Function Modeling Issues

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Abstract
The paper reviews function modeling and further investigates the Function/Attribute Analysis, according to the Subject-Verb-Object typology. Some difficulties in function modeling arise from time dependencies, subsystem definitions, , choosing the verb and number of functions. An attempt is made to describe a more strict formulation of function modeling. An analogy with thermodynamics and systems theory is suggested resulting in new definitions such as function states and process functions, equilibrium of a system, dynamics of changes in a system and irreversibility of functions resolving the former mentioned conflicts. Several laws of evolution provide an additional help to complete the function model.

Keywords
Function modeling, system modeling, Thermodynamics, process function, law of evolution, state function

1 IN SEARCH FOR THE IDEAL FUNCTION MODEL

The notion of function modeling is one of the most important in TRIZ because it lays at the basis of achieving the Ideal Final Result. A "function" is defined as the effects of a tangible object to change the parameters of another tangible object. [1] [2] [5] [24]. The notion of "function" was used by Altshuller in several ways such as representing the main function (used in Su-Field or vepole as it was called in Russia, A Su-field is a minimal, functioning model of a Technical System [17]), as an ideal function in the development of a Technical System and as the purpose of a Technical System (as described in ARIZ 85C 1.1).

The primary function of a Technical System is the reason why the Technical System was designed for mankind. A pen was designed for writing. A car was designed for driving. Ideally the technical system will disappear and the function will be performed by the product/object itself [28]. Ideally the object will no longer have need of a Technical System. This means writing without a pen but leaving a trace on the surface of paper [29]. Using computers could be seen as writing without a pen, but of course the pen was replaced by another Technical System, the computer. Ultimately it would mean that we are able to write without any means unless this function transitions to the super system. The latter means that we no longer need a surface to leave a trace on the paper or the person hasn't got the need for a paper any more. (Law of Transition of a system to a super system) The function will be inherent in the object.

A Technical system is characterized through the law of completeness [4]. I have added "information" as an extra element in the law of completeness.

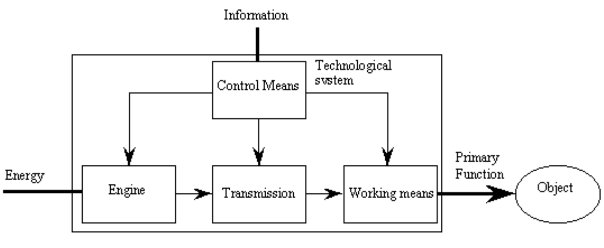


Figure 1. Law of System Completeness [4]

Of course this notion of a function is only an abstracted representation of what the object or Technical System is doing enabling us to describe situations we can repeat and even predict. A system is called complex when the relations between the objects are unknown [16] so function modeling can be used to describe the unknown relations, trying to make "the unknown known". This can never be correct without proper checks in reality and or with tests accordingly. This is exactly what science is about.

The different roles that a Technical System can play in different environments or super systems, creates a lot of ambiguity in defining functions [1] [3]. A pen for example could also be used to stir the coffee or used to blow darts. This is ambiguity more clear in archeological finding of a supposed Technical System.

The concept of functions was introduced in Technical Systems by General Electric's Lawrence Miles, the father of value engineering [22]. It is worth mentioning that in the beginning of VAVE the ladder of abstraction was used [7].

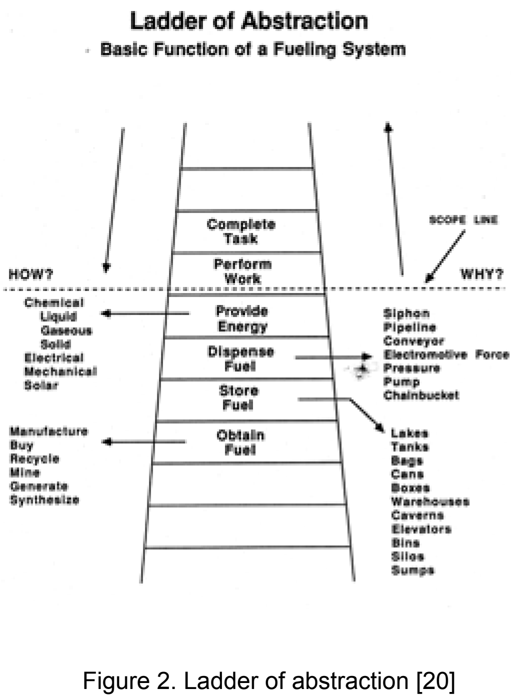


Figure 2. Ladder of abstraction [20]

Climbing up the ladder means asking the "why" question and moving down means asking the "how" question. A similar technique was developed by De Bono called "Concept Fan" [8] [13].

