

Emergence and the art system ‘plus minus now’

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Emergence is discussed in the context of a practice-based study of interactive art and a new taxonomy of emergence is proposed. The interactive art system ‘plus minus now’ is described and its relationship to emergence is discussed. ‘Plus minus now’ uses a novel method for instantiating emergent shapes. A preliminary investigation of this art system has been conducted and reveals the creation of temporal compositions by a participant. These temporal compositions and the emergent shapes are described using the taxonomy of emergence. Characteristics of emergent interactions and the implications of designing for them are discussed.

Keywords: aesthetics, creativity, perception, user participation, emergence

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This paper presents a new view of interaction by considering emergence in the context of a practice-based study. Emergence occurs when a new form or concept appears that was not directly implied by the context from which it arose. The paper focuses on the design, classification and evaluation of emergent interactions in an art system called plus minus now. It begins with a summary of prior work framed by an artist’s practice-based approach to art and research. Emergence is defined and a new taxonomy of emergence is proposed. The art system plus minus now is discussed in terms of its artistic aims and its relationship to emergence. This includes a novel method for instantiating emergent shapes. It is followed by a description of a preliminary study of participant interaction with plus minus now. The taxonomy is then used to classify the different kinds of emergence that occurred during interaction with plus minus now. Finally some design issues for enabling interactive, emergent experiences are presented.

1 Background

Plus minus now is the third iteration of a series of art systems created by the first author. The first art system *Glass Pond* was completed in 2005. The second system *Silicon Rainbows* is a close variation of *plus minus now*. Both were completed in 2007. The series of art works and accompanying research has been conducted at the Creativity and Cognition Studios.

The three systems share the conceptual background of being a response to a particular place. This place can be briefly described as a natural setting with a body of water in the New England landscape of the USA. The site easily afforded wandering i.e. meandering or following contours and features that are revealed. The wandering experience is reflective and features non-goal oriented exploratory behaviour. It is similar to being lost in an activity. The design of the first system *Glass Pond* aimed to create this type of reflective, exploratory experience through the interaction between the system and its participants.

After conducting an evaluation on *Glass Pond* (Seevinck et al., 2006), it became apparent that the participants exhibited different types of reflective, exploratory and compositional behaviour and that the type of behaviour the artist wished to see occurred when there was an escalating cycle of feedback between the participant interaction and interpretation of system and the system's response. An example of this was when a participant was composing interactively with the system, changing intentions and the composition throughout.

Other outcomes from this study include a perceived lack of control and system unpredictability. Upon reflection, the artist decided that these latter qualities were necessary in order to facilitate the range of experiences she was interested in. She also observed these qualities occurred in the natural landscape which had inspired the work. The artist subsequently revisited this natural landscape in more depth and reformulated her approach to the work. Her new, broader approach aimed to mimic certain qualities observed in the natural world: namely the rich variety of behaviour and interpretation nature can afford. The creation of an art system, which allows depth and variety of participant interaction, was considered by the artist to support the types of interaction she was interested in, for example, the aspect of changing intentions.

Theoretical research into the field of emergence further informed the conceptual structure. The qualities of emergence are very similar to those of the intended participant experience. Specifically, the emergent qualities of unpredictability, surprise and the creation of something new are considered conducive to an experience that allows for depth and variety in interpretation.

The practice-based research has been informed by the process of iteratively creating work, evaluating it, and reflecting on it during the process of creation and on the evaluation outcomes, and, in addition, by theoretical research. The research practice has led to reformulating the aesthetic question from considering exploration and reflection in participant behaviours, to designing for conditions which approach the depth and variety of the natural world and for emergence. Research practice has also led to a new system of classifying emergence and a new method for instantiating emergent shapes.

