What is Modelling?

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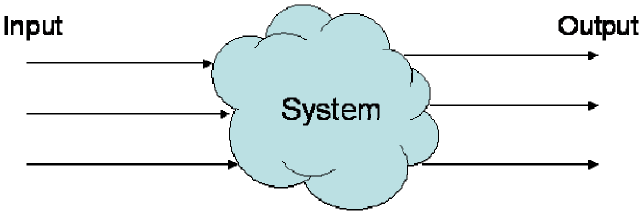
Model, like so many words in the English language, has a multitude of meanings depending on the context in which it is used. In a systems context model means:

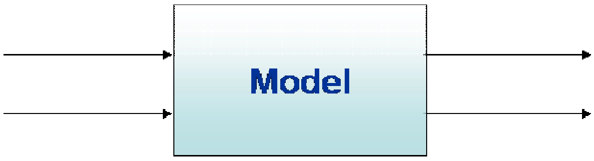
A simplification of reality intended to promote understanding.

Modelling is a way of thinking and reasoning about systems. The goal of modelling is to come up with a representation that is easy to use in describing systems in a mathematically consistent manner.

Most systems are so complex as to be beyond the limits of intuitive comprehension. As such, we construct models, simplifications of the real thing, which allow us to study that which we seek to understand.

Whether a model is right or wrong is simply a value judgment, whether it is correct or incorrect is something that will be evident in time. The most important question to ask should relate to the extent to which the models we develop promote the intentioned development of our understanding. The extent to which a model aids in the development of our understanding is the basis for deciding how good the model is.





In developing models there is always a trade off. A model is a simplification of reality, and as such, certain details are excluded from it. The question is always what to include and what to exclude. If relevant components are excluded there is a chance of the model will be too simple in nature and will not support the development of the understanding desired. On the other hand, if too much detail is included the model may become so complicated that, again, it fails to promote the development of the deeper levels of understanding one seeks.

Process Modelling

The term 'process modelling' has come to be associated with a number of ideas, all concerned with the dynamic behaviour of systems. The basic idea is that such systems can be thought of as operating or behaving as a number of interrelated processes. To study and understand systems, one constructs 'process models' according to particular viewpoints and using particular modelling techniques. These ideas of forming different types of process models are described in a little more detail below.

- **Descriptive Modelling** giving more information about techniques used for process models whose purpose is to describe processes and organisational behaviour

- **Active Modelling** giving more information about the idea that process models can be used to provide support for systems.

Descriptive Modelling

Descriptive process models are just that; models which in some way 'describe' systems in terms of processes. Such models may be formed in a variety of ways, using a plethora of different techniques. A number of specific techniques (and tools) have been developed to support the production of models. Examples of these include Systems Dynamics models.

Active Modelling

Active models support the actual performance of a system according to well defined processes. Such systems are based on information about the processes to be supported and the state of the relevant parts of the process during its operation.

Simple Modelling Process

- **First**, to identify a set of measurable variables associated with a given system
  - ex) temperatures, particle positions and speeds, voltages, capacitances…
  - By measuring these variables over a period of time, collect “data”

- **Second**, from the identified measurable variables, to select a set of “input variables” as time functions that we have the ability to vary over time

$$\{u_1(t), \ldots, u_m(t)\} \; t_0 \le t \le t_f$$

- **Third**, from the identified measurable variables, to select a set of “output variables” as time functions that we can directly measure while varying the input variables, that is, "response" to the "stimulus" provided by the input variables

$$\{y_1(t), \ldots, y_n(t)\}\ t_0 \leq t \leq t_f$$

- .Some variables which have not been associated with either the input or the output are referred to as "suppressed" output variables

Wyatt Woodsmall: The Science of Advanced Behavioral Modeling, Next Step Press, 1988.