This jumping back and forth between can be considered as a creative process in which moving is more important than evaluating the alternatives.

Building further on the work of Miles, Charles Bytheway developed the concept of function models in 1965. The technique Bytheway developed was called Function Analysis System Technique or FAST [6]. In building a FAST model, the engineer asks how, when and why things happen in a system looking like the ladder of abstraction but tilted 90°. Bytheway liked the idea of function modeling but was bothered with the difficulty of getting an agreement on the basic function of an assembly or product. In 1975 a five day seminar between seven value specialists was held to discuss function modeling. This resulted in two types of FAST. One developed by Ruggles called Technical Oriented FAST and another called Task Oriented FAST as developed by Snodgrass. [20]

A function tree also used in VAVE tries to describe the several levels of dependencies as the example in an overhead projector shows in figure 3.

Originating from VAVE in the early 1980's S. Litvin, V. Gerassimov, B. Zlotin and others acting as engineering managers gradually used and improved function modeling often called Function Cost Analysis while learning TRIZ from Altshuller. [6] [30] [31]

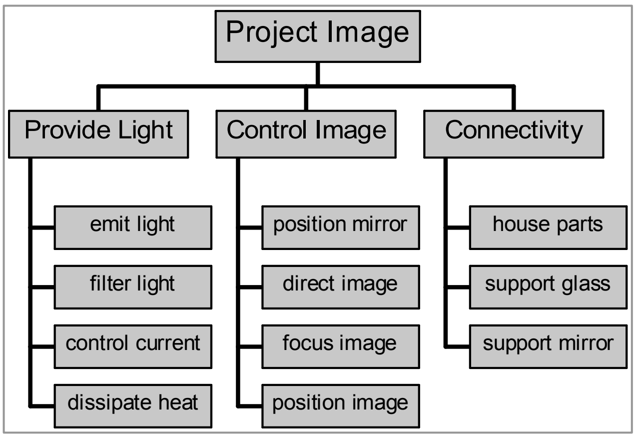


Figure 3: Functional tree

Malkin et al introduced useful and harmful functions into function models [6]. The use of harmful functions makes it possible to use the function model to identify three basic ways to improve system performance: improve useful functions, reduce harmful functions and resolve contradictions between useful and harmful functions. This is basically a cause and effect analysis approach which has been perfected, patented and implemented in the Innovation Workbench software [15] on the one hand and Goldratt [9] [16] on the other hand.

The problem formulator shows four types of links: providing something, eliminating something bad, causing something bad or hindering something good.

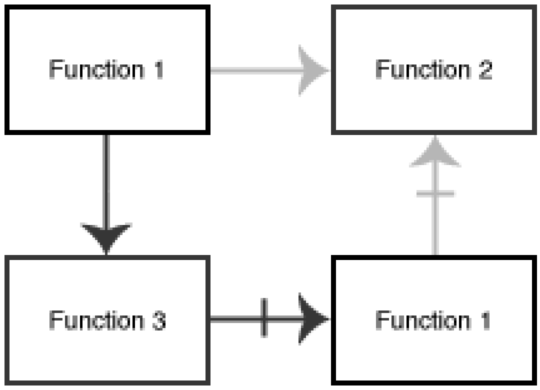


Figure 4: Functional Model from Ideation [15]

This type of function modeling reveals cause and effect in a system. These cause and effect function models are more functional models. They explain step by step what happens to the system or subsystem and evaluate (good or bad) the transition from step one to two.

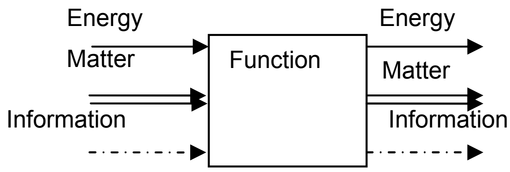


Figure 5. Flow model

A distinct other representation of a technical system is based on flow of energy, matter and information (or signal) as seen in figure 5 [10] [11] [12] [27]. This is why I added information on the law of completeness earlier.