2 Emergence

Emergence occurs when a new form or concept appears that was not directly implied by the context from which it arose. The emergent whole is greater than the sum of its parts: it is new and different to what was there before. It is unpredictable or not immediately deducible. Edmonds, Candy, Jones and Soufi (1994) define an emergent form as one which "...displays characteristics not present in its source". For example, in figure 1 two squares intersect to afford interpretation of a new shape: a triangle. The triangle is the whole that emerges from the interaction between the squares (the parts).

Insert figure 1 here

2.1 The qualities of emergence

Emergence literature has been synthesized to propose a new taxonomy. The qualities of emergence are classified in table 1. The first level of classification distinguishes emergent properties by *origin*. Thus those types which rely on an observer's perception of them in order to exist are distinguished from those which are independent of an observer. 'Perceptual emergence' therefore includes emergence research from the design and Gestalt community; whereas 'Physical emergence' includes research contributions from the complex science and physics communities.

The second level of classification considers the emergent system's *structure type*. It distinguishes between 'Extrinsic' and 'Intrinsic' structures. Emergent properties which occur only at the global level of the whole are considered to have an extrinsic type of structure (see 3A and 3C in table 1). Emergent properties which also feed back into the system to change the conditions of the parts are considered to have an intrinsic type of structure (see 3B and 3D in table 1).

A system can render more than one kind of emergence. For example, the 'V' shape of a flock of geese is a form of extrinsic perceptual emergence when the shape is perceived by an observer. The perception of this 'V' shape is similar to the perception of the triangle in figure 1 and follows the design community's characterisation of emergent shapes, as in Mitchell (1990b: 103) and Soufi and Edmonds (1995 and 1996). At the same time intrinsic physical emergence is occurring because the flock formation which creates this 'V' shape is a physically based process that benefits each individual bird through reduced wind resistance. This is an example of an emergent property of the flock as characterised by researchers in the artificial life community, for example Reynolds (1987) and Langton (1987). Here the same system – a flock of geese – is characterised as emergent in different ways. This demonstrates the versatility of the proposed taxonomy in linking the different definitions of emergence across different disciplines. It also supports the interdisciplinary research of Poon and Maher (1996) who draw on computer and life sciences to evolve design solutions.

The theories of emergence were a strong influence on the design of the artwork *plus minus now*.

Insert table 1 here

3. The art system '*plus minus now*'

Plus minus now asks the audience to consider the different ways users can 'be'. It focuses on the deep involvement one can experience in certain types of interaction, such as being engrossed in a conversation or lost in an activity. A related element to the overall experience of *plus minus now* is to improvise in time, or with the history of one's gestures. The created objects now become perceived objects that exist, though not directly a product of the computer. An everyday comparison might be

cloud gazing, and the interpretation of shapes and figures one might attach. As one starts to interpret form and infer meaning, are they not losing themselves in their surroundings?

The interactive art system uses sand as an interface. The art system's set-up consists of a glass bottom tray on top of a column. The tray holds fine, white beach sand up to 8 mm deep. A video camera located inside the column detects gestures in the sand and this is used as software input. Computer generated imagery is produced and projected directly onto the sand surface and on a screen in front of the sand table. Figure 2 shows the art system's set-up.

Insert figure 2 here

A participant's gestures are sampled by the system and the imagery is projected in real time. Gesture sampling and rendered imagery also include the gesture's direction and speed. Gestures in the sand are rendered as corresponding shapes (figure 3). The shapes are visually transparent. They are also repeatedly created and displayed, accumulating and dissolving over time. Thus a stroke in the sand will afford four shapes consecutively layered on top of each other. The transparent, layered shapes are analogous to echoes in repeatedly rendering the input data. These 'echoes' also outlast the input data. Thus it is possible to superimpose a current gesture with one from a few seconds ago, and one can interact with a history of one's gestures. Interacting with an image from a previous gesture is similar to calling out to an echo of one's voice. The echo analogy illustrates the potential of the system for creating and interpreting time based structures.

