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FUNCTION AS METONYMY

Paul Winkelman
University of British Columbia, Canada

ABSTRACT

Design aids often seek to map function to form. Hierarchies offer possible models but risk emphasizing competition at the expense of more cooperative relationships. Cooperation can be seen in the biological concept of the "correlation of parts", where the presence of one part in an organism (*e.g.*, sharp teeth) implies the presence of others (*e.g.*, sharp claws). We can thus reconstruct the whole based on the knowledge of a part, creating a part-to-whole mapping. The mapping is made possible, not by causal linkages (*à la* physics) but by the cooperative interactions of parts in a containing system exhibiting a function. This concept can be represented by metonymy, a linguistic device where one entity refers to another related entity. A picture of a person's face, for example, can represent the entire person. Function echoes this concept in that the function of a part is assigned and understood in light of the whole. From the perspective of conceptual design, we start with one or a few parts and continue to add parts, guided by function, to create a finished product. Function-as-metonymy suggests a model for a function-to-form mapping scheme.

Keywords: function, metonymy, engineering science, biology

1 INTRODUCTION

What enables engineers to assign physical embodiments to functional concepts? How can a list of multiple functional requirements be converted into a single product that embodies all of them? If we wish to create a virtual system that aids in this conversion process, what model or models should be employed?

Gero *et al.* see *behaviour* as the link between function and structure, forming the Function-Behaviour-Structure concept of design [1]. Behaviour refers to what the structure does. A given structure may exhibit multiple behaviours, only some of which contribute to the desired function. The extent to which this model can be employed in a virtual system is by no means self-apparent, as the connection between function and behaviour is based on experiential knowledge. Hence, the point at which the transition from functional descriptions to structural descriptions occurs is unclear [2].

The idea of knowledge can, nevertheless, suggest possible directions for exploration. For some, knowledge within design implies the need to bring design under the umbrella of science. Given the strong affinity between science and engineering, as evident in the "application of science" definitions of engineering [3][4], such a move is not unexpected. Hubka and Eder [5] present what they refer to as "design science", claiming it to be a "new" science (p. 3). Their concept of science seems to be centred on knowledge, for they see design science as "a system of logically related knowledge, which should contain and organize the complete knowledge about and for designing" (p. 73).

Within this concept of "design science", the idea of *logic* is very appealing if one wishes to create a virtual computerized design aid. There are, however, many different kinds of logic (*e.g.*, deduction, induction and abduction, to name a few). To what extent can (or should) these various forms of logic be accommodated? There are also different kinds of *knowledge*: we might distinguish between what might be termed "scientific" knowledge ("the moon revolves around the earth"), and other "non-scientific" knowledge (e.g., "the Vancouver Canucks won the Stanley Cup"). Then there is the question of *organization*. Simon [6] favours hierarchical structures. What kinds of hierarchical structures are there and which might be best suited to facilitate a function-to-structure transition? Are there non-hierarchical structures that might provide a better organization of design knowledge and what might these structures look like? Do changes in organization lead to changes in design? In other words, if one can, at least in part, separate knowledge from its organization, will the design "solutions" change if the knowledge is constant but the organization is altered?

2 MOTIVATION

The motivation for this explorative study arose as a result of research in an "intelligent design catalogue". This catalogue seeks to combine traditional catalogues of standard parts with a virtual design environment, where selected components are assembled. To facilitate the selection process, initial function-to-form (or structure) mappings were based on hierarchies, where classes of functions (*e.g.*, "fastening") contain subclasses of generic parts (e.g., "bolt", "rivet"), eventually leading to fully specified components. The organization seemed to be fairly straightforward, although potentially tedious due to the large number of components. In contrast, the design activity itself is not straightforward (even with standard components) and not necessarily tedious, at times enjoyable. There appeared to be a mismatch between between the model and the phenomenon being modelled. This suggested that the current hierarchical organization could only truly be termed a design "aid" if confined to fairly well defined standard designs. A more comprehensive design aid would require a substantially more flexible or complex organizational structure.

Given what to me was an "obvious" mismatch, I found my predisposition to hierarchical structures troubling. Where did this bias come from? Perhaps it came from the object-oriented programming language, with its classes and subclasses, used to develop the virtual catalogue. The use of the word "object" with respect to computer programming suggests the existence of yet a previous antecedent. Science would appear to be a likely candidate, as it prefers to treat entities as objects, thereby granting powers of "objectivity". Could engineering's affinity to science be counterproductive when developing design tools?

