Chapter 2
Emergence

Abstract This chapter establishes a broad understanding of emergence and provides a tool for classifying it, the Taxonomy of Emergence in Interactive Art (TEIA). This framework sits across the debated concept of emergence. It draws on the variety of understandings of emergence in the physical and life sciences through to design research communities, to reveal differences and similarities between them. The classifications fit an overarching, broad understanding of emergence as occurring *when a new form or concept appears that was not directly implied by the context from which it arose; and where this emergent whole' is more than a simple sum of the parts*. Emergence also has some core qualities and characteristics. As implied by the definition, something *new* is created that is a *whole* with *parts,* which exists across *levels* and has the potential for *feedback* between those levels, namely from the whole to the parts. *Unpredictability, creativity* and *open-endedness* and the subjective interpretation of emergence are other key concerns that have come out of emergence literature. A new concept that I introduce here is *referencing*. While new to the domain of emergence it is significant to the visual arts. It facilitates a more differentiated understanding of emergence in the context of interactive art by distinguishing those instances of emergence that are associated with something else in the world (as in figurative and representational work in the visual arts) from the more direct and material concerns of Concrete art. The various qualities of emergence and organizing TEIA discussed here go on to inform the analytical and creative activities in later chapters. A more in-depth discussion of emergence follows in Chap. 7, for the interested reader.

Two Approaches to Emergence

The concept of emergence has challenged philosophers through to biologists and scientists since the time of Aristotle. Questions about the origins of life and qualities of being alive have directed enquiry for many (Weber and Esfeld 2008; Aristotle in Pickard-Cambridge 2015). Questions of life, particularly through computer models of artificial life (AL), have also informed contemporary arts practice (for example

J. Seevinck, *Emergence in Interactive Art*, Springer Series on Cultural Computing,
DOI 10.1007/978-3-319-45201-2_2

Sommerer and Mignonneau 1998; Rinaldo 1999 as discussed later in the book). Computer scientists and artists have modelled theories of emergence in the natural, physical world through computer based simulations through iteratively applying simple rules to collections of simple entities. Organic structures of trees through to ant colonies have been re-created digitally in this way, facilitating understanding into their structure and the natural world as well as aesthetic outcomes (e.g. Prusinkiewicz and Lindenmayer 1990; Resnick 1994). These research and creative efforts in emergence understand it as something that occurs in the natural, physical world.

In another context, however, emergence is understood as a subjective concept one that explains how we can come up with new design solutions, such as how an observer can interpret a new shape like the triangle in Fig. 2.1 (e.g. Mitchell 1990; Edmonds and Soufi 1992).

While these understandings may at first seem to be about different things, they share some key characteristics. In each case *a new form or concept has appeared, that was not directly implied by the context from which it arose.* And in each case, *this emergent 'whole' is more than a simple sum of the parts*. Whether it is a flock of birds or an emergent triangular shape, it is qualitatively new and different to its constituting parts—birds or the simple Pac-man shapes in Fig. 2.1.

The two understandings each draw upon different bodies of research in emergence. Design research including Gestalt theory and visual thinking takes a personal, subjective approach to focus on emergent structures that seem to appear, such as the emergent shape and the new understandings that it can facilitate. Here the emergence is something that is occurring in the eye of an observer, or as relevant to that body of research, being a designer or artist.

On the other hand, research in the physical and natural sciences is focused on emergence as it occurs in that natural, physical world. This is not as something that occurs perceptually, rather here the concern is with structures originating from living and non-living physically based processes in the real world. The

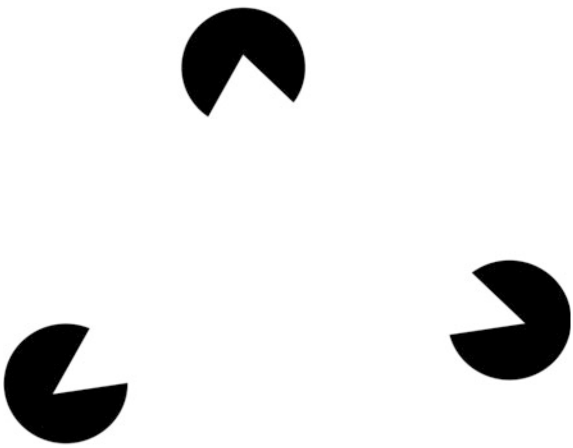

Fig. 2.1 The Kanizsa triangle illusion is not perceived as a result of an image on the retina, rather it is induced by the three Pac-Man shapes

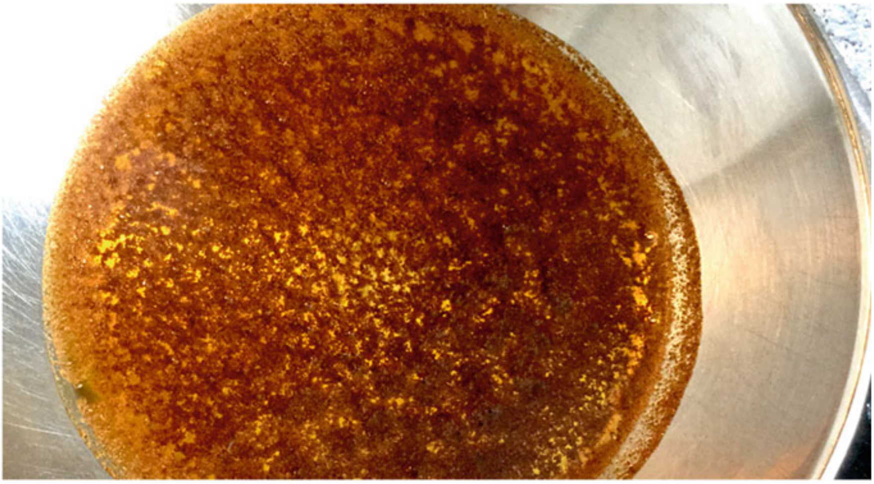

Fig. 2.2 As chilli powder is heated in oil, hexagonal structures (Bénard cells) become evident. Photo © Yani Seevinck 2016

