AFFORDANCE-BASED DESIGN: STATUS AND PROMISE

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1. Motivation

The discipline of design in the field of Mechanical Engineering has changed dramatically in the last few decades. From the nineteenth through the mid-twentieth century, design classes focused on drafting and on dimensioning. Classes on design of machine elements complemented theories related to mechanics of materials, including failure theories, fatigue, and somewhat obliquely the ability of components to achieve some function. With the advent of the modern digital computer, and in response to a consumer society that pushes products to do more, the discipline of design has adapted. Computer Aided Design tools have been developed, together with analysis tools with ever improving accuracy and abilities. Simulation, visualization, and prototyping have become available, and together with the evolving field of optimization, these tools help the engineer accomplish more with less, to stretch the boundaries of the possible, and to help designers make better and more informed decisions. The main consequence of this evolution is the ability to design artifacts that range from simple and elegant to robust and extremely complex. The increasing complexity level of modern products poses special demands on designers as it challenges them to bridge disciplines, bringing computers and other electronics into devices, and to develop ever better, ever lighter, ever stronger designs. Thus engineering schools now teach students how to use computers to draw complex artifacts, and while schools still teach mechanics and machine elements, the modern mechanical engineering curriculum now includes courses in numerical analysis, optimization, and the process of design and decision making.

Simon [13] was one of the early proponents of studying design as a science. Throughout his

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career he recognized the challenge of complexity, and utilized the “divide and conquer” strategy of functional decomposition as a means to deal with this complexity. At around the same time, functional design methods were being developed by a range of German authors (as canonized later by Pahl and Beitz [11]) as a basis for mechanical design.

Following the early work of Simon and the thorough treatment of functional methods in design covered by Pahl and Beitz, most subsequent design researchers have used the functional formalism and developed design aids using this formalism. We have also done the same. However, there is increasing awareness among the design research community of some fundamental limitations of the concept of function, that leads to some difficulties in practice. Examining the properties of functions, we identify the following:

- functions are active, intended, transformative relationships
- a functional artifact by embodying a function accepts input and transforms it into output
- functions, as transformations, represent one-way processes
- functional representations do not involve the human user explicitly
- the concept of function is not based on any underlying theory
- fundamental assumptions and consequent limitations of the concept of function are therefore unknown
- functions are algorithmic, and not open to dynamic input
- functions are well suited to describing closed systems, but have difficulty describing open systems
- hence functions apply neatly to even complicated mechanical systems, but fail to capture real-world complexity

Based on these observations, we sought another formalism that could be used by designers to deal with complex systems, that could be applied to open systems, that may not necessarily be algorithmic, but should be based on a theory, that could involve the human explicitly, and that could capture dynamic (not necessarily one-way) relationships. We could have developed a new concept to suit these needs, but we were able to identify an existing formalism, the concept of *affordance*, already grounded in an external theoretical base.

Roughly speaking, an affordance is what one system provides to another system. Originally introduced in the field of perceptual psychology by James Gibson [4], the concept of affordance has been applied to engineering design by the present authors in a series of papers [5, 6, 7, 8, 9], leading to a novel approach we call *Affordance-Based Design* (ABD). ABD builds upon a significant theoretical base from psychology, as well as on encouraging experimental results from fields as diverse as early childhood

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development, robotics, and user-interface design, as discussed in the next section.

2. Supporting Theory

The theory of affordances was originally proposed by the perceptual psychologist J.J. Gibson (Gibson, 1979). Briefly stated, an affordance is what one system (say, an artifact) provides to another system (say, a user, or even another artifact). Simple examples of affordances are that knobs afford turning, keyboards afford typing, and iron affords casting. The concept of affordance thus allows us to describe a broad array of complex relationships that exist in design; relationships in and between designers, artifacts, and users. These relationships are shown in Figure 1, which depicts the Designer-Artifact-User (DAU) complex system (Maier and Fadel, 2006).

