Spiral Jetty and Systems Theory

(This is an extended version of the talk and is a paper in progress reporting on thought in process; as such it is opened ended)

Introduction

Coming to Utah to document the appearance of the Spiral Jetty represents the end of my thesis on Art History and Systems Theory

Spiral Jetty is also where I began my thesis.

In October 1999 a conference held at the Courtauld institute in London and jointly organised by Jonathan Harris and Eric Fernie posed the question – which I have attempted to situate my own research in relation to - *Has art history changed over the last 40 years?*

There were a number of answers to the question involving the many and varied methodological twists and turns that the discipline had responded to in the latter half of the 20th Century.

The list of how Art History may have changed in response to influence from outwith its borders is, I am sure, familiar to us all, regardless of what discipline we study –

Psychoanalysis Marxism (late and post, take your pick), Critical Theory, Anthropology, Post-structuralism, Feminism, Visual Culture Studies, Museology.

But Art History also faced a specific threat to its method that came not from without its specific borders but from within…

This internal conflict concerns the means and methods of artistic production which have also taken place in the last 40 years, that is to say Art after Modernism,by which is meant art that calls the autonomy of the monadic modernist art work into question.

In other words – another reason that Art History may require a dramatic shift in its modus operandi – lies in the fact that the object of its analysis – that is to say artistic practice has itself also undergone a dramatic shift in that there has been a move in emphasis away from the single object into more complex engagements with the artistic institutions which surround and support the practice of artistic production and reception.

This move is exemplified in the work Spiral Jetty hence making it an ideal starting point for a thesis on such matters. This is because it presents major problems to the tried and tested methods the art historian has at their disposal

Art history has a rich history – of what Podro calls the Critical Historians of Art – that is a largely Germanic history of Kunstwisschenschaft (systematic study of art history)

This includes Wolfflin's analysis of art based on Formalism, Riegl's based on style, Panofsky's humanist method based on iconography and Gombrich's psychological investigations into the work of art as a mode of representation.

Parallel to this history of art history we also see the related discourse of Bildwisschenshaft (study if visual culture) which is currently undergoing a revival as a 'cure' for the limited vision of Art History.

Yet both studies hit something of a brick wall in their attempts to deal with this <IMAGE> complex artwork.

This is because Art History and Visual Culture Studies deal with discreet objects, be this the artwork, or the object of visual culture, in terms of their visuality – that is they attempt to account for the work in terms of the way it looks.

Spiral Jetty, I would argue, doesn't fit into such schemes. However this is not unique to the Jetty but it does provide an excellent example both
1 – because it is complex (we might even call it a system)
2 – because of its physical intransigence

Looking for Spiral Jetty
In 1972 the brackish waters of the salt lake rose to submerge Robert Smithson's Sculpture.
This created a problem which most art historians will have to face at one point or another in their career - the loss of their object.
And there is an outstanding question which emerges from the submersion - Does The Spiral Jetty still exist?

In his edited companion to the work of Robert Smithson Robert Hobbs gives the following physical description of the location and composition of Spiral Jetty - 'Spiral Jetty, Rozel Point, Great Salt Lake, Utah, April 1970; Mud, precipitated salt crystals, rocks, water; coil 1500 ft long and 15 ft wide.'[1]

But this is not the whole story.

Spiral Jetty is a complex work. Different aspects of it include:
The Sculpture in the Salt Lake, which Smithson completed in 1970; the 35 minute 16mm film which Smithson made; the Essay Smithson wrote about the essay; the photographs taken by Smithson and Gianfranco Gorgoni of the work and its creation; the sketches Smithson made in preparation; the performance of the work's creation, and so on., and so on.

Given the multiple sites (and non-sites) which offer themselves up for critical attention in Spiral Jetty the problematic of how to prioritize becomes the central feature of the way in which the work is approached. As Owens observes:

'Like the nonsite the Jetty is not a discreet work, but one link in a chain of signifiers which summon and refer to one another in a dizzying spiral. For where else does the

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[1] Hobbs, *Robert Smithson; Sculpture*, (1981, ref.) pg. 191

Jetty exist except in the film which Smithson made, the narrative he published, the photographs which accompany that narrative, and the various maps, diagrams, drawings, etc. , he made about it? Unintelligible at close range, the spiral form of the Jetty is completely intuitable only from a distance, and that distance is most often achieved by imposing a text between viewer and work… That Smithson thus transformed the visual field into a textual one represents one of the most significant aesthetic "events" of our decade; and the publication of his collected writings constitutes a challenge to criticism to come to terms with the textual nature of his work, and of postmodernism in general. That challenge is formidable, since it requires the jettisoning of most of our received notions about art; it can only be acknowledged here.'[2]