characteristic V-Shape of snow geese flying in formation is an emergent structure or behaviour that becomes physically manifest and can be differentiated from a disordered group of birds. The organisation of ant colonies or formation of termite mounds can be characterised the same way (Flake 1998). Non-living systems also exhibit this 'self-organisation'. Scientist Stephen Wolfram describes such systems as those that "*…start disordered and featureless but then spontaneously organize themselves to produce definite structures*" (Wolfram 2002). For example, when heating oil and chilli in a pan, one can see self-organisation of the chilli powder. It will rearrange from its disorganised configuration to settle into beehive patterns, or Bénard cells (Emmeche 1994) as shown in Fig. 2.2. Such natural structures challenge our assumption of the world as moving towards randomness, intriguing researchers and artists alike.

Theories of evolution and adaptation can help us understand new organisms and life forms. Complex systems research also provides insight, as is discussed in more depth in Chap. 7. A fine grained view of physical materials and context can also provide insight into how natural form comes about. D'Arcy Thompson articulated the concept of *Morphology* in 1917) to explain the shape of an antelope horn in terms of the horn's increasing weight over time and uneven rate of growth parallel to the axis; factors which direct the growth of the animals' horns to mirror logarithmic spirals (Thompson 1992). Thompson proposed these explanations as alternatives or complementary to natural selection. As Phillip Ball describes it more recently, "*as an explanation for natural form, natural selection is not entirely satisfying. Not because it is wrong, but because it says nothing about mechanism*"(1999). The morphologists approach can also render a more economical answer than evolutionary theory.

There are a number of approaches to understand emergence, within and across disciplines. They do however share the above broad definition. They also share some key or core qualities, which is discussed next. Some of the controversy between qualities of emergence is also discussed here while more depth is offered to the interested reader in Chap. 7. The primary aim of the current chapter is establishing a basic understanding of emergence in the context of interactive art, and presenting an organizing framework for applying it, the TEIA. This Taxonomy for Emergence in Interactive Art is a pragmatic effort to aid understanding and navigation of emergence across the literature. It can also facilitate the application of models and understandings of emergence from one domain into to the next.

Qualities of Emergence

Emergence has some key qualities. To begin with, there is a whole with constituting parts. This also implies the idea of different *levels* between that *whole* and its *parts*. Similarly the idea of something qualitatively *new* appearing implies a notion of surprise or *unpredictability*. As the following discussion shows, each quality can be unpacked to reveal some depth in understanding emergence. These qualities become useful to characterise interactive artworks, as is shown throughout the book.

The Whole and Parts

The term 'emergent' was coined by philosopher George Henry Lewes in 1875 to describe a phenomenon that is neither a mixture nor a sum of constituting parts but rather heterogeneously new and irreducible to those parts (1875). Max Wertheimer's articulation of Gestalt psychology in 1924 sounds very similar: "*There are wholes, the behaviour of which is not determined by that of their individual elements, but where the part-processes are themselves determined by the intrinsic nature of the whole*" (Wertheimer 1938).

50 Years later computer scientist John Holland describes emergence in very similar terms to those of Wertheimer: "*for emergence, the whole is indeed more than the sum of its parts*" (1998). Other researchers within the natural sciences have also described emergence in this way (e.g. Emmeche et al. 1997; Flake 1998).

The notion of a whole that cannot be understood reductively and in terms of parts alone has been familiar for some time and it has featured across different disciplines. However, while there is agreement on this concept, there is also debate. Not being able to explain something in terms of its constituting parts alone has, in the past, challenged the concept of emergence by leaving it open to mystical explanations. A holistic view of emergence is, however, increasingly gaining traction in physics (Laughlin and Pines 2000; Bar-Yam 2002; Chap. 7).

Explaining and Predicting Emergence

The tension between reductivism and holism accounts for much of the debates between theories of emergence. A reductionist position seeks to understand things in terms of their parts alone (Oxford Dictionaries 2010). However, when a concept cannot be simplified to theories or properties of the parts (Lewes 1875) this can become problematic. One argument to reconcile reductivist explanations with unexplainable outcomes asserts that our understanding of the parts is simply inadequate… and more knowledge here could sustain an explanation of the so-called emergent phenomenon as a sum of those parts. This argument is part of a broader idea of emergence as "*relative to some transient state of scientific knowledge"* (Weber and Esfeld 2008). It does, however, have its own problems, as is detailed in Chap. 7.

For example, deterministic chaos systems are, by definition explainable because we can trace every causal step to arrive at the outcome. They are also predictable—at least in the short term. For example, we can look outside to see if it will rain this afternoon, but predicting the weather for next week is less reliable.