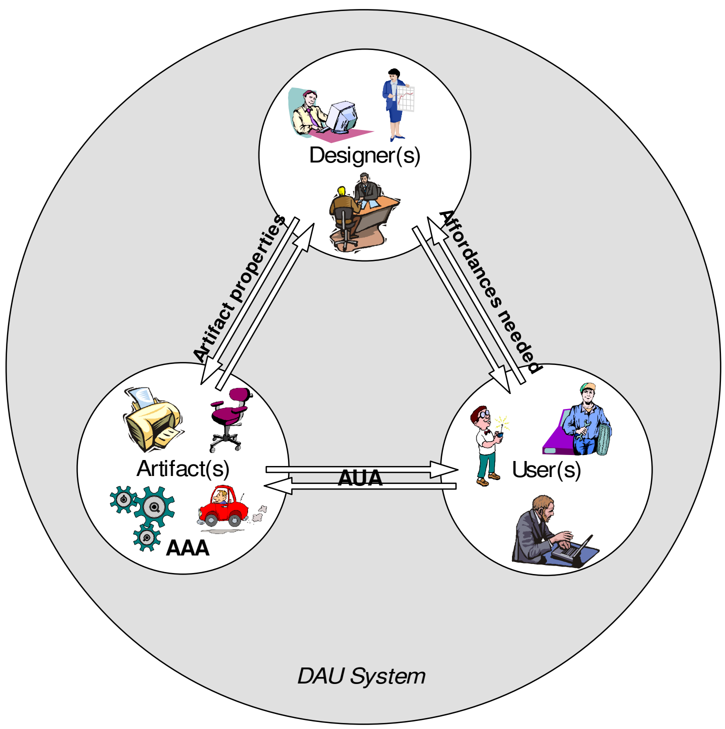

Figure 1. Designer-Artifact-User (DAU) Complex System Showing Affordance Relationships

The Designer-Artifact-User complex system has been elaborated in more detail in previous work by the authors (Maier and Fadel, 2006). An important result is that this formalism is also a Complex Adaptive System (CAS) following the same cycle as other CAS (cf., Cowen et al., 1994).

The concept of a Complex Adaptive System (CAS) has been described rather informally as a

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system “with many different parts which, by a rather mysterious process of self-organization, become more ordered and more informed than systems which operate in approximate thermodynamic equilibrium with their surroundings.” (Cowan et al., 1994, pg. 1). The physicist Murray Gell-Mann identifies the cycle in which all CAS seem to operate as follows:

I. Coarse graining of information from the real world
II. Identification of perceived regularities
III. Compression into a schema
IV. Variation of schemata
V. Use of the schema
VI. Consequences in the real world exerting selection pressures that affect the competition among schemata

However, perhaps the most important property of a CAS (that distinguishes it from most of the systems with which engineers are accustomed) is that CAS are open systems. CAS are situated; they operate and interact within a larger environment wherein the CAS accepts energy in and exports energy out. Moreover, because the CAS is adaptive, some of the energy in is used to change the internal state of the CAS. Usually this flow of energy in and out is continuous; thus the CAS is continually in a state of flux, constantly adapting to what is usually a changing environment. Another important consequence of CAS being open systems is that the second law of thermodynamics, which is formulated expressly for closed systems, is not applicable. Thus in CAS we often see a decrease in entropy (increase in order) over time, sometimes seen as evolution.

Within a DAU system, relationships between artifacts and users are described as artifact-user affordances (AUA) which indicate what uses the artifact provides to the user. As in all affordances, AUA can be either positive or negative, depending upon whether the potential behavior is beneficial or harmful to the user. Positive affordances must be designed into the artifact, while negative affordances must be designed against. Therefore, an important task for designers is to ascertain from users what positive affordances should be designed and what negative affordances must be designed against. Relationships in-between artifact subsystems are described as artifact-artifact affordances (AAA). These affordances describe what artifact behaviors are possible depending upon the structure of the artifact subsystems. Five general properties of affordances have been identified: complementarity, which says that an affordance exists between two or more subsystems, not in isolation; imperfection, which says that there is no such thing as a perfect affordance; polarity, which says that affordances can be either positive or negative;

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multiplicity, which says that multiple affordances can be associated with a particular subsystem; and quality, which describes how well a particular behavior is afforded.

Meanwhile, the mathematical foundations of Affordance Based Design are found in complexity theory, which the investigators have discussed at length recently (Maier, 2005; Maier and Fadel, 2002, 2006). Researchers in the computer science community, particularly Wegner (1997, 1998) have proven the superior computing power of open interactive systems. Meanwhile, in complexity science, the openness of complex systems has likewise been linked to their richness of behavior (cf., Cowan, et al., 1994). This is especially true in the biological sciences, where the phenomenon of life has been strongly linked to the complexity of biological organisms (Rosen, 1997, 2000). The concept of affordance is an open formalism that embraces the interaction between human users and engineered artifacts, in contrast to the concept of function, which best describes closed transformative operations (cf., Pahl and Beitz, 1996; Chandrasekaran and Josephson, 2000; Brown and Blessing, 2005; Maier and Fadel, 2002, 2005).