This reading of Spiral Jetty follows Owens' own political agenda and his prioritization of the textual forms part a polemic application of the literary form of Post-Structural critique within the visual field of art history. It may be observed that Owens' politicized application of the strategies of deconstruction took place at a particular historical moment. It may also be claimed that the wake of the waves of deconstruction which crashed upon the island shores of Art History have abated somewhat. Nevertheless the central challenge which Owens identifies which Spiral Jetty presents to Art History remains. This is a challenge which goes to the very heart of Art Historical method and calls its very reliance upon visuality and iconography into question. For if, as Owens states, Spiral Jetty is but one link in a chain of signifiers which are not only visual but textual, aural, oral and even olfactory, then how is it that we as Art Historians approach it? It would seem that the Art Historian's trusty apparatus of formal analysis and visual iconography - of doughty detective work and sleuthing in the archives to find things that look like other things
Like spirals, circles and shoes
- will not work in the face of a work which will, by its very complex nature, resist such easy simplification. This is because with work such as this it is the very visuality, upon which the method of iconography, relies is itself up-for-grabs. Central to this challenge is the questioning of the structural form of iconography itself. This challenge involves an interrogation of the positing of a discreet, direct and logical symbolic correspondance within the visual icon (or sign) to that which it signifies.

Given this complexity the key questions to ask of this complex system - Spiral Jetty - is not only what is being represented? But - how is the work representing? And also - How is the work itself represented?

In approaching these questions I hope to show a further demonstration of the application of a Systems Approach to art historical problems to that which I have investigated elsewhere in my thesis.

Spiral Jetty as a Complex System
Let us first remind ourselves of some of specific terminology which I'm seeking to apply.

[2] Craig Owens, 'Earthwords', *Beyond Recognition*, (University of California Press, 1992), pg. 47

Firstly – an aspect of systems theory concerns its interdisciplinarity. IE – its principles can be applied within many different spheres to identify complex systems at work within different spheres of activity.

Examples of this include:
Weather systems – butterfly flapping its wings causing a tidal wave.
Economic Systems – W. Brian Arthur and VHS vs Betamax example
Models of Consciousness – models of Artificial Life and Intelligence

Spiral Jetty as a Complex System
Let us first remind ourselves of some of specific terminology which I'm seeking to apply.

The key word here is Complexity. Complexity suggests that the whole is greater than sum of parts – as Coveney and Highfield say in Frontiers of Complexity – 'in order to understand the value of money, we should stare at dollar bills.'
So too – in order to understand how Spiral Jetty works we shouldn't stare at Spiral Jetty.

Spiral Jetty is identified as a complex system in so far as it is a System as Ackoff defined it in 1960 -
'The term system is used to cover a wide range of phenomena. We speak, for example, of philosophical systems, number systems, communication systems, control systems, educational systems, and weapon systems. Some of these are conceptual constructs and others are physical entities. Initially we can define a system broadly as any entity, conceptual or physical, which consists of interdependent parts. Even without further refinement of this definition it is clear that in systems research we are interested only in those systems which can display activity - that is behavioural systems.

'The essential characteristic of a behavioural system is that it consists of parts each of which displays behaviour. Whether or not an entity with parts is considered as a system depends on whether or not we are concerned with the behaviour of the parts and their interactions.'[3]

This idea that a systems approach is characterized by an inter-disciplinarity which is founded upon isomorphic systems principles shared amongst diverse complex systems gives a legitimacy to its application within Art History.

And Spiral Jetty is identified as a complex system in so far as it is complex as Luhmann defined it:
'when the number of elements that must be held together in a system or for a system as its environment increases, one very quickly encounters a threshold where it is no longer possible to relate every element to every other one. A definition of complexity follows from this: we will call an interconnected collection of elements "complex" when, because of immanent constraints in the elements' connective capacity, it is no longer possible at any moment to connect every element with every other element. The concept of "immanent constraint" refers to the internal complexity of the

[3] Ackoff, 'Systems, Organizations, and interdisciplinary Research', *General Systems Yearbook*, vol. 5 (Society for General Systems Research, 1960), p3

elements, which is not yet at the systems disposal, yet which makes possible their "capacity for unity". In this respect, complexity is a self-conditioning state of affairs; the fact that elements must already be constituted as complex in order to function as a unity for higher levels of system formation limits their connective capacity and thus reproduces complexity as an unavoidable condition on every higher level of system formation. Leaping ahead, we may hint at the fact that this self-reference of complexity is then "internalized" as the self-reference of systems.'[4]

This idea that it is impossible to relate every element to every other one except by virtue of their interconnectedness suggests that complexity is about unity of system as a whole which is greater than the sum of the parts.

In other words a complex system demonstrates behaviour which is unpredictable and which can't be quantified by an atomic analysis of the separate constituent parts of the system as discreet elements. Thus the whole of the system is a separate theoretical entity which cannot be described purely in terms of its interactions of interconnected parts. This is the idea that complex system display emergent properties which arise from out of their structural organization.
[This came up in relation to fractals].

Representation in complex systems
In order to demonstrate the manner in which Spiral Jetty represents in the manner of a complex system we could look at the way in which we can apply the model of representation within complex systems to the way in which Spiral Jetty as an artwork both represents and is itself represented.

