

Feedback, Planning and Control - A Dynamic Relationship

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1 Feedback, Regulation and Control

Control is the process of ensuring that operations proceed according to some plan by reducing the difference between the plan and reality. Normally, control over the system is facilitated by using the feedback (and feedforward) mechanisms. Control can only be exercised over the components internal to the system and cannot be affected upon the external environment.

Control theory is based on the explicit premise that change is, or can be planned. This introduces two sets of problems; one related to the assumptions made explicit by this view (such as frozen products, closed systems, linear sequential progression, isolation from the external environment and limited change) and the other to the limitations inherent in planning attempts.

Planning inevitably implies a continuous and evolving process that anticipates actions and problems and allocates resources to attain the desired goals. The problems associated with the act of planning can be enumerated as follows:

- A difficult, if not impossible, cognitive activity
- Requires acknowledgement of inherent uncertainty of situation
- Reduces perceived freedom
- An intensive effort
- Computationally tedious,
- Changes in planning assumptions require rework

In relating the two sets of problems, the obvious clash between their assumptions highlights the intractability of controlled planning. A difficult cognitive activity is thus simplified by unrealistic assumptions about change which preclude the acknowledgement of the inherent uncertainty. The freedom that is required for effective control is surrendered in the interest of frozen assumptions and a closed environment. The intensity of the effort is limited by the constraints and the assumption of linearity which lead to the allocation of limited scarce resources and by the limited attention that can be allocated by the organisation to any one problem. Lack of resources clashes with the need for creativity and open thinking and does not help an already limited cognitive ability. The need to re-work changes clashes with the assumed simplified linearity and other assumptions addressing lack of change and frozen boundaries and baselines. It also makes an already complicated cognitive activity more intractable and less amenable to advance planning. Not only is it difficult to plan ahead, it is even difficult to plan the planning.

A system of follow-up and control is essential to ensuring that the results agree with what was anticipated during the planning. Such a system of control requires the following components [4]:

- establishing standards
- measuring performance against the standards
- correcting deviations from the standards

The provision of adequate control enables the controller to provide direction that will ensure a momentum towards a goal is maintained. Time lags in knowledge can build up to defeat regulation systems. Rather than focus on isolated snapshots and expend large quantities of resources and urgent attention at what are perceived to be critical episodes and junctures, it thus becomes possible to improve overall efficiency through the provision of continuous progress monitoring.

Feedback is concerned with the control of a mechanism on the basis of its past performance and consists of procedures to determine deviations from plans and desired states and to indicate and execute corrective action regarding these deviations.

Feedback refers to the method of controlling a system by reinserting the results of its past performance [6]. This entails gathering data on the state of the output, searching for deviations from the plan, and adjusting the input based on the results of the output (see figure 1). It thus establishes a relatively closed system of causes and effects.

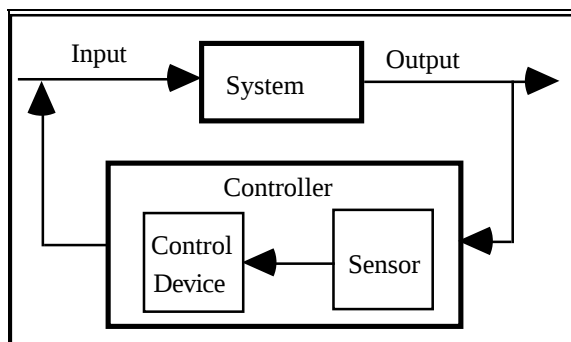


Figure 1. Feedback Control for a System

Feedback information needs to be timely to encourage rapid corrective action. The entire concept is predicated on the continuity of the action and the constant rate of feedback that caters to the system's need for information about its performance with regard to the objective. The use of feedback may not necessarily improve performance in an absolute sense, as a mistake, a misunderstanding, or a misapplication of goals, may lead to the acceleration of problems.

Feedback and control presuppose planning, at least in the form of setting goals and performance levels, as plans furnish the baselines and standards of control. The pattern of goal seeking behaviour exhibited by a system is then expected to stay true to the identified goal. The implicit, and rather mechanistic assumption is that the plan or target does not change and that future conditions will remain identical to past conditions. In a change intensive environment these assumptions, and the resulting self-regulating mechanisms clearly do not work and either a forward looking anticipation strategy or a double loop feedback system is employed.

