Food Orbits: A novel design tool for complex systems

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Abstract

Food and our relationship with it is important to our very survival. To understand the different natures of various food systems it is critical to understand some of their general characteristics. We must know the components of the system and how they work together. Currently, there are several conceptual models of food systems available to facilitate the understanding of such: the linear, radial and loop models, none of which seem suitable for a design application. Natural food systems are complex adaptive systems that operate in a closed loop, with all inputs emanating from and all residuals returning to the source. However, rather than resembling these closed-loop ecosystems, modern food systems have much more in common with 19th century factories designed around a strong input/output efficiency model. Food Orbits is a novel graphical tool for plotting the relative industrial intensity of a food as it moves through the system from soil to dinner plate. This paper will introduce the concept of food orbits through a brief discussion of their context in the modern food system, their composition and construction, and an overview of a brief study done to assess their graphical intuitiveness. The focus of the paper will be the application of food orbits as a design tool and a device for understanding complex adaptive systems.

Keywords

sustainable design, systemic, eco-design, life cycle analysis

In this paper we consider the 'food system' as all those products, processes and activities that become entrained in the passage of a component of human nutrition as it moves and transforms from source to residue, a cradle-to-cradle system (McDonough & Braungart, 2002). There is a long historical association involving design and components of this food system from the design of simple utensils like bowls, pots, knives and forks through complicated scientifically-based appliances like microwave ovens and eventually genetically modified (designed) foods like tomatoes (Martineau, 2001). All of these associations, however, tend to reflect the activities of conventional design practices and operate at the low systems level, i.e.: a product rather than a system of products.

Design practice is now entering a higher systems level, often referred to as strategic design, and whilst this has generally been associated with design's relationship with and in business (Best, 2006) it also gives rise to new kinds of designers (Press & Cooper, 2003; Inns, 2007). In these respects, we believe strategy also applies to food systems and that 'food orbits' is a strategic design tool, which applies to the designer's visual and intuitive skills in this field (food) and at the systems level. Recently, Baxter (2010) has referred to this strategic move as “design thinking entering new domains”. In doing so it widens its perspective and links the systems' scale, from product, to service and ultimately to a “comprehensive anticipatory design science” (Fuller, 1969). This latter perspective is at the worldview level. Baxter also suggests, however, that this is only one dimension (vector) of what will create the new 'field of play' for designers. A second key dimension is the ecological perspective in which “ecological thinking enters design domains”. These dimensions taken together – ecological thinking entering design and design thinking entering new domains, constitutes what Orr (2002) has called “ecological design”, Wann (1990) has called “deep design” and Baxter (2005) refers to as “natural design”. This new combination will, according to Baxter (2010), lead to the *transmutation* of design and give rise to a new breed of designers, who he refers to as the “new alchemists”. Orbiting (Brogan & Baxter, 2010) often applied to the design of food systems (food orbits), is a technique which is located at the interfaces of these two dimensions of thinking (ecological design). It is a contribution to the transmutation of design practice.

Design and complex systems

Understanding the system or the environment in which a design functions is critical to the efficacy of that design. Conventional design methods are, often by necessity, reductive – reducing difficult design problems to systems of smaller solvable problems. Whilst this approach is powerful and effective it means the solution will be optimised, and essentially designed for that simplified context. However, even these designs are always part of larger systems that then operate as part of other truly complex systems such as the greater human society or a natural ecosystem.

Some designs function directly within a complex system, such as a social network. It is within these systems that a reductionist approach often yields unintended results because the design process cannot model the level of complexity needed to explore all consequences. There are numerous examples of large-scale designs, such as hydroelectric schemes or highway networks, having large and unpredictable impact on society and the natural environment. There are also many examples of small designs such as mobile telephones or web-based social networking sites, having similar effects.

