Multimodal Systemic Anticipation

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Abstract
Anticipatory Modelling and Computing (AMC) can be seen as a Systems Science. This approach will place AMC in an Anticipatory Dynamic Web (ADW) of systems concepts. Those concepts and their relations will help guiding further learning and research concerning AMC. Further, the Anticipatory Loop will explain the cyclical character of anticipatory activities. A Multimodal approach may increase the accuracy of anticipatory predictions. At last, the design of an Anticipatory Computer Laboratory is given.
Keywords: Multimodal and Systemic Anticipation, Anticipatory Dynamic Web, Anticipatory Loop, Space hypothesis, Anticipatory Computer Laboratory.

1 Introduction

Systems stand out as the key concept in Rosen's (1985) definition of Anticipation and Anticipatory Computing. Hence, anticipation obviously belongs within the boundaries of Systems Science, as that scientific endeavour has been defined by Klir (1991) and others. Consequently, many system concepts and system findings ought to be of relevance also in anticipation.

Further, the computer can be seen as the laboratory of system scientists (Klir, 1991). Hence, the impact of those system concepts on anticipation theory and its application ought to be practically tested and verified with help of simple computer based models.

Hence, the purpose of this paper is to find out which system concepts can help improve anticipation theory and its proper application on real world problems. As far as possible simple computer based models will be provided in order to illustrate and give evidence for the findings.

In striving for that goal the discussion will focus on the following main questions:

- What relations can be found between anticipation and principle systems concepts?
- What are those relations implying on forthcoming anticipatory research and applications development?
- What can be done with help of computer based models and computer simulations in doing anticipatory research?

2 The Anticipatory Dynamic Web

Anticipation may not be seen as an isolated concept or activity. Rather, if we start with the common definition of an anticipatory system, i.e. a **system** which develops and contains a model of itself and its environment and which base its current decisions and behaviour on the predictions that model makes of future states (Rosen, 1985), we can identify system as a pivotal concept. Hence, from "system" in the definition we find obvious links to related concepts and knowledge areas like modelling, complexity, control, evaluation, decision making, systems theory, systems thinking and so on. This can be best understood as a system of related terms or, in other words, as an anticipatory dynamic web (ADW) as expressed in figure 1.

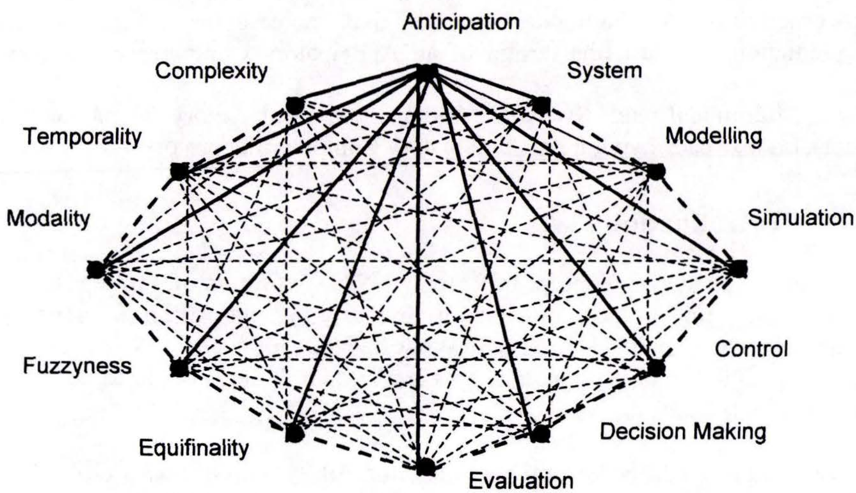

Fig. 1: General outline of the ADW (all concepts and connections are not shown)

Seen in the framework of the ADW, anticipation becomes a tremendous rich and complex concept. In other words, Anticipatory Modelling and Computing (AMC) will be embedded in an ever changing system of system concepts, i.e. an Anticipatory Dynamic Web (ADW). That ADW network can serve several purposes. Firstly, it will help highlight or identify many knowledge areas, which can help us in understanding anticipatory phenomena. Secondly, the web will also point at different areas, which need to be further investigated by new research. Lastly, the ADW will help in relating anticipation to other human activities and fields of inquire.