The notion of feedback relies on a certain amount of deterministic thinking and the assumption of a closed system independent of its environment where the future always resembles the past. This suggests a limited emphasis on entropy and the concept of information and as a result a total ignorance of decisions and their impacts. By freezing all other interactions and ignoring all other factors, it becomes possible to envisage a situation whereby an action can ripple through a system and eventually affect the actor in a closed sequence of causes and effects, so that the cause becomes an (indirect) effect of itself. In theory, this enables any single variable to control and stabilise the entire system over a given period, as long as no other actions and causes are permitted, and all actors and reactions contain themselves.

The notion of feedback reduces the risk of failure and the effect of residual complexity and ambiguity by limiting commitment. The perception of feedback as a mechanism that enables adjustment offers emotional security and progressive, on-going justification system for actions.

The main difficulty with feedback systems is in the acceptance and interpretation of the observed results and their translation into action. When the feedback data and the systems model of reality do not agree, most actors tend to discard the data. Most actors seek 'rational' data, that will confirm their worldview. When disconfirming data is received the tendency is to repeat the 'offending' action, but normally with additional force. The only way of justifying this persistence is by either ignoring or challenging the validity of the suspect feedback. Being

‘locked into’ a model or a perspective also means defending the investment in that model and rejecting information that may challenge its validity. As it is easier to construct a somewhat convincing explanation of what went wrong, the path of least effort is thus adopted

Double-loop Feedback Offers a more sophisticated alternative that allows for the adjustment of the input variables to the process as well as the adjustment to plans that are used to dictate performance standards. The ability to respond to change and alter performance standards encourages adaptability and improves the chance of long-term survival. It also enables the control mechanism to benefit from most feedback data and avoid defensive routines to discredit suspect data.

Double-loop control requires long-term planning in designing the double-loop and will consume larger resources. It enables the organism to become more adaptable and to do so more rapidly rather than bind itself to historical patterns. This adaptation means that the organism is capable of long-term learning and continuous improvement in a search for greater efficiency. In contrast, traditional, single-loop feedback only focuses on the short-term adjustments during the duration of the control activity that will maximise the efficiency of the current product. Such improvements only apply to the current control loop and do not feed back into long-term changes to the overall process. In other words, lessons are neither learned nor retained.

Software development processes lack the long-term perspective and tend to omit the double-loop component which could have enabled closer monitoring and adjustment rather than adherence to historical plans and budgets. Settling for major adjustment at the post-release stage instead, suggests that resources have already been spent and time allowed has already been exceeded before the first comments can be taken on board.

2 Choice, Feedback and Control in a complex World

The choice of a feedback model depends on the conditions of the environment. Feedforward

strategy calls for a relatively static and change-free system, whilst feedback strategy relies on the significance and position of delays in terms of time and perceived effect.

Feedback often proves to be the *de facto* choice of systems developers for the following reasons:

- it minimises cognitive effort
- it relies on a simpler model
- it ‘satisfices’; by promising results that are good enough
- it is self-perpetuating to the extent that the choice is driven by a partial and imperfect model in the first place. Unless this feedback can show that the model it is based on is too limiting, i.e. challenge itself, there is no way out of this vicious circle.
- it saves resources (including time and attention).

One obvious implication of this choice is the self-justifying incompleteness paradox. Decision makers hold a partially defective model of the task. Until they obtain a well-developed model, they are incapable of perceiving the limitations in the model they hold. This is of course impossible while they are applying this model. This self-perpetuating procedure ensures that the need will not be obvious to them. It may prove unbreakable, unless a major failure triggers attention and other resources.

The discussion so far has referred to a simple choice between control mechanisms. In reality, such choices are embedded in complex environments with nested and interconnected control loops and a plethora of partial models justifying their persistence. System conduct may become very complex if several feedback elements are interconnected; the resulting dynamics will often be too difficult to calculate. The more complex the system, the more remote cause and effect are from each other in both space and time. It doesn’t take very many feedback loops before it gets tough to predict the behaviour of a system or even to observe the domain of influence of each feedback loop.

Combining positive and negative feedback cycles can lead to the emergence of complex, responsive and adaptive webs of interactions governed by complex dynamics. The complexity inherent in the dynamics of interaction means

that a system can only be as strong as its weakest component, regardless of the location of this component [2]. It could be positioned at the bottom of the system hierarchy but it still makes the entire system vulnerable to failure.

Traditional science bears the responsibility for many self limiting and self-fulfilling loops and prophecies. Scientists are selective in their choice of situations, phenomena and variables. By forcing the system to display closed characteristics for control purposes, many interactions and responses are excluded. In particular, input gained from the external environment is excluded, or is at the very least limited.