A Technical System can be represented by energy or fields (as in Su-Field), by function as in function modelling but also through information.

A function is here defined as a general and desired input/output relationship of a system with the purpose to perform a task. For static processes it is enough to determine the inputs and outputs; for dynamic processes (processes changing with time), the task must be defined further by a description of the initial and final magnitudes as well as all relevant magnitudes within the considered time span.

I will not go into the function models mentioned so far and focus on a specific way of function modeling characterised by the Subject-Verb-Object typology.

2 THE NOTION OF DEFINING FUNCTIONS IN A SVO WAY

Similar models were created based on the Subject-Verb-Object typology dating back to Larry Miles and TRIZ implemented by Invention Machine [14], Darrell Mann [13] and Alex Pinyayev [24].

Larry Miles used the phrase "what does the object do" to find the function being performed by the system. He suggested using "verbs and nouns". So another way of finding the function of an object is putting it in a sentence like "SUBJECT does VERB with OBJECT". For instance "PEN does LAYING ON with TABLE" or the "pen lies on the table". This approach is called the Subject verb Object typology and is also known in linguistics.

At first Larry Miles distinguished 2 types of function e.g. aesthetic functions and use functions. An aesthetic function were the elements of cost which are the purpose of pleasing the buyer through color, shape of feature, causing him to buy. The use functions are the costs that are required to cause the product to perform a use which the buyer wants and wants to pay for. Since the main goal in VAVE is decreasing cost it is logical that the functions were allocated with costs. Later on second degree functions were defined. These are functions necessary in order to cause the designers choice for means of accomplishing the basic function effectively. In production we could make the distinction between processes delivering the basic functions and second degree functions installed to reduce the time and improve the quality of the basic functions. For instance a gear wheel is not grinded at once. First it is milled speeding up the time for grinding afterwards. The choice of milling is done by the process engineer, the choice of grinding by the customer.

Adding harmful to functions was a big step in function modeling [6]. However it is subjective.

Several other types of functions have been defined since. Valeri Souchkov added insufficient, excessive and uncontrolled functions to the whole spectrum of function modeling [25]. Most function modeling is done to describe an issue, e.g. through the conflict between a “useful” function and a “harmful” function in an operational area [24]. This coloring is very subjective and depending on the problem.

G. Yezersky & G. Frenklach proposed to consider a *neutral function* (NF) as opposed to harmful and useful [22].

3 THOUGHTS ON SYSTEM MODELING

The systematic study of technical systems and their system functions are considered the foundation of TRIZ [22]. I believe that function modeling is system modeling.

In analogy to Thermodynamics I would like to use the terms: state, irreversible processes, dynamic equilibrium. These terms will help to solve some difficulties in function modeling.

3.1 A system and Technical System

A system consists of objects (subjects), attributes and functions working together to perform a system function that is acting to the super system. It possesses behaviors and properties that cannot be reduced to the behaviors and properties of its separate subsystems. Altshuller said that the wing of an airplane doesn’t fly. Nor does the motor, hull, cockpit, pilot. But together they do. This is a system delivering the function of flaying. Yet if the wing didn’t have the light weight and specific shape, if the engine wouldn’t provide enough power, if the pilot would know what to do: the plane would not fly. All the parts have specific functions with material and or function attributes. This statement is true for technical object and not for organic objects. A set of bones, meat, muscles, nerves and brain will not make a person.

If there was no air or pilot, which I would consider objects of the super system, the plane would not fly too. A super system contains those objects or systems that cannot be changed.

A technical system is a system that is characterized by the laws of system completeness, “energy conductance” and of rhythm coordination [29].

3.2 A system consists of objects

A single object without a relation to another object doesn’t exist. What is the meaning of a pen without paper or a person to write with it? This means there is always at least one relation between an object and its surrounding. Even every word is connected through other words in a dictionary. For this reason I believe that Su-field 1.1 is not necessary. Every system will have at last one process (field) towards its surrounding. This leads to the fact that no product exists without having at least one process. So every product is having one process towards its surrounding.