The function of representation within complex systems can be illustrated by looking at other complex systems to see how they represent and then looking for a common ground. Two complex systems in particular are instructive. They are -
1 - Thought, which can be mapped using Cognitive models
and
2 - Language, which can be mapped using Linguistic models

Both cognitive and linguistic systems are involved in the representation of the world. Systems of thought represent the world with regards to epistemological representation; and systems of language with regards to linguistic representation. Also in both cognitive and linguistic models both language and epistemology are taken to be profoundly interconnected
(e.g. - explain Language of thought models, Chomsky, Fodor[5]?).

Further, both models provide us with demonstrable examples of how the application of complexity and a systems approach provides us with models which can account for the Dynamic ordering and chaotic complexity of both the biological system of the human brain and the social system of linguistic expression. These examples also provide us with examples of where a Systems approach, or a strategy which

[4] Luhmann, *Social Systems* (ref.) pg. 24
[5] One of the most complete defenses of this position can be found in - Fodor, *The Language of Thought*, (Thomas Y. Crowell, 1975) - whereby the argument is advanced that thought is based on the symbolic logic of syntactic structures and semantic ordering.

acknowledges complexity and emergence, brings a new conceptual paradigm to proceedings.

Models of Intelligence and complex systems

The application of complexity to the problem of models of intelligence (which grew in research profile during the 1980's[6]) provoked and ongoing and increasingly fierce debate within the Artificial Intelligence (A.I.) research community between two differing models of cognition. One is based on formal, symbolic logic as the basis for mental representation; I will argue that this approach can be seen as Iconographic in its outlook. The other side of the debate feature a defence of cognitive models based upon complex, connected or what is called Distributed Representation. Complexity provides a way of thinking about how the mind might work in a different way to a computer

In other words rather than functioning upon a system of formal symbolic logic - in an iconographic fashion, like a computer - it might be a complex, dynamic and connected system.

It is this idea of Distributed Representation (within complex systems) which form the central focus of my argument with regards to suggesting that Spiral Jetty is a complex and Distributed system of representation.

[[See pg. 76-7 Pinker and Price Cognition.] There are three ways to conceive of the debate regarding the impact of connectionism on cognitive modelling.
1 - That it can be used to replicate symbolic processing in a biologically plausible way; in this sense the 'language of thought' idea is retained but is implemented upon a connectionist system.
2 - The connectionist system augments the symbolic language of thought model and fills in the gaps by providing, for example, a description of how systems might learn in a self-determining fashion but without the need to jettison the symbolic 'language of thought' notion altogether.
3 - The Connectionist models replace the symbolic/logical 'language of thought' models of cognitive architecture and the concept of representation itself. This radical approach is what Cillers would argue in his attempts to provide a synthesis between connectionism and post-structuralism at the linguistic and epistemological levels.
For me the jury' still out on whether we can, at the moment, reach a final conclusion with regards to the implications of connectionist models. Nevertheless, what is clear is that the very existence of such models is forcing us to think about the way the mind works and to provide biologically plausible models of that operation. Such plausible models suggested by connectionism will account for the dissimilarity between the von-Neumann computing machine of G.O.F.A.I. in which the mind is taken to be like a computer running the software of thought, and a biological system of interconnected elements from which intelligence may be seen to emerge out of complexity]

2 Models of Artifical Intelligence

[6] references

Regardless of the models used to achieve the aim the central aim of artificial intelligence is to provide a model of human cognition (this being the model with which we are most familiar). The aim of this is to provide:
1 - an explanation of human consciousness
2 - The theoretical possibility of generating an 'Artificial' (that is non-human) consciousness of some description.

The basis of Modern, western philosophy is, as Descartes observed in explaining how we bridge the epistemological gulf between internal mental life of apperception and the world of mind independent reality. Descartes obeserves:
'Nature also teaches by these sensations of pain, hunger, thirst etc., that I am not present in my body merely as a pilot in a ship; I am most tightly bound to it, as it were mixed up with it, so that it and I form a unit.' [7]
[Descartes' celebrated idealist intercession of the rationalist soul with the physical world was achieved through the Pineal Gland[8] which mediated between the two worlds of the mental and the physical. Such Cartesian dualism is epistemologically unsatisfactory and it is an uncontroversial claim to assert that the successful modeling of the mind must provide us with a physical account of mental life and that we should not rely upon positing a mind/body split with a physical body being seen as ontologically distinct from mental activity and the apperception of a metaphysical soul/sprit.]

The task of artificial intelligence is, then, to find the physical basis of mental activity and to model it using an non-human (or artifical) technology. Thus, if we can ever make a machine 'think' then three questions are thrown up:
1 - What is the physical support of this 'thought'?
2 - What is the nature of this 'thought'? (is it, for example, what Roland Penrose has called 'a very human prerogative'?[9])
3 - What form does this 'thought' take?

In doing so we can conceive of cognition as the act by which the world (whatever this may be) is represented in the mind of the subject.