Perhaps it is the *particular* science from where we draw our inspiration which determines the success of our design aids. Historically, science was "practically identical with theoretical physics" ([7], p. 92). Although written more than 35 years ago, there is still reason to believe that physics continues to dominate the concept of science of many engineers (although certainly not all). This is the sentiment which has been most often expressed by my (mechanical engineering) students over the years and is echoed in the literature where designing is said to be "based not only on mathematics, physics and their branches –mechanics, thermodynamics etc ...." ([8], p. 29). The centrality of physics is so strong that this statement appears in the second sentence of the chapter entitled, "Fundamentals".

The esteem engineers place on physics is also woven in the historical narrative we tell about it. So I will begin with a brief jaunt through the history of physics. I will then turn my attention to biology, a science all too often overlooked by engineering (with an accompanying lesser-known narrative), and show how it arranges the world in vastly different ways than physics, in ways that are more in keeping with engineering design. Finally, I will show how one of these arrangements can be captured through the use of the linguistic concept of metonymy.

3 PHYSICS

The beginnings of physics can perhaps be traced to Galilei Galileo (1564-1642), the "father of modern physics" ([9], p. 155). Galileo is probably best known for his promotion of the Copernican model of the universe. Galileo claimed that observational data suggested that the sun rather than the earth was the centre of the solar system. As this was contrary to the established view, a confrontation ensued between Galileo and religious authorities. The issue would seem to have been whether the removal of the earth from the geometric centre implied that humans should also be removed from what might be called a "cosmic" centre. From a physics point of view, however, Galileo was merely fitting data to a (Euclidean) geometric model. Galileo's "fatherhood" and the "modernity" of physics are based on the idea that theories of the cosmos should be based not on preconceived ideas, but rather on observational data supported by mathematical modelling.

From an engineering perspective, this mathematical approach of physics would seem well suited to analysing problems, such as using "mechanics" as mentioned earlier ([8], p. 29). Such, however, is not sufficient for design and Reuleaux writes in 1856 that the "knowledge of those principles borrowed from mechanics does not suffice in any way to generate a layout of a machine to be constructed" (quoted by [5], p. 18). Something is missing.

Within engineering design, many branches of study beyond physics have been proposed to provide the missing element or elements. In addition to other branches of science, management, economics, ethics, communication studies, the study of politics and social issues have all been topics deemed pertinent to the engineering cause. Although these do indeed impinge on engineering design and knowledge in these areas is beneficial to the design process, they do not succinctly pinpoint what is missing from physics. How might we succinctly point to the missing element?

The missing element, I believe, can be summarized well with respect to *function*. Physics is constructed completely outside of the concept of function. Instead, physics deals with *effects*. One does not ask the *function* of the tilting of the earth's axis. The closest one can get to this concept is to ask the *effects* of the earth's tilt. If we wish to model engineering design, at least initially, after some pre-existing science, perhaps we should concentrate our efforts on a science that actively makes reference to function. It is here, then, that we turn our attention to *biology*.

4 BIOLOGY

Biology's predecessor was known as "natural history". Natural history was concerned with the study of living things and was largely descriptive, creating systems of classification. Prior to the arrival of biology, natural history was quite physics-like in its view of the world, creating classification schemes based on the readily apparent attributes of form, number, arrangement and magnitude [10]. The close alignment can be seen in Galileo's solar system, which had a particular (geometric) form, with a certain number of planets of various magnitudes in a particular arrangement. Natural history went beyond physics to a degree for it did make reference to function. However, function played a relatively minor role and was used alongside form. Form and function were applied independently, yet coincidentally, to a given organ. Form was used for the purposes of identification; function spoke of the organ's utility.

Biology began to take shape with the work of Georges Cuvier (1769-1832) [10], a French natural historian, often credited with the founding of comparative anatomy and paleontology [11]. Cuvier noticed that, for a given organism, certain characteristics can predictably be seen to occur together. For instance, if an organism has sharp teeth, we can expect this same organism to have sharp claws and a particular kind of digestive tract. Thus was born the concept of the "correlation of parts" [10].

The "correlation of parts" was significant on many fronts. Organs that had previously been considered independently were now united in *systems*. Systems cannot be identified with respect to form, for the digestive tract of a lion does not resemble the fangs of a lion. Systems can, however, be identified with respect to *function*. As a system, claws, teeth and digestive tracts perform a function that cannot be accomplished by any one of its parts on its own.