The designer, by training and experience, is prone to immediately designing toward an end defined by brief or specification, whether real or implied. If one is employed as an engineer with a large microwave oven manufacturer it is unlikely that any non-microwave oven solution would even be considered when developing a new cooker. Part of this problem exists at the beginning of the process when the design problem is defined. The problem is defined in both context and scope. Often widening the scope of the design is referred to by the cliché of 'Thinking outside the box'. This is often done through a brainstorming exercise in which different possible solutions are explored. In the example of the microwave, “thinking outside the box” might mean investigating microwave-convection ovens, halogen cookers or possibly even a gas cooker, but almost certainly not solar cookers, raw food diets, or communal campfires. Clearly, this level of complexity is too much to handle.

Simply thinking about these systems, possible problems, possible solutions and their consequences is too much for a designer or even a design team – no matter how large. The usual outcome is to simplify and return to the proverbial box. Our ability to effect change has now outstripped our ability to understand the consequences of the change.

The problem with design and complex systems is that the systems cannot be assessed by standard design methods, as the least understood part of these systems tends to be at a higher scale and traditionally conventional design works at a lower scale. Therefore, a new suite of methods are required to better assist designers in their understanding of these systems and to help them design *within* the system whilst leaving space for emergence and growth.

J. Chris Jones explained something of these levels of complexity in his justification of the need for new design methods, breaking the sphere of design influence into four strata – community, systems, products and components. He explains that “Many of the unsolved problems of designing occur at the systems level of the hierarchy.” but that conventional design methods are only effective at the two lowest levels. He goes on to suggest that:

> such an extension of the design process is at least as great as that from craft work to design-by-drawing (a shift from the lowest tier to the two lowest tiers). This change (to what Buckminster Fuller has called 'comprehensive designing') cannot fail to have drastic consequences, implying, as it does, the power to continuously remodel the whole fabric of industrial society from top to bottom. (Jones, 1992)

Jones contends that the tendency to move the designer's role from the products level into the top two tiers results in too much control and he rightly dismisses it as having drastic (likely catastrophic) consequences. However, the notion of 'comprehensive design' may be appropriate when one considers 'comprehension' to mean 'understanding of the whole'. It is this area of design that is lacking in many established methods and practises.

To date there have been some methods, such as systems modelling (Odum, 1983), pulsing, lensing (Baxter & Bruce, 2008) and orbiting (Brogan & Baxter, 2010), developed to help designers navigate this 'systems geography'. Orbiting is an exercise that designers can participate in to understand something further about the interrelationship between a system and a design. This concept is exemplified here in relation to food as it provides an excellent example of complex systems and the implications of design. It also provided the original basis for the concept developed by Brogan and Baxter.

Food orbits

Aside from design issues, there are many reasons why we may want to understand the origin of our food and especially the system, which brings it from the field to the plate. Of most importance to the consumer is probably that of food quality. Issues of food adulteration are as old as food itself - Unscrupulous producers or processors somewhere along the way 'bulking out the loaf' or 'watering down the whisky'. The Food Adulteration Act of 1860 banned these practises and eventually led to a system of inspection and enforcement that guaranteed foods to be safe, sanitary and pure (*The fight against...*, 2005). However, the lack of international standards and the lax definition of what is safe, sanitary and pure can lead many people to look deeper in to a food's origin to assure themselves of its claims.

After food quality, concerns might be expressed about a food's secondary or external qualities. These issues might not be directly linked to the food's internal quality, but often have what are best described as *health* implications. An example is feedlot-fed beef. Two physically near identical steaks purchased at a supermarket may be clean and unadulterated beef that earns the highest grade, but have travelled through very diverse channels. One may originate from a local farm where the animal was raised on pasture grass until it grew to market weight after which it was processed, humanely, in a local abattoir that sold it directly to the supermarket. The second may come from the American mid-west where the animal spent 80% of its life in the cramped and dirty conditions of a feed lot eating low-grade corn, subsequently being slaughtered in a large plant employing unskilled migrant workers, boxed and sent along to a cutting plant where it was cut into a steak, frozen, shipped a few more times until it landed at the supermarket, where it was thawed and repackaged for sale. The second steak represents what many consumers would term 'unethical' food, but in terms of health (of the environment, animal, workers and the local economy) it is also the unhealthy choice, despite the identical nutritional information 'sticker' on either steak.