If it feels as if we are diverging from the argument at this point then what is suggested is that this definition of complex systems and their representative capacity, which we are ultimately seeking to apply to Spiral Jetty, finds another expression in models of how the mind works. By looking at the mind as a complex system it is suggested an understanding of how cognitive representation takes place can be formulated. Models of cognition which argue that the mind is a complex system suggest that it is a Distributed System of Representation and that mental activity is distributed over the whole cognitive system rather than being located in one particular area of the brain.

Mapping the Mind

Put very simply; the human cognitive system is a network of neurons. That's what the soft-machine (to use a William Burroughs term) of the brain is. These neurons are single cells which operate in conjunction with one another by transfer of electrical

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[7] Descartes, 'Meditations on First Philosophy' Section 6, *Philosophical Writings*, Ed./Trans. Anscombe & Geach, (Nelson University Press for The Open University, 1970) Pg. 117.
[8] Descartes, *Traité de L'Homme* 1664, (ref. required here)
[9] Penrose, *The Emperor's New Mind*, (ref.) pg. 3

current and it is by this current that the biological system of our body is able to communicate with itself and, hence, think. Each one of these neurons is connected with up to 10,000 other neurons within the system via axons which transmit information and dendrites which receive information. The meeting point between the transmitting axons and the dendrites are the synapses. And these synapses are mediated, chemically, by neurotransmitters. 1 neuron by itself is almost insignificant and cannot 'think' by itself. Any significant form of mental activity requires the firing of millions of these neurons at once to generate thought.

In other words there is a physical basis for 'the mind' and this is a complex, biological system or interconnected cells. Here are two examples which demonstrate the grounding of consciousness in the complex biological physical system of the brain. The way psycho-active drugs work is by interfering with the activity of these neurotransmitters and in doing so altering thought patterns and hence perception. This provides us with an example of the impact a physical process can have on mental life. Here is a more particular example[10].
In 1998 surgeons at the University of California Medical School, using a 16 year old epileptic girl, applied a tiny electric current near to a part of her left hand side of the brain. This part was known to be related to humour. It was where Franz Gall, the founder of Phrenology, had located what he called the Organ of Mirthfulness[11]. The current caused the girl to laugh. When they asked her what was so funny she just said, 'you guys are just so funny - standing around.' When the applied the current again the girl found the picture of a horse in the room hilarious, and again, a third time she was amused by something else. What this example demonstrates is that a genuine human emotion, humour, can be explained by a physical cause in the cognitive system of the brain.

But, despite identifying a physical basis for thought as being grounded in this complex network of interconnected neurons there are various models for describing the ways in which that physical system thinks. As mentioned earlier representation provides us with ways of conceiving of this activity.

Classical Representation
When the discourse of artificial intelligence first began to emerge (in the early 1940's)[12] the brain was taken to operate and thus represent in the same way as a computer. This approach to cognitive modeling has been called both Classical Representation and Good Old Fashioned Artificial Intelligence - or G.O.F.A.I..
Both names, which one finds are often used interchangeably, provide a means of distinguishing this approach with the Distributed model of cognition we find in Connectionist models. These Distributed or Connectionist models of cognition bring a conception of the ways in which information is represented differently in complex systems to the question of cognitive representation. This approach, which I will call the Iconographic Approach, can be critiqued from a Systems perspective.

Early attempts to map the mind relied upon an understanding of computers based upon the von Neumann machine. The machine created by Hungarian mathematician John von Neumann (date - 40's) was a prototype digital computer and most

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[10] Nature, 1998, [Pg. 11 Carter, *Mapping The Mind*]
[11] Carter, *Mapping the Mind*, pg. 11
[12] Some footnote references required here.

computers today can be identified as conforming to the same van Neumann architecture. This architecture consists of a central processing unit which does the raw data processing of the machine according to principles of symbolic logic; that is bits of information have a symbolically representative function. This logical processing unit is the C.P.U. (central processing unit) of the computer. Secondly this C.P.U. works in parallel to an area of memory where information can be stored rather than symbolically interpreted. This area of memory can be accessed rapidly and at random and it does not need to be accessed sequentially (like information on a tape would have to be[13].) This Random Access Memory (or R.A.M) thus uses information in a non-semantic sense and provides it for the C.P.U. to semantically order.

The von Neumann machine works by storing instructions - the software - as binary values (1's or 0's, or the states of connections being either on or off). These binary values , (the 1's or 0's) are the raw data of the system and they are the instructions which are run, sequentially via the central processing unit. This data gains its symbolic, logical form relative to both its syntactic and its semantic ordering; the syntactic ordering corresponding to the order in which they're placed and the semantic ordering relating to the symbolic correspondence to their referents.
To reiterate - these computers function through the operation of a sequence of symbols presented to the central processing unit and its subsequent operation according to its particular, logical, interpretation of the symbols. In effect the von Neumann machine is an iconographic system.

