CHAPTER 3

STUDY ON FEEDBACK CONTROL

3.1 Introduction

Projects, product lines and organizations are encountering the need to adapt to and manage increasing rates of change in their business objectives, business processes, competitive environment and technological opportunities. This increases the need for feedback in project, product line and organizational life cycle processes to ensure that the processes are well matched to their changing process drivers and the result/outcome is optimized [63]. In order to develop a computer based system to support the process management, it is necessary to represent the feedback from an information point of view. This chapter discusses types of feedback control and its components. Various definitions of feedback controls are presented and the difficulties in establishing the feedback control are explained. The hierarchy of feedback control is presented and finally feedback in global software process is discussed.

3.2 Feedback Control

In a complex situation, an analyst will attempt to reduce the complexity of the problem. The traditional approach is based on fundamental perspective. That is, breaking down the problem into functions and then analyzing individual functions. On the other hand, the fundamental idea of system is to recognize and analyze a situation within a overall perspectives in terms of system. A system can be viewed as a transformation process which converts a set of inputs into a set of outputs. The input and output of a system are the main interfaces between the system and the outside
A system may be further divided into sub-systems and components each of which will receive inputs and transform them into outputs. A sub-system can be a total system itself, consisting of all the components, attributes and relationships necessary to achieve the particular objective which its wider system has set for it.

Research work carried out by Lehman [27,28,29] justifies for more substantial study for feedback perspective. Feedback is a sub-system function that compares the output with a given criterion in order to reduce the deviation between the actual state of the system and the desired state, when the system is subject to unpredictable disturbances from its environment. Therefore the system feedback takes place whenever information about any of a system output is used to correct its operation [56].

A system performing properly generates positive feedback, which signals the control function to maintain the system's current course towards its goal. A system whose performance is deteriorating - deviation from the attainment of its goal - generates negative feedback. Control is accomplished by the following: ① detecting a feedback, ② measuring size, quantity, direction or intensity of the feedback, ③ comparing the results to the established standards of proper performance ④ transmitting control signals that initiate corrective actions to adjust the activities of the system components and ⑤ bringing system performance under control, that is, back within an acceptable range of performance that leads to the attainment of system goals [22].

The essential components of the feedback control operation are shown in fig 3.1.
3.3 Types of Feedback Control

There are two types of feedback [56] – intrinsic and extrinsic. Intrinsic feedback is shown in fig 3.2. Intrinsic feedback is also called integrated feedback and occurs when feedback and control are within the system’s boundary and undertaken by elements belonging to the system.
Extrinsic feedback involves feedback and control outside the system boundary and thus involves entities which belongs either to the wider system or the environment (fig3.3). In general, the presence of intrinsic feedback is not readily not apparent to an outside observer.

Fig 3.3 Extrinsic feedback [56]

The concept of feedback control can be contrasted with that of feedforward or open loop control. Feedforward control is shown in fig 3.4. In a feedforward control system no information from the system process is used to correct the system operation. If disturbances to the system are predictable and can be measured in advance, feedforward control is a useful way of compensating for or canceling the undesirable effects of these disturbances upon the system output before they actually materialize. The major difficulties with effective feedforward control are, the requirements that firstly the relevant environment disturbances can be forecast and secondly the decision making sub function is capable of taking the right action to eliminate the
undesirable effects. It is always not possible for feedback control to achieve accuracy [56].

![Feedforward Control Diagram]

**Figure 3.4. Feedforward Control [56]**

It is often necessary for feedforward control to work together with feedback control so that sub system of feedforward control minimizes the effect of measurable disturbances, while sub system of feedback control corrects the error caused by unmeasurable disturbances and at the same time increases the overall control accuracy by compensating for the limitations of feedforward part [56].

Feedback control systems are not limited to the field of engineering. It is also common to find feedback structures in economics, biology and business organizations. In engineering applications, a control system is usually operated by electricity, by mechanical devices, by pneumatic or hydraulic power. In a business organization, control is accomplished through meetings, procedures and managerial actions.
3.4 Hierarchy of Feedback Control Systems

Feedback control may appear at more than one level. A higher-level control governs the lower levels by monitoring their overall performance and setting the desired reference levels for them. It is apparent that the concept of multi-level control is closely related to the concept of system hierarchy.