Considering the design research view of emergence yields a more nuanced understanding again. Here the focus is on something become explicit that was previously implicit, or the appearance of something that is "*not present in its source*" (Mitchell 1993; Edmonds et al. 1994). Emergent shapes, like the triangle in Fig. 2.1 are more than a simple sum of their parts—the pacman shapes. They are qualitatively different and new relative to their parts. This research therefore understands emergence as possibly, but not necessarily, being wholly unpredictable. Rather the question of unpredictability is more usefully understood as unpredictable from the vantage point of the parts. Put another way and as is discussed next, it is concerned with the appearance of something heterogeneously different and new to what was there before.

The Appearance of Something New

The creation of something new is another core quality of emergence. For Danish philosophers Claus Emmeche, Simo Køppe and Frederik Stjernfelt, emergence involves the "*…creation of new properties*" (Emmeche et al. 1997). Similarly for design researchers "*…an emergent form displays characteristics not present in its source*" (Edmonds et al. 1994). A whole that is more than the sum of its parts is necessarily new relative to those parts. Specifically, the newness is qualitatively different to what was there before. It is *heterogeneously* new (Lewes 1875; Mill 1889) or, as physicist John Crutchfield describes, it is different to the system's pre-existing character (Crutchfield 1994).

These first three aspects—the system as a *whole* with *parts,* exhibiting relative *newness*—provide a starting point for understanding emergence. A nice example here is von Ehrenfehls 1890 experiment on the perception of a musical melody. He found that it could not be distinguished from exposure to the separate notes. We intuitively understand this too—a melody is a whole that is qualitatively different, new and more than a simple sum of its parts, the notes (1890 von Ehrenfels experiment described in Wertheimer 1938).

Creativity Through Emergence

The occurrence of something qualitatively new can also mean that something creative has occurred. As Edmonds argues, "*emergence is fundamental to creative thought because the creative thought introduces something new*" (1995). For example, when you look at Fig. 2.1 you can interpret a new shape, the triangle. As architectural designer and theorist William Mitchell describes, designers can respond to their drawings to come up with new understandings: "*Designers … frequently recognize emergent subshapes, and subsequently structure their understanding of the design and their reasoning about it in terms of emergent entities and relationship*" (1990). These new shapes are interpreted through the designer's reflection on their drawing. It is an activity that is integral to the creative drawing process.

Creativity is an integral concern in emergent shapes research. The design research community has pursued Computer-Aided Design (CAD) tools to facilitate the designer in their creative and less routine design tasks. The efforts aim to facilitate computer recognition of emergent sub-shapes, something which is not straightforward given that CAD systems explicitly specify shapes, while an emergent shape like the triangle in Fig. 2.1 is, instead implied (Mitchell 1993; Gero 1996). Various computational models that address these questions to support creative design processes have been proposed (e.g. Mitchell 1990; Soufi and Edmonds 1995; Poon and Maher 1996; Gero 1996).

One such system differentiates between four types of emergent shapes—these range from those that are embedded within the original drawing, such as the heart appearing from overlapping teardrop shapes in Fig. 1.2, through to emergent shapes that function through perceptual qualities responding to occlusion or spatial extension. A fourth kind is an illusory emergent shape such as the Kanizsa triangle pictured in Fig. 2.1 where interpolation or subjective contours contribute to perception of this triangle (Soufi and Edmonds 1995).[1]

Emergence can also lead to creative behaviours in interactive art, such as the ability of a participant to interactively *compose* music through navigating the audio-visual virtual world *Feeping Creatures* (Berry 1998). In this artificial life environment, creativity occurs as you move through the virtual world to compose new soundscapes with the evolving virtual creatures in the art system. That is, both new acoustic

[1]Further discussion of emergent shapes can be found in Chap. 7.

compositions are created and, at the same time, virtual creatures are also ‘created’, while the biological life simulation unfolds. Other examples of creative, emergent interactions and experiences are discussed in Chaps. 4, 5 and 6. Emergence is integral to creativity but both are also intertwined with ambiguity and openness. As stated by Umberto Eco: when someone is completing the open work (as participants of interactive art systems arguably do) they are, in many ways, acting creatively (Eco 1962).

Perceiving Emergence

Computer artists and scientists have pursued the digital modelling of life processes to emerge new forms and virtual creatures. Such simulations can, however, be contentious. Neuroscientist and researcher Peter Cariani argues that most computer simulations cannot really generate emergence. This is because within the domain of the computer nothing truly new can emerge: given the same starting conditions, the result will always be the same. Put another way, emergence within the closed domain of the computer will be predictable because the system is ‘informationally closed’. Cariani believes the only true emergence to occur in this situation is that which occurs within the observer’s mind: those new understandings or concepts that might form in an observer watching the simulation. Emergence here, says Cariani, is through “*…creating new ways of seeing the world [and] …changing the way we think and interact with the world*” (Cariani 1991); and the emergence that occurs in simulations is ‘*computational emergence*’.

Of course the simulation of emergent processes, including artificial life, remains useful for understanding natural phenomena, creating art, supporting design practices and so on. However, Cariani’s concept of computational emergence also reminds us that finite, deterministic computer simulations differ from the natural world in terms of openness. Openness is a recurring theme throughout this book due to its relationship to both emergence and art (and is discussed in more depth in Chap. 3).

Through articulating the concept of computational emergence, Cariani also describes emergence in subjective, personal and experiential terms.This parallels the approach to emergence taken in visual thinking and design research. It demonstrates another similarity in how emergence is understood between disciplines. In the design research approach, however, there is a focus on the actual creative experience of perception; such as the shapes, patterns or order that can be *perceived* by an observer. In the context of interactive art this observer can be a participant with that interactive artwork. We can then say that where such a ‘participant-observer’ is interacting with the system, they would be experiencing emergence in interactive art.