[Putnam argues this in 1988 (See Cilliers pg. 60)]

This model of the sequential, logical symbolical processing machine, when applied to how the mind works leads to a conception of the mind as, in effect, a wet von Neumann machine as GOFAI[14] argues then the mind operates in the following way. A dualism is posited between hardware and software. On the one hand we have the physical hardware which provides the architectural support for the logical operations of the system. In the computer this would be the hardware of the computer system and in the human brain the hardware is the biological soft-machine of gray matter. On the other hand we have the software or the language of thought which is the set of logical rules to be run on that hardware. This language of thought operates at a distinct logical level from the hardware. In the classical view of cognitive representation thought emerges because a type of software is being run on the brain.

Thus each 'thought' that the system has is taken to correspond to a particular logical function operating upon a particular part of the system. Hence each 'thought' is generated via the turning on of a bit of the system. GOFAI relies upon there being a symbolic correspondence between thoughts and the objects of those thoughts. And in contrast to the virutal engrammes of Classical Representation, Smolensky [15] notes that in the connectionist model of distributed mental representation each 'thought'

[13] hence difference between the von Neumann architecture and a Turing Machine which runs on a sequential tape.
[14] In their connectionist models of cognitive architecture Rummelhart and McClelland have claimed that they are attempting to 'replace the "computer metaphor" as a model of the mid with the "brain metaphor."' Rumelhart & McClelland, 'on learning the past tenses of English verbs.' In Rumelhart, McClelland and the PDP Research Group (Eds.), *Parallel Distributed Processing, Volume I,* (M.I.T Press, 1986), pg. 75.
[15] Pg. 4 Boden - follow up reference

generated by the system is not the result of the turning on of one bit of that system, or the implementation of a particular, discreet piece of data. Instead in a distributed system of representation the whole system must be on and each thought is distributed over the whole of that system.

The Language of Thought - Mental Iconography
Models of Classical Representation are based upon both a particular conception of mental representation and computation which are, essentially, iconographic in structure. The key issue here is that there is a direct correlation posited between the specific data processed by the cognitive system and mental representation. This symbolic correlation between thoughts and particular configurations of information means that we can identify classical mental representation as an Iconographic model of thought. Classical representation is iconographic in so far as the model is based upon the positing of a rational correlation between signifier (in this case the semantic/syntactic ordered information) and the signified (the mental representation or thought). This rational correlation is mediated by the symbol system, or the logic of the language of thought.

In this model cognitive systems are modeled as computational systems whereby thoughts are physical 'states' of the system and are expressions of a particular semantic and syntactic ordering of information. These physical states are thus the symbolic representation of particular thoughts. This could be called computational in so far as Cummings observes - 'The system merits inferential characterization because it computes representations of conclusions from representations of the corresponding premises.'[16] And, hence - 'The basic assumption of orthodox representationalism is that under proper interpretation, formal symbol crunching is cognition.'[17] In other words a thought is conceived of as a program, a set of instructions or an algorithm which is run on the hardware of the brain and is understood by virtue of the symbolic language of thought.

Another way to look at this would be to invoke the idea of Engrammes and suggest that Classical Cognitive representation relies upon virtual engrammes. Engrammes are an old-fashioned way of thinking about the mind as a library. [They formed the basis for Warburg's library as memory project in both his library and the Mnemosyne] Engrammes are the physical bits of the brain where particular memories would be stored. Thus if in the library if we burn down floor 11 then we'd have no Art Historical memory, similarly in the analogy of the engramme, if we lose the physical bit of the brain where we store our memory of horses then we will have no memory of horses. The classical approach is not an unsophisticated as to suggest that there is a particular physical location of every memory in the brain - it does not argue that we could point to the horse bit of the brain. However virtual engrammes form the basis of the Classical (G.O.F.A.I.) approach to cognitive modeling. This is because specific semantic and syntactic orderings of information, or precise data-strings, correspond, iconographically, to particular thoughts.

The major problem with classical models of classical representation lies in their basis upon the Engramme form. And until the Distributed models of Cognition based upon complex systems emerged in the 1980's models of the mind viewed the mind as a

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[16] pg. 94 - philosophy and connectionist theory
[17] pg. 95 - Philosophy and Connectionist Theory

Physical Symbol System which was governed by rules of symbol manipulation[18]. Such models are

Brittle, non-dynamic, complicated, no common-sense, don't learn.

As a result of these shortcomings such systems are characterised by their inability to deal with language as it is spoken and understood by humans. Language is not necessarily ordered and rational but is itself a complex, dynamic and fluid system full of redundancy and ambiguity. Language is not an expert system for describing the world in a discreet (i.e. non-redundant) manner, and there is no direct and unchanging, iconographic, symbolic relationship between the system of language and the objects it describes. Words can mean different things at different times and in different contexts. Similarly there is not an unchanging, symbolic and logical relationship between a language of thought and the content of that thought. Classical representation is not an effective model for describing the way in which complex systems store and represent information. It is a logical, linguistic and, I would tentatively suggest a structuralist approach to cognitive modeling.

