Simulation and the Search for Stability in Design

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In making a design proposal, the designer is implicitly assuming some view of future events to which the design corresponds, yet the scenarios to which designers often respond are often too complex and difficult to define, so prediction is out of the question. Complex systems that appear unstable at one level of detail are often predictable at a higher order, and it is this that makes design possible. In the state space of the system in question, some regions will be stable basins of attraction in which design moves can be made with confidence, while others will be unsuitable. Suggestions are made for the use of simulation—in particular that it is less useful as a tool for scenario prediction as for mapping out this state space to search for such stable regions.

1.0 Introduction

Design problems, if they can be called problems at all, are complex. They are what Rittel and Webber [1] describe as “wicked problems”, in that they naturally resist any kind of clear definition. Disciplines such as architecture and planning are described as dealing almost exclusively with situations in which the brief is relatively ill-defined relative to the real range of problem considerations, the perception of the problem itself may change radically as design progresses, and the solution is typically arrived at by a unique process that cannot be predicted in advance.

Even where the situation can be clearly specified, complexity exists of a more formal nature. Jacobs [2] introduced the problem of urban planning with specific reference to complexity theory, quoting Weaver’s [3] description of ‘disorganised’ versus ‘organised’ complexity. Both involve a large number of parts or variables, but whereas those in the first do not affect one another and so the system may be treated statistically, those in the second are interconnected in such a way that their structure resists a statistical description. The behaviour of molecules in a gas is an example of the first; biological systems, cities and other targets of design are examples of the second.

Such systems are notoriously sensitive to initial conditions, and any inaccuracy in modelling them can accumulate to make exact prediction of their behaviour impossible. Where the system's possible future trajectories diverge in this way, it is called chaotic. The weather is perhaps the paradigmatic example. If the variables that diverge in this way are relevant to the goals of the designer—that is, if the success of the proposal rests on the prediction of the system being even approximately accurate—then design becomes impossible.

Thankfully, many complex systems exhibit stability, sometimes in particular regions of their state space, and sometimes at a higher level of abstraction. In agent based models of economic behaviour, the individual agents' matter very little, but the structure of their interactions constrains the behaviour of the entire system [4]. In Arthur's [5] models of bounded rationality, behaviour of a single agent will be entirely unpredictable at any given moment, while the behaviour of the group as a whole will in the long term converge to fluctuate around a stable, predictable outcome. At this higher level, and because of the system's structure, certain measures that describe the behaviour of the system are *invariant* with respect to changes in any of the individuals. This is highly relevant to design because designers typically do not need to work toward the precise behaviour of an individual at a precise moment in time, but for a varied group and over a relatively long period. Recalling the example of urban planning makes this obvious.

This position paper proposes that all design is aimed at stable regions within a system's state space. These basins of attraction, in which the performance of the system is invariant to small changes in conditions or a failure in collecting precise data for the model, are in fact the only possible areas in which design is possible at all.

2.0 Higher level invariants in complex domains

Several design related examples will serve to illustrate the higher level invariants that may be useful in each domain.

The prediction of air flow using computational fluid dynamics can achieve a high degree of accuracy, and thus result in a believable picture of the effects of wind on a new tall building in an urban context. However, because the system is chaotic at this level there are at least two difficulties in compiling the necessary data for true prediction. First, no matter how precisely the new and existing buildings can be specified, it is certain that the state of surrounding buildings will change in future, and possibly affecting the air flow drastically enough to make analyses of the current environment obsolete. Second, even in the relatively stable state of an unchanged urban environment, most phenomena to be simulated are continuous and can take on any of an infinite range of real values. In such cases, the probability of simulating the exact values for wind speed, direction or other factors approaches zero (Figure 1). This can often pass without causing problems, but if conditions lie within an instability regime, in which a minor change in the wind causes big differences in performance, then the simulation becomes useless.

