Dynamic semantic systems — an information systems' impact model

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ABSTRACT

This paper presents a descriptive framework comprised of a high level model of the manner in which information systems impact on social systems — in particular the dynamic semantic systems which determine how information is interpreted and used. The framework draws on existing theoretical components: Wittgenstein's language-games, and the concepts of bifurcation, resilience and stability in social systems qua complex systems far from thermodynamic equilibrium. It is suggested that the framework is valuable in three respects.

First, it provides a model of the impact which information systems and information technologies have on the human systems within which they find meaning and application. This furnishes us with a basis for predicting the kind and extent of the disruption likely to be caused to a dynamic semantic system through the introduction of or changes to an information system. It also provides a basis for designing intervention strategies to exert control over such disruption and the likely results thereof.

Second, it is built upon an appreciation of and hence provides a conceptual 'handle' on the constant, dynamic and temporally distributed relationship between human systems and information systems.

Third, through appeal to 'indirect steering' and the concept of structural coupling between a system and its environment, it offers a novel approach to the problem of steering and controlling highly complex equilibrium far systems.

Keywords: Dynamic Semantic Systems, Language-games, Information Systems Design, Ecological Systems, Indirect Social Steering, Structural Coupling.

1. DYNAMIC SEMANTIC SYSTEMS

A theoretically solid semantic model is necessary for and highly relevant to a coherent approach to the analysis and synthesis of information systems. The success of an information system is defined and determined by the application of some evaluative criteria to the relationship between that system and its users. This relationship derives from how users understand, use and relate to the system — fundamentally, the meanings that they ascribe to it.

Wittgenstein provides such a semantic model, demonstrating how meaning can be seen to arise from the participation of individuals in systems of practices, called '*language-games*' [1]. Wittgenstein rigorously rejects grounding meaning denotationally, in terms of reference to 'interpretation independent' (sic) real world entities and logical relationships between them. Instead, he argues that we should think of ourselves as cocooned in and defined by coherent, self-referential and overlapping webs of shared practices, which allow us to co-ordinate with and make sense of one another and the world in which we act. Language is a form of behaviour that extends well beyond 'meaningful vocalised utterances'. So conceived of, one might argue that language is the basic substratum of the social system, and is itself ordered further through its role in that higher level system.

Wittgenstein's interpretive semantic theory not only welcomes a systems perspective, but also is enhanced itself through such a liaison. Wittgenstein does not really deal with the issue of how systems of social practices adapt and evolve over time, which some commentators view as a serious deficit (Harris [2], for example). This deficit is remedied if we view semantic communities as dynamic systems composed of behaviours and practices shared by participant individuals. The systems perspective brings with it the concept of an ongoing entity surviving and responding to perturbations over time. The term 'dynamic semantic systems' is suggested to capture the idea of a dynamic systems perspective applied to the language-game concept — a perspective typically lacking in traditional approaches to software engineering and information systems design [3, 4].

The idea of semantic phenomena emerging from the coordination of practices between individuals within a particular environment, giving rise to an essentially arbitrarily bounded sign - meaning relationship, has been adopted much more recently from a systems perspective. Maturana and Varela [5, 6] see language as arising through the structural coupling that occurs between frequently interacting and mutually perturbing self-producing systems, resulting in self-referential systems of recursively coordinating practice and behaviour — "consensual domains". Similarly, Luhmann [7], drawing heavily on Maturana and Varela's work (although abandoning the former's strict grounding in chemically composed biological systems), focuses on *communications* as the basic component of social systems.

In terms of the proposed impact model, it is the dynamic semantic system, so conceived of as an autonomous, self-maintaining and self-referential system of practices, which is perturbed by information systems changes, and hence for which an impact model is required. There is currently no way of evaluating the degree of this sort of perturbation in the context of information systems' analysis and design, or the

likely consequences thereof. Nor, for that matter, is there much recognition of the close relationship between semantic systems and how information systems are used and understood — although the work of Ehn [8] is a notable exception, and one that also draws directly on the work of Wittgenstein.

The potential significance of an information system derived perturbation to a dynamic semantic system is powerfully illustrated by Despres [9], who provides a very powerful ethnographically grounded account of this phenomenon, whereby the introduction of an information system into an organisation brings with it an implicit Tayloristic mind-set. Whilst this is successful from an impersonal perspective — profits increase and so on — practices, relationships and processes within the social system of the organisation are changed radically and traumatically, which effectively undergoes a significant change of identity in terms of its fundamental organisation.

