**Is There a Common Functionality?**

A Comment by Erik W. Aslaksen

Every systems engineer is familiar with the distinction between what a system *is*, i.e. its composition in terms of physical components - hardware and software, and what a system *does*, i.e. its functionality. And many of us also commonly work with functionality in the sense that we use the system concept to decompose a complex functionality into a set of interacting *functional elements*, thereby creating a system in the *functional domain*, the latter being the set of all functional elements. But whereas we all understand physical components very well - how to categorise them, measure them, visualise them, interconnect them, and so on - it is not clear that we can say the same for our understanding of functional elements.

Take the very simple example of the common corkscrew, an implement I am happy to say I employ quite frequently. It comes in countless physical guises, and they all have the same purpose or functionality - to remove the cork from a bottle. But what is this functional element - decorking a bottle - of which the corkscrew is a representation? It is completely divorced from any particular physical realisation; it does not exist within the familiar space-time manifold. It cannot be described in terms of weight, size, colour, or any similar parameters. As a matter of fact, in itself it cannot be described at all; what can be described is its effect on the physical world. But is that all? Are there no characteristics of functional elements and of the functional domain that are peculiar to this domain? For example, how do functional elements interact to create systems of functional elements? Such a system is again a functional element, just a more complex one; are there any limitations on the interactions under which the functional domain remains closed? Are all functional elements physically realisable? Is there some way of measuring the complexity of a functional element? Can the functional domain be turned into a metric space, such that we can speak of the distance between elements, e.g. that two elements are closer to each other than to a third element?

These, and other questions, can be approached in a systematic fashion. But before arguing what the first step in such an approach should be, we need to ask, and answer, the question: Does it matter? Having worked on these questions for the better part of the last twenty years, I would have to say that the answer from the overwhelming majority of the engineering community has been a resounding No! The abstract concept of functionality is simply a useful figure of speech, but all real work in systems engineering is carried out in the physical domain, and the results, which is what matters, are in any case always measurable in the physical domain. Both of these assertions are accurate. The latter is, as far as engineered systems are concerned, a truism; the former may be more a characteristic of the current state of engineering than any enduring truth. The question has much in common with asking: Do such concepts as truth and justice matter? Do they have any validity except in the context of "acting truthfully and justly"? Only such actions can be manipulated by us, e.g. carried out or not, or related to each other; and it is only the results of such actions that can be measured. Well, perhaps, but this point of view reduces human mental activity to a pretty primitive, goal-seeking activity. And as far as engineering is concerned, it ignores, or at least severely undervalues, the fact that engineering is a creative activity and that creative thinking relies on the ability to abstract from what is in order to imagine what could be.

As long as the importance of working in the functional domain is denied or ignored, there is, of course, no benefit in pursuing the above questions. However, even if the ability to work in the functional domain is recognised as being important to engineering, we soon come up against a practical problem - it is currently very inefficient. Building the conceptual models required for problem-solving in the functional domain is very time-consuming, and the benefit of doing it for an individual case outweighs the cost only for very complex systems, if at all. The solution to this problem is the same as that adopted in the physical domain; design in the physical domain is only efficient because we have literally millions of standardised components. If you had to design every nut, bolt, resistor, capacitor, etc. every time you wanted to design a piece of equipment, it would be hopelessly inefficient, and the rate of technological development would be slowed to what it was five hundred years ago. To make design in the functional domain equally efficient, we need to create a similar collection of standardised functional elements.

But is that possible? Is not every case different? The answers to these questions are yes and no, respectively, and as to the latter, it is not difficult to identify some high-level functional elements that are found in many systems. Take the functionality of transport, i.e. moving something, be it a substance, power, information, or anything else, from one point in space to another. Or the functionality of storage, i.e. moving something unchanged from one point in time to a later point in time. But, of course, not all systems incorporate these elements, and we are almost compelled to ask the question: Is there any functionality that is common to all systems? I believe the answer is yes, and that the existence of such a common functional element is crucial to a rational view of the functional domain.

The basic argument is simple. The creation and operation of any system must involve an expenditure of resources in some form, such as labour, energy, information, and materials, and even forms that are not normally or easily measured in monetary terms. But would anyone incur a cost without any prospect of a return? The return might not be directly in terms of money; it can be in the form of personal well-being, absence of illness, peace of mind, a sense of achievement, and so on, but indirectly, as with the cost, this can always be measured in monetary terms.

The return can only occur once the system has been created and put into service, so that the expenditure must come before the return and is therefore an *investment*. All engineering projects are subject to this cycle of investment, creation, and return, and as there are infinitely many possible projects, all competing for a finite set of resources, the fundamental purpose of the engineering process is to maximise the return on investment, in the sense that while all other considerations may be ignored in a process of simplification, this one cannot be ignored or simplified away without making the design process irrational. Or, in other words, the constraint of competition for limited resources is the essence of the process of engineering; that which makes it fundamentally different from a science. Engineering is not about truth, but about cost-effectiveness, with the effectiveness being judged by the users. Consequently, the functional element representing this fundamental purpose, Return on Investment (ROI), can be said to be an *irreducible* element, and it is not dependent on the particular system, but is, because it has its genesis in the process that creates all systems, universal to all systems.

Now, I can already hear the howls of protest. Talk about primitive, goal-seeking process! Reducing all of engineering to an issue about the bottom line! What about human values? What about social responsibility? What about all those benefits that cannot possibly be measured? Well, my answer to this is, firstly, that we need to distinguish the process of engineering from the process of assigning value to the output produced by the system to be engineered. Once the value or benefit of the output of a proposed system has been defined in quantitative terms by a company, society, or whoever is empowered to make that assignment, the process of engineering will attempt to design the system so as to optimise the cost-effectiveness of the system, or its ROI, irrespective of whether it be a gas chamber, an atomic bomb, an artificial heart, or a life-saving drug. This does not mean, of course, that engineers should not be concerned about moral values, and may refuse to participate in the design of certain systems and actively oppose them in other ways, but they do so as humans, not as engineers. The engineering profession has no special insight into moral values.

Secondly, as to the benefits that cannot possibly be measured, I cannot think of any. Whenever such benefits are put forward, e.g. the benefit of saving a human life, it is not that a value could not be assigned, it is simply that whoever should do it, most often society, does not want to do it in quantitative terms. Implicitly it is being done all the time, of course, in the government's budget allocations, in decisions about using armed force, etc.

It is the existence of this irreducible element that gives a structure to the functional domain and provides the point of departure for the development of further elements. From every element there must be a path, through other elements, which leads back to the irreducible element. Or, in other words, if an element has no influence on the ROI, it should be removed from the description of the system functionality.