The "correlation of parts" also heralds a new beginning, where natural history, now biology, deviates markedly from physics. We can compare Cuvier's "system" with Galileo's "system". Galileo's solar system was based on observational data fitted to mathematical models. These models described the pathways of planets around the sun. Later, Newtonian gravity provided the "glue" that held the system together. Cuvier's system, too, had "pathways" and we can perhaps imagine Cuvier tracing the pathway of food flowing through an organism and being digested (*i.e.*, a process). However, no mathematical model can be used to describe this pathway; nor can something like gravity hold the system together. Cuvier had to resort to a non-Newtonian glue, and this he found in *function*.

The "glue" of these two systems, in holding the systems together, provide important *predictive* powers to the sciences. It was now possible to predict the path of a planet based on its mass. Cuvier, too, could predict, using the "glue" of function. If he were to find an animal have sharp claws, he would have predicted that it also have sharp teeth. This kind of prediction is fundamentally different than the types of predictions associated with the solar system example. If we takes Cuvier's "correlation of parts" to its theoretical extreme, we could conceivably reconstruct (or predict the appearance of) an entire organism based on a single bone. This part-to-whole mapping, made possible by function, can be captured by the concept of *metonymy*.

5 METONYMY

Metonymy is a linguistic device and refers to the use of "one entity to refer to another that is related to it" ([12], p. 35). For instance, in the statement, "He likes to read the Marquis de Sade", "Marquis de Sade" actually refers to the *writings* of the Marquis de Sade. An associated linguistic device is that of synecdoche, where the part stands for the whole (or vice versa), such as "I got a new set of wheels" (p. 36) (as this can still be thought of as one entity referring to another, Lakeoff and Johnson [12] see synecdoche as falling under the more general term of "metonymy"; for this reason, it is this latter term that I will be using rather than the more obscure term of "synecdoche"). Perhaps a more revealing example would be that of a photograph. If I show you a picture of my friend's face and say, "This is my friend", you will be satisfied; if I show you a picture of this same person with the face missing, once again claiming, "This is my friend", you will not be satisfied.

The example of the photograph of a face representing the whole person draws our attention to another important aspect of metonymy, for not all parts can be called upon to represent the whole. I cannot, for instance, show a picture of my friend's foot and legitimately claim, "This is my friend", for our culture finds such a part-to-whole mapping unacceptable. The foot is a part of the person, but not in the same way that a face is part of a person. When it comes to identifying a person, a person's face is much more important to most people than the foot of the same person. It is not that a person cannot be identified by a foot, but it is not the normal means of identification. This distinction gives rise to the two important concepts of *revelation* and *importance*.

5.1 Revelation

Metonymy reveals that which is hidden. When I see a picture of my friend, *i.e.*, my friend's face, the part-to-whole mapping means that I am able to add details that are not directly evident in the picture. The face allows me to "see" the whole person. When I see the picture of a person's face, I may suppose that this person has feet and hands as well. This is akin to the concept of design as disclosure [13]. The same can be seen in the world of biology: the sharp claws of an animal reveal its sharp teeth, even if these teeth are never actually seen.

By the same token, metonymy also serves to hide elements of the whole. Although I may suppose that the person in the picture has feet, it may be that the person, due to an accident, has no feet. The hiding can be accidental or deliberate. If I am asked to forward a picture of myself prior to attending, say, a school reunion, I may crop the picture to show just my face so that my less-than-streamlined torso remains out of view. My hope is that, upon seeing my picture, my old classmates will envision me as my former self when physical activity took up a larger part of my day.

Physics, too, is concerned with revealing that which is hidden, but these revelations tend to be contained within the form-number-arrangement-magnitude framework. The atomic structure of an element fits this framework quite well. In a more indirect sense, we can think of physics giving rise to an electron microscope, which then allows us to see things that are very small indeed. By way of contrast, "seeing" the teeth of an organism is not a matter of magnification. Physics, of course, also has its hiding features, as do the sciences in general. This is normally referred to as reductionism where we simplify the complexities of the physical world in order to make the analysis more manageable.