From an IS perspective this is highly significant — where an information system perturbs a dynamic semantic system, this in turn effects how the information system is used and understood:

> "I uncovered a sociocultural / info-technological juggernaut in my research: sociocultural dynamics shaped the information system, the information system recursively shaped its socio-cultural milieu, which then shaped the information system anew in a context warping spiral of events." [9]

2. PERTURBATION AND BIFURCATION: CHARACTERISING IMPACT

Laszlo [10], drawing on concepts from macroevolutionary and ecological theory — dealing with non-equilibrium thermodynamic phenomena, particularly the concept of "punctuated equilibrium", looks at the evolution of social systems in terms of possible responses to environmental perturbations. The concepts of 'bifurcation', 'stability' and 'resilience' that Laszlo focuses on offer an opportunity to similarly evaluate the degree of environmental perturbation which an information system transformation can inflict on a dynamic semantic system, as well as the likely consequences thereof — the much needed information systems' impact model.

If the perturbation to an equilibrium-far system in a meta-steady state is of a sufficient magnitude, a point of bifurcation is triggered (the prefix 'meta' is used, for systems far from equilibrium are by definition dependent on higher-level processes). A 'sufficient' perturbation is one that causes a fluctuation within the system that is outside of the range of tolerance of the system's non-linear processes of self-production. When this occurs the system is thrown into an indeterminate state, from which there are two possible outcomes: either the system disintegrates, reduced to its stable components, or it settles into a new meta-steady state — see figure 1.

This concept of a stark choice between self-adjustment and disintegration in response to perturbation is fundamental to *structural coupling* between systems, which occurs over a period of non-destructive alterations to the structure of a system. This concept is discussed in section 5 of this paper.

The possibility of the system settling into a new meta-steady state is particularly significant, in that it represents the system becoming more closely coupled to its environment.

Introducing a new information system, or making changes to an existing one constitutes an environmental perturbation to the dynamic semantic systems that interact with the information system, which may or may not trigger a point of bifurcation.

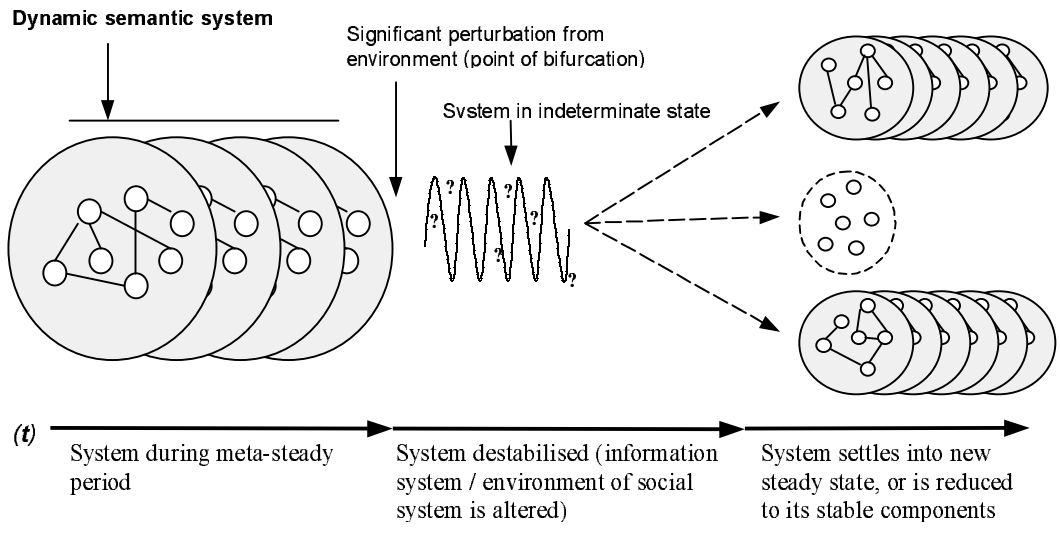
A point of bifurcation implies change to the system — in the case of a dynamic semantic system, changes to practices and conventions, affecting how information is used and understood (and potentially, to anything else which is interpreted within that system, including relationships with other human beings).