As an example, some main aspects and relations of the ADW will be discussed in the rest of this paper.

2.1 The Anticipatory Loop

Developing a system model, i.e. modelling, and consequently manipulating or computing the resulting model in simulation runs are crucial activities in all types of anticipation. However, the total anticipatory picture will be even more complex, i.e. to understand anticipatory behaviour in all its width it will be necessary to consider a chain of activities or coupled concepts from the ADW. That chain, I prefer to call the Anticipatory Loop (AL) according to figure 2.

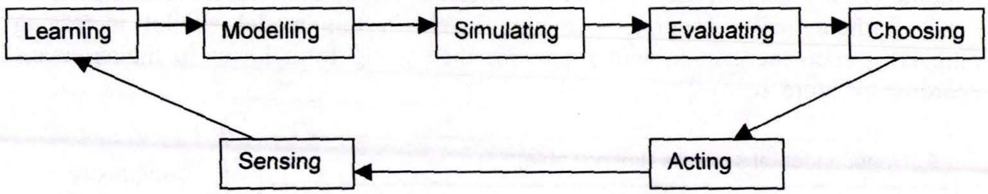

Fig. 2: The anticipatory loop (AL).

In the next step, having got the model's predictions, it will be necessary to evaluate or assess those outcomes in order to arrive at a choice or decision. Further, the decision has to be implemented, i.e. the real system has to be affected or steered according to the decision taken. At last, once the decision has been implemented it will be necessary to learn from sensed or measured results in order to refine and adapt the model and to improve the assessment and decision making process.

2.2 Equifinality

The system concept of equifinality (Bertalanffy, 1968) roughly says that independent of its trajectory and initial state a system's final state will always be the same due to the systems internal properties. At a first glance, this seems to make anticipation and anticipatory computing a futile or doomed activity. The final result will anyhow always be the same according to figure 3.

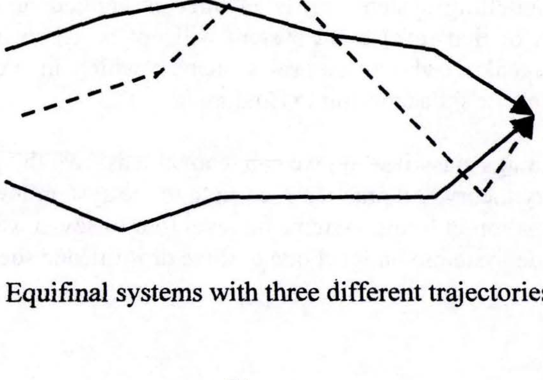

Fig. 3: Equifinal systems with three different trajectories.

However, the equifinality principle can also be interpreted in quite the opposite way. This positive interpretation says that even if the final state is given, the trajectories leading to that final state may be very different. Hence, anticipatory computing can help us in choosing good trajectories and to avoid bad ones. Seen in this later way the equifinality principle can be taken as a strong support for anticipatory computing.

2.3 System Hierarchies

Boulding (1956) has proposed a "*system of systems*", i.e. a hierarchical arrangement of levels of theoretical discourse. The nine levels in this model exhibit increasing complexity and emergent system properties then going from lower to higher levels according to figure 4.

9. Transcendental systems (unknowable)	↑ **Complexity**
8. Socio-technical systems (roles, communication channels)	
7. Humans (self consciousness, language, symbols)	
6. Animals (teological behaviour, self-awareness)	
5. Plants (genotype/phenotype, division of functions)	
4. Cells (open systems, life structures)	
3. Thermostates (information processing, feedback)	
2. Clockworks (determinate structures)	
1. Frameworks (static relationships)	

Fig. 4: Hierarchy of increasing complexity with some emergent system properties.

From Boulding's classification it can be seen that systems on different levels exhibit quite different properties. This will obviously have an impact on modelling and consequently also on anticipation. An example, if a modelling method or technique that works well for modelling systems on level three is applied on level eight the most interesting aspects of that level eight system will not be taken into account. Further, Rosen (1985) is speaking about "natural systems", which in most cases seem to be systems on level five or six according to Bouldning.