B = Beliefs

V = Values

S = Strategy (Internal mental processing)

P = Physical activities

Performance = f (b, v, s, p)

Steps of the Modelling Process

NLP Modelling	Control System Modelling
Select expert	Select system
Elicit Components of expert behaviour	Identify system parameters using input-output measurements
Synthesise	Simulate model
Test	Design controller
Universalise	Apply control to model
Design Training	Apply control to system
Conduct training	

Cognitive Models

Stepping away from the mathematics, state evaluation can also be based on cognitive models. Instead of analysing possible next states in a model in precisely defined terms, cognitive approaches to state evaluation rank these in relation and according to personality features, personal preference, and previous experience. When dealing with artificial agents, it is difficult to define personality features or personal preferences satisfactorily for state evaluation. Previous experience, however, can be easily integrated through various forms of *reinforcement learning*.

Personality Modelling

Personality model is a set of attributes that define the personality of the character. What is required are attributes that describe how the character feels, how he reacts to the other characters.

There has been more serious work among psychologists on the problem of true personality modelling. Moreover, these people are trying to solve a problem we don't need to solve: they want to model real human personality; we need only model characters.

Personality models are highly subjective. There is no such thing as a "correct" personality model. This is all a black art, and if you and I produce different personality models, there is little basis for one to claim absolute superiority. Everybody will do it, we'll have lots of religious wars over which model is best, and nobody can know what the outcome will be.

Brain Modelling

The predicted patterns between brain structure and function (and behaviour) can now be examined in an unprecedented manner, using an array of Computerised Brain Imaging Technologies – that reflect “When” and “Where” activity occurs in the human brain.

There also now exists for the first time, a numerical simulation (model) that bridges the gap between physics and the brain as a biological system. This model has been built up by using realistic mathematical elements (parameters) representing directly the physiological manner in which the brain functions. It is the first such whole brain model in which the simulations of brain function match to real human brain electrical activity (EEG and ERP) with a high degree of accuracy.

The brain’s “resting state” is characterised by positive feedback between the thalamus and the cortex. Any stimulus induces a sustained (approximately one second) excitation in of the thalamo-cortical networks that are primarily engaged in processing that stimulus, and a selective damping or switching off (by lateral inhibition or negative feedback) of all other networks.

Behavioural Cloning

The idea of *behavioural cloning* (a term introduced by Donald Michie, 1993, but probably first carried out by Donaldson, 1964) is to make use of the operator's skill in the development of an automatic controller. A skilled operator's control traces are used as examples for machine learning to reconstruct the underlying control strategy that the operator executes subconsciously.

The goal of behavioural cloning is not only to induce a successful controller, but also to achieve better understanding of the human operator’s subconscious skill. Behavioural cloning was successfully used in problem domains as pole balancing, production line scheduling, piloting, and operating cranes.

Example of behavioural cloning is Riding a bike. Riding a bike is a challenging control task that requires maintaining the balance on the bike and driving it to the goal. Maintaining a balance on the bike is a very hard task and requires the proper adjustment of the front wheel direction by applying torque to the handlebars and/or the proper displacement of the centre of mass.

Behaviour Modelling

People learn what to do by watching each other, and by copying what they see others do. People who work for effective managers tend to develop effective patterns of behaviour themselves, because they learn from the examples that are set. And when people work for ineffective managers they tend to be ineffective too, also because of the example that is set for them.

Managers, trainers and other people who influence the behaviour of the people around them need to know what example they set by modelling behaviour. It is not good enough for someone to turn on a model meeting or training session, laying out the ideal way to handle things, then go away and act differently to their own model.

Often a person's own behaviour is hidden from him or her and, even though that person might "get by"; their example is not adequate for others who want to improve their personal performance.

By defining the strengths of effective sales people, for example, and the limitations of less effective sales people, comparison of the two outputs leads to a model that will strengthen the less effective people as well as enhancing the sales leaders. That same model is useful when replacing losses from the team, enabling you to identify ideal applicants.

The manager or supervisor who understands the behavioural needs of any subordinate is more able and likely to set specific examples so the subordinate may model his or her behaviour on the supervisor or manager.

