 1995), 2.

40 KJ Åström & T Hägglund T in Levine W S (ed.), *PID Control: The Control Handbook* (CRC Press, 1996), 198.

41 Ibid.

42 Please see note 38.

43 These parts as well as appropriate sensor technology and supporting software are provided by Merlin Robotics based in Plymouth (UK). For further information about Merlin Robotics, please see http://www.merlinrobotics.co.uk/merlinrobotics/

44 Bill Gates, "A robot in every home", *Scientific American,* January 2007, 51.

45 C Evans-Pughe, "Masters of their fate?", *Engineering and Technology,* April 2007, 26 – 30.

46 C Biever, "If you're happy the robot knows it", *New Scientist,* March 2007, 30.

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Tracy Cordingley is a Senior Lecturer in Product Design at Nottingham Trent University (UK) and has worked across a wealth of different design disciplines from furniture and product design to new media and graphics. Tracy's current research explores new synergic models of experience between virtual systems of information and physical environments.

Dr Sophia Lycouris has been a Reader in Interdisciplinary Choreography at Nottingham Trent University (UK) since 2003 and was recently appointed Director of the Graduate Research School at the Edinburgh College of Art, Edinburgh, Scotland (UK). Her current research is concerned with the use of interactive technologies in interdisciplinary choreographic projects and the role of choreographic approaches in interdisciplinary projects which address issues of movement in social and public space.