What is Distributed Representation?
The best way of describing a distributed system is to provide an example. Ants provide a great example of a distributed system.
This is an example which Eric Bonbeau presented at the O'Reilly Emerging Technology conference in Santa Clara - in the middle of last month. [May 2002]
For several years Bonabeau has been studying insect systems for examples of what he calls Swarm Intelligence from the Sante Fe Institute in New Mexico [which is center of complexity research]. He's arrived at some examples of how an collective system of individually stupid ants (or other insects such as termites) can perform complex teleological tasks (that is tasks with a collective purpose).[19]
The example Bonabeau provided is how a system of ants may find food in a maze. Bonabeau argues that the colony as a whole will eventually find the shortest route to the food. Given a collection of hungry ants (they must, Bonabeau observes be given a collective reason to find food) in a maze, they will all wander about in a generally random way; this is because each single ant is pretty stupid. However, given their random, non-rational, distribution throughout the maze. Some ants will find the food. Ants communicate with one another through pheromones[20]. Thus on finding the food source and wandering back through the maze they leave a trial of these pheromones for other ants to smell. Those ants to arrive at the start of the maze first are, obviously, the ones who took the shortest route and will have left the strongest scented pheromone trail as it has had less time to evaporate. The remaining ants will be naturally drawn to the strongest pheromone trail and thus the ants will be drawn back again and again to the shortest route to the food. The striking thing about this system is that it contains within it the potential to remain dynamic and can learn future routes

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[18] The phrase 'physical symbol system' is attributed by Rumelhart to Alan Newel. See 'Preface', ed. Ramsey, Stich, Rumelhart, *Philosophy and Connectionist Theory*, (Lawrence Erlbaum Associates, Inc., 1991) pg. xi.
[19] References to Bonabeau's work required here.
[20] Pheromones are 'Chemical substances secreted by an organism that elicit a behavioural response from other organisms usually of the same species, especially substances that act as sex attractants.' Uvarov & Isaacs, *The Penguin Dictionary of Science*, 7th Edition (1993), (Penguin Books, 1993)

should they present themselves. If any ants should randomly find a better route then the system can adapt to this; the way to the food isn't fixed.

The ants are a connectionist system. And despite their individual stupidity they could be argued to have a collective, or Swarm Intelligence. In his book Out of Control: the New Biology of Machines, Social Systems and the Economic World, Kevin Kelly calls this the Hive Mind.
'Ants, too, have hive mind. A colony of ants on the move from one nest to another exhibits the Kafka-esque underside underside of emergent control… The marvel of "hive mind" is that no one is in control, and yet an invisible hand govers, a hand that emerges from very dumb members. The marvel is that more is different. To generate a colony organism from a bug organism requires only that the bugs are multiplied so that there are many, many more of them, and that they all communicate with one another. At some stage the level of complexity reaches a point where new categories like "colony" can emerge from simple categories of "bug". Colony is inherent in bugness implies this marvel. Thus there is nothing to be found in a beehive that is not submerged in a bee. And yet you can search a bee forever with a cyclotron and flouroscope, and you will never find the hive.'[21]

If we consider the ants to be a complex system then we can conceive of the path which they find to be a representation, and in doing so the power of this analogy becomes present. The path within the maze to and from the food is a representation of the optimum path to and from that food.

Connectionism argues that our brains are like the ant colony. A distributed system of representation represents by virtue of aspects related to its complexity; these aspects are - non-linearity and interconnection. Like the ant colony a distributed system of representation is a network of interconnected elements. This interconnection is a parallel interconnection in so far as the separate elements can function simultaneously and do not have to work sequentially (in contrast a linear set of functions which must be executed one after each other.) It is because of this simultaneous interconnectivity that the operation of the system cannot be understood as a discreet sequence of rule based activities, but rather that the way that any part of the system operates and any particular representation within the system must be conceived of in terms of the functioning of the whole of the system.

In Frontiers of Complexity Coveney and Highfield give the following description of complex models of A.I.;
'Artificial neural networks mimic the brain's complexity through their non-linearity and a high degree of interconnectivity among their nodes. Like the brain, they are inherently parallel devices that can do many things concurrently. Qualitatively, their processors behave like neurons and the connections between them act like synapses. Any "programming" of such a net consists of rules to alter the all important strengths of connections between processors. And the "programs" that solve various problems emerge within such networks spontaneously.'[22]

A connectionist cognitive architecture is based upon a network of interconnected nodes, or meeting points. The links between the nodes are referred to as being

[21] Kelly, *Out of Control*, (Perseus Books, 1994), pg. 13
[22] Coveney and Highfield, *Frontiers of Complexity*, (ref. req.), pg. 302

Weighted. In a distributed system of representation information is shared by the whole network rather than being specifically located. Thus the information of the system is remembered and distributed over the system by the different weights of the connections between the nodes (or neurones) within the system. The Weight of an interconnection corresponds to the amount of information that each connection carries. A weight can have a positive or a negative value depending upon whether the connection assists or inhibits the flow of information between the nodes. Thus as Cummins states:
'The state of the network at a given time is revealed by the pattern of activation at that time, that is, by specifying the activation level of each node at that time, and by the connection weights.'[23]

As a result of this representation and memory by differing weights between nuerones a certain 'thought' generated by the system is expressed as a pattern within the system. This pattern, or output, is a function of the weights of the connections within the network. We can think of these weights as being like the pheromone tracks of the ants with strong weights representing the shortest path to the food by a strong smell of pheromones and weak weights corresponding to a low smell.