In terms of the relationship between an organisation and its information system, failure to find a new meta-steady state following bifurcation constitutes a potential calamity — the dynamic semantic system in question loses its identity as a viable autonomous system. The degree of damage could range from the functional and social failure of a sub-departmental workgroup, to the whole company losing viability in its business environment.

However, even if it is a relatively minor system that loses its identity, the consequences for the wider social system of the organisation cannot be predicted. As its sub-systems and the relationships between them generate the behaviour of the larger system, an alteration to the nature of one of those systems could have a significant effect on the wider system. Morgan [11] uses the same idea, expressed in terms of chaos theory, to explain how we might think of organisational (in the business sense) systems — as susceptible to significant behavioural shifts via small strategic interventions.

The same applies at a lower level to the dynamic semantic system - information system

Figure 1. Bifurcation in Dynamic semantic systems



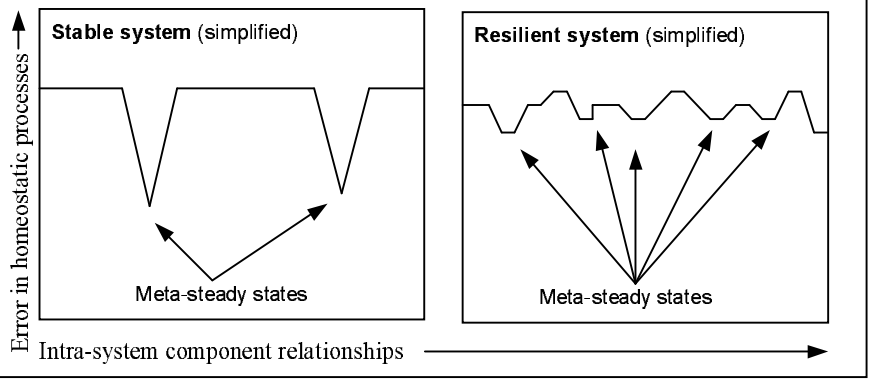
relationship under examination here — an information system transformation may only need to have a minor perturbatory effect for this to have significant consequences for the dynamic semantic system, and in turn for the next level system. The same principle, of sensitive dependence on initial conditions, establishes the possibility of a butterfly (enervated or otherwise) indirectly affecting major weather patterns. As Despres observes in the context of information system based perturbations, "…a new technology does not add or subtract something. It changes everything." [9] This emphasises the importance of having a framework within which such risks can be articulated, and intervention strategies suggested through which they could be minimised.

3. BIFURCATION — CONDITIONS AND POSSIBILITIES

The response of a system to a perturbation is determined entirely by the qualities of that system. Laszlo [10] distinguishes between *stable* and *resilient* systems, qualities that he suggests are inversely related.

Systems with a high degree of stability have a narrow environmental niche to which they are likely to return after a perturbation. However, after a novel or major perturbation, a system with high stability may be permanently affected, if it does not collapse altogether. Conversely, resilient systems, whilst less likely to return to a given state after a perturbation "are able to respond to a wider range of environmental disturbances, absorb the changes, and settle into a new steady state even across a wide range and variety of fluctuations" [10]. Figure 2 provides a simplified representation of this distinction.

Figure 2. Stable vs. Resilient System Characteristics



The significance of the different outcomes from a perturbation to a dynamic semantic system depends on the context within which the perturbation occurs.

If an important goal in designing a particular information system were for it to integrate seamlessly with users' existing work practices — in an ambulance control room for example (c.v. the notorious *London Ambulance Service* control room case [12]), then one would wish to avoid perturbing the dynamic semantic system sufficiently to cause a point of bifurcation, which represents a shift in practices. This might be achieved on either side of the system-environment relationship — by minimising changes to the dynamic semantic system's environment, or by attempting to increase the 'stability' of the system — which may or may not be feasible in a short space of time (c.f. *intervention strategies*, below).

Bifurcation can be also seen as affording a valuable opportunity to shift users' practices out of entrenched habits, effectively offering a 'fresh start' through a process of structural coupling (discussed below) with an altered or new information system. Lyytinen and Hirshheim refer to cases where systems live on unused by end-users, despite design objectives, as instances of "a classic phenomenon" [13]. A number of kinds of failure of this kind may be identified and dealt with using the model outlined here: when an information system is not used; when users' attitudes are negative; where there is resistance from users. All of these problems may be laid at the door of the dynamic semantic system involved.