A crucial difference between function based approaches and the affordance based approach is that functions are form independent whereas affordances are *form dependent*. The idea behind systematic function-based design methods (such as Pahl & Beitz (1996)) is that customer demands and wishes can be translated into functions, which can then be accomplished by physical working principles, which are then embodied by particular physical parts. It seems reasonable that following the rigorous steps of these methods should produce more carefully considered designs, however it is not clear whether this is a consequence of the methods being functional as opposed to merely systematic. In fact, there is at least one noted example, coming from a very successful design firm, that a systematic method, which does not explicitly consider functions but which does move very quickly to form solutions is creative, effective, and fast (Kelly and Littman 2001). In this work, therefore, a systematic approach is maintained, however the concept of affordance is used as the fundamental theoretical construct, rather than the concept of function.

The central idea of Affordance Based Design is that design is the specification of a system structure that possesses certain desired affordances in order to support certain desired behaviors, but does not possess certain undesired affordances in order to avoid certain undesired behaviors. By changing the structure of a system, designers can change the system’s affordances. The affordances, in turn, determine how the system can potentially behave. Designers define the structure of a system, and thus its

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affordances, and thus how not only the artifact will behave but also how the user will behave with the artifact.

Distilling the theoretical tenets described above in ecological psychology and complexity science, the following principles are foundational to Affordance Based Design:

- The impetus for any design project can be understood in terms of creating and changing affordances.
- The design process can be viewed as the specification of an artifact that possesses certain desired affordances, and does not possess certain undesired affordances.
- An artifact with more positive affordance is considered better.
- An artifact with more negative affordance is considered worse.
- The theory of affordances can be used to support a wide range of design activities because affordance ties the two very different aspects of function and human implications together.

The state of the art in affordance based design, however, is still mostly theoretical. Limited methodological support is offered based upon the underlying theoretical assumptions, as discussed in Section 4, but first, it is helpful to understand how affordances have been used in other disciplines, as discussed in the next section.

3. Use of the Concept of Affordance in Other Disciplines

The theory of affordances was first put forward by the perceptual psychologist James J. Gibson (Gibson 1979). Although the term has its roots in concepts from Gestalt psychology (cf., Koffka, 1935), Gibson coined the English word "affordance" as follows (all emphases are his):

> "The *affordances* of the environment are what it *offers* the animal, what it *provides* or *furnishes*, either for good or ill. The verb *to afford* is found in the dictionary, but the noun *affordance* is not. I have made it up. I mean by it something that refers to both the environment and the animal in a way that no existing term does. It implies the complementarity of the animal and the environment." (Gibson, 1979: 127)

Gibson's book The Ecological Approach to Visual Perception is most concerned with how animals perceive their environment, which Gibson argues is through the perception of affordances in the

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environment. As such, Gibson's theory of affordances is a *descriptive* formulation: it describes how animals perceive their environment. Since Gibson's introduction of affordance theory and his ecological approach in general, the concept of affordance has been the subject of much study and application within perceptual psychology (see, e.g., Warren, 1984; Riccio and Stoffregen, 1988; Heft, 1989; Mark, et al., 1990; Turvey, 1992; Oudejans, et al., 1996; Sanders, 1997; Zebrowitz and Collins, 1997; Bingham, 2000; Gibson, 2000a, 2000b; Lintern, 2000; Pickering, 2000; Stoffregen, 2000).

A decade after Gibson seminal work, another psychologist, Donald A. Norman, took Gibson's theory of affordances and extended it into a *prescriptive* formulation: Norman gives some guidelines as to what certain objects should afford and should not afford. However, Norman, in his book The Psychology of Everyday Things, also published as The Design of Everyday Things (Norman, 1988), is concerned primarily with, as the title says, "everyday things" and not the design of artifacts in general. Hence Norman's theory culminates in two design-for-x methodologies (design-for-usability and design-for-error) but stops short of incorporating the concept of affordance as fundamental to the design of *any* artifact. Norman and others have further refined his approach with respect to *interaction design* (which includes graphical user interfaces (GUIs) as well as human-computer-interaction (HCI) in general) (Gaver, 1991; Norman, 1999; Hartson, 2005). In a similar vein, *Ecological Interface Design* (Vicente and Rasmussen, 1990) emphasizes high-level processing of data by human users and speaks chiefly to the layout and configuration of displays. Meanwhile, Warren (1995) and his students have applied the concept of affordances to design specific artifact-user relationships, such as the height of stair treads. An excellent summary of the ecological approach to physical interfaces and prospects for the future is given by Pittenger (1995). A more detailed treatment is offered in a collection of articles edited by Flach, et al. (1995).