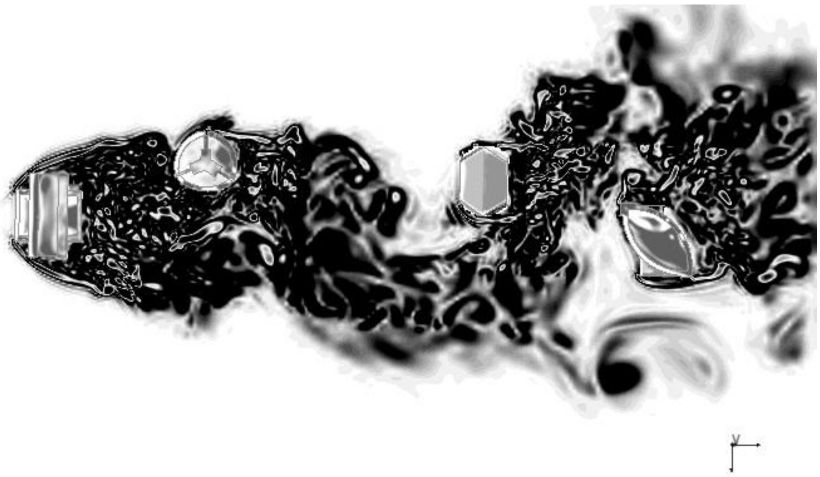

Fig 1. A single simulation gives precise values for wind velocity, but some regions can be particularly sensitive to initial conditions. Image: Next Limit Technologies.

Such models are not used in the hope of predicting the particular level of air pressure at any given point however, but can be useful to show the areas in which turbulence may occur over the long run, or to estimate the entire range of pressures than can occur when the simulation is run over time. Often, the range of pressures in a certain region may be invariant at this lower level of resolution. In current practice, due to the expense in computation and time taken to perform such simulations, the designer often makes a series of best guesses, and then plans for multiple scenarios. With faster models the opportunity arises in which the state space of the system may be sampled and mapped out more methodically with respect to design options, to reveal those in which outcomes are less sensitive to chaotic fluctuations, and therefore more robust design proposals.

For many complex problems, such as with many kinds of human behaviour, there is insufficient knowledge on how to even model the system. Space Syntax methods of analysis [6, 7] have proven reliable in doing so. Part of the reason is the acknowledgement that the prediction is ultimately founded on the cumulative results of a vast number of people—in the simulation of visual agents [8], a single agent moving through a building will trace a path that appears unlike that of a normal person, however the total effect of a large number of agents in a virtual model will correlate highly with the movement of real people in the actual space. In this case behaviour is given by the invariant of the space itself, and interaction can be reduced to the biologically realistic 170° cone of vision, common to most people.

Analysis is possible because the agent behaviour is determined, in the long term only, by the spatial configuration, and can thus be predicted as the convergent steady state purely by analysis of the topology of the space given as a graph. Again, it is a higher level stability that is relevant. It is important to note that the model is in no way deterministic with respect to the behaviour of any individual agent (or real person), but only at the level of the group. As with Arthur's [5] models, any differences between people in terms of their personalities or goals effectively cancel one another out—they are variables that do not matter in terms of the model.

In both instances, the obvious description of the system consists of apparently unpredictable variables such as the air pressure at points over a field, or the location and direction of a walking agent. At another level, these can be recast, for example, as standard deviations of pressure in stable zones, or the density of pedestrian traffic over time. These variables may be invariant, more stable, and directly dependent on controllable design parameters such as building geometry and spatial configuration.

3.0 The use of simulation in design

The above examples illustrate several of the ways in which models can be both accurate and inaccurate at different levels of detail, and thus the fact that simulation can be useful only for prediction in certain cases. In terms of methodology, this has two important implications:

1. When attempting any kind of simulation of modelling, the purpose is not to attempt to predict the course of future events by refining the ac-

curacy of data, but to find invariants, often at a higher level, that promise stability.
2. One is thus looking for convergence in the model, but given the ill-defined nature of design problems, it cannot be presupposed where this will arise. It becomes an essential task is to find an appropriate recasting of the relevant variables in order to achieve this.

With respect to the second, Weaver's [3] distinction between disorganised and organised complexity is relevant because the statistical approach used to deal with the former also operates by assuming an invariant and allowing lower level variables to cancel one another out—the particular velocities of particles in a gas, for example. The principal feature of the organised system however, is that its structure plays an important role. The two cases above used the physics of fluid dynamics and the biologically determined visual system to provide this structure, but in many design situations this is not known in advance. In many cases this structure can be found in real world data itself, as has been done by machine learning algorithms with structural performance [9] and urban morphology [10]. In other cases designers rely on intuition or existing typology to do the same. Jacobs [2] warns against the statistical approach to such complex systems because it often leads to drastically inappropriate proposals. What is suggested here is that the problem with the statistical approach is that it simply assumes the structure of the system and relevant variables in advance. With organised complex systems this must be carefully investigated to find those levels and regions in which prediction might be possible. It is the task of the designer to do this.

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