Insert figure 3 here

The layering of the transparent shapes can result in new shapes. Any combination of shapes can intersect including those that originate from the same gesture and those from different gestures in the sand. The low opacity from individual shapes contributes to brighter areas where several shapes intersect. Brighter areas may be interpreted as new shapes. The ability to interpret two four-sided polygons as new shapes in Figure 3, frame 5 illustrates this. These new shapes are not directly represented by the system; and their recognition as discrete entities rely on being perceived.

3.1 The relationship of emergence to the art system ‘plus minus now’

The conceptual structure behind *plus minus now* includes the intention to support a certain type of experience in the participant. It draws on the interaction one can have in the natural world. These nature-based experiences have been interpreted by the artist as being open and unbounded; i.e. with many possible interpretations and behaviours. The experience which *plus minus now* aims to facilitate is further characterised as possessing the capacity for change, ambiguity and surprise. Emergence supports these conceptual aims because, by rendering something heterogeneously new to what was there before, it has the capacity for change and by being unpredictable it can provide for surprise. Both qualities of newness and unpredictability also support ambiguity. The potential of emergence to effect ambiguity has been discussed by Mitchell (1990a: 32) and is evident in the range of possible shapes that can be interpreted from figure 3. These shapes were generated during interaction with *plus minus now*. The interaction gestures are presented alongside the system renderings. Frames 1 and 3 show marks in the sand and frames 2, 4, 5, 6 show the corresponding system output.

The shapes presented rely on the reader’s ability to interpret new shapes from the system output. These new shapes can be seen in frame 5, appearing as a participant would see them. They have been identified for the reader in figure 4.

Insert figure 4 here

The construction of the new shapes in *plus minus now* draws on methods used to create emergent shapes in the design community. Here, emergent shapes research has been of interest as it can inform the ability of the computer to assist in creative design. Mitchell (1990a: 30) argues that for a computer to facilitate design it needs to both instantiate and recognise emergent shapes. That is, the computer system should be able to detect or generate all the emergent shapes possible and it should be able to recognise the shapes directly so that they can be manipulated by the designer.

Different methods for instantiating emergent shapes have been explored in the research community. Decomposition of the source image into an intermediate representation is one method. The intermediate representation samples the image according to the representation used, for example

breaking it into construction lines (Tan, 1990) or regions of pixels (Edmonds and Soufi, 1992; Soufi and Edmonds, 1995). New shapes are constructed out of these intermediate representations. Emergent shapes have also been instantiated using shape grammars (Stiny, 1993).

Plus minus now builds on the methods of intermediate representation using area (Edmonds and Soufi, 1992; Soufi and Edmonds, 1995). However, here the use of area is based on opacity in image layering. As the gestures in the sand are sampled they render corresponding transparent shapes. The areas of overlap between these transparent layers are more opaque and stand out visually as brighter areas. In this respect they are similar to the new triangular shape that emerges from the intersecting squares in figure 1.

The two polygons identified in figure 4 can be considered emergent shapes: each shape is a new form which was not directly implied by what preceded it; an emergent whole that comes about from the intersection of many parts. The layers of transparent shapes produced from gestures are the parts. These emergent shapes can therefore be described as *extrinsic perceptual emergence*.

Plus minus now facilitates the interpretation of new shapes. Its use of opacity and a history of gestures is considered a novel method for instantiating emergent shapes. Here, emergence is also an aesthetic approach that can satisfy the conceptual requirements for the interactive art system by supporting ambiguous and varied interaction.

4. Experiencing emergence in 'plus minus now'

In order to begin to understand the participant experience of emergence in *plus minus now* a preliminary investigation using one participant was conducted. The evaluation involved an introductory discussion on the work followed by a period of unobserved interaction with the piece (approximately 10 minutes) and lastly an open interview (approximately 20 minutes). The study took place in an artist's studio where a laptop screen was used instead of the large projection screen pictured in figure 2.

