An architectural framework for system analysis and evaluation*

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THE PROBLEM

In any situation where a large amount of information must be handled, the need for structure soon becomes evident. When one must process a quantity of information and reduce it to a small amount (for example, from a large set of evaluations decide whether to buy system A or system B) the need for hierarchical structure is especially evident because of the inability of the human mind to consider more than a very small number of pieces of information simultaneously. If one is presented with 100 facts and asked to make a single overall judgment in terms of three or four possibilities, he must have some means of aggregation.

A second aspect of the problem is the diversity of the information involved in the evaluation of a complex system. For example, evaluating a political information retrieval system might involve consideration of technical facts, projected usage patterns, the attitudes of politicians toward mechanization of previously intuitive processes, etc. What is needed is not only an aggregation scheme, but (hopefully) a small set of common factors that underlie the larger number of measurements. Apples and oranges can be compared if you know that each provides nutritional value.

The evaluation of an operating system is a good example (and, in fact, is the one that prompted the development of the approach presented here). Suppose you wish to make an evaluation that judges the system's performance, suitability to a market, use of hardware, and suitability for further development.

What you are given (or, rather, what can usually be obtained) are external performance measurements, sketchy overall descriptions of the system, some (usually incorrect) internal documentation, listings, and perhaps some internal performance measurements. You also know the hardware it uses, the general state of operating system technology in terms of the mechanisms used in other systems, the kinds of people using the system, and some rough (almost never quantitative) idea of the computational needs of those users. From such a polyglot of data you must develop succinct judgments and explanations that accurately characterize the system.

Examples of other complex evaluation and analysis tasks are:

- determine where a set of design goals is in relation to the state of the art;
- determine if a system meets its design goals;
- propose the logical successor to a given system;
- collect and evaluate all known data on a system.

These and similar tasks require one to build up a coherent view of the object being studied. This in turn requires the hierarchical structuring of information into a small number of categories. The framework presented here is a way of achieving this.

THE FRAMEWORK

Some day we may understand complex systems well enough to permit the definition and use of factors common to all systems (just as we now evaluate diverse electronic components in common terms of power drain, number of circuits used, operating temperature, etc.). Currently, however, the best we are able to do is to find a set of interesting dimensions along which to evaluate some small set of systems. The trouble is that these dimensions are usually chosen on the basis of readily available data and not on the basis of their

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ability to cover a diverse range of information or provide a basis for total evaluation.

The framework presented here was developed in analogy to the problem of developing a thorough and, at the same time, an overall analysis of a building. It consists of six dimensions that encompass most of what one would want to know in such an evaluation. The dimensions are not necessarily independent and may be thought of as representing six ways of looking at an object.

Imagine that you are an architect asked to evaluate a large building. The data points that you can collect may be as diverse as those in our illustration above. There are, however, six categories which will serve to group information of interest about the building: its location, the foundation it is built upon, its structure, the functions it is meant to provide and/or that it actually provides, its finish, and its adaptability to new purposes. If you make a judgment about the building along each of these dimensions and combine them in a manner that agrees with the importance assigned to each (which may change from building to building), you can obtain a coherent evaluation.

Further, preparing the judgment on each dimension will require a number of subsidiary decisions that may be of final interest themselves (for example, how strong is the foundation, does it take account of special local soil conditions, etc.). More importantly, the categories will force you not only to sort out data into convenient equivalence classes but will permit the use of a single piece of data in several ways (for example, the observation that concrete block is used throughout is pertinent to an evaluation of the foundation, the finish and the adaptability as well as the structure).

Our framework is based on the following definitions of the six dimensions:

Location: The system’s position with respect to another object, set of concepts, set of mechanisms or techniques.

Foundations: Objects, concepts, techniques, practices, etc., whose effect is felt throughout the system.

Structure: The way the system is physically or logically built and put together; the basic mechanisms that provide the functions of the system.

Functions: Services or actions provided by the system.

Finish: Polish, absence of “rough edges”, smoothness, external appearance.

Adaptability: The ability to be changed to provide new functions or reside on new foundations.

These definitions are not very precise, nor do we want them to be. They are meant to indicate six major views that should be considered; their exact definitions may vary somewhat from situation to situation.

As illustration, the following definitions-by-example show the categories of information, or to put it another way, some of the questions to be asked along each of the six factor dimensions for the evaluation of an operating system.

Location:
1. with respect to competing systems;
2. with respect to hardware technology;
3. with respect to software technology;
4. with respect to design goals;
5. with respect to conceivable systems.

Foundations:
1. functional concepts used;
2. implementation concepts used;
3. basic resource sharing algorithms;
4. coding quality;
5. internal documentation quality.

Structure:
1. physical layout of code and tables;
2. subpart interconnections;
3. data flow;
4. control linkage mechanisms;
5. measurement sub-system;
6. test sub-system.

Functions:
1. functions provided;
2. evaluation of performance;
3. additional needed functions;
4. completeness of functions provided (internal consistency).

Finish:
1. user interface;
2. user documentation;
3. ease of doing simple tasks;
4. error handling;
5. crash rate;
6. crash recovery.

Adaptability:
1. growth possibilities;
2. ability to be tailored;
3. extensions possible.

USE OF THE FRAMEWORK

The purpose of presenting this framework is primarily to provide a starting place for the development of more coherent system evaluation methods. Nevertheless, at least three different uses can be made of it in its present form:
Generation of analysis questions

When evaluating a complex system, one is often hard-pressed to know what questions to ask. Simply measuring the performance of various components or analyzing their logic may be insufficient. By taking this framework of six dimensions, defining appropriate sub-dimensions, and then asking what must be known in order to evaluate the system along each such direction, one can arrive at a more complete set of measurements to be taken and analyses to be made.

Data organization

Given a large amount of data about a system, one must structure it as we pointed out above. Normally one wishes to organize it in an hierarchical fashion that groups like data or like subcomponents of diverse data together. This framework provides such an organization.

Guide to evaluation

If one is evaluating several systems for purposes of comparison or wishes to arrive at an overall judgment of a single system, this framework can provide the nucleus of an approach. After the framework is fully defined for the situation at hand an attempt can be made to assign relative weights to the different dimensions and sub-dimensions. Although one may not wish to rely totally on such a procedure (although it should be seriously considered), attempting to determine quantitatively the relative importance of different factors that enter into the final decision will prove to be of great help in arriving at a rationalized evaluation.

SUMMARY

We have presented a framework for the analysis and evaluation of complex systems that can serve both as an organizer of existing data and a generator of measurements to be made. Its primary feature is the grouping of diverse pieces of data into a small number of factors that have common and intuitive meanings. Its hierarchical nature allows one to gain an overview of a large amount of dissimilar data and to aggregate individual judgments from a wide variety of evaluations.

The ability of the approach to reduce the amount of information that must be considered at each level, its adaptability to differing evaluation problems, and its guidance to what questions to ask recommend its use. Further, its (albeit slight) quantitative character puts it a step ahead of the completely informal and unstructured methods commonly used. Use of the approach by the author in the total evaluation of a medium scale time-sharing system indicates that it does indeed provide a good evaluation framework.

Clearly, there is much work left to be done here. We must further refine and formalize system analysis and evaluation techniques. We must try to get a more quantitative understanding of the relationships between various dimensions and factors. We must evaluate in as rigorous a fashion as possible many systems.

Our intent has been to define a new framework for the analysis of complex systems. If its grouping of concepts proves to be useful in practice, fine. If not, perhaps its insufficiencies will spur others to develop better frameworks.
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