In such closed systems the starting state becomes less important in determining the final state than the most recent sequence of events. Decay of representation as well as the normal decay of information further limit the usefulness of representations.

Such emphasis on control isolates the object or organism from the external environment. The identification of a set of control variables displays the limitations of 'controlled' scientific experiments focusing on a very limited set of variables which are allowed to change and an even smaller repertoire of allowed responses. Tight control can only be achieved through isolationism and at the expense of lost potential.

The model principle in control theory states that every good regulator of a system must be a model of that system [1]. In order to control a system, a control device, or a decision maker, must have (or be) a model of the system it seeks to control. Decision making is in effect, the process of achieving control over a system in order to produce a desired outcome. The mental model that is produced during decision making is limited and susceptible to cognitive, memory (historical), and perceptual biases.

Feedback loops link various components and sub-systems, binding them in both time and context. The importance of organising relations between basic entities in a system gives rise the possibility of emergence of novel properties from the structure that is imposed on the entities. Systems engineers are concerned with predicting and designing both structure and emergence, as

structure gives rise to emergence, resulting in new properties that appear at a certain level of complexity. Complexity thus results in emergence which in turn, introduces new pervasive and complex aspects.

The design of complex systems is therefore not just a bigger version of small systems design but an undertaking on a totally different scale. The complexity of interaction, feedback dynamics and emergence add to the complexity of detail, to introduce a higher level effort requiring internal re-organisation and rapid attention to responses and feedbacks. Such systems can be described as complex, evolving, interactive and responsive, leading to challenges that do not exist at lower levels of complexity.

"The more complex the network, the more it is inter-connected. The stability of such networks is very little understood. If one makes some changes to the system with the intention of producing a certain effect, the actual response often turns out to be something quite unanticipated" [5].

Such counter-intuitive results apply in the context of modern technology and more generally to any intensive feedback driven system. Attention and effort levels are rather high, as controllers are obliged to wait for the system to stabilise small increments, observe their effect, and plan the next 'feedback testing' increment.

Unfortunately, complex systems rarely repeat themselves. Each system requires a concentrated effort to decipher and plan the inherent dynamics and its effect on overall operations. The sensitivity of any particular link is not a fixed characteristic of it, but depends on the state of the rest of the network.

When simple feedback loops are aggregated and interconnected within a larger system they become a complex and dynamic feedback system. Cause-effect relationships become circular patterns that are inherently difficult to anticipate, control and rectify.

Acknowledgement of delays and their role in feedback dynamics and recognition of the need for rapid response, aid in addressing problems early. The theory of attention as a

scarce resource suggests that attention can only be spared for the most urgent and critical problems. By the time problems are identified as critical, they tend to have accumulated a mass of data that exceeds the cognitive or physical limits of what the regulator (or people) can manage. In fact, information overload and mismanagement under stressful regulatory conditions have been identified as key events in the build-up to many infamous failures and disasters (including Bhopal, Three Mile Island, Challenger, and Chernobyl) [3]. Early response to feedback therefore, makes sense in terms of both reacting early enough to deal with the dynamics of the system and of avoiding cognitive overload and the need to address critical attention-intensive disaster situations.

While feedback is clearly a driving factor in terms of the dynamics of success and failure, it also directs the essence of the system which dictates the overall behaviour, and over time, narrates and marks the evolutionary path of the system. This position paper attempted to focus attention on some of the dynamic aspects of regulation and feedback in complex systems and

to highlight their dramatic impact on the creative processes of systems construction.

References:

- [1] Ashby W. R., *Introduction to Cybernetics*, Chapman and Hall, London, 1956
- [2] Dalcher D., "Lessons For The Future: Safety Critical Systems", *IEEE Engineering of Computer based Systems Symposium (ECBS99)*, March 1999, Nashville, TN, IEEE Press, Los Alamitos, 1999, pp. 281-293.
- [3] Dalcher D., "Disaster in London: The LAS Case Study", *IEEE Engineering of Computer based Systems Symposium (ECBS99)*, March 1999, Nashville, TN, IEEE Press, Los Alamitos, 1999, pp. 41-52.
- [4] Koontz H. and Weihrich H., *Management* (9 ed.), McGraw Hill, New York, 1988.
- [5] Waddington, C. H., *Tools for Thought*, Cape, London, 1977.
- [6] Wiener, N., *The Human Use of Human Beings; Cybernetics and Society*, Houghton Mifflin, Boston, 1954.