

A Computer Science View of Artificial Life

[David Al-Dabass](#)

Dept of Computing

The Nottingham Trent University

Nottingham, NG1 4BU, UK

Email: david.al-dabass@ntu.ac.uk

One of the ultimate goals of computer science is to understand and emulate the capabilities of biological systems. Examples include the ability of flying birds to spot a prey, voice recognition and comprehension from a single utterance and identifying a face in a Picasso's painting. Higher level faculties possessed by biological life systems include the use of analogical conceptual structures to understand the meaning of messages embedded in metaphor and the ability to 'enjoy' the outcome of this message comprehension process. One such area of human activity is the appreciation of works of art in their multitude of forms, for example in operatic performances such as Madam Butterfly and, taking this analogical metaphor process yet another step, the transformation of this well known opera plot into the musical show Miss Saigon.

The history of the subject, and the subject itself, are polarised between analogy and numbers, between physics and algebra: the continuous world of Newton and Maxwell on one hand, and the discrete symbols of Babbage and Turing on the other, to name but a few. The practical needs of one subject, such as the calculation of navigation charts and gun trajectories to high accuracy, and code breaking, motivating the work of the other.

Let us take this interaction between models based on physical realities and computer science a step further and consider the question: What measure can we use to tell whether we have enough information to make a decision?

CASE 1: MONITORING MAN'S BEHAVIOUR FOR SIGNS OF DETERIORATING PERFORMANCE.

Formulate a dynamical model of man's behaviour to relate man's Action to his Thoughts and Senses.

Senses: all input into man: sight, hearing, touch etc: model as an r -vector S which influence the Thought rate by a $n \times r$ C matrix.

Actions: as output, model as an m -vector A .

Thoughts: as internal mental state, model as an n -vector T .

Within a dynamical systems context: the Thought vector T evolves in time according to its: *i) present state and ii) input*

T' is the Rate of Change of Thoughts : T' is influenced by i) current Thought value, plus ii) input from Senses.

Therefore the **man's Thought dynamics equation** is:

$$T'(t) = F.T(t) + C.S(t)$$

Where F is $n \times n$ matrix which determine how the rate of change of each Thought variable is influenced by all the current values of the other Thought variables.

Actions: are mappings of sub sets of the Thought vector through a $m \times n$ matrix $H(t)$.

Therefore the mapping between observed actions and thoughts, i.e. '**Actions as derived from Thoughts' equation**, is:

$$A(t) = H.T(t)$$

Observable: measurement of the Actions is sufficient to determine the Thoughts behind the action; i.e. when a suitable 'observer' or state re-constructer, can be formed to estimate the values of its Thought vector from its Actions trajectories.

Implications: the 'system' (man) can become unobservable.

Definition: Man (or any intelligent entity) is observable if its Thought vector $T(t_0)$ can be determined from its Actions trajectories $A(t)$, $t_0 \leq t \leq t_1$, for some finite t_1 . If this is true for any t_0 , the entity's Thoughts are completely observable.

Observability Matrix: is given in terms of Thought Transition matrix TT and Action mapping matrix H as:

$$OM = \int_{t_0}^{t_1} \{TT^T(t, t_0) \times H^T(t) \times H(t) \times TT(t, t_0) \times dt\}$$

Where TT^T indicates transpose of TT etc.

Observability Condition: the observed Man (Entity) as modelled by the linear system T and A is completely observable if and only if the symmetric $n \times n$ matrix OM is positive definite for some finite time $t_1 > t_0$.

Dynamical Systems Model of 'Lying': man/entity may change its own parameters to induce the 'observer' to use a model different to that used by the entity to generate its actions, i.e. different thought transition matrix and different action mapping matrix, such that the re-constructed state is i) sufficiently close to a 'benign' Thought value and is ii) sufficiently and deliberately different from the real Thought values to prevent the observing machine from getting alarmed and taking any remedial action.

CASE 2. A COMPUTATIONAL MODEL OF CREATIVITY IN METAPHOR

Creativity comes in a wide spectrum of forms. One of these concerns the transmission method of conveying a message. In art, a painter chooses or invents a new style to draw a face, e.g. Picasso; the message, which is the face in this instance, is conventional, but the way of transmitting it is new and can be seen to manifest creativity.