The perception and experience of emergence are key concerns here. Their consideration has informed two primary classes of emergence: *perceptual* and *physical*. The first type of emergence is focused on the subjective, interpretive action of *perceiving* emergence, and the creativity this involves. It draws on research from the design research and Gestalt domains, including emergent shapes research. The second type of emergence is concerned with the real, natural world and living and non-living physically-based processes, and does not rely on an observer. For example, a group of birds will flock regardless of whether or not we are there to observe them. This latter class of *physical* emergence is informed by research in the complex sciences, biology and physics as well as the tools used in those domains, including simulations of these processes such as artificial life research.

Emergence Across Levels

Another useful aspect to the concept of emergence is the different types of relations between the level of the whole and the level of its constituting parts. Contemporary Gestalt psychologist Rudolf Arnheim points out that there is feedback between the emergent whole and the parts: "*In a gestalt, each unit [part] is affected and modified by its relations to other units of the system [whole]. Each relation [whole], in turn, is affected by the agent generating it [parts]*" (Arnheim 1996). While the whole gains its meaning from some combination of the parts that is more than a simple summing, the parts are also affected.

As noted earlier, the distinction between a whole and constituting parts logically implies a difference in scale, or levels. An emergent new aspect is occurring on one level of organisation that is not predictable from a lower level. Philosopher Emmeche and his colleagues recently described four such levels in our world: physical-chemical, biological, psychological and sociological. Each level has its own sub-levels, and emergence occurs any time a level is transcended—for example, as we move from physical-chemical building blocks to biological life, or as we move from disordered groups of atoms to crystalline structures. In each case, there is something 'heterogeneously new' occurring at one level up (Emmeche et al. 1997). Furthermore, this emergent phenomenon cannot be explained or anticipated in terms of its originating level or parts.

From this characterisation of emergence as something that occurs across levels we can see there is a capacity for mutual dependence and feedback between the levels of the parts and the whole. For example, an emergent crystal structure is not only heterogeneously new to constituting molecules, that structure will also affect the solubility of the molecules; that is their state, at a local, lower level. There is feedback from the higher level of the whole back down to the level of the parts.

Physicist James Crutchfield describes this as intrinsic emergence.[2] He characterises newness as occurring at two scales or levels (Crutchfield 1994). Firstly, new behaviour such as pattern formation occurs at a global scale where the system as a

[2]Interestingly, the early Gestalt conception of a whole as both coming about from the interaction of parts and informing how those parts relate to one another mentioned above also expresses this idea of feedback (Wertheimer 1938). Once again we can see similar understandings of emergence across disciplines.

whole exhibits this emergent property. Secondly, it can also occur at a local scale, when the local interactions between the parts themselves change. New patterns of structure can be said to emerge at a local level and this "*newness with respect to other structures in the underlying system*" is described as intrinsic emergence (Crutchfield 1994). The change in interactions between the parts at a local scale creates a feedback loop between global and local levels, where they inform one another. For example, when birds fly in a flock they both affect and are affected by the changing formation of the flock. Each bird flies differently when in formation than it would on its own. When in formation, a change in one bird's flight affects its neighbours (for example, to avoid collision), who in turn affect their immediate neighbours. Thus the behaviour of the individuals affects the flock. Conversely, flying in a flock benefits the birds through reduced wind resistance, which in turn creates new local bird behaviour because it improves their performance. In an emergent system, the whole and its parts can relate to one another through feedback loops. This notion of feedback informs the second layer of the taxonomy. That is, emergence can be further differentiated as firstly *intrinsic*, where the emergent whole affects the system across levels at both the level of the whole and of the parts… On the other hand, in *extrinsic* emergence there is no feedback from the whole back to the parts. The parts remain unchanged by the emergent whole and as such, emergence is said to occur at the level of the whole only.

To recap, the definition of emergence provided at the start of this chapter identified some core qualities that have now been discussed: *new*, *unpredictable*, a *whole* that is made up of *parts* and the *levels* that these sit across. Creativity is another quality that has also been discussed. The remainder of this chapter builds on this understanding of the qualities of emergence to describe an organising framework for emergence in interactive art.

The Taxonomy of Emergence in Interactive Art (TEIA)

The TEIA organises the debates and qualities of emergence discussed above into one framework to position emergence in the context of interactive art. In many ways it is a pragmatic effort: the characteristics that differentiate classes of emergence seek to serve the creative arts and particularly interactive art. A practitioner seeking to instantiate the characteristics of emergence can look towards the models and approaches collected here, to identify possible approaches or mechanisms. That is, an approach for creating emergence in one domain can be used to affect it for another. While the TEIA is largely informed by theory, empirical evidence from participant interactions with artworks as well as the creation of artworks themselves have also influenced its development. The TEIA is summarised in Fig. 2.3.