The structure of a management control hierarchy is a good illustration of this more sophisticated control concept, as shown in Fig. 3.5. This shows that the activities of an organization are regulated by a hierarchy which may consist of several levels of control. At the business level, control of the organization is exercised by the government or by regulatory agencies (laws and regulations, tax on income), the bank (bank loan, interest payments), the stockholders (dividend payments, shareholders’ committee). Note that at this level the effects of the competitors, the trade union (welfare of workforce), the local communities (environmental protection), and so on, are exercised through environmental influence rather than control because these do not directly regulate the business. At the organizational level, control is carried out through management decisions on the level of production, product prices, the level of employment, the level of investment, and so on. These decisions have to be made on the basis of the performance of the organization in relation to the business target which is set for the organization. At the operational level, the departmental managers are responsible for the fulfillment of the operational tasks necessary to satisfy the organizational requirements. At the unit level, each individual process is controlled by a designed physical and/or human-operator approach.
3.5 Difficulties in feedback systems

The main difficulty with feedback system is in the acceptance and interpretation of the observed results and their translation into action. When the feedback data and the system 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 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. Feedback often proves to be a de facto choice of the system developer for the following reasons [15]:

- it minimises cognitive effort
• it relies on a simpler model
• it 'satisfies' 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).

The theories available for process evolution, process improvements, process systems and architectures are not enough to set the controls on evolution process. So research needs to be carried out to establish appropriate theories to derive control mechanisms and to establish settings and effects. Also, there may be feedback overload in which the various feedback paths interact in unknown ways and hinder the understanding of individual feedback and control mechanisms [32].

3.6 The Definitions of Feedback

The following is an attempt to give in a nut-shell a few definitions for feedback:

• Feedback compensates an error or deviation from the goal after it has happened [59].

• The return of the output, or a processed portion of the output, of a (usually active) device to the input [61].

• Formal, private communication between the provider and consumer about the consumer's expectations and standards and provider's responsibilities and performance [57].

• A mechanism that regulates the action of something else [64]
• Return of part of system’s output to its input, so that a control device can use information about the current state of the system to determine the next control action [62].

• Feedback is giving specific information about a person’s current behavior in order to help him/her either continue the behavior or modify the behavior [67].

• Feedback is information about progress towards specific goals measured by mutually agreed-upon standards [65].

• Feedback is defined as information about decision making process or its outcome [3].

3.7 Feedback in the Global Software Process
Software processes intrinsically involve feedback systems. Feedback mechanisms and its influences appear at many levels and in a variety of forms [33]. E-type software* operates in an unbounded countably infinite real world domain [25,26] and its development is initiated by formulating an application concept or changing the existing concept. The formulation includes the setting of bounds to the concept and its operational domain. Application bounding involves many clients, users, managers, marketers and development staff. All their views must be reconciled, merged and limited to form a technically feasible definition, within time, resource, budget and other constraints. This provides a starting point for the development and evolution of the software system. This iterative process is illustrated in fig 3.6. The bounds of both the a application and its domain are moved by the process in order to

* E-type software is a software that supports applications operating in the real world.
converge to a view that is acceptable to the decision makers. The bounding process has the structure of a feedback loop in which the output of a process is applied to and modifies its input. Once the decision to go ahead has been made, further development steps can be pursued to produce a validated system ready for installation [33].

Figure 3.7 identifies basic steps required to develop a satisfactory operational system and the end product of this is the validated program. It is installed in the application domain as shown in figure 3.7. Over time, the original environment (eg: CPU, operating systems, business rules and external product characteristics) for which the software was developed is changed. As software is used, the customer/user will recognize additional functions that will provide benefit. Also installation and use of the software system changes the perceptions, understanding and goals of both users and developers [30]. So the application and its operational domain that provided the initial input to the development process is changed by the output of that process. At the level illustrated in figure 3.7 too, the software development constitutes a feedback system.
There is a gap between the finite software and the unbounded domains and this gap is bridged by assumptions. Since the real world operational domain is always changing, individual members of the assumption set progressively become invalid. This results in an unending stream of corrective or adaptive changes. This constitutes a positive feedback in that it produces pressure for change, growth in the queue of change requests.

Figure 3.7. Intermediate Loop [33]
Figure 3.8 shows a higher level of feedback and there are other driving forces such as constraints imposed by the management or the market place, different needs and personalities of the users, arrival of new technologies and development environment influences on and in the process. They are exercised by local and executive management, marketers, support personnel, users and many other people and processes in the operational and development domains. All involve feedback loops, in one way or another. The inner cloud is intended to symbolise the bound of the operational domain at some moment in time. The arrows and outer clouds convey a fundamental property of $E$-type applications i.e. this boundary changes as the system is adapted to remove functional and performance limitations and to support a changing environment.
The above three levels are merged in figure 3.9 to provide a wider view of the global process. This level conveys the learning, communication and iteration that are an integral part of each of the steps and between steps. This level portrays the global software process as a complex multi-agent, multi-loop, multi-level feedback system [33].

Figure 3.9. The global process [33]

3.8 Discussions
This chapter has presented various definitions of feedback and investigated the difficulties in feedback systems. It reveals how feedback affects the whole project development process. This shows feedback control in project management is a
research problem. The discussion on feedback control in global software process shows the magnitude of the difficulty of feedback in software projects. Hence, a mechanism is needed to represent feedback control.