3.3 A system is characterized by attributes through Thermodynamics

When a system is at a dynamic equilibrium under a given set of conditions, it is said to be in a definite state or condition. The state of the system can be described by a number of variables. The properties of the system can be described by an equation at an equilibrium state. The equation specifies the relationship between these variables. For instance: a pen contains a spring. When the pen is laying on the table, this spring is “active” what is called the spring tension. Although this force exists the spring and pen don’t move. This dynamic state may be thought of as the instantaneous quantitative description of a system with a set number of variables held constant. This is the reason why all attributes don’t need to be described. Adding the attributes or features in a function model decreases the readability. So, fortunately not all attributes need to be added. Where do you put them? Basically they should be added between brackets at either the functions or the objects. That fact that the objects and functions contain more attributes than being used in the system function contains a clue of possible improvements or resources. In an ordinary pen, the electrical, magnetic features of some of the subcomponents are normally not used providing an opportunity.

3.4 Thermodynamic process

A thermodynamic process is defined as the energetic evolution of a Technical System changing from an initial state to a final state. This thermodynamic process I would call “process function” differing from the reversible “state functions”. State functions are functions not changing during the thermodynamic process. A clamp holding a work piece will keep on holding when a process function changes the work piece. The “process of holding” goes so slowly it appears that reversibility is at hand. If a process is reversible, there is no heat (entropy) lost to the environment. The spring has this spring tension. Another example is a battery. A rechargeable battery will wear down after numerous uses but appears when working to be fully reversible. A spring appears to be fully reversible too. Mark that if the period is long enough the battery doesn’t have reversibility which means that state functions can only be described as in a “state” during a certain period.

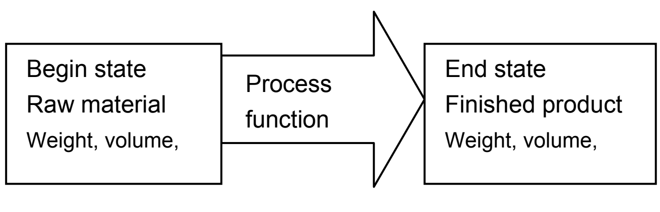


Figure 5: A process description

4 SOME DIFFICULTIES IN SYSTEM SVO FUNCTION MODELING

The following issues & points I would like to bring up as possible difficulties in function modeling.

1. What verb to use?
2. Is function modeling cause and effect?
3. Number of verbs
4. The verb in the correct state
5. Functions that act on functions
6. Completeness of function model
7. Different functions on the same object
8. Depth of function model

I can imagine that many more questions can be asked so I suppose this list is far from complete.

Before describing these issues, I have experienced that finding the correct set of objects is easier than starting with a function tree (see figure 3) without objects. However defining object sometimes misses obvious objects such as air and dirt. But in most cases it is easy to define all objects because they are tangible. Let's focus now on the issues when making a function model according to the Subject-Verb-Object typology.

4.1 What verb to use?

In making a function model I have encountered numerous times that defining the verb was an issue. Which verb should you use and also in which direction? Is it A towards B or the other way around? Normally passive verbs like "will, should, were, are, is being…" should be avoided. They usually express a more interesting inverse relation. E.g. "The object A is being held by this object B" is better changed to "B holds A". Try reversing the functions to define which one describes better what actually is going on. The question is not to find as many as possible verbs but rather to find the minimum of verbs describing the maximum of system effects. The system effects are those effects why the system was created. It is like creating a basis. If you consider XYZ as a base any forth axes will be a combination of the former three. So if you add verbs like A supports B and B stands on A you have created one function too many. I would not describe all the possible functions but only those that are independent and describe how the system works.

Also the type of function is important. In studying technical English verbs I defined four classes of verbs. The first class is something like "Subject A changes Object B". This type of verb is absolutely useless. You don't know what it changes, except if you specify which parameter or attribute is being changed. But even so I try to avoid these verbs. I call these functions general functions, other examples are: alter, cause to, and improve. The second class I call generalized functions. These are types of functions like increase, decrease, start, and stop. These functions express to my impression a bit more than change. It gives a clue what happens although it is not specific enough. The third class of functions I call specified functions. Examples are: cool, heat, melt, move. These verbs already have an association with a specific attribute, like melt and temperature. One should try to avoid these verbs in describing a specific problem. Instead one should use in making a function model what I call class 4 verbs. Suppose you we look at riding a horse. Asking the question "What specifically does this do?" helps to find the specific function.