Hence, from Bouldings classification we can learn at least two things. First, we need to modify anticipatory theory and practice according to the system level at hand. Second, by studying anticipation in living systems on level four to seven we can learn to build artefacts (man made systems) on level one to three or influence socio-technical systems on level eight.

3 The Multimodal Approach

With help of its model the anticipatory system throws a searchlight into the future. Here, it seems reasonable to assume that the quality of anticipation, i.e. the capability to anticipate or look into the future, would increase if more than one searchlight were put into use. In this context, the Multimodal approach of de Raadt (1991, 1997) can serve as an excellent base even for a Multimodal Anticipatory Approach (MAA).

In his Multimodal Systems Thinking, de Raadt (1997) applies a two dimensional approach according to figure 5. On the horizontal axis we have different levels of interacting and interdependent biological and social system such as, orchards, families, trade firms, cultural institutions, schools, transport systems, courts and, hospitals. Within those systems mankind realises its vocation and finds its fulfilment.

In order to describe, understand and discuss what is taking place on the horizontal axis seventeen different, but unifying, modalities are layered on the vertical one. Those commanding modalities are: credal, ethical, juridical, aesthetic, economic, operational, social, epistemic, informatory, historical, logical, psychic, biotic, physical, kinetic, spatial and numeric. Due to scientific fragmentation, today each modality has its own scientific branch. However, multimodal systems thinking aims to stress the unity of the modalities – without denying their variety – and to provide a bridge for the integration of the sciences. It may also be important to observe that the higher modalities are guided by normative laws while determinative ones rein the lower modalities.

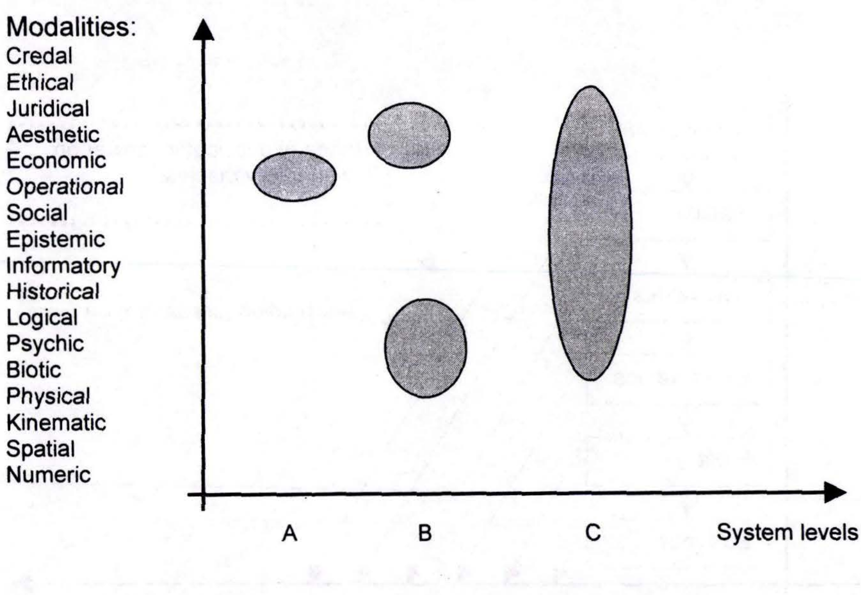

Fig. 5: Modelling in a multimodal systems framework.

The advantage of applying multimodal systems thinking and modelling in anticipation can be illustrated by figure 3. Suppose that the ovals above system A, B and C respectively are models of those systems. For system A we have just one model in just one modality, for system B we have two models in two different modalities and for system C, at last, we have a model spanning over several modalities. It has been demonstrated by de Raadt (1997) that in this way we will get a much better comprehension of system B and C than of system A.

Further, Schwaninger (Espejo et al, 1996) does not make an explicit reference to multimodal anticipation but his approach is very similar. For a business firm Schwaninger (Espejo et al, 1996) identifies six levels of indicators and parameters, i.e. six different models of the organisation. Those models are not identical with de Raadt's modalities but the basic idea apparently is the same. The difference being that de Raadt is more elaborated and general while Schwaninger's scheme is more straight forward and operational.