To add to the ambiguity of the various food choices, the process of tracing the origin and genesis of foodstuffs in a globalised market has become quite difficult. Most processed foods contain a myriad of ingredients from different sources, which then merge to become one product that may then be again combined with other products shipped onwards through a complicated distribution network. Even whole foods, foods that are consumed in the same state in which they were harvested, may have equally complicated origins as evidenced by the aforementioned steak example.

Adding to these problems, there is the general situation of public knowledge. Whilst a certain sector of the population may be well informed about food and its origins, an American study showed that most people think very little about the origin of their food, mostly due to the lack of a mental 'model' of the system, stating: "...the lack of a specific model of food systems means that certain kinds of information has no place to 'stick' in people's minds." (Aubrun, Brown, & Grady, 2005). Unpacking this mystery inevitably leads to the construction of a model or simplification of some sort.

The first type of model we considered to help us understand such complex systems was a spatial-survey model showing where food had been and perhaps some detail as to what had happened to it at each point in the food system. The result would be either a geographic map with pinpointed locations and descriptive boxes or a more logical box-and-arrow systems diagram. The latter affords the viewer a more generic depiction that can then be easily compared with alternatives by eliminating the spatial confusion of a map and crossing lines. Such box diagrams are commonplace in engineering and science fields and are best suited to analyses that target process efficiencies. The focus of such box diagrams is on the process rather than the product itself.

The process-based model has at its core the weakness/strength problem of most models. In any model, the more that is left out to help focus the user on a solution, the greater the danger in neglecting certain parts of the system. In a complex, non-linear system, leaving out what might appear to be a small or even insignificant component can have large effects. So, whilst a systems-based model is critical to the understanding of systems-aspects such as layout, relationship and flow, it is only a part of a suite of models that could together shed light on the entire system.

One of the main challenges of constructing a systems-model for something as complex as a food system is actually gathering information about the system, especially when so many systems converge and diverge. Often what is most critical about the process (the product and the environment) is lost. In the 1980s, engineers facing just such a problem in one aspect of the food system, potato production, developed a novel solution to view the system from the inside by creating what is now commonly referred to as the 'electronic potato' (Anderson and Parks, 1984). The electronic potato is a potato-shaped data-logger, which monitors various physical parameters that a potato might encounter, such as: physical force, temperature and relative humidity. The 'potato' is then buried in a field and eventually retrieved at the processing facility days (or weeks) later. The data, once downloaded, provides a story of what has happened to the potato. This can illuminate where in the process the potato is exposed to excessive heat, moisture or physical force. It is a 'potato's eye view' of the post production process and often shows a very different story from that told by the systems model.

An alternative method at the early design stage is the use of a model, which exploits tacit knowledge, readily accessible information and intuition.

Understanding macro organic mass flow through the world's modern food system ultimately leads us to the study of naturally occurring food systems, because, despite our best efforts to mechanise, the food system still has living systems at its base. It is comprised of living organisms and systems that have been modified by our efforts to adjust or control the flow of water, nutrients and organic mass, resulting in natural systems with varying degrees of intervention. Whilst systems thinking has been applied to ecology (Odum, 1983) and this has, to a great degree, influenced our understanding of how they function, there are still many unknowns. Nevertheless it is known that natural systems have a variety of common characteristics such as a tendency to be highly stable over the long term, a high degree of complexity, self-sustaining characteristics and usually operating in a closed-loop with a high degree of feedback and redundancies. They are resilient. The entire premise of agriculture is the isolation of small components of natural systems with intensification of certain aspects for the benefit of mankind. By definition it is a disturbed ecosystem. Agriculture, in effect, takes humans, as a species, not just to the top of the predator-prey pyramid, but out of it, free to browse the entire structure. This then gives humans the unique ability to stand back and consider the structure, which compromises every other living organism. In recent history it would appear that we have seen this system as a simple machine that can be optimised and fine-tuned.