Inspired by the work of Norman, some researchers in the industrial design community have also adopted the concept of affordance as a psychological tenet underpinning *product semantics* (Bush, 1989; Krampen, 1995; Krippendorff, 1990, 1995). Product semantics is defined as the "study of the symbolic qualities of man-made forms in the cognitive and social contexts of their use and application of the knowledge gained to objects of industrial design." (Krippendorff, 1995). A concise review of the use of affordance in this field as opposed to its use in HCI is given by You and Chen (2005).

The idea of affordance has also been applied in the field of artificial intelligence, e.g., how to

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design robots that recognize affordances in their environment (Murphy, 1999). The application of the theory of affordances to engineering design has been advocated by the present author in a recent series of papers (Maier and Fadel, 2001a, 2002, 2003a, 2003b, 2005a, 2005b). In the next section we review some of methods available for affordance based design.

4. Affordance Based Design Methods

Taking the theoretical precepts of affordances into consideration, various affordance based design methods have been advanced by the authors previously (Maier and Fadel, 2003, 2005; Maier, 2005). Other researchers have advanced affordance based methods as well, in particular the Funtion-Task-Interaction-Matrix developed by Galvao and Sato (2005, 2006). However, in this paper we discuss only the two most fundamental affordance based methods: a high level affordance based design process, and a method for designing individual affordances. The high level affordance based design process is shown in Figure 2.

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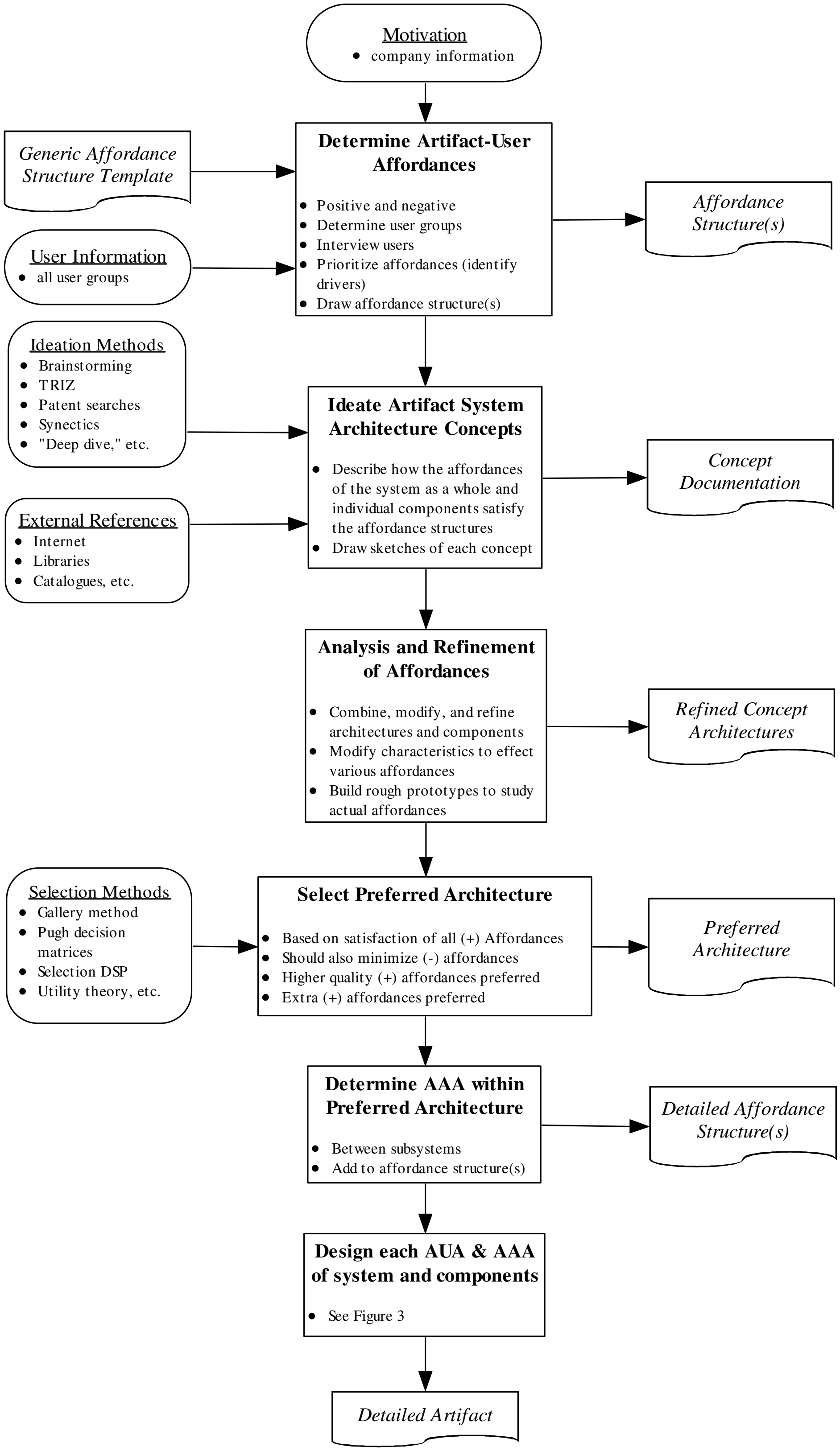