Class 1 General function: Horse changes (position) rider

Class 2 Generalized function: Horse increases (relative position) rider

Class 3 Specified function: Horse transports rider

Class 4 Specific function: Horse carries the rider

The classes of functions are apparently interrelated.

The law of completeness also points to the control, motor and transmission system. The motor and transmission system in this case is the horse itself. The control system is the rider. But this is not entirely true. The horse follows up the commands and 'controls' its own functioning.

I prefer to use the specific functions in describing the current situation. Although, going down the classes changes psychological inertia. [22] TRIZ general purpose is to alter the viewpoint and stepping away from the slang used in the specific model to find solutions. The specified, generalized functions can help to find higher level solutions. Mark that these classes are connected as the functions in the ladder of abstraction.

4.2 Cause and effect?

Function model is not necessarily a cause effect model in my view. A pen is laying on the table and doing nothing but laying; no cause and no effect. But is this a Technical System? No, it is more a system of technical objects [29]. However, this system is in dynamic equilibrium. All the functions acting at that time are state functions.
A system can evolve when another object of the super system acts but it is in the variation of possible functions (process functions) that a change will occur in the system. Not just one function will change. Several processes occur simultaneously when the person is calling. When using a phone, the battery is wearing down but this will not affect the normal state. The person might accidentally drop the phone also. Several states of the function model may be described. For instance when describing the use of a cellular phone following system states could come into mind:

- Normal working conditions while calling
- Phone is dead
- Phone is on but not used
- Working conditions in the beginning or end of the product life cycle
- When being bought
- When being maintained
- When being charged (too quickly)
- Under conditions that cause wearing down such as in the pocket, falling on the floor, being put in car kit

So a system model may contain reversible and irreversible functions. When drilling a hole, this cannot be "undrilled".

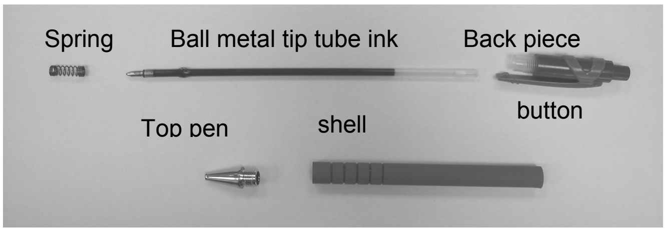
Defining the states of a system means zooming out in time. What will happen within 1 second, 1 hour, 1 month, 1 year, 1 lifetime, 1 millennium? For instance: an operator can lift an object of 23 kg easily but what will happen in 20 years with his back?

4.3 Number of verbs between subject and object.

Normally one tries to identify all different kind of functions that can be associated with the subject relations to object. I would consider only direct relations, in the sense of if this object touches or influences the other object directly there is a function.

If a pen is laying on the table and we want to define more precise which objects do what one could argue that the tube holding the ink is not touches the table so there is no direct relation or function between the table and the shell.

At this point I introduce a “dash dot dot dash” box surrounding objects to visualise that the object inside it act as one piece. I use this dashed box surrounding the objects ball/metal tip/tube because the act together. Also the back end of the pen is on piece (at this time). It is clear that even further back in time these pieces are manufactured as separate parts and assembled.



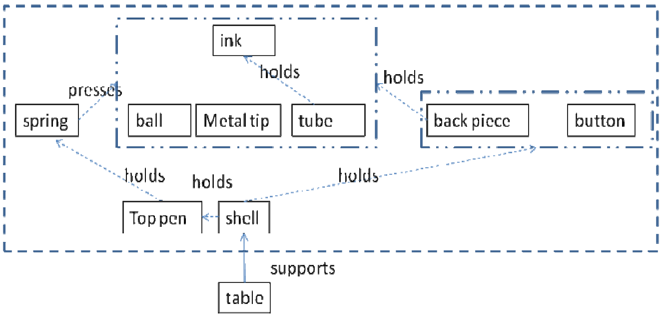


Figure 6: Function model of pen laying on table (the ink will also have contact with metal tip and ball, but this is not mentioned here, also the back piece and button relation)

Mark in the example that the pen is not writing and no ink is flowing. This model doesn’t contain process functions. I would like to notice that function modeling of a system doesn’t really need a problem. All the functions are in equilibrium so these are all state functions. The process function of ink transport only appears when a “person writes with the pen”. However, the spring is in a dynamic equilibrium because it will press the ball/metal tip/tube for as long as the person or another object from the super system in this case doesn’t alter this condition or state. The whole pen is also one object we normally accept as one part.