An extension of this idea is that model norms may be established for any position or role. Learning approaches can then be developed to model the wanted role or position behaviours, and people will be better prepared when they find themselves in the real situation.

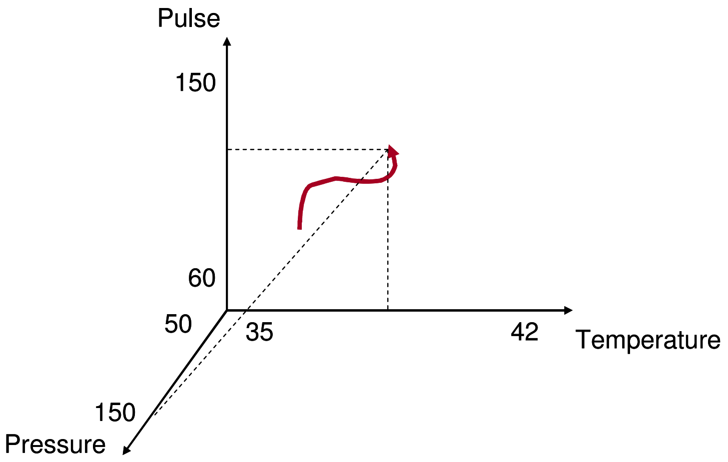
Dynamical modelling within cognitive science

Natural cognitive systems are certain kinds of dynamical systems, and are best understood from the perspective of dynamics.

The hypothesis suggests a heavy reliance on the area of mathematics known as *dynamical systems theory*. The word *dynamics* refers to the way a system changes or "behaves" as time passes. A *system* in this sense is a collection of related parts which we perceive as a single entity, e.g. the solar system, the nervous system, etc.

Within a dynamical model, salient aspects of the system are represented by numerical variables, e.g. the positions and masses of planetary bodies in a model of the solar system. The *state* of the system at any specific time *t* then is simply the set of those values at that instant. In a dynamical system, some or all of those values will change over time, and a dynamical model seeks to make the relationship between time and the evolving state of the system explicit.

Suppose we can describe the state of a specific system of interest using 3 values: x_1 = heart rate, x_2 = temperature and x_3 = blood pressure. Each of these variables can take on a limited range of values, and the space of all possible values (in this case a 3-D volume) is called the *state-space* of the system:



At a given instant, the state of the system is a single point within this space, and as time passes, the state moves, tracing out a trajectory within the state space. The usual way to describe such a model is with the use of differential equations, which describe the relations of change among the variables.

An explicit description of the dependence of each variable on the variable *t* (time) is called a solution to the equations. Solutions to most differential equations are impossible to arrive at, but nonetheless techniques exist for providing strong statements about long-term behaviour of a system. For example, does the system tend to settle to a stable equilibrium or does it exhibit periodic behaviour? Do trajectories tend to diverge or converge? Are some parts of state space never visited? Do all variables change at comparable time scales?

Dynamical systems theory is the currency of physical modelling. This provides a wealth of mathematical tools and modelling methodologies which have evolved over the last 300 years, and are now being applied for the first time to issues in cognitive science. The fact that extant theory provides a novel set of metaphors such as *state space*, *variables*, *stability*, etc with which to think about processes in the brain underlying cognition is in no small measure responsible for its attraction to scientists.

The state space is a mathematical space that contains all the possible states for the problem. It is a *mathematical representation* of the possibilities.

- *State Space*: all the possible situations.
- *Initial State*: precise specifications of the initial situation.
- *Goal State(s)*: final situations that constitute acceptable solutions.
- *Operator or Successor Function*: gives the set of states reachable in one step from the current state.

References

Van Gelder, T. and Port, R. (1995) "It's about time: an overview of the dynamical approach to cognition" in *Mind as Motion: Explorations in the Dynamics of Cognition*, Port, R. and van Gelder, T. (eds), Ch. 1.

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