The degree to which we intervene in the ecosystem might be referred to as 'intensity', coming from 'intensive agriculture'. The idea of intensity can be applied to most processes such as: intensive training in education or intensive care in health. At its root, 'intensity' simply means the application of stronger or more forceful action and is well appreciated by most people at the intuitive level. Applying the term to systems it can be said that intensive systems are those which are designed to apply strong or forceful action toward the achievement of their purpose. Living systems, by their very nature, are not intense. They may well be complex, detailed and adapted in execution, but usually eschew strong and forceful action, despite often having very significant outputs. Food systems, being comprised of living systems, which cannot be designed themselves, must then undergo intervention. In food system terms, it is not the intensity of the system we refer to but rather the intensity of the intervention.

Quantifying intervention is easiest done in qualitative terms with an arbitrary numerical scale (i.e.: one through five or one through seven). Whilst it would be possible to develop a numerical or statistical method to derive an intensity 'score', this is unnecessary given the simply didactic application of the food orbits tool.

A qualitative numerical scale has been adopted here. Such a scale allows for the scoring of various aspects of the system – a rating for each major part of the system that is encountered. This activity allows the designer to think about each aspect of the system individually in terms of intervention and how they affect the complexity of the overall system.

To further develop this scale into a powerful visual tool, we decided that the best form would be that of a loop or orbit, further emphasising the 'cradle to cradle' concept. The food orbit is then formed between concentric circles denoting the intensity scales. Radial arms show each step of the process from beginning to end. Typically, the following stages are represented – Source, Processing, Marketing, Consumption and Residuals, giving five arms. The arms are scaled as per the intensity scale chosen and points plotted and connected to form an orbit around the centre. An example is shown below in Figure 1:

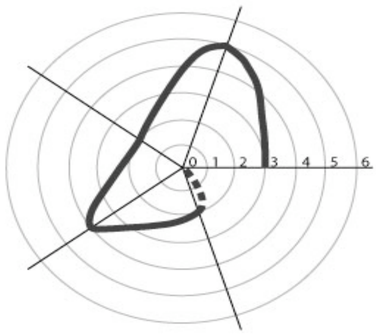

Figure 1: Example food orbit.

The orbit itself was developed as a design tool, but can have application elsewhere. Visually, it offers a very simple way of seeing the intensity of the system. The circular shape adds emphasis to greater intensification. A designer can look at the orbit and quickly see which part of the system is most intense. The orbit and the process of creating it are quite intuitive, simple and holistic, making it a quick exercise for designers to perform to help them balance some of the detail-oriented systems modelling.

We acknowledge that there may be many other applications for this concept – including those which take it down a much more predictive or calculated route – but at this stage it was most critical to evaluate the strongest property of the concept: its basic intuitiveness. What follows is an early exploration of the intuitive nature of the food orbits concept.

Preliminary exploratory experiment

A group of design students from the University's Masters of Design and Masters of Design Ethnography programme were taken as a sample group. The group were not all specialist designers, but most had some traditional design experience, either in the form of a Bachelor's degree or in industry.

The group was given a very brief introduction to the concepts of intensity and orbiting, totalling no more than fifteen minutes and then given the task of drawing four food orbits for selected foods, individually. Each food was described minimally (see Table 1). Two minutes were given to draw each orbit on a blank sheet, showing only the scale via concentric circle. Questions were answered on specifics as asked – although no numerical intensity values were given for the first food. In the three subsequent foods, intensity scores were given for parts of the orbit. The table below summarises the information given. A picture was also shown to the participants.

Local Strawberries	Grown locally under poly-tunnel, some chemicals use, sold at nationally branded supermarket, consumed at home with cream.
Tinned Baked Beans	Beans grown in USA under conventional agriculture, processed with sauce added in the this country, tinned and sold here, bought and eaten on toast, *Source = 5*.