4.4 The verb in the correct state

A process function changes the condition or state of a tangible object. But once it has been changed the function appears as an attribute of the object. Let’s look at how the pen in our previous example was assembled. Now disassembled to show the relations. In the production process a process step will be the assembly of all the parts as seen in figure 6.

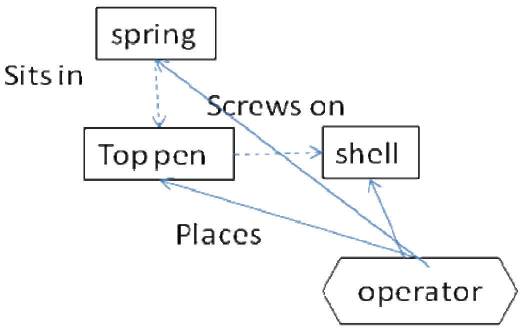


Figure 7: function model of assembly step

The first step in the assembly might look like above. The operator first takes the spring from a shelf or table (since we don’t know this at this time we’ll leave these objects such as table, box and pallet etc. out) and mounts it in the top pen. Then the operator screws the whole in the shell.

As soon as the parts have been screwed the function changes to “sits in” with the attribute “force”. The dash dot dot dash box means that this part cannot be disassembled any more without destroying it (irreversible). The dashed box means that in this moment these parts behave as one part.

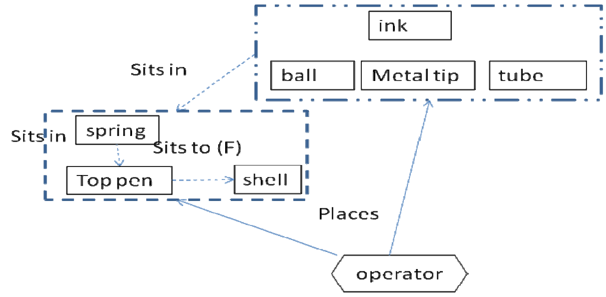


Figure 8: function model of assembly step

The next step is to mount the back end.

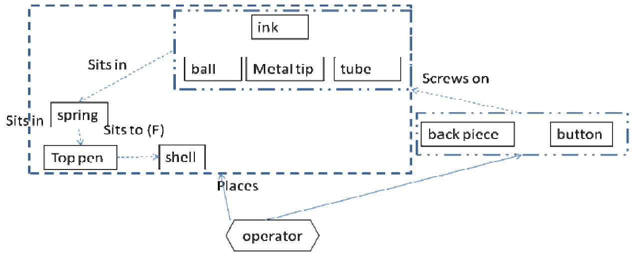


Figure 9: function model of assembly step

The final assembled end product looks like figure 6. (I left out the packaging, transporting, buying, opening of packaging, etc.)

Note also that the operator takes the whole (dashed) subsystem so the function is stopping at the dashed line, not the object itself!

A similar description can be found in [21].

4.5 Functions that appear to act on functions

Describing a catalytical reaction means that a relation between the functions is needed [13]. What di we do with objects that seem to act on the function between 2 other objects? This can easily be solved with the dashed boxes. Note that “attaching” changes to “sitting on”.

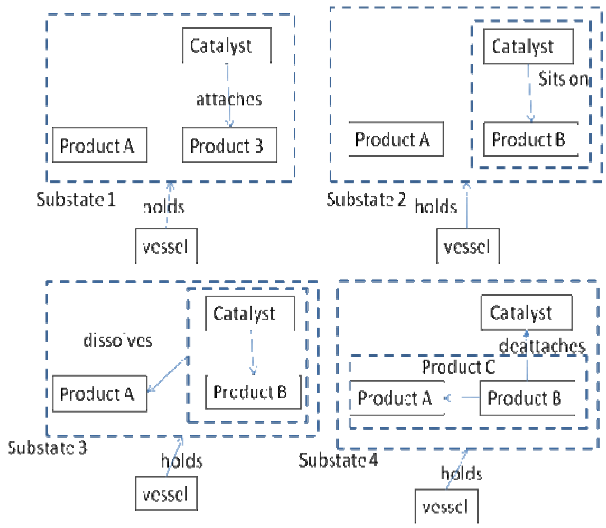


Figure 10: Example of lock open en closed.