From the point of view of anticipation, one of Schwaninger's conclusions is specially interesting. That is, it is not possible to control or anticipate the variables in one of the models with that model. On the other hand, models on a higher level has a good pre-control or anticipatory function in relation to the model on the next lower level. Further, models on higher levels sees longer into the future concerning what will happen with the lower levels. This is expressed in figure 6.

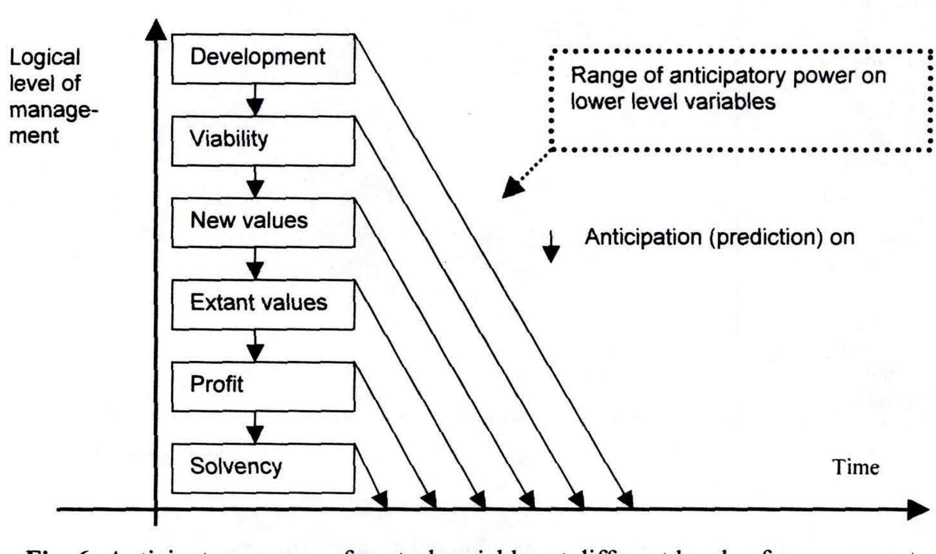

Fig. 6: Anticipatory power of control variables at different levels of management.

4 The Anticipatory Computer Laboratory

In order to study anticipatory systems and anticipatory phenomena in practice, an Anticipatory Computer Laboratory (ACL) is been planned to be implemented. The main design blocks of ACL according to figure 7 closely follows the original definition of Rosen (1985). The design approach is based on the Space Hypothesis (Holmberg, 1998) but is also open and evolutionary. Changes and amendments will continuously be introduced.

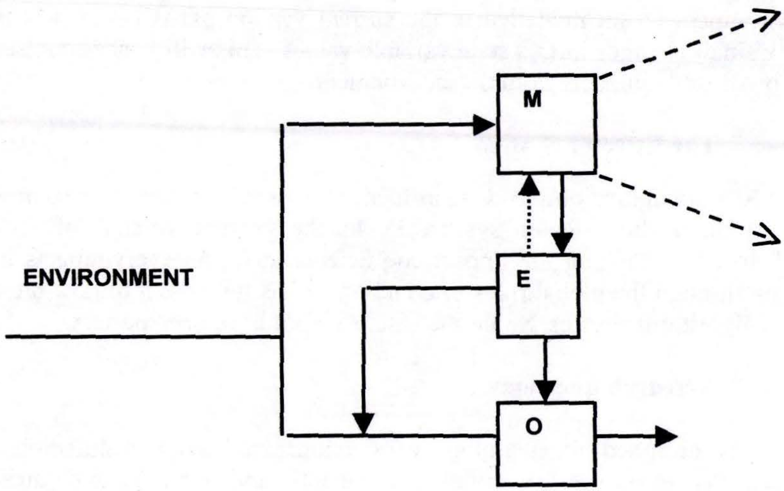

Fig. 7: The building blocks of the Anticipatory Computer Laboratory (ACL).