Olive Oil	Cold pressed from organically grown Spanish olives, bottled in Italy, sold locally at a small organic market and eaten on a salad, *Residuals = 3*.
Baguette	Locally baked from conventional Canadian HRS wheat flour, purchased from a small shop near the university, *Source = 4, Residuals = 0.*

Table 1: Information given to students to generate food orbits.

The group consisted of 24 individuals who produced a food orbit for each specified food. The resulting sketches were collected and results compared. It was expected that, should the food orbit concept be basically intuitive, the results would be similar in shape and scale.

As it would be impossible to visually compare the results, each food orbit was converted in to a series of numerical values, representing the five stages of the process. The standard deviation for each sample of intensity values was calculated, shown in Table 2 below.

Table 2: Standard deviations of intensity scores.

	Source	**Processing**	**Marketing**	**Consumption**	**Residuals**
Strawberries	*1.5*	*1.2*	*1.1*	*1.4*	*1.1*
Beans	*0*	*1.2*	*1.1*	*1.3*	*1.3*
Oil	*1.4*	*1.2*	*1.5*	*1.1*	*0*
Baguette	*0*	*1.4*	*1.3*	*1.7*	*0*

Omitting the standard deviations of zero, where the value was given, the others ranged between 1.1 and 1.7. This indicates that, whilst there were a range of values, the majority sat within one to two units of the mean. We realise this is not an exhaustive analysis, nor was the experiment intended to be conclusive, but simply a first look at the validity of the concept.

As discussed in the main body of the paper, the greatest value of the orbiting concept is as a design tool to work in concert with other systems modelling tools. Further research is planned to both further investigate the intuitive nature of the food orbit as well as its efficacy as a design tool in assisting the designer's awareness of complex systems

Conclusion

Understanding complex systems is critical to the ability able to design in a holistically effective manner. Not simply knowing the environmental impact, which is usually framed in a negative sense, but the place and appropriate function of a design as part of a natural system is necessary. Natural food systems are complex adaptive systems that operate in a closed loop, with all inputs emanating from and all residuals returning to the source. Food Orbits are a novel graphical tool for plotting relative intensity of a food as it moves through the system from soil to dinner plate. This concept has been shown to have some intuitive value and future studies are planned to investigate further application outside the realm of food. It would appear to be well suited to the early design stages of a complex problem.

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Author Biographies

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Born in Charlottetown, Prince Edward Island in 1978 and raised in Nova Scotia, Canada he trained in Agricultural and Bioresource Engineering at Nova Scotia Agricultural College and the University of Saskatchewan. Steve worked for several years in Western Canada in field crop research and later with an engineering consultancy. His varied design experience includes abattoir layouts, municipal waste treatment and green energy systems. He is currently pursuing a PhD in Natural Design at Duncan of Jordanstone College of Art and Design at the University of Dundee and lecturing in mechanisation topics at the Scottish Agricultural College, Aberdeen. His research interests include design methods, salutogenic design, sustainable food systems and eco-building. He lives in Dundee, Scotland.

Seaton Baxter

Seaton was born in Aberdeen, Scotland in 1939. He has academic qualifications in building technology and philosophy. He worked for 20 years in agricultural research mainly concerned with the design of buildings and equipment for animal welfare, before joining the Robert Gordon University, Aberdeen in 1983 as Head of the School of Construction Management, Property and Surveying. At the Robert Gordon University he acted as Assistant Principal, Dean and Reader where he established the Centre for Environmental Studies (c1994) and the first ever MSc in Ecological Design. He is currently an Honorary Professor at Dundee University where he heads the Centre for the Study of Natural Design. Seaton has worked with several Scottish environmental NGO's - Scottish Environment Link, Association for the Protection of Rural Scotland, Deeside Forest Advisory Group and was formerly a board member of Scottish Natural Heritage.

He was awarded an OBE by the Queen for his services to Scotland's Natural Heritage in 1998. He currently lives in Fife, Scotland.