4.6 Completeness of system

A pen laying on the table is missing an “engine” and “transmission” and “control system”. It is not a Technical System but merely a system, a set of object that are grouped together [29]. If energy does not pass freely through the entire system, a certain part of it will stay without energy and will not operate [22]. The pen laying on the table will not write by itself. So it useful to describe the motor, transmission and control subsystem associated with providing the necessary energy. (See example next paragraph although in this case the control system is poorly controlled by the operator). Note that the arrows used in figure 1 are in fact also functions and that the box indicating the technical system has always been there which is nothing else than the dashed box! A changed “law of completeness” is found in figure 11. The full lines though from Energy and Information are according to the Su-Field analysis symbols.

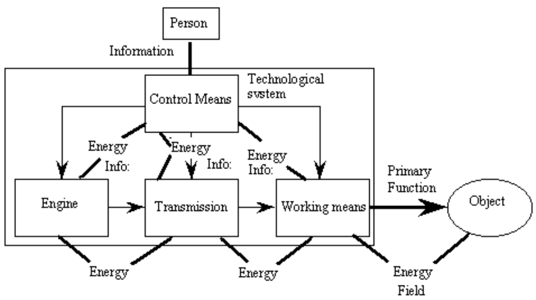


Figure 11: Interpretation of Law of Completeness

4.7 Different functions on the same object

If a function is acting on one part of an object (zone, space or time) and another function on another part of the object it is interesting to have a formalism that shows that the part is one.

In the pen example we could write ink 4 times. Once for the tube, once for the ball, once for the metal part and once for the paper but in fact it is all the same ink merely at different times. So it is not necessary to write ink four times.

To give a more precise example of this issue is to consider a case where two different subjects act on the same object at the same time in such a way as if the part ‘acts’ on itself. A large metal sheet is being held by means of a blocking system (eg a clamp) and at the same time but at another place of this object the sheet is being deformed. If we would divide this into more virtual parts such as a crystal metal structure we could argue that one structure is pulling the blocked structure.

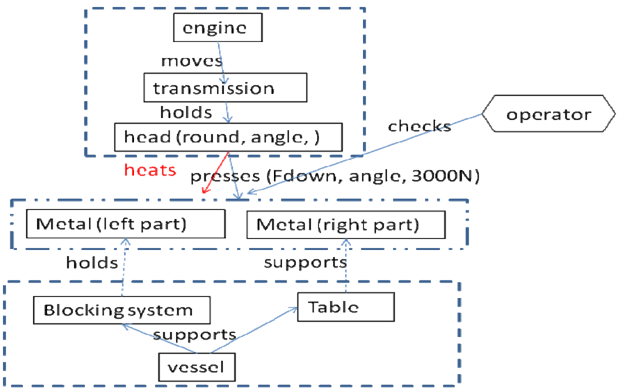


Figure 12: Example of imaginary split up product.

4.8 Depth of function model

Following the example of imaginary splitting up a metal part, a question that comes in mind is how “deep” the function model should go? Considering a problem, a logical answer is “so deep” that the model shows how the system works and there is a thorough understanding of the problem so the problem can be solved. The model can be described so deep that you can imagine the atoms or molecules as being little dwarfs acting as living people☺

5 SUMMARY.

This article’s main function is to give an alternative solution to several function modelling issues such as number of verbs, completeness of model, ‘correct’ verb, ..

A set of classes are suggested to help clarify the type of verb to use. This subject needs to be explained in a new article.

Refuge is found using the structure of Thermodynamics and the laws of evolution.

Introducing a dashed (and dash dot dot dash) box indicating a sub state, an undividable object or an object containing different parts but acting as one object helps to overcome some of the issues.

I can imagine that not all issues in function modelling were described and that the alternative provided solves every case.

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