Figure 2. Overview of the affordance based design process

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The affordance based design process begins with motivation—a perceived market need, a novel idea, a scheduled product redesign, etc. The parent company, if there is one, would typically provide this information and initial product cost targets, schedule targets, marketing targets, etc. to the designer or design team.

In affordance based design, the first task for the designer(s), is to determine the artifact-user affordances that the artifact should have and not have. To wit, because of *polarity*, the designers should identify both positive affordances and negative affordances. And because of *complementarity*, the affordances will depend on different users, so the designer(s) must identify the different users, perhaps grouping them as convenient, and then interviewing various users to determine wanted and unwanted affordances. Following the methods presented below in Section 3 for creating affordance structures, the affordances should then be prioritized (the highest priority affordance can also be considered the design drivers), and finally one or more affordance structures can be constructed. As described in Section 3 the generic affordance structure template should also be consulted in the process.

The second task for designers is to ideate to generate concepts for the artifact's overall architecture and components. Various established ideation methods can be used here, such as brainstorming, TRIZ (cf., Altshuller 1984, 1996, 1997, 2000), patent searches, Synectics, IDEO's "deep dive" process (cf., Kelly and Littman 2001), etc. External references may also be consulted for ideas, such as the Internet, traditional libraries, industry catalogues, etc. Sketches of each concept are typically produced using these ideation methods, however these sketches are particularly important for affordance-based design, because each concept should be analyzed for how well it satisfies the desired positive affordances with reference back to the affordances documented in the affordance structure(s) created in the previous step. The sketches made for each concept are important for analyzing affordances since affordances are form dependent. It is generally recommended (cf., Kelly and Littman 2001) that concepts should not be criticized in the ideation process, so that the positive affordances of each concept should be described, but negative affordances should not generally be analyzed until later, often after a large number of concepts have been generated.

The third task for designers is to analyze and refine the affordances of the concepts generated in the previous stage. This involves modifying the characteristics of concepts in order to modify their

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affordances, as well as analyzing the negative affordances of each concept, and modifying their characteristics accordingly to remove those negative affordances. Concepts from various architecture concepts can also be combined, switched around, and refined in order to modify the affordances of the overall artifact. The construction of prototypes of concept architectures or components may also be needed in order to better understand the affordances of each concept, which again are form dependent.

The fourth task for designers is to select a preferred architecture. Various selection methods can be used in this process, including the Gallery method, Pugh decision matrices (cf., Pugh 1990), a Selection Decision Support Problem (Kuppuraju et al. 1985), Utility theory (cf., Hazelrigg 1996), etc. However, the decision should ultimately rest on how well each concept satisfies the desired positive affordances while eliminating or minimizing undesired negative affordances, giving preference to concepts with higher quality affordances, and preference to concepts with extra positive affordances. Note that affordance based design does not suggest a preferred selection method, but it does inform the criteria to be used in the decision-making process.

The fifth task is to determine the artifact-artifact affordances (AAA) that should exist between the subsystems in the preferred architecture. For example, the transmission of forces, heat, fluids, electricity, and information between subsystems must be afforded. As these individual AAAs are elucidated, they should be added to the affordance structure(s) previously created.

The sixth task is to design individual affordances. Since an affordance is a relationship between two interacting subsystems such that a behavior is possible between the two that is not possible with only one of the systems in isolation, in order to design an affordance, we must consider certain properties of two different subsystems. In the case of AUA, we usually do not have control over the properties of the user, but we do have control over the properties of the artifact under design. In the case of AAA, we usually have control over both artificial subsystems.