The above discussion of emergence research has already identified some of the different ways in which emergence is understood in the natural and computer sciences through to Gestalt theory and design research. These inform the first two levels of the TEIA. First is the role of the observer and second is the concept of

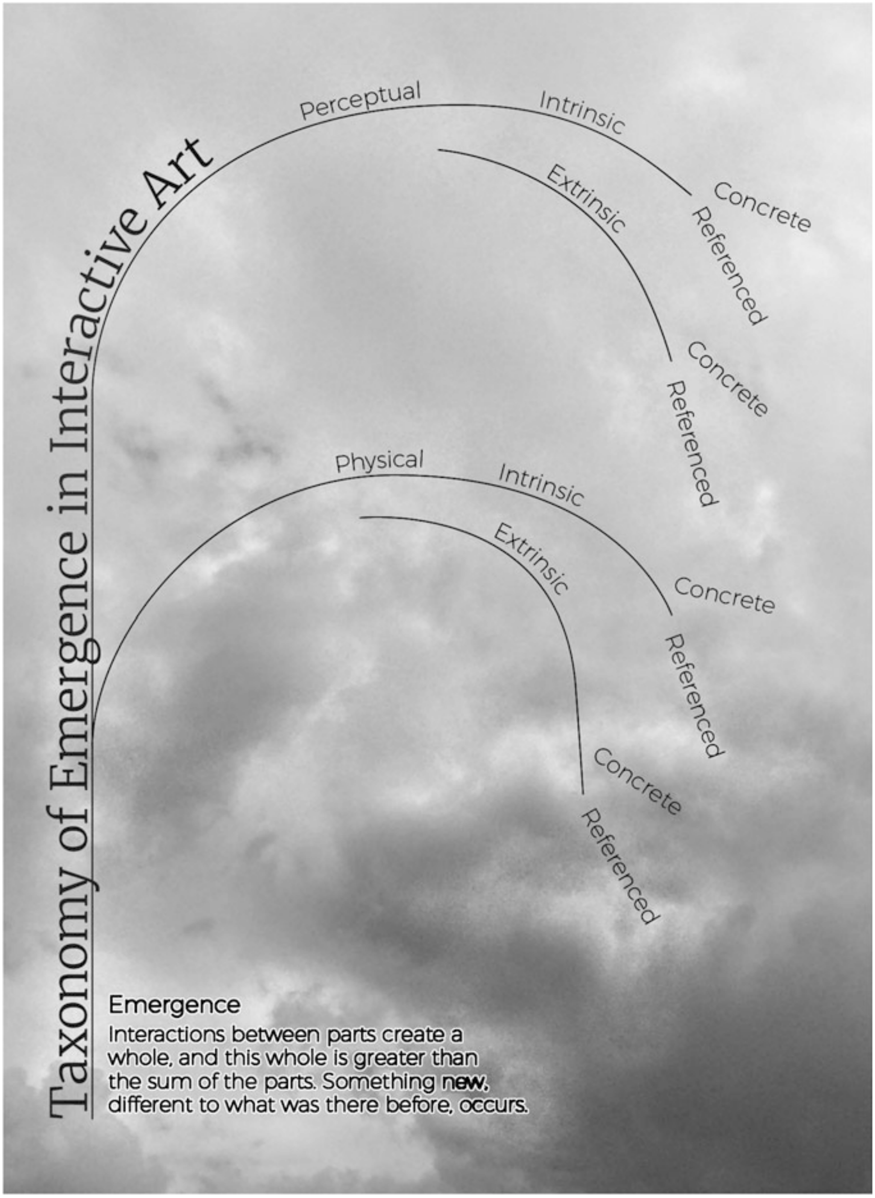

Fig. 2.3 The TEIA comprises three differentiating factors, resulting in eight classes of emergence in interactive art.

feedback across the levels. The third and final layer of differentiation in the TEIA concerns how the quality of novelty, or newness can characterise the emergent instance within an art context. In this section I discuss each of these layers in detail.

First Level: The Observer

To start with, it is useful to differentiate emergence that is experienced by us from that which occurs in the natural world. The first level of the taxonomy therefore distinguishes between situations where the emergent 'whole' relies on the perception of an observer to exist (*perceptual* emergence) and situations where the emergent 'whole' is considered independently of an observer (*physical* emergence). These two primary types of emergence, *perceptual* and *physical* emergence, are non-exclusive and may be spatial or temporal. To recap, the first includes research into the perception of shapes in the field of design and composition in the arts. The second includes structures in natural systems and the efforts to model or simulate these.

It's useful to note that the perceptual type of emergence often occurs at the same time as physical emergence has occurred. For example, when we perceive patterns or order in the natural world, such as the emergent hexagonal shapes that form in the hot oil as in the Bénard cells pictured in Fig. 2.2, there is not only the physical emergence that is occurring through the self-organisation of these complex systems, there is also the perceptual emergence occurring within us as we perceive these shapes and develop this new understanding.

Since the context of this book is digital, interactive art, *perceptual* emergence is a critical concern. It is also more novel—mostly the research into emergence and interactive art is in the simulated rendering of natural processes rather than being concerned with a participant's emergent perception and experience.

Second Level: Feedback

The second level of classification differentiates between instances where the emergent whole 'feeds back' into the parts and alters them, and those instances where there is no feedback from the whole to the parts. Where there is feedback, the emergent quality is *intrinsic* to the structure, and where there is no feedback it is *extrinsic* to it (e.g. Wertheimer 1938; Crutchfield 1994; Arnheim 1996).

These two first layers of the taxonomy can be illustrated with an example. Consider the typical V-shape formation of snow geese. We can think of this as an emergent structure or behaviour that is physically manifest in the world independent of our perception. In this sense it is an instance of *physical* emergence. Furthermore, the flock formation benefits the individual birds by providing reduced wind resistance to the individuals. In this sense, the emergent whole structure is 'feeding back' into the level of the parts and it can be understood as a *physically intrinsic* instance of emergence. On the other hand, where a person is watching these birds and remarks on their characteristic V shape, they are also experiencing a form of emergence, specifically *perceptual* emergence. However, unless that person acts on their new, emergent understanding to influence the birds, the emergence is solely at the level of the 'whole': the emergent V shape we perceive. In this case it is, at the same time as demonstrating *physically intrinsic* emergence, also an instance of *perceptually extrinsic* emergence.