4.1 The Object System

The object system, O in figure 7, is the system that has to be modelled, predicted and controlled according to simulation or prediction data. In ACL the object system O is build according to the Spatio-Temporal Fuzzy Model (STF) (Holmberg, 1998). Hence, ACL will be best suited for studies of spatial systems but is also expected to have some generality. In STF space is modelled as a cellular automata (CA) with global rules and a fuzzy, i.e. continuous normalised state variable. Compared with ordinary CA:s, STF exhibits two main differences. First, normally just local rules are employed but here each cell, by means of global rules, is impacted by all the other cells in the grid. Second, while a binary state variable is used in ordinary CA:s a continuous or fuzzy one is used in STF. The STF is set up as an abstract space but each cell in STF can contain a pointer to an arbitrary geographical region or geographical polygon. Of computational reasons the STF will also be linearized into vector form.

4.2 The System Model

The system model, i.e. M in figure 4, is also a STF but compared to the object system O small controlled errors are introduced in the values of state variables and impact coefficient. In this way it is possible to study the effects of not having an exact model. M works in an other time scale than O. In this way it is possible to having M iterate one or several steps into the future while O is remaining in the current time slot.

4.3 The Environment

The environment is not modelled in the current version of ACL but it is possible to introduce small changes in O's state variable values. This will hence represent random and not predictable impacts from the environment.

4.4 The Effector System

Based on M's simulation outputs O is influenced in order to optimise system goals. This is done through the effector system E. In the current version of ACL this is accomplished by changing the impact coefficients in O. As everything is influencing everything through the global rules or couplings it has turned out to be a bit difficult to find good algorithms for this. So far the results do not have been perfect.

4.5 Research questions

The ACL is designed for learning, verification, knowledge acquisition and, idea generation. As examples of initial experiments and experimental questions the following points may be considered:

- How big errors can be tolerated in the model M relative the objective system O without jeopardising the corrective actions?
- What is the trade off between errors in state variables and impact coefficients?
- What can be gained in correction or steering effectiveness if the model can iterate many steps in advance compared with the case where the model can iterate just one or a few steps ahead of the object system?
- How big disturbances can be tolerated from the environment without jeopardising the corrective actions?
- What is the trade off between environmental disturbances and effects of errors in the model?
- According to Ashby's (1956) Law of Requisite Variety the information-processing capability of a controller has to be comparable and compatible with the information produced by the system on which control is exercised. Hence, it will be interesting to see what happens if the effector system E (see figure 7) can influence less than all of the impact coefficients or if the influence are very weak
- What will be the differences if the model M (see figure 7) is based on recursion, incursion or hyperincursion according to definition given by Dubois (1998)?

5 Synthesis and Development

So far, three different approaches, i.e. a systemic one, a multimodal one and, an experimental one, to anticipative studies have been presented. A synthesis of those approaches seems to be an appropriate way in order to widen and strengthening the theory and knowledge around anticipatory modelling and computing.

With such a consolidated knowledge base as a starting point it also seems reasonable to take a first step toward practical anticipatory applications. Such an application may, for example, be an anticipatory system helping decision makers in assessing different decision alternatives. Another example may be different types of monitoring systems giving alarm if the operator makes something that risks to drive the system into a hazardous state.

This development work is best started in the form of small and simple experimental prototypes. As experiences and knowledge from the prototyping grows it will be possible to have the prototypes gradually develop into fully operational systems.

6 Closing remarks

This paper may have raised more questions than it has answered. Anyhow, rather strong evidences have been found for the following general conclusions:

- Systems Science can be used as a primary knowledge base for research on anticipation and as an integration key for any knowledge about anticipation.
- A computer laboratory, like ACL, can be of great help in increasing and broadening our understanding of anticipation and anticipatory computing.
- Anticipation has to be seen in a context, or a web, of related concepts – an Anticipatory Dynamic Web (ADW).
- Anticipation may also be perceives as a chain of coupled activities – the Anticipatory Loop (AL).
- A Multimodal approach can give several complementary searchlights into the future.
- Complexity is not the same as Complication and Systemic Modelling is not the same as Analytical Modelling. Systemic models will be ever changing or developing. They are functions not only of the modelled entity but also of the modeller and the specific time and context.
- Environment and Subject are important entities in any anticipatory modelling and computing activity.
- Anticipatory computing can be differentiated or adapted for different levels of systems.
- There is now time to start design and implementation of anticipatory prototypes of practical applications.

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