Recalling the notion of *polarity*, which divides affordances into those that are positive, i.e., beneficial, and those that are negative, i.e., harmful, then AUA can be positive (+) or negative (-) , and AAA can be either positive (+) or negative (-), this yields four major categories of affordances to design: (+) AUA, (-) AUA, (+) AAA, and (-) AAA. The general method for designing any affordance is presented in Figure 3.

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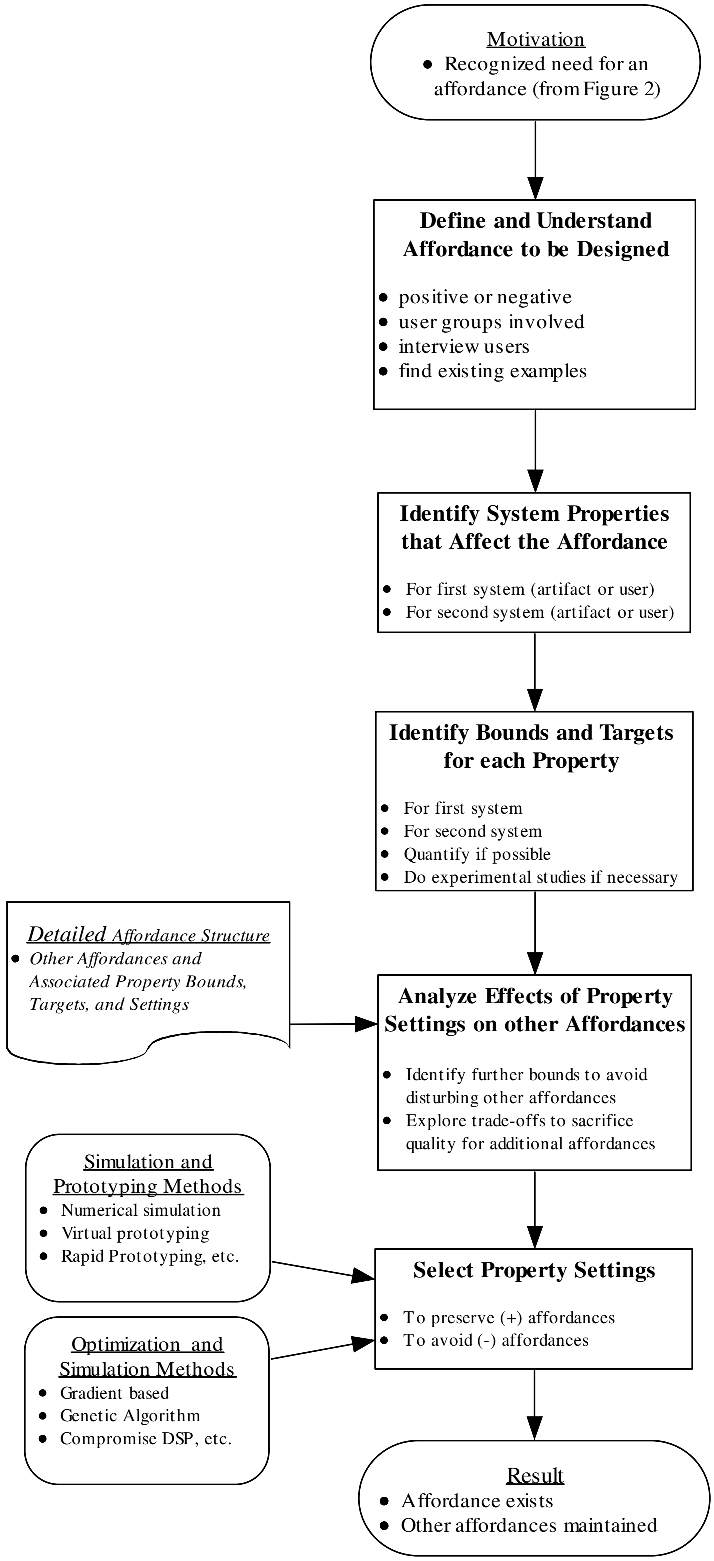

