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DESIGNING OBJECTS THAT IMPROVE WITH USE

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ABSTRACT

A new design methodology called "agathonic design" is proposed; one that specifies the intentional design of objects so they improve with use. Individual and/or group interactions with an agathonic design object result in an increase in functionality, as perceived by the user. The materials, geometry, kinematics, stress and user interactions of design objects are anticipated and considered. An object's functionality can increase with use as a result of directed wear. A theoretical analysis of the concept is discussed, as many design objects embody the unique characteristic of "improving with use." Agathonic objects are improved by lasting user generated changes in two distinct regions: (I) at the user interface, and (II) anywhere within the object. Definitions and distinctions are made to establish the classes of objects described by agathonic design theory. Applications of agathonic design theory to consumer products are detailed, along with thoughts on extending the theory to non-physical (virtual) designs.

Keywords: Design theory, interactions, entropy, functionality, adaptive systems

1 INTRODUCTION

There exist physical objects and systems whose functionality increases with use. There are precedents for considering the use and wear that an object will experience, and anticipating both in the design. The process of design requires intent, e.g. "Everyone designs who devises courses of action aimed at changing existing situations into preferred ones." [1]. Meta-design [2] allows for and embraces emergence in designs, based on a co-adaptive process between users and systems. Large systems have been reviewed [3] for their emergent functionality based on use. Research into interaction design [4] notes the importance of the connection between thinking and doing, which depends upon physical interactions. The primary article [5] that first explored the concept of "designing objects that improve with use" noted that interactions determined the location on the object where the changes will take place, and provided the energy required to produce those changes. Increasingly, designers realize that objects do not exist in a vacuum, but are connected with users and their environment through physical interaction.

2 THE ORIGIN OF AGATHONIC DESIGN

Real life experiences can offer valuable lessons if we can only find the time to reflect upon our actions, activities, and results. The theory of agathonic design emerged from personal experience and reflection upon rebuilding a worn-out 4-cylinder gasoline engine in an old pick-up truck. One issue was that the repair budget was limited, and a second challenge was learning that an expensive metal timing chain would have to be replaced to ensure correct valve timing. A new short block assembly was combined with a rebuilt head, and the used timing chain was reinstalled. The old timing chain was judged unlikely to fail catastrophically, so it was installed with one tiny difference: the valve timing was advanced by one tooth on the valve train gear.

The end result was that the rebuilt engine ran very well, even with incorrect valve timing. With use, the chain continued to stretch, further improving the engine's performance. The engine valve timing gradually improved as the timing chain continued to stretch and shift the valve timing closer to its optimum. The functionality gradually improved as the mileage increased. The surprising result was the realization that the engine was getting better with use. Reflection on this phenomenon suggested an interesting possibility: that objects could be intentionally designed so they would improve with use.

The research moved on to consider another classic example of an object that improved with use: a pair of new denim blue jeans. New jeans that are sold in retail stores are stiff as the fabric is saturated with sizing that permits the material to be cut and sewn. As a result, the new jeans do not fit the user very well. It is common knowledge that the owner/user needs to machine wash new jeans several times, and then wear the jeans to soften them up so they will fit correctly. Denim jeans change dimensions as they conform to their users over time, through use. The forces and geometry of use are different for each user – so jeans quickly become customized to the owner's physical form – through use. They are prized for their comfort and custom fit. It appears that using and improving objects like jeans results in an improvement in functionality.

The inquiry led to the consideration of objects and systems that need some use before they reach their optimal functionality. Many designs came to mind when the concept of "breaking in" was reviewed. The initial use procedure of "breaking in" objects and systems (i.e. customizing them and/or finishing their manufacturing via use) has long been part of our consumer culture. Examples of "breaking in" include automobile and motorcycle engines, hiking boots, auto tires, sporting equipment, clothes, and personal use items. An object or system which is customized by the user through use is indeed a design that improves with use. Many examples of similar objects and systems soon became apparent.