Network Learning
The above example of the 'weighting' in a distrbuted network provides another distinction between Connectionist and Classical systems with regards to how they 'learn'. In contrast to a Connnectionist system a system of Classical representation 'learns' by being given information from an external source in the form of a different program (algorithm) to be run on the hardware. A classical system treats memory as increased data in so far as there is more information provided about a particular symbolic (iconographic) representation.

To compare this with a connectionist system let's consider the example of the ants again and how they 'learnt' to find their food. If we were to give the same problem to a classical, or iconographic, system , then the representation of the optimum path would have to be presented to the system symbolically from an external source in order for the system to 'learn' that path. It would need to be told the optimum path and then iconographically represent this path according to its own symbolic logic.

In contrast the connectionist system of the ants 'learns' the path through self-determination. It 'finds' the solution. Similarly a connectionist model of cognition (such as a neural network) treats memory in terms of the changing and irreversible structure of the whole representative system. A connectionist cognitive architecture learns not through the processing of more information but rather through an interaction with its environment during which time the environment changes the system and hence its output/patterns of representation, just as more and more of our ants found the best way to get to and from the food in the maze.

As well as providing a plausible model of cognitive activity with regards the complex biological system of the brain the connectionist model also provides a useful account of how such systems can learn and how such learning has significant effects upon future thought.

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[23] Cummins, 'Representation in Connectionism,' in *Philosophy and Connectionist Theory*, ref. required, pg. 95

As we have seen the information being represented by the network at any particular time is the pattern distributed over the connections of the whole system at that particular time. Also, because representation is a corollary of a pattern at a given time the pattern is temporally specific. This means that the pattern representing the system's state and hence the output of the system is dependent upon the previous state of the system. As a result of this the system can be said to have learnt according to its previous state. Hence it can be said that a complex, interconnected system of representation, by virtue of its temporal specificity and its irreversibility, can be said to have a memory.

A distributed network 'learns' by changing the weighting structure and by changing the strengths of the interactions between the nodes a different pattern will be produced given the same input. By comparing and then changing the weighting pattern for any given input in relation to an expected or required output.
To reiterate, there is a clear distinction between classical and connectionist accounts of representation in relation to how these systems learn. This difference is that in
1 - orthodox, classical, iconographic, systems - learning is just another set of rules being run on the same system. in other words the architecture itself remains unaltered but the information circulating with the system changes.
2 - in Distributed or Connectionist systems - learning, and hence producing different representational content in response to particular inputs, means that the patterns within the system are themselves altered. The ants follow a different path. The system changes by the weights of the nodes changing which means that the system itself changes to meet the demands of producing different representational output.

(E.g. - Rumelhart & McClelland, have shown how a virtual connectionist system can be taught to 'learn' the English past tense of verbs and convert the present into the past tense in both regular and irregular verbs. The striking claim that Rumelhart & McClelland made of their model was it was given no specific rules for learning and that in the learning process that it duplicated some of the mistakes which children actually make[24]. Rumelhart & McClelland's model is critiqued extensively by Pinker & Prince and Fodor &Pylyshyn[25])

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Let us end this comparison of Iconographic and Distributed systems of representation by noting a potential criticism of connectionism which also throws its epistemological significance into relief. As Fodor & Pylyshyn (et al.) have argued - as a cognitive model for all its talk of distribution connectionism doesn't account for the fact that there is a rational language of thought and that language itself, through which we express that thought is logical, symbolic and iconographic.

However the major impact of the post-structural critique of language and rationality lies in the questioning of the direct and logical symbolic correspondence of the signifier and the signified in favour of a fluid, dynamic free-play of signifiers mediated by their temporal difference (to use the Derridian term) from one another.

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[24] Rumelhart & McClelland, 'on learning the past tenses of English verbs.' In Rumelhart, McClelland and the PDP Research Group (Eds.), *Parallel Distributed Processing, Volume I,* (M.I.T Press, 1986), pg. 75.
[25] Both critiques appear in *Cognition*, 28, (1988)

As Cilliers has noted in his discussion of the common ground shared between complexity and poststructuralism- 'A distributed representation is not a representation in the conventional sense of the word. It dispenses with all the components of a representational system. There are no symbols that 'stand for' something, there are no grammatical relationships between them, and the system itself has no need of a semantic level of interpretation at all. We need neither a central processor nor an outside observer.'[26]

I.e. - distributed representation is not iconographic in its form in so far as there is no discreet correspondence between signifier and signified which is mediated by the structural logic of the form of the sign (Sausurre).