In literature, metaphors are fertile means of generating creativity to convey an ordinary event or situation. Example 1 from Romeo and Juliet, concerns the spilling of neighbour's blood to calm the anger of one's hate:

Rebellious subjects, enemies to peace,/ Profaners of this neighbour-stained steel/. /That quench the fire of your pernicious rage/ With purple fountains issuing from your veins.

Example 2 from Hamlet:

But look, the morn in russet mantle clad/ Walks o'er the dew of yon eastward hill.

Message Model: The message is represented by a collection of concept variables, which are mathematically recorded as an n -vector X . This vector evolves in time such that its rate of change X' is influenced by its current value plus a suitable input in the form of an m -vector U , such that:

$$X' = A.X + B.U$$

Where A and B are $n \times n$ and $n \times m$ matrices which determine how the rate of change of each concept variable is influenced by all the current values of the other concept variables and all the inputs.

Transmission/Creativity Model: This message (concept variables) is projected to the world through a collection of output variables represented by a p -vector Y through a 'Metaphor-Creativity' matrix C such that:

$$Y = C.X$$

Where C defines how each element of the output vector is related/composed of all the concept variables.

Observer Model: An intelligent entity receiving Y wishes to determine the original message by estimating the values of all concept state variables. A systems theoretic approach to this problem, typified by the Kalman filter technique, is:

1. Have an 'analogue' of the message generating model and output model within the observer.
2. The locally generated version of the message output is compared with the measured/received output and an error is generated.
3. This error is fed back as input to the local message model through a suitable matrix K.
4. This feedback loop causes the error to converge to zero.
5. The zero error is taken to mean that the local version of the message (as expressed by the X vector) is a good approximation of the actual message.

To distinguish between the real message variables and model (X, Y, A, and C) on the one hand, and their analogue in the observing entity on the other, use the letter o (for observing entity) to distinguish between the two, i.e. X_o, Y_o, A_o and C_o, so that

$$X'_o = A_o.X_o + K.(Y - Y_o)$$

But

$$Y_o = C_o.X_o$$

Therefore equ. 1 becomes:

$$X'_o = A_o.X_o + K.Y - K.C_o.X_o$$

And combining the X_o terms give:

$$X'_o = (A_o - K.C_o).X_o + K.Y$$

Which constitute the observer model. It is clear that the dynamics of the observing entity are not the same as those of the creative entity that generated the message, i.e. (A_o - K.C_o) for the former and simply A for the latter. One interpretation of this difference is that the observing entity needs to work at much faster rate to 'lock on' to the concepts being received before they change.

Uniqueness: Different observer model matrices A_o and C_o will produce the same local output but to a different concept, e.g. exactly the same sound would have different meaning in different 'contexts' such as languages.

Creativity: On receiving the output for the first time, the observer tries out different A_o and C_o values until a meaningful X_o is produced, and this is where data fusion must play a significant part to determine what are 'meaningful' concept variables.

Observability Condition: The received output Y must contain sufficient information to enable the observing entity to reconstruct the message. This is dealt with by the device of the observability matrix; in the 'discrete' time/space formulation, this means that there must be as many unique relationships as there are unknown variables, which are then determined by solving a relevant set of simultaneous algebraic equations.

The Observability Matrix: is given in terms of Concepts Transition matrix CT and the metaphor/Creativity matrix C as:

$$OM = \int_{t_0}^{t_1} \{CT^T(t, t_0) \cdot C^T(t) \times C(t) \cdot CT(t, t_0) \cdot dt\}$$

Where C^T indicates transpose of C etc.

Observability Condition: the Creative Entity as modelled by the linear system X and A is completely observable if and only if the symmetric n x n matrix OM is positive definite for some finite time t₁ > t₀.

Observable Creativity: it is important to note that during the whole process while the observing entity is trying out different combinations of A_o and C_o, the observability condition must remain satisfied for each and every combination tried. This implies the availability of a higher level mechanism for guessing when the right message has been discovered while continually changing its own versions of the creativity model (A_o and C_o) and checking the observability condition.

Conclusions: This paper sets out the foundations for establishing a computational dynamical systems approach to the modelling of thoughts and creativity in artificial life. The work needs to be extended to consider other aspects of systems theory such as stability and controllability and their application to formulate computational models of creative work in literature and art as a first step and later for music and the process of scientific discovery.