The preliminary discussion covered the work's conceptual background and the use of sand as an interface. The participant was subsequently directed to the sand column. She stood in front of it to interact with the work. She could see system imagery rendered on the sand and also on a laptop

monitor screen on top of a table, in front and slightly to her left. The participant was left to interact with the piece on her own. When the interviewer joined her she was asked what she was doing and thinking at that time. At this stage the participant's interaction was directly observed by the interviewer and her comments and actions noted. She was later also asked for comments or thoughts on the work and her interaction with it.

4.1 The resulting experience

When the observer first asked the participant what she was doing or thinking at the time, she described her actions as making a "heartbeat." She was observed to make an arc shaped mark in the sand with her fingers, wait for the system to respond and then make another, mirrored, arc adjacent to the first. She repeated this gesture a number of times, alternating between the arcs and varying their size. Her hands were observed to hover slightly above the surface between each stroke and she appeared to be working rhythmically to layer the imagery. Each stroke was followed by a series of visual 'echoes' which intersected with each other and the preceding gestures. By continuing to draw the mirroring arcs, she sustained a fluctuating image that appeared to 'beat.' She described her interaction as "it's a kind of pulsating, repeating thing. I like that..." She commented about the work as "it's about movement."

At a later stage in the interview the participant described a different set of interactions as creating "a monster eating an ant." At this time she drew a large arc in the sand with a small dot close to its centre. She repeatedly drew arcs in the sand, increasing their circumference around the dot and their proximity to it until the dot was entirely surrounded. While she worked she watched the LCD screen. The rendered image was observed to show an arc shape moving from one side to another, slowly deforming into a circle shape. In the centre was a dot shape. The participant explained that the arc was the 'monster' and the dot was the 'ant', and that the 'monster' had eaten the 'ant' when the arc was closed around the dot.

4.2 Discussion

The section above describes two compositions that the participant created: a 'heartbeat' and 'a monster eating an ant'. In both cases the participant is interacting with an image of a previous gesture to create a composition. These are time-based or temporal compositions. These temporal compositions can be

considered the whole that emerges from the parts. The dynamic shapes created through gestures, including emergent shapes, are the parts. In the first, 'heartbeat' composition the parts are the pulsating shapes; while in the second the deforming arc shapes are parts.

These emergent compositions also inform the participant's next action and gesture and therefore the next shape. The participant responds to the emergent composition by altering their behaviour: subsequent shapes are deliberately created to sustain the emergent composition. In this way the temporal composition feeds back to change the conditions of the shapes made in the sand (the parts). When the parts and the whole are informing each other the emergent condition manifests at the level of the parts, and becomes intrinsic to the system. The temporal compositions presented in this study can therefore be classified as *intrinsic perceptual emergence*.

Two other examples of intrinsic, perceptual emergence can be drawn from the literature on gaming and design. Firstly, the change in participant behaviour and intent also occurs during game play. (Juul, 2002) considers player strategies that are not immediately deducible from the game rules as emergent. For example, bluffing during the game of Poker is an emergent behaviour or game strategy (Salen and Zimmerman, 2003:171). It is not explicitly stated in the rules. It comes out of playing the game (i.e. emerges at the level of the whole) and changes the way people interact with the cards (i.e. it changes the parts).

Secondly, a creative design can be considered an emergent whole that is afforded by the designer's interpretation and reinterpretation of drawings (the parts). For example, Edmonds, Candy, Jones and Soufi (1994) describe the development of the Lotus bicycle frame as an 'emergent design' created through a collaborative design process that involved heterogenous interpretations of drawings by designers with varying backgrounds.

Mitchell (1990a: 25) argues that design intentions "...evolve through the course of a creative design process ... [to] ... determine how emergent shapes in drawings will be recognized, interpreted, and reinterpreted..." As an intention is formulated the shapes are interpreted differently. In this way the

emergent design (whole) feeds back into the drawings and their emergent shapes (the parts), changing their condition.