The successful result of bifurcation in this kind of context would be similar to that obtained through business process reengineering — a 'fit' relationship between socially embedded activities and information system structure, but operative down to a fundamental cultural and semantic level and effected without violating the autonomy of the dynamic semantic systems involved. 'Fit' in this sense implies the closure of gaps between expectations and practices within a dynamic semantic system, and the state of some information system that constitutes an environmental feature of that dynamic semantic system (c.f. [13]).

4. INTERVENTION STRATEGIES — RESILIENCE VS. STABILITY

As suggested above, the likelihood of bifurcation occurring in response to perturbation to a system depends on the qualities of that system — in particular, where it falls on the continuum between resilience and stability. A system's resilience or stability in turn influences the outcome of a point of bifurcation, with resilient systems being much more likely than stable systems to settle into a new meta-steady state, as a greater number of such states are available to them (c.f. figure 2).

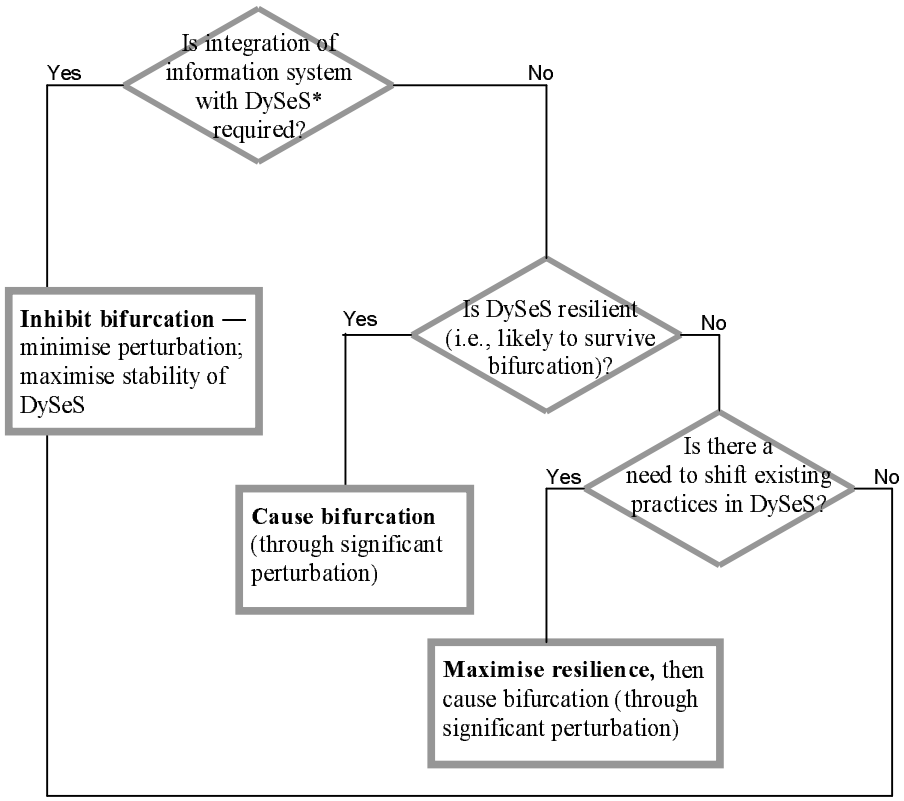
Figure 3 (below) presents a high-level guide for information systems' design and management, based on these relationships.

Inhibition of bifurcation, either through minimising perturbation to the dynamic semantic system, or by maximising its stability is suggested in two situations. If an information system must integrate closely with existing practices in a dynamic semantic system, one must avoid shifting those practices. Where a dynamic semantic system is stable rather than resilient, and there is no need to shift cultural practices in the dynamic semantic system, bifurcation represents an unnecessary risk, given that meta-stable systems have fewer steady states available to them (c.f. figure 2). This correspondingly increases the chance that the consequence of bifurcation will be dissolution of the system — hence its undesirability in these conditions.

However, in an organisational context where change is desirable, for example where users' practices are not responding to new opportunities offered by implemented information system innovations, bifurcation offers an

appealing opportunity to re-align practices, as suggested above.