Figure 3. Procedure for designing individual affordances

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An example of designing a positive artifact-user affordance is that a car must afford comfort to the driver and other occupants. Comfort is an affordance that must be maintained across many vehicle subsystems. For the purposes of illustration, consider only the comfort of the driver seat. Like any other affordance, comfort has the property of varying *quality*. Furthermore, because of *complementarity* as discussed above, in order to create a desired affordance, in this case, comfort, the designer must understand the particular characteristics necessary on behalf of both the user and artifact. Following the procedure in Figure 6, we now need to define and to understand what this affordance is. First, we note that this is a positive affordance, something we want the artifact to afford. Second, we note that the relevant users are drivers of the vehicle. Perhaps these could be further divided into driver, front passenger, and rear passengers. The next steps involve information gathering. Comfort is determined fundamentally by the structure of the artifact, taken with respect to the user. Fortunately, the physical characteristics of seated automobile drivers have been well studied, and are available in the form of anthropomorphic data. The challenge for the designer is to match seat structure to human driver structure. Seat designers may also avail themselves of the many existing examples of seat comfort already in existence, from household and office furniture to existing vehicle seats. The specific properties that determine comfort would then need to be identified. These would result in this case in a list of relevant anthropomorphic dimensions and seat dimensions.

The next step in designing the affordance entails identifying bounds and targets for each property identified above. Since we are dealing with an artifact-user affordance, we do not have direct control over the properties of the user, but we do have complete control over the properties of the artifact. A principal goal of the design effort is determining the relevant bounds and targets for the range of driver dimensions deemed appropriate. A seat for a large SUV or truck may need to accommodate larger size drivers than say a compact car, for example. This decision will impact the target height and width of the seat back, elasticity of the seat components, etc. Experimental studies would be an invaluable tool in quantifying the relevant dimensions.

After bounds and ideal targets are identified for seat comfort, the artifact's affordance structure needs to be consulted to identify which properties that impact the affordance of comfort impact other positive and negative affordances, for example pertaining to strength of the seat, or behavior in a crash.

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What is ideal for creating comfort (such as a very soft seat) may not be strong enough in critical loading conditions, for example. They key here is to select property settings that maximize the affordance of comfort subject to the constraints of maintaining previously designed affordances while attempting to safeguard against negative affordances. As additional affordances are designed, the effort should be made to check that previous affordances are indeed maintained, while attempting to identify any new negative affordances. For example, in the vehicle seat, it may be discovered that a seat that is too comfortable in fact promotes the driver sleeping, which is a behavior to be designed against!

5. Reactions to Criticisms of the Affordance Based Approach

The presentation of these ideas has recently sparked some debate within the engineering design research community. In a recent paper Brown and Blessing (2005) contrast the concept of affordance with the function-behavior-structure framework advanced by Chandrasekaran and Josephson (2000) and Rosenman and Gero (1998). Brown and Blessing surmise that "one could consider the affordances of a device to be the set of all potential human behaviors that the device might allow. This, of course, is *a very large set*." They continue:

> "We see a role for affordances in the design process in addition to functional reasoning. Functional reasoning as proposed in particular in the German literature, assumes that the behavior intended by the designer is the actual behavior of the device, which is considered to be the behavior desired by the user. As a consequence, the focus of reasoning is narrowed down to the functions the device should have, rather than could have. Other potential positive functions, as well as negative functions, might not be identified during the design process, but only during the use phase, due to unexpected modes of employment, user intentions, or constraints."
>
> "Designers need to be encouraged to think about other possible behaviors and environments, rather than only focus on securing the intended functionality. The affordance approach requires *a broader, more environment-centric view* that could help identify potential failures or negative effects which the other methods have difficulty identifying. In our view, considering affordances is a perspective that complements the functional view. This design approach will never provide the designer with all potential user actions, but it helps change one's viewpoint to a more reflective,

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critical one."

"Our conclusion is that while affordances, as 'possible actions', are an important consideration while designing, *it isn't always easy to reason out what they are, as the search space is large*. Using function helps to focus the search, as it is backward reasoning. However, once a design or a conceptual design is developed, affordances clearly have a role to play in investigating undesirable possible actions, perhaps leading to designs that are safer and easier to use." (Brown and Blessing, 2005)

As leading proponents of function based approaches, their final conclusion that affordances are important to the design process, indeed complementing the functional view, is most welcome. However, we would like to discuss the assertion that reasoning about affordances cannot be done until after a conceptual design has been developed. While the affordances of a conceptual design can and should be analyzed, in affordance based design, the affordances of the final artifact, and any potential concepts thereof, can and should be determined first. The formal identification of affordances the artifact should (and should not) embody serves to guide the remainder of the design process, including generation of concepts and later detail design (cf., Maier and Fadel, 2003, 2005, 2006b; Maier, 2005). Finally, in the above quotations, emphasis has been added to several statements made by Brown and Blessing that raise a concern over how broad the concept of affordance is, and the consequent difficulty of identifying affordances in what is practically an infinite search space. Indeed these concerns are valid, and have been raised by other reviewers of the affordance based approach.