The temporal compositions that came out of the *plus minus now* study can be interpreted as creative efforts. This is supported by a theoretical relationship between emergence and creativity. Within the design community, emergence has been described as “... fundamental to creative thought” (Edmonds, 1995: 185). The importance of emergent shapes and emergence to the creative design process has been discussed (Soufi and Edmonds, 1996; Poon and Maher, 1996). The use of emergent shapes in drawing to generate new solutions to design problems has been addressed by Mitchell (1990a and 1990b) who asserts that the ambiguity of a drawing leads to multiple interpretations and potential design solutions: “...design is not a description of what is, it is the exploration of what might be. Drawings are valuable precisely because they are rich in suggestions of what might be” (Mitchell, 1990a: 32). Emergence occurs when new forms are interpreted from the drawings. Perceptual emergence, which occurs in an observer, or participant, has the potential to afford creativity in them.

In *plus minus now* a participant creatively interprets the emergent shapes in the same way that a designer elicits emergent shapes from drawings during the creative design process. It is also possible to see creative, participant behaviour afforded in other interactive artworks. For example, when interacting with *Feeeping Creatures* (Berry, 1998) a participant navigates a virtual world with evolving, artificial life organisms (‘Feeeps’). These organisms emit unique sounds which become audible on approach. While the participant navigates the virtual environment with a microphone they are also composing the sound to the work. In the same way as a melody can be considered emergent, the composition of a sound piece can here be considered emergent. This ability to improvise an acoustic composition also provides the opportunity for creative behaviour.

In *plus minus now* and *Feeeping Creatures* the participant is placed in a creative role by interpreting the work creatively. Emergent interaction engenders a relationship between participant and artist that is closer to collaboration than creator and appreciator. The artist cedes some control to the participant in the interactive artwork; while the participant’s responsibility for the work and its form is also heightened.

While the preliminary study of *plus minus now* is promising, additional evaluation remains necessary to gain a broader understanding of the nature of emergent interaction. The opportunity for creative interaction with *plus minus now* is one aspect that will be addressed. Evaluation will also provide a better indication of the range and type of interpretations afforded by this work.

5 Implications for the design of emergent interactions

While emergent interactions can involve creative participant behaviour there are other aspects that also need consideration. For example, unpredictability and reduced user control can accompany the emergence of something 'new'. These two issues were found to be of concern during the pilot study of *Glass Pond* (Seevinck et al., 2006). The design of *plus minus now* seeks to address these concerns for user interaction without reducing the potential for creative and emergent behaviour.

As described, *plus minus now* relies on the layering of transparent shapes over time to build up the brighter emergent shape. Each transparent shape directly corresponds to a participant's gestures in the sand. In this way the process of the brighter emergent shape's construction is made apparent to the participant. *Glass Pond* relies on a different algorithm with more randomness. Its patterns do not give the participant either a sense of how they were created nor how the interacting gesture relates to them. By illuminating the process of shape construction and maintaining a direct link between gesture (participant action) and image; the approach used in *plus minus now* is intended to increase participant understanding of how the shapes come about. This increase in understanding is reasoned to increase their sense of being able to control and predict the system's behaviour and their interaction with it.

Emergent interactions can facilitate interpretation and creativity. These aspects are however accompanied by user interaction issues such as unpredictability and lack of system control. While informal evaluations can provide some feedback about the success of the design approach, evaluation with multiple participants remains necessary. This will be pursued in the future.

6 Concluding Discussion

By considering emergent interactions we are availed of a range of new possibilities for design. The qualities of new-ness and ambiguity of interpretation provide opportunities for less defined and more open interactions. This mimics the range of experiences and depth of interaction afforded by experiences in the natural world.