Third Level: Referencing

The final third distinction in the TEIA has not yet been discussed. This concerns the quality of emergent newness by drawing on concepts of the figurative, abstract and concrete in art. Specifically, it draws on a distinction in aesthetics that differentiates artwork that refers to something, such as a figure or landscape, from the type of abstract artwork that eschews all reference to the outside world. This latter class is the 'Art Concrete' movement. It was proposed by artist Theo van Doesburg in 1930 (Baljeu 1974). Here the plastic, essential or 'concrete' elements of the art work (for example colour and form) are employed for their own sake. This is rather than them being in the service of a representation (Gooding 2001; Chilvers 2009).

Other art movements, such as Constructivism and De Stijl, hold similar ideas about the plastic, or concrete, elements that make up an artwork. Constructive artist Naum Gabo describes the content and form of an artwork as being "*one and the same thing. It does not separate Content from Form …they have to live and act as a unit, proceed in the same direction and produce the same effect*" (Gabo 1937). Art historian Herschel Chipp writes of a similar focus on form in De Stijl: "*in terms of painting the plastic means were reduced to the constitutive elements of line, space and colour, arranged in the most elemental compositions*" (Chipp 1968). A Mark Rothko painting, for example, is concerned with the material aspects of the medium such as the brush stroke or interaction between adjacent colours. This is different to the reference the painting may make to that outside itself, to the outside world—such as a portrait of the *Mona Lisa*, or the abstracted, colourful city lights in Mondrian's *Boogie Nights*. Identifying instances of concrete emergence in interactive art can, potentially, facilitate better understanding of the material aspects of interaction.

The taxonomy therefore differentiates between emergence as relating to representation, and art in these two ways. That is, emergence that references something else in the world such as through modelling or interpreting something familiar can be considered *Referenced* emergence. Conversely, emergence that does not reference anything and is completely local to its plastic or 'concrete' elements can be called *Concrete* emergence.

In addition to aesthetic theory, this last level of the taxonomy has also been informed by observations of people interacting with artworks. As is discussed later in Chap. 6, this includes instances in which people have interpreted images and then manipulated these images during their interaction with a work. In one case during interaction with the art system +−*now* (Seevinck 2008), a participant perceived a stick figure in the computer imagery. He subsequently interacted with the figure to 'make it walk'. This is an example of *Referenced Intrinsic Perceptual* emergence, as shown in Fig. 2.3). The image is a perceived object which relies on the participant to interpret it in order to exist as the 'walking man' composition. The 'walking man' interpretation also works to sustain the composition because the participant creates gestures in the sand to 'keep the stickman walking'. Each of these gestures is a stroke in the sand for the legs, sharing the meaning of the stick figure walking. The emergent *whole* therefore informs the *parts*, *feeding back* into them. As such it is *intrinsic* to the whole. Finally, the interpretation *references* a 'stickman walking'.

Through these three levels of differentiation we can think about emergence in interactive art in terms of eight types. Each of these classes is now briefly reviewed.

Concrete Extrinsic Perceptual Emergence This first class of emergence relies on being perceived to exist, and is where the emergent whole does not change or affect the parts that make it up. Here the emergent whole also does not refer to anything. For example, a melody is qualitatively different and new, whole to its constituting musical notes (the parts), and it does not change the notes. In this case it would also lack references to other sounds such as a babbling brook or canons firing or familiar sound motifs to evoke other aural compositions. The shifting rhythms one can perceive in a Steve Reich composition is an example of concrete extrinsic perceptual emergence.

Referenced Extrinsic Perceptual Emergence This is a type of emergence that relies on being perceived to exist, where the emergent whole does not change or affect the parts that make it up, and where the emergent whole refers to something else in the world. The emergent heart shape pictured in Fig. 1.2 is one example. This came about from the transformation of the teardrop shapes. Furthermore, the emergent shape, such as the heart (whole) does not change the constituting shapes (parts); while the interpretation of this heart is in reference to our pre-existing understanding of this symbol. Another example is the emergent composition of a face, perceived during interaction with +−*now* (Seevinck 2008), discussed in Chap. 6. Here the interpretation of the face compositions (whole) does not affect the constituting shapes and gestures (parts). It also refers to faces in the real world.

Concrete Intrinsic Perceptual Emergence This is a type of emergence that relies on being perceived to exist, where the emergent whole changes or in some way affects the parts that make it up, and where the emergent whole does not refer to anything. It can include new strategies or behaviours—for example, *bluffing* in the game of poker (Salen and Zimmerman 2004) and the 'following lights' behaviour during interaction with +−*now* (Chap. 6). Here the *bluffing* behaviour (whole) affects the way in which cards (parts) are treated (e.g. with suspicion).