The "trouble" with affordances is not that they are ill-defined. Indeed, the precise meaning of affordances has been the subject of discussion and refinement over the last thirty years (cf., Gaver, 1991; Sanders, 1997; Norman, 1999; Gibson, 2000b; Lintern, 2000; Hartson, 2005; Maier and Fadel, 2006). The "trouble" with affordances is that they are so very broad. Other concepts, such as function and behavior, while broad enough to describe either intended or actual action of an artifact, do not directly entail the interaction with the artifact's environment, especially users. But affordances do directly entail interaction, and herein lies the conceptual power of affordances. What one system offers to another can be just about anything, depending upon the two systems involved. The key to understanding what is actually afforded in any given situation is this: *it is the structure of the two systems (internally and externally) that determines what affordances exist, and their respective quality.*

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In the case of an artifact designed to be used by people, such as a consumer product, the designers are concerned at the highest level with the affordances between the artifact and user. At a lower level, the designers are concerned with the affordances that exist between the artifact's subsystems (i.e., parts). The basic idea of affordance based design is that the affordances of the artifact must be determined with respect to the artifact's users, and that the structure of the artifact is specified such that certain intended (positive) affordances exist while at the same time eliminating, minimizing, or mitigating certain negative affordances of the artifact. Whether a particular affordance is beneficial or harmful is taken with reference to the human user.

Notice that we are restricting ourselves to only *certain* affordances in the design process. That a drill, or a chair, or a any of a multitude of common artifacts can all be used to break a glass window, and thus afford "window-break-ability" is probably too general to be of interest to designers unless these items are being specifically designed for people living in glass houses. Yet consider the fact that a chair can also be used as a stepping stool and thus pose a risk of falling, or that a drill might be used in a wet environment and thus pose a risk of shock; these scenarios should be of interest to designers, and it is not unreasonable to expect designers to foresee these kinds of negative affordances in the design process, before accidents occur in practice, people are injured, and companies are sued. What is needed is proper methodological support and practical tools—design methods, prototyping technology, ethnography, domain specific knowledge, etc.

That an affordance can be anything simply means that anything can be designed. If it were not so, the concept of affordance could not be used to design any artifact. In other words, using the concept of affordance, designers maintain complete design freedom. Just as using the concept of color does not limit the limitless choice of colors, but rather describes them, the concept of affordance does not limit either the structures that designers can design, or the consequent behavior of those structures. And just as there are an infinite number of colors, so too are there an infinite number of affordances.

This breadth does not inhibit the usefulness of either the concept of color or the concept of affordance. The designer must exercise control over this breadth, by determining which affordances (and which colors) are of interest. Central to this activity is the ability of designers to identify affordances. In other work (Maier and Fadel, 2006), we discuss four strategies for identifying affordances:

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predetermination using the affordance based design process, direct experimentation using prototypes, indirect experimentation based on the designers experience with similar artifacts, and automated identification utilizing a database of common affordances.

6. A Look Ahead

The affordance based approach holds promise for addressing some of the gaps in existing knowledge, and the potential for integrating an array of currently disparate approaches. So far, the theoretical aspects of affordance based design have been used to tackle some design problems that current function based methods do not handle well, in particular issues of complexity and in human interaction. The form-dependent nature of affordances also allows designers to consider form concepts and perform physical prototyping effectively earlier in the design process.

While several affordance based methods for design have been proposed, only a limited number of case studies have been performed (cf., Maier and Fadel, 2005; Maier, 2005; Galvao and Sato, 2005, 2006). The practical utility of affordance based methods has yet to be tested in any real world industrial design problems.

Meanwhile, the affordance based approach has been attracting increasing attention from engineering design researchers from North and South America, Europe, Asia, and most recently North Africa. The ideas discussed in this paper have been or will be presented in one form or another at conferences and informal gatherings at research universities in each of these continents, with the result of increased awareness and valuable feedback. At Clemson University, several researchers and students are continuing to advance the theory and develop methods for the affordance based approach, and we have recently begun an NSF sponsored project to utilize the concept of affordance as a framework for manipulating semantic information in a computer supported environment. We look forward to the continued advancement of the affordance based approach, and are indebted to our collaborators for their invaluable support.

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