Given its intellectual proximity to physics, it is also worth noting the revealing/hiding qualities of mathematics. Herbert Simon often used examples from mathematics to demonstrate his theories about design and the "sciences of the artificial". For instance, he states that "All mathematics exhibits in its conclusions only what is already implicit in its premises…. Hence, all mathematical derivation can be viewed simply as change in representation, making evident what was previously true but obscure. This view can be extended to all of problem solving — solving a problem simply means representing it so as to make the solution transparent" ([6], p. 132). Simon is speaking of revealing ("making evident") that which is hidden ("obscure") through a series of logical transformations. In sharp contrast to metonymy, the logic here is very mechanical and very definitive, for with it one is able to render the obscure completely visible. The word "transparent", as the antithesis of hiding, implies that mathematics is all about revealing and never about hiding. This is hardly the case. As we apply the mathematics in the "real world", such as in physics, we cannot assume that the abstract concepts of mathematics can be meshed seamlessly with physical reality. The use of the word "true" seeks to hide the fact that something is likely to have been lost in the transfer.

5.2 Importance

The second important concept of metonymy is that of importance itself. When it comes to identifying a person, the face is considered more *important* than the foot. Hence, certain elements of a person contribute more for identification purposes than others. Based on these various levels of importance, I can now "rearrange" a person, where the face figures more prominently than the foot. Some may take exception to my arrangement. A podiatrist, upon examining my importance map, might seek to locate the foot somewhere else. As some elements may be very important, others may be of very little importance. Thus, certain elements may be missing without adversely affecting the arrangement as a whole. It could be that, due to an accident, my friend does not have feet. My friend would still be deemed a person, although my ability to identify him or her might be slightly compromised.

The concept of importance abounds in biology. The lungs, for example, are seen as an important element of the respiratory system; the tongue, less so. These distinctions are critical in the related field of medicine. In a military hospital, for example, those attending the incoming wounded perform triage where they decide the order in which the patients are to be treated. One who has a damaged heart, for example, is treated ahead of one with a damaged finger, as the heart is deemed to be more important (to life) than a finger.

In the world of physics, importance is not important. It makes no sense to ask, Which is more important in a water molecule, the hydrogen or the oxygen? The question is equivalent to asking, Which can we most easily do without? Elements of the whole cannot be removed without completely destroying the whole; water without oxygen is no longer water. Returning to Galileo's solar system, we might claim that the sun is the most important element in the solar system. However, in making this claim, we are likely to rely on the old form-number-arrangement-magnitude paradigm. We support our claim of importance on the grounds of number (there are 9 planets, but only one sun), arrangement (the sun is at the centre), or magnitude (the sun is the biggest). More to the point, however, is that there exists really no reason to posit the sun as "the most important". Physics doesn't really care.

The various levels of importance combined with the various views of what actually is important (the face to me; the foot to the podiatrist) indicates that metonymy allows for multiple arrangements of the elements within a given system (or unit). The importance of any given element has no pre-determined value. Returning to the concept of "design science", the organization of knowledge refers to particular kinds of arrangements. As for the *types* of arrangements or organizations being considered here, the guiding principle is that "at all places shown, hierarchical ordering should be accomplished, and quantities, sub-quantities and hierarchical structure should be formed" ([5], p. 84). We are now compelled to turn our attention to hierarchies.

6 HIERARCHIES

We learn about hierarchical structures from an early age, if not by name, at least by experience. We notice a difference between ourselves as children and our parents. At elementary school, we acquire a sense of ordering with the principal at the "top", then the vice-principal, then the teachers, and ourselves at the bottom. We are left to ponder where the guidance counsellor and the janitor fit into the overall scheme of things. In history class we learn about the feudal system, where the monarch sits on the top, followed by the nobility, then several layers of additional social classes until one reaches the peasant at the bottom. A naïve interpretation sees the layering as merely a question of numbers: one monarch but many peasants; one principal but many teachers. These hierarchies are, of course, more than that, and as youngsters we were all to aware of power and authority. We knew that what the parents thought was more important than what the children thought; what the principal thought was more important than what the teachers (or students) thought; and what the monarch thought was certainly more important than what the peasants thought. Importance fits well in a hierarchical structure.

Hierarchies, however, need not be constructed around notions of importance and several kinds have been suggested. Hierarchies can be categorized into four groups [14].

An *order* hierarchy consists of entities which are ordered according to some selected variable. For example, we can create a hierarchy of cities based on population.

The second type is the *inclusion* hierarchy. Herbert Simon's "Chinese boxes", where one box is located within another, is of this type. An entity is thus a container which contains other containers. In order to arrive at a given container, one must pass through all the containers which contain it. One might also think of this as a *nested* hierarchy.