An emergent interactive system also features opportunities for creative interaction. This is evident in the definition of emergence which includes the creation of something new as the key characteristic. Creative interaction was also an outcome from the *plus minus now* study. The creation of a 'heart beat' and 'a monster eating an ant' are new forms that were not planned by the participant but rather came out during interaction with it. These creative interactions were also a surprise to the artist and they cannot be deduced from the work. They rely on a dialogue of interaction between participant and system. Creative interaction with an emergent system increases the participant's opportunity for creative collaboration with the system. It alters their role from that of a user to that of a collaborator. As such, it also increases their responsibility for the work and its form.

Along with the creative potential of the participant and the open-ness of the system to interpretation and ambiguity, comes the potential for it to be perceived as unpredictable and/or for the participant to feel a lack of control. Design for emergent interaction is very much about balancing these factors. Keeping the process of shape construction visible and maintaining a direct link between gesture (participant action) and image (output) is intended in the design of *plus minus now* to facilitate participant understanding. It is hoped to address the participant feelings of lack of control and unpredictability which were outcomes of the *Glass Pond* pilot study. Additional evaluation with multiple participants will however be necessary to determine any remaining user issues.

The taxonomy of emergence relates the differing approaches to emergence from different disciplines. It also demonstrates the ability of some systems to exhibit more than one kind of emergence – e.g. both perceptual and physical emergence. Linking the disciplines of emergence research emphasises the potential of one discipline for effecting emergence in another. For example, the modelling methods used in physical emergence can be useful for effecting perceptual emergence.

Emergence literature is the basis of the taxonomy, particularly concerning the role of the observer which has largely informed the distinction between perceptual and physical emergence. The taxonomy has been useful to describe the study outcomes and to link these to other emergence research. It characterizes the heartbeat and ‘monster eating an ant’ compositions as examples of *perceptual, intrinsic emergence*. The emergent shapes in the work are characterized as examples of *perceptual, extrinsic emergence*. This latter type of emergence uses a novel method for instantiating emergent shapes which draws on a history of interactions and creates them with opacity.

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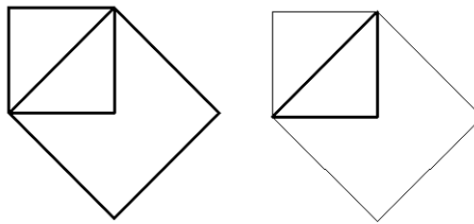


Figure 1 A triangular shape emerges perceptually from the intersection of 2 squares.



Figure 2 Installation view of 'plus minus now'.

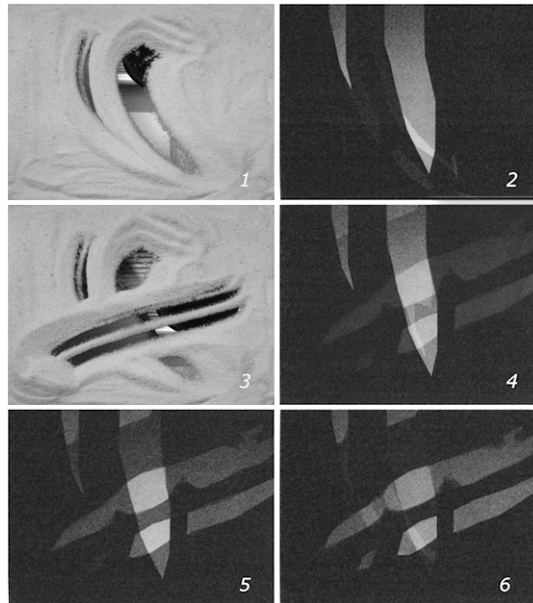


Figure 3 Gestures in the sand and the corresponding imagery projected on screen in the art system 'plus minus now'. A gesture in the sand (1) creates a shape (2). Another gesture (3) intersects with (1) to create brighter areas and new shapes (4), (5). In (5) and (6) the first gesture fades out while the second fades in.