Referenced Intrinsic Perceptual Emergence This is a type of emergence that is independent of an observer's perception, where the emergent whole changes or in some way affects the parts that make it up, and where the emergent whole refers to something else in the world. For example, during the collaborative design of the *Lotus* bicycle the creative team would recognise aspects of the drawings in different ways, as is consistent with their own area of expertise (Edmonds et al. 1994). When shared among the group, these varied interpretations resulted in surprisingly new design intentions. The emergent intentions would 'feed back' to change the meaning of the drawings and their emergent shapes. Thus the emergent design (whole) feeds back to change the condition of the shapes recognised in those drawings (parts). Another example is the interpretation and animation of a 'stick-man' during one participant's interaction with *+−now*. As described earlier, the animation behaviour (whole) affects the way in which the sand, coloured and white image are interacted with (e.g. rhythmically, to make a 'man' 'walk'). Furthermore, this interpretation is referenced in that the behaviour is referring to animation and a man walking in the real world. Interestingly, this also points to *analogy* as being, by definition, referenced.

Concrete Extrinsic Physical Emergence This is a type of emergence that exists independently of being perceived, where the emergent whole does not change or affect the parts that make it up, and where the emergent whole does not refer to anything. A coastline's shape is one example. We can understand that this edge between land and sea does not refer to anything, and that its self-similar structure does not feed back in to affect the rocks that it is made up of (parts).

Referenced Extrinsic Physical Emergence Once again, as a form of physical emergence, this class is considered to exist independently of being perceived. It is also a case of where the emergent whole does not change or affect the parts that make it up. Finally, as an instance of referenced emergence, in this case it will refer to something else in the world. For example, this might be a fractal rendering simulating a coastline. Here the fractal algorithm (whole) does not affect the constants within this algorithm (parts). It also refers to a coastline.

Concrete Intrinsic Physical Emergence As another case of physical emergence this class also describes instances of emergent processes in the natural world which can be understood to exist independently of being perceived. Here however there is feedback and the emergent whole changes or in some way affects the parts that makes it up. Also here the emergent whole does not refer to anything outside of what it is. Examples include an insoluble crystal or a skein of geese flying in formation. Here the insoluble crystal (whole) affects the molecules (parts) by changing their solubility. Similarly, a flock (whole) affects the individual birds (parts) by reducing their wind resistance and flying effort.

Referenced Intrinsic Physical Emergence This last class of emergence is also physical. Here the emergent whole changes or in some way affects the parts that make it up. The emergent whole also refers to something else in the world. An example of this type of emergence is the *Boids* computational model that simulates the flocking behaviour of birds (Reynolds 1987). Within this simulation the 'flock' (whole) affects the individual behaviour of the 'birds' (parts), demonstrating feedback from that whole to the parts. As a simulation of real-world bird flocking behaviour it is also necessarily a form of referenced emergence.

Conclusion

The Taxonomy of Emergence in Interactive Art (TEIA) organises the literature and various positions on emergence into one view. It facilitates understanding and comparisons between different types of emergence. In the first instance it differentiates between emergence that is reliant on an observer to exist, from that which relates to the physical and biological processes of the natural world to exist independently of being perceived. The second and third layers of distinction concern feedback between the whole and the parts and whether or not the instance of emergence refers to anything.

The TEIA can also function as a map, locating mechanisms to facilitate emergence in interactive art alongside aspects of audience experience of it. In so doing, it can facilitate a more differentiated understanding of emergence. Furthermore, the explicit focus on the concrete, material and local aspects of an emergent system means that the TEIA provides the opportunity to look at aspects of emergence that are local to an artwork and not, for example, metaphorical or based on analogy. This also serves to orient the taxonomy in the context of interactive art.

As mentioned, the TEIA can *map* across the different enquiries into emergence, providing a route that might facilitate one kind of emergence by effecting another kind. For example, a physically emergent simulation can facilitate perceptual emergence. The practitioner interested in different ways of facilitating perceptual emergence can look at the models and understandings in physics and computer science as well as biology and artificial life communities (i.e. physical emergence). Conversely, the researcher who is interested in how people understand and interpret their simulation of natural systems could look towards the ways the design research community understands and models (perceptual) emergence. My interactive artwork *Of me With me* (Seevinck 2014) demonstrates such a cross-mapping. Here an understanding of self-similar structures (physical emergence) has informed a creative participant experience. That is, the work employs a generative, fractal algorithm to take incoming gestures of a participant drawing and 'echo' these for transformed and iterated imagery. The overall participant experience is one of drawing interactively 'with their own mark'. It is a work that seeks to enable agency and ownership as well as compositional unity through visual pattern and rhythm. As discussed in Chap. 6 *Of me With me* was found to facilitate emergent participant experiences (perceptual emergence). The art system employs an understanding and model of emergence from one side of the TEIA tree to facilitate instances of emergence as shown on the other side.

Understanding the potential of interactive artworks to facilitate emergent participant experiences is another useful application of the TEIA. I demonstrate this application through evaluation of participant experience of my own works (Chap. 6), as well as through the characterisation of six key interactive artworks from around the world (Chap. 4). The TEIA and the qualities of emergence that have been discussed here will also inform the data analyses and critiques to identify various aspects and potentials for emergence.