The *control* hierarchy is commonly used to describe social organizations. These hierarchies are often constructed with a single entity at the highest rank. A good example of a control hierarchy is the military where the soldiers constitute the entities (note that if the entities are command units, such as platoons and companies, the arrangement forms an inclusion hierarchy). An important concept of the control hierarchy is that of flow: orders flow down and requests and information flow up (similar to criminal organizations where governance flows down and money flows up [15]). Those of the lower ranks are expected to obey those of the higher ranks.

The *level* hierarchy consists of entities arranged in levels according to their particular spatiotemporal scales. Entities within a given level are fairly autonomous from entities of other levels. This type of hierarchy is characterized by causation: upward causation refers to higher-level entities being composed of lower level entities; downward causation refers to changes to the properties and interaction modalities of the lower-level entities as they are incorporated into the higher level entities. Examples of this kind of hierarchy include physics/chemistry (elementary particles, atoms, molecules), biology (cells, organs, individuals, species), economics (individuals, departments, firms) and linguistics (letters, words, phrases, sentences). Some may also be classified as inclusion hierarchies. The examples provided suggest that this type might be better called a *building-block* hierarchy.

One cannot but notice that the level hierarchy leads to a misrepresentation of biology. Biology is seen as paralleling physics, for the cells of biology are seen as the equivalent to the elementary particles of physics (*i.e.*, as building blocks). This parallelism completely fails to capture Cuvier's "correlation of parts" without which biology is not even possible.

7 IMPLICATIONS

If we wish to organize design knowledge based on a hierarchical structure, we must be very careful of the structure we use. The structure we choose may be more a reflection of our previous dispositions than the real needs of the design tool.

If we are drawn to mathematical constructs, we may, like Simon [6] with his "Chinese boxes", be partial to the inclusion hierarchy. Computer programmers who think in terms of object-oriented programming are also likely to gravitate here as classes and sub-classes are modelled this way. This hierarchy may serve well to link generic parts to specific components, but not functions to generic parts, for once placed within the category of "fastening", a bolt cannot fulfill any other function.

Those predisposed to a more scientific outlook are likely to be drawn to the level or building block hierarchy. Not surprisingly, the sciences themselves have been ordered according to it, perhaps attracted by the feature of causation. At the bottom of the hierarchy is elementary particle physics, followed by solid state or many-body physics, chemistry, molecular biology, cell biology and on to physiology, psychology and social sciences at the top ([14], referring to work by Phil Anderson). This hierarchy has some applicability within design, where multiple identical items are put together to create a new product, such as building a house from identical bricks and mortar. The properties of the house can, in many ways, be derived from the properties of the bricks and mortar. Bricks and mortar cannot, however, speak to the function of the house. Furthermore, for the majority of design cases, the building block approach will not suffice as a given component within an assembly is often unique to that product.

The control hierarchy is probably the most promising for use in design tools. At first glance, we may be tempted to interpret the hierarchy as echoing engineering control. At the top is that which must be controlled, such as maintaining room temperature; below, lie all the interrelated components that contribute to the overriding function. The ordering logic of the system flows down, and the activities that make the control realizable, akin to a Goldberg machine, flow up. The upward flow, however, hints at a hierarchical mismatch, for Goldberg machines are causal, suggesting a level hierarchy. The blurring of the boundaries between the level and control hierarchies can also be seen by re-classifying the sciences, this time within a control hierarchy. The key concept here is that of "law". This places physics, as the lawgiver, at the top of the control hierarchy with the social sciences at the bottom. All the levels below physics provide a context in which the laws can be validated. Hence, physical laws flow down and legitimation flows up. Physical laws, compared to social laws, carry a much stronger sense of causality, and the control hierarchy once again leans toward the level hierarchy.

Metonymy (and the "correlation of parts"), on the other hand, is not causal, keeping the level hierarchy at bay. The importance implied by metonymy also points to a control hierarchy. Within the function-to-form mapping, importance can, for example, tell us which starting points are likely to be more promising. If building an irrigation system, for example, a pump is probably a better starting point than a hose clamp. To a certain extent, those parts that are more numerous (*e.g.*, hose clamps) are less importance than those that are unique (perhaps a single pump). A complex mechanical engineering product may, however, have but a single washer which is of no great importance but nonetheless helpful. In terms of flow, if we begin our design with a pump (akin to the "single bone" of Cuvier), the downward flow refers to the selection of the next part (as guided by function). Once selected, upward flow ensures that the overriding function is still intact.