Here are some distinctions between
Iconographic Thought - vs. Connectionism and the hive mind
1 - G.O.F.A.I. - Symbolic correspondence between thought and objects. Complicated - Expert Systems - Data - logic - rules - inference engine - brittle - no 'common sense' (i.e. no capacity for self-determination and learning) - Iconographic representation.
2 - Connectionist systems - No quantifiable correspondence between thought and objects, success of system expressed in terms of input and output -non-iconographic - Distributed representation - Complex - Pattern - memory - adaptable - self determination - learning.

CONCLUSIONS 1 & 2
[still in progress; are conclusions plausible?]

Conclusion (I) - Spiral Jetty is a distributed representation

In 1972 the brackish waters of the salt lake submerged the Spiral Jetty. And so we come back to the question where we began - does Spiral Jetty still exist? And as we also posed at the outset this question can be couched in terms of representation and we can ask of Spiral Jetty only
what is being represented?
But also - how is the work representing?
And also - How is the work itself represented?

[I'm sure you can see where this is going]
As we saw in cognitive systems, a distributed system of representation because representations are distributed over the whole system, and do not reside in a single part of the system. Hence mind as connectionist system demonstrates memory in a connectionist manner. Part of brain destroyed doesn't correspond to the loss of a particular memory (see Fodor and Pylyshyn pg. 52). Instead due to distributed nature of the representations when damaged connectionist systems display what is know as 'gentle degradation' of their representations.

This conclusion therefore invokes Owen's observation

[26] Cilliers, *Complexity and Postmodernism*, (ref.) pg. 27

that 'Like the nonsite the Jetty is not a discreet work, but one link in a chain of signifiers which summon and refer to one another in a dizzying spiral.'
in the light of the complex system of Spiral Jetty

Conclusion (II)
I'm going to conclude here by revisiting a theme which I discuss elsewhere in the thesis and which forms, arguably, the central underlying concern of the whole project to apply of the concept of complex system within the arena of art history.

This underlying concern is the interconnection between different orders of representation. In the argument above they are:

1 - Particular Epistemological models - or ways of representing knowledge about the world.
Complex systems - Deconstruction
2 - and particular cognitive models - accounts of the ways in which that knowledge is represented to the conscious subject
Complex Systems - Connectionism
3 - Particular artistic activities - again concerned with methods of representation
Here I've used the specific example of Robert Smithson's engagement with complex systems.
4 - Particular art-historical activities - or the ways in which those artistic acts of representation are themselves represented.
Complex systems - the attempt to see artistic and art historical activity from the critical perspective of a systems approach

However, I'm *not* arguing that this interconnection which I've posited between Epistemological, Cognitive, Artistic and Art-Historical models is peculiar to the systems approach which I am suggesting.

We can observe another example of this matrix of representational systems in history.

As Panofsky famously argued, The Renaissance model of Single Point Linear Perspective (as exemplified by Alberti's model in Della Pittura 1435[27]) could be taken as a representation of a particular Cartesian epistemology or, as Panofsky states, that it is the Symbolic Form of Renaissance knowledge[28]

Hence the interconnection between
1 - An epistemology - Cartesian
2 - A cognitive model - world represented in mind according to single, sovereign subject

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[27] Leon-Battista Alberti, *On Painting*, trans. Grayson, intro. Kemp, (Penguin Books, 1991)
[28] This argument has been taken in different directions by different writes - Damisch, *The Origin of Perspective*, (ref.); Holly, *Past Looking*, (ref.); Edgerton Jr., *The Renaissance Rediscovery of Linear Perspective*, (Harper and Row, 19760; Elkins, *The Poetics of Perspective*, (Cornell University Press, 1994); Moxey, 'Perspective, Panofsky and the Philosophy of History,' *New Literary History*, 26, (Autumn, 1995,) pg. 775-86; Goldstein, *The Social and Cultural Roots of Linear Perspective*, (MEP Publications, 1988). And arguably Panofsky's identification of Perspective as a 'seeing through' the picture plane (taken from Durer's reading of the Latin 'perspectiva') with a particular order of knowledge can be equated with Foucault's identification, in *The Order of Things*, of the 'transparency' of classical representation; the analogue of which he famously identifies in *Las Meninas*.

3 - artistic model - perspective
all of which have their analogue in the Panofskian, art historical method of iconography.
Discreet and rational representations

And, Smithson's art is used here as an example of artistic practice which we may refer to, variously as -
non-iconographic; non-perspectival; contingent; post-humanist; anti-cartesian
and which therefore, I argue, requires a different art-historical method in order to be effectively accounted for. I'm just looking for ways in which to do this.

Or as Coveney and Highfield state in their book Frontiers of Complexity - 'in order to understand the value of money, we shouldn't stare at dollar bills.'[29]

[29] Coveney & Highfield, *Frontiers of Complexity*, (ref.) pg. 320