References

Arnheim R (1996) Form as creation. In: Arnheim R (ed) The split and the structure twenty eight essays. University of California Press, Berkeley, pp 151–155

Baljeu J (1974) Theo van Doesburg, First American Edition. Macmillan Publishing Co. Inc, New York

Ball P (1999) The Self-Made Tapestry: Pattern Formation in Nature. Oxford University Press, Oxford

Bar-Yam Y (2002) General features of complex systems. Encyclopedia of life support systems EOLSS. UNESCO Publishers, Oxford

Berry R (1998) Feeping Creatures, interactive artwork

Cariani P (1991) Emergence and artificial life. In: Langton CG, Taylor C, Farmer JD, Rasmussen S (eds). Addison-Wesley, pp 775–797

Chilvers I (2009) Concrete art. Oxford University Press, Oxford

Chipp HB (1968) Neo plasticism and constructivism in abstract and non-objective art. In: Chipp HB (ed) Theories of modern art a sourcebook for artists and critics. U.C. Press, USA, pp 309–366

Crutchfield JP (1994) Is anything ever new? Considering emergence. In: Cowan G, Pines D, Melzner D (eds) Complexity: metaphors, models, and reality. Addison-Wesley, Reading, pp 479–497

Eco U (1962) The poetics of the open work. In: Bishop C (ed) Participation. The MIT Press, London, pp 20–40

Edmonds EA (1995) Creativity: interacting with computers (panel discussion). In: Edmonds EA, Katz I, Mack R et al (eds) CHI '95 conference on human factors in computing systems. SIGCHI: ACM Special Interest Group on Computer-Human Interaction. ACM Press, Denver, pp 185–186

Edmonds EA, Soufi B (1992) The computational modelling of emergent shape in design. In: Gero JS, Sudweeks (eds) Computational models of creative design. University of Sydney, Sydney, pp 173–190

Edmonds EA, Candy L, Jones R, Soufi B (1994) Support for collaborative design: agents and emergence. Commun ACM 37:41–47

Emmeche C (1994) What is Life? In: The Garden in the Machine The Emerging Science of Artificial Life. Princeton University Press, pp 23–46

Emmeche C, Køppe S, Stjernfelt F (1997) Explaining emergence towards an ontology of levels. J Gen Philos Sci 28:83–119

Flake GW (1998) The computational beauty of nature computer explorations of fractals, chaos, complex systems, and adaptation. A Bradford Book, Cambridge

Gabo N (1937) The constructive idea in art. In: Circle: international survey of constructivist art, 1st edn. London

Gero JS (1996) Creativity, emergence and evolution in design. Knowl Based Syst 9:435–448

Gooding M (2001) Abstraction: an introduction. In: Gooding M (ed) Abstract Art. Tate Publishing, Cambridge University Press, Cambridge, pp 6–11

Holland JH (1998) Emergence from chaos to order. Addison-Wesley, Redwood city

Laughlin RB, Pines D (2000) The theory of everything. Proc Nat Acad Sci (PNAS) 97:28–31. doi:10.1073/pnas.97.1.28

Lewes GH (1875) Resultants and emergents. Problems of life and mind. James R. Osgood and Company, Boston, pp 368–375

Mill JS (1889) On the composition of causes. In: a system of logic ratiocinative and inductive being a connected view of the principles of evidence and the methods of scientific investigation, Peoples. Longmans, Green, & Co., London, pp 242–247

Mitchell WJ (1990) A new agenda for computer aided design. In: McCullough M, Mitchell WJ, Purcell P (eds) The electronic design studio architectural knowledge and media in the computer era. The MIT Press, Cambridge, pp 27–43

Mitchell WJ (1993) A computational view of design creativity. In: Gero JS, Maher ML (eds) Modeling creativity and knowledge-based creative design. Laurence Erlbaum Associates Inc., Hillsdale, pp 25–42

Dictionaries Oxford (2010) Reductionism. Oxford University Press, Oxford

Pickard-Cambridge WA (tran) (2015) Topics/Aristotle. eBooks@Adelaide, Adelaide

Poon J, Maher ML (1996) Emergent behaviour in co-evolutionary design. Artificial intelligence in design. Springer, The Netherlands, pp 703–722

Prusinkiewicz P, Lindenmayer A (1990) The algorithmic beauty of plants, electronic version published Springer, New York, in 1990 and reprinted in 1996. Springer

Resnick M (1994) Turtles, termites, and traffic jams explorations in massively parallel microworlds. The MIT Press, Cambridge

Reynolds CW (1987) Flocks, herds, and schools: a distributed behavioral model. In: Stone MC (ed) Proceedings of the 14th annual conference on computer graphics and interactive techniques (Siggraph 87). ACM Press, pp 25–34

Rinaldo KE (1999) The Flock. Leonardo, The MIT Press, pp 405–407

Salen K, Zimmerman E (2004) Rules of play game design fundamentals. The MIT Press, Cambridge

Seevinck J (2008) +-now, interactive artwork

Seevinck J (2014) Of me With me, interactive artwork

Sommerer C, Mignonneau L (eds) (1998) Art as a living system. In: Art @ science. Springer, Vienna

Soufi B, Edmonds EA (1995) A framework for the description and representation of emergent shapes. In: Teh M, Tan R (eds) Proceedings of computer-aided architectural design (CAAD) futures. Singapore, pp 411–422

Thompson DW (1992) On growth and form: the complete revised edition. Dover Publications, Momence

Weber M, Esfeld M (2008) Holism in the sciences. Encyclopedia of Life Support Systems (EOLSS), vol 1. UNESCO, Paris, pp 91–109

Wertheimer M (1938) Gestalt theory. In: Ellis WD (ed) Source book of gestalt psychology. Harcourt, Brace and Co., New York, pp 1–11

Wolfram S (2002) A New Kind of Science. Wolfram Media, Inc., Champaign, IL USA

http://www.springer.com/978-3-319-45199-2

Emergence in Interactive Art
Seevinck, J.
2017, XIV, 182 p. 50 illus., 40 illus. in color., Hardcover
ISBN: 978-3-319-45199-2