Figure 3. Intervention decision model



In this sense, resilience may be thought of as a generally desirable property, representing flexibility, and an aptitude for survival. It may even be the case that resilience equates to *variety*, in which case the strategy suggested below to develop resilience in dynamic semantic systems also represents a method for developing variety. This would support the suggestion that *resilient* dynamic semantic systems are likely to respond effectively to information system derived changes in their environment. These qualities, in particular the ability to produce new patterns of behaviour on a continuing basis in response to the environment in which a system is embedded, are those which in an organisational context characterise *learning organisations* [14]. Whilst 'organisations' cannot be captured in their entirety in terms of dynamic semantic systems, the 'dynamic semantic system' concept does capture the socio-semantic relationships between individuals and cultures within organisations. Learning at this level is essential to, and perhaps even sufficient for organisational learning. In this sense, resilient dynamic semantic systems are of great potential value, in that they have an inherent disposition to learning, as manifest in alterations to system states.

5. INDIRECTLY STEERING DYNAMIC SEMANTIC SYSTEMS TO SUPPORT INFORMATION SYSTEMS USE

It is suggested that it is possible to indirectly steer dynamic semantic systems, by causing a point of bifurcation, and allowing structural coupling (see below) between the system and its environment to take responsibility for guiding the process of structural morphogenesis, and thus adaptation, which is nigh impossible to control 'by hand' in highly complex systems. The same principle applies in the evolution of hardware using *field programmable gate arrays* (FPGAs) — complex relationships develop between components that exploit physical properties of hardware, such as electromagnetic coupling, and whose role in successfully producing some desirable output is opaque from a human perspective [15]. The role for the deliberate 'guiding hand' lies in maximising the chance that the process of evolution will have a desirable outcome.

As with many other natural systems, social systems continually produce their own fundamentally unstable structure. This is the basis of their ability to manifest self-organisation, and exhibit considerable structural changes over time. Independently of the smouldering issue of 'are social systems *autopoietic*?' (last major eruption: *International Journal of General Systems* 21(2), 1992), Geyer [16], Bertalanffy [17], Luhmann [7], and Morgan [11], to name but a few more immediately recognisable proponents, all take this approach to social systems.

Ongoing self-production within an environment or medium which is itself dynamic and susceptible to change gives rise to a phenomenon which Maturana and Varela term 'structural coupling' (c.f. [5, 18, 19]). They argue that if a system succeeds in maintaining its organisation over a sequence of perturbations from its environment, it will necessarily develop a structural state disposing it to appropriate responses (non-destructive to the system) to future environmental perturbations of a similar nature.

It would be foolish to prompt adaptation of this kind — morphogenesis effected within and *by* the system — within a dynamic semantic system by triggering bifurcation if the system were stable rather than resilient, thus having few alternative steady states available to it and hence a greater chance of destruction. However, because dynamic semantic systems are able to change over time in response to environmental activities just like other natural self-organising systems, they can move between resilience and stability over a period of time, depending on the perturbatory characteristics of the environment in which they operate (c.f. [10]).

This phenomenon provides the basis of an approach to the management of dynamic semantic systems, to develop in them the resilience that will allow them to respond rapidly and positively to information system based environmental changes.

Through a deliberate strategy of frequent perturbations driven by deliberate institutional intentionality, it should be possible to develop and maintain resilience in dynamic semantic systems within organisations. This would yield in turn dynamic semantic systems likely to respond naturally, positively and successfully (via self-steered adaptation) to environmental shifts derived from information system transformations. In practical terms, this translates as a disposition in user groups to respond and adapt to changes in their information systems environment, and thus to take maximise and capitalise upon the benefits that can derive from taking advantage of IT.

6. CONCLUSION

We have seen how by applying ideas from general systems theory to Wittgenstein's *language-game* construct, one derives the concept of the *dynamic semantic system*. Wittgenstein's work captures the socially embedded (and socially defining) nature of human meaning-making practices — practices which determine how information and information systems are interpreted and used. By applying concepts from complex thermodynamic equilibrium far systems theory to this idea, we add a dynamic temporal dimension to the relationship between human and information systems.

This approach circumvents many of the problems associated with static, descriptive and 'veridical' models of human activity frequently used in information systems design (c.f. [20, 21]). It also provides a basis from which we can analyse the impact that information systems have on dynamic semantic systems, and develop strategies to influence both the extent of impact and the likely outcome thereof. By engendering resilience in dynamic semantic systems, we can exploit the phenomenon of structural coupling, effectively creating user groups which respond and adjust of their own accord to alterations to their environment caused by information systems changes.

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