Despite its promise, the control hierarchy does not fit seamlessly with the concept of metonymy. It is not immediately obvious what should be in each of the layers of the hierarchy and how one moves between and within the layers. Part of the problem, I believe, lies in the concept of hierarchy itself and this can perhaps be demonstrated with reference to Bertalanffy's "General System Theory" [7].

Bertalanffy is concerned with biology and sees concepts from classical physics as being insufficient to account for the biological phenomena. Biology needs to be studied as part of an open system, for the increased differentiation exhibited by organisms implies a *decrease* in entropy which, according to the laws of physics, must result in an *increase* in entropy of the system which contains the organism. Bertalanffy's physics-biased system differs from that of Cuvier, for the "correlation of parts" stands without reference to entropy. In terms of organizations, Bertalanffy speaks of "wholeness, growth, differentiation, hierarchical order, dominance, control [and] competition" (p. 47). The "correlation of parts" is *not* about competition or dominance, but rather cooperation (such as in "symbiosis"). The heart does not compete with the lungs; the ignition system of a car does not compete with the exhaust system. We may speak of competition when selecting a part (a bolt vs a rivet) but, once selected, the new part forms a cooperative relationship with the parts already in the assembly. Importance does imply some domination, such as the overriding function, but this does not necessarily lead to competition. What is most striking about Bertalanffy's list is that once "hierarchical order" is mentioned, we are only left with "dominance, control [and] competition". Cooperation is eliminated. Hence, hierarchical structures are likely to emphasise competition at the expense of cooperation.

8 CONCLUSIONS

The shift from a physics-centric approach to one based on biology reveals some new possibilities for the construction of a function-to-form mapping model as part of a design aid. Biological systems are held together not by the "glue" of forces, but by the "glue" of function; the pathways are processes, not mathematical equations. This "glue" points not to future pre-determined positions, but of how things might best fit together. An important biological concept is that of the "correlation of parts" where the presence of one part in a system implies the presence of other parts in that same system. The part-to-whole mapping contained in the "correlation of parts" can be captured with the linguistic device of *metonymy*.

Metonymy tells us that we can start with a single part and from that potentially construct (or reconstruct) a whole. If we see one particular part, we can expect to see other, related parts. Hence, we construct the whole not by the repeated duplication and arrangement of the part in view (the building block mentality), but by drawing on our expectations (knowledge), arranging diverse, anticipated elements to form a whole which accounts for that which is seen. We immediately recognize, of course, that the construction process is subject to error. Metonymy further draws our attention to the fact that some parts are more important than others (*i.e.*, they are more meaningful). In other words, not all parts contribute equally to the whole. At the same time, we understand that what is important and meaningful depends on one's perspective and multiple (conceptual) arrangements of the same parts are to be expected. Metonymy also tells us that because there is a part, there must also be whole and that the part depends on the cooperation of the whole.

As metonymy ties parts, both seen and unseen, together, so function links components together. Metonymy suggests that I can begin my design with a single part (*e.g.*, a pump), with a function in mind (*e.g.*, irrigation). I do not construct my system by linking a long series of pumps, but anticipate (such as through design knowledge acquired from a virtual system) the various parts that contribute to the function in mind. In designing my system, I believe I will have greater success if I start with the more important elements or, equivalently, with elements of greater functional value. Hence, I believe a pump is a better starting point than a hose clamp. Other designers may look to alternate starting points. As I further construct my system, I must ensure that all the parts cooperate, not compete (*e.g.*, do not interfere) with each other.

In promoting "function as metonymy", I recognize that the solution to the original "mismatch" problem is still incomplete. As with metonymy itself, my aim is to provide some important "part" from which a more comprehensive function-to-form mapping system may be successfully constructed.

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Contact: Paul Winkelman
University of British Columbia
Department of Mechanical Engineering
2054-6250 Applied Science Lane
Vancouver, B.C. V6T 1Z4
Canada
Tel: 1 (604) 822-2805
Fax: 1 (604) 822-2403
E-mail: pwinkel@mech.ubc.ca

Paul Winkelman is a Research Associate and Sessional Instructor in the Department of Mechanical Engineering at the University of British Columbia in Vancouver, Canada. His teaching and research interests lie in the philosophical dimensions of engineering design, in particular the interplay between science and design. He collects supporting data through case study research, interviewing students, teachers and practicing engineers.