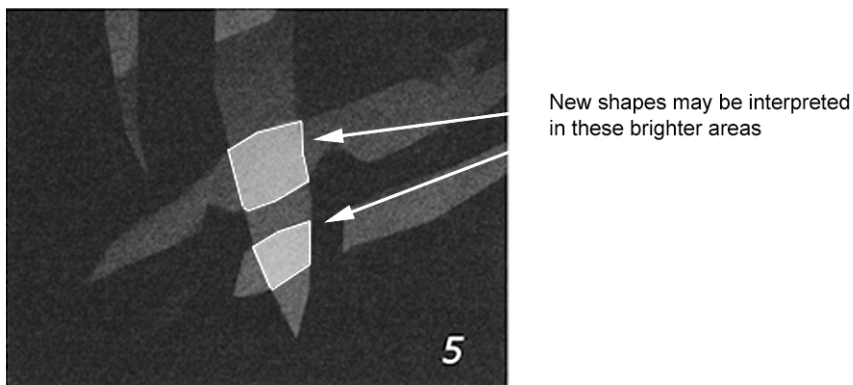


Figure 4 Enlarged excerpt from figure 3. New shapes are traced in white for the reader.

Table 1 Taxonomy of emergence

Generation		Categorising Qualities	
		Terms and Examples	
1		1 Emergence (Interactions between the parts create a whole; and this whole is greater than the sum of the parts. Something new, different to what was before occurs. It is unpredictable, or not immediately deducible.)	
2	Origin	2A Perceptual emergence (Emergent properties rely on perception by an observer to exist.)	2B Physical emergence (Emergent properties originating from physically-based processes, including living & non-living real world processes. Independent of an observer's perception.)

3	Structure type	3A Extrinsic (the emergent whole does not affect the parts)	3B Intrinsic (the emergent whole changes the parts)	3C Extrinsic (the emergent whole does not affect the parts)	3D Intrinsic (the emergent whole changes the parts)
	Examples with explanations	<p>1. Emergent shapes. See Figure 1; and non-interactive shape modelling research (Tan, 1990; Edmonds and Soufi, 1992; Stiny, 1993).</p> <p>2. A melody in Gestalt theory (Wertheimer, 1938).</p> <p>Explanation: The interpretation of the triangle shape (whole) does not affect the constituting squares (parts). A melody is a qualitatively new, different whole to its constituting musical notes (parts). It also does not change the notes.</p>	<p>1. Emergent design, for example of the Lotus bicycle (Edmonds et al., 1994).</p> <p>2. Emergent goals during interaction (Seevinck et al., 2006)</p> <p>3. Bluffing in the game of Poker.</p> <p>Explanation: During the creative design process, emergent shapes (parts) are interpreted and reinterpreted, evolving the design intentions (Mitchell, 1990a) This change in intentions affects the subsequent interpretations of the emergent shapes; and the emergent design (whole) can be said to feed back to change the condition of those shapes (parts).</p> <p>The Lotus bicycle frame is a design that has emerged during a collaborative, creative design process involving the varying interpretation of drawings.</p> <p>Emergent goals (whole) during interaction with the art work <i>Glass pond</i> informed the subsequent action on the system imagery (parts), changing their conditions.</p> <p>Emergent strategies (whole) also change the condition of the cards (parts) (Salen and Zimmerman, 2003)</p>	<p>1. Fractal theory.</p> <p>Explanation: Structural forms emerge from an algorithm. The constants within the algorithm are the parts which remain unaffected by the emergent fractal form (whole).</p>	<p>1. Flocking behaviour and modelling algorithms. (Reynolds, 1987)</p> <p>2. Crystal structure.</p> <p>Explanation: The flock behaviour (whole) benefits individual birds (parts). Similarly an emergent crystal structure changes the condition of the parts such as the solubility of the molecules.</p>
	Emergent Properties within <i>plus minus now</i>	Emergent shapes due to overlapping renderings of gestures.	Temporal compositions emerge (whole), informed by shapes and behaviours from gestures (parts).		