3 A DEFINITION OF AGATHONIC DESIGN

The methodology seemed concept had the potential of being novel, so a comprehensive search of engineering design literature was conducted to find any previous work in this area. When nothing close was located, a name for the methodology was desired to facilitate discussion and use. The process of directing entropy to a greater good ("toward goodness") led to the expression "agathonic design". The word "agathonic" was synthesized from the Greek words for good "agatha", and the word for earth "chthonic." Agathonic design results in objects and systems whose functionality increases with use.

Several distinctions are required to clarify the definition. Agathonic objects improve with use, which may take place either over a brief period of time, or over a longer interval. Objects that improve solely due to increased age (e.g. wine, liquor or cheese) are not considered agathonic. Objects whose value increases solely due to age, rarity and/or increased cultural attributions of value (e.g. old automobiles, fine art, coins, gems, autographs, stamps, sculpture, etc.) are not considered agathonic. The distinction is that agathonic designs improve with use, not solely by increased age.

Agathonic objects and systems do not have a discrete, identifiable computer control (network, CPU, software and memory), like a computer controlled carburetor on an automobile. Objects with discrete computer controls are usually referred to as adaptive systems, and/or computer controlled systems.

The differences in the functionality of agathonic objects and systems suggest that each follows one of four different patterns. See Figure 1 for a sample plot of each pattern. Note that these four lines on the graphic are both generic and illustrative, as each different pattern will have its own trajectory, and each will follow the stated guidelines which separate one pattern from another.

Pattern One - Functionality begins at a useful state, and then decreases and/or ends as the object is used. This is the typical or most common pattern of use and functionality. Examples here include batteries, light bulbs, computer monitors, compact disks, baseballs, baseball bats, Ping-Pong balls, windshield wiper blades, and printers. The end of use may be sudden, or gradual.

Pattern Two - Functionality begins at a useful state, and is maintained at the same level as the object is used. This design is found less frequently. A mechanical example is a spring-loaded belt tensioner used on a V-belt/pulley drive system. An example of this design is a knife sheath with a built-in sharpener. A sharp knife edge is maintained by the repeated act of placing the knife into the sheath, and removing it. Eventually the parts degrade such that the system can no longer maintain its functionality.

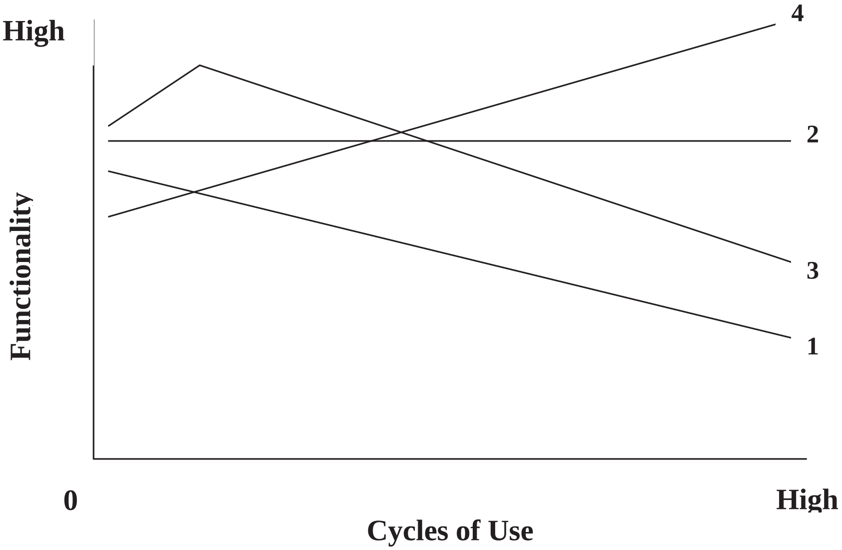


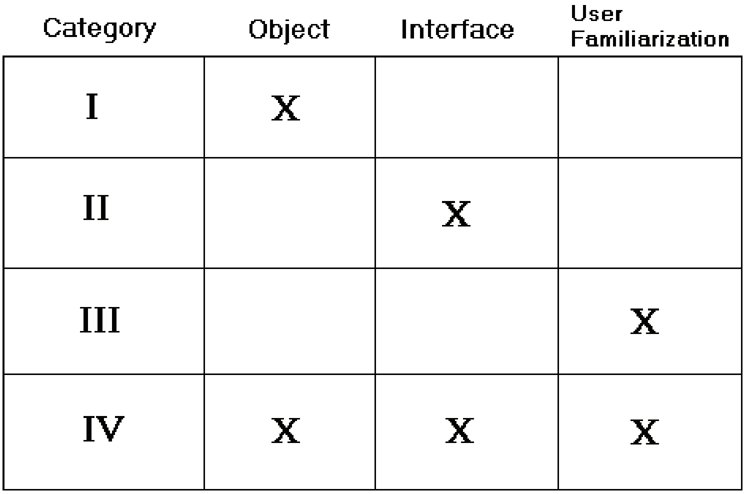
Figure 1

Pattern Three - Functionality increases briefly, and then decreases with use. This describes the "breaking-in" pattern that is found with new engines, hiking boots, gloves, equipment of all types and most complex mechanical systems. The functionality may be increased externally again as the object or system is serviced, maintained, repaired or otherwise tuned up. Many objects and systems are given special attention and/or new parts to restore or create functionality.

Pattern Four - Functionality increases with use. The full scope of agathonic design encompasses Pattern Four only, as these objects and systems see their functionality steadily increasing with use.

There is another quality of agathonic objects and systems, which has to do with where on the object the use-induced modifications take place. Are the changes taking place all over the object, or just at the user interface? Or are there discrete changes to both? And what is the contribution of a user getting to know the object? Certainly there is a system dynamic here, with the user adapting to the object while the object adapts to the user. This may be the best possible world, as the combinations of changes (when intelligently directed) may result in the directed entropy of the system creating something special – an increased functionality, and better performance.

Though infinite combinations are possible, it appears that an agathonic object will usually belong to one of four categories:



Category	Object	Interface	User Familiarization
I	X		
II		X	
III			X
IV	X	X	X

Classes of Agathonic Objects and Systems

Figure 2

Category I - The entire object and systems (or large portions of it) improves with use. The improvements are not limited to the user interface area. Examples include musical instruments (e.g. violins, guitars, pianos, cellos, etc. as the wood soundboards improve with many hours of vibration).

Category II - The interface of the objects and systems improves with use. Examples include clothing (shoes, boots, gloves, mittens, denim jeans, hats), lignum vitae bearings, auto tires, leather chairs, auto engines, leather baseball gloves, cooking utensils (cast iron flying pans, woks). In some instances the material itself changes properties (e.g. a leather baseball glove changes dimensions as the leather becomes softer and more pliable with use). In other instances the interface or boundaries are changed by addition of material through usage (e.g. a cast iron frying pan that is "seasoned" by repeated heating and applications of cooking oil).

Category III - The objects and systems improve with use, primarily due to user familiarization with the interface and/or system. There are minimal changes to the interface and object. Examples include carpentry tools, musical instruments, surgical tools, sporting equipment. Users develop high levels of performance and skill due to their familiarity with the objects, attaining a higher system utility. Good interface design may speed up the learning curve, but the distinguishing feature of this category is that the user's skill and familiarization improves with use, so they can achieve high levels of performance.

Category IV – The objects and systems improve with use as a result of a changing interface, a changing object and increased user familiarization. This appears to be a much rarer case, and is probably a special subset of categories (I) and (II) mentioned previously. Examples here include musical instruments that use anisotropic vibrating wood plates (e.g. violins, guitars, pianos) to translate mechanical energy inputs into sound and also have the property of the user changing the interface points on the instrument. Some exterior guitar interface surfaces may conform to the hands of their users (e.g. necks, fretboards), and violin bows may adapt to their users in a similar manner.

There is history describing earlier uses of agathonic objects, particularly one example found in the nautical domain. Agathonic designs and materials have been used for many years, without their special design characteristics being recognized. One example of an agathonic design object is a lignum vitae wood bearing. Another is a replacement material for lignum vitae wood bearings that have the proprietary name Woodex (http://www.woodexbearing.com/). The Meco Seal website explains:

"Since 1906, Woodex has produced a bearing material from rock maple, impregnated with petrolatum wax. This highly durable substitute for lignum vitae is used extensively in wet and dry screw and roll conveying machinery, frequently in agricultural service. When the inevitable sand or grit invades the journal interface, a wood bearing compresses, absorbing the pollutant into its surface, and covering it with a film of oil: the very substance which typically destroys shafts becomes a benign part of the bearing! The wood releases lubricant when the shaft begins to spin and the journal interface heats; when the shaft stops and the journal cools, the natural capillary action of the wood retrieves the lubricant. Woodex bearings are thus permanently lubricated."

The interface between the shaft and the bearing material (lignum vitae, or in this case, the commercial equivalent called Woodex) is the area of interest. The spinning of the shaft creates friction, which generates heat. The heat causes the material to release lubricant to the spinning interface, reducing friction. As the joint is lubricated, the friction is reduced, cooling the interface to a steady-state temperature, which causes the bearing material to stop supplying lubricant. When the shaft stops, and the system cools down to ambient temperatures, the lubricant is wicked up from the interface by the "natural capillary action of the wood". This is a great example of a Case II agathonic design that maintains the functionality of the system at a consistent level even when it experiences heavy use.

4 INFORMING A NEW THEORY OF AGATHONIC DESIGN

An unambiguous definition of agathonic design requires that it be differentiated from similar definitions, like autopoiesis (self-producing systems). One crucial difference is that autopoiesis involves living systems, while agathonic design is limited to non-living objects and systems. An explicit definition of autopoiesis [6] is:

A dynamic system that is defined as a composite unity as a network of components that,

a) through their interactions recursively regenerate the network of productions that produced them, and

b) realize this network as a unity in the space in which they exist by constituting and specifying its boundaries as surfaces of cleavage from the background through their preferential interactions within the network, is an autopoietic system.

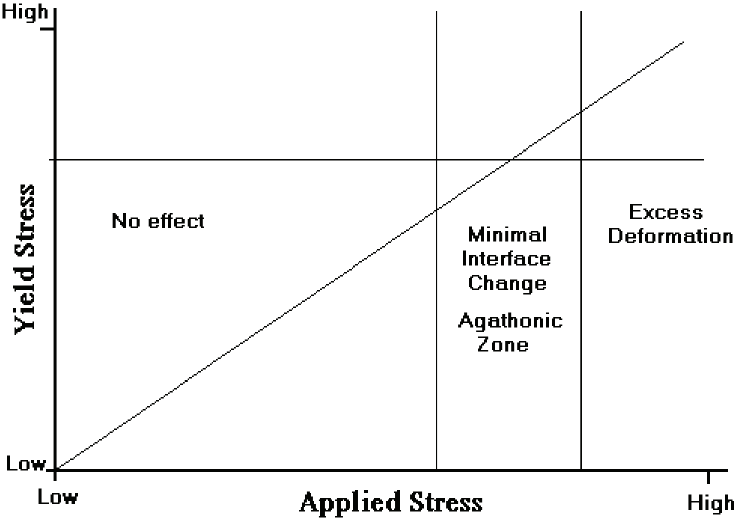


Figure 3

An autopoietic system is living, and can self-produce. An agathonic system is non-living, and does not self-produce. An agathonic system can change in response to interactions within its environment.

Autopoietic systems can inform agathonic design theory. Similarly, an examination of cognition and structural coupling may assist in clarifying a theory of agathonic design. The goal is to understand that what happens in the interaction process may result in improved functionality for the object or system. And what is the role of cognition and representation in autopoiesis that applies to agathonic design?

One model for understanding the characteristics of an agathonic interface is to use a stress & yield diagram, such as shown in Figure 3.

If the forces on the interface material are less than the yield stress, there will be no change in the dimensions or material properties, and therefore there is no agathonic effect. This is shown as the "No effect" zone on Figure 3. If the forces on the interface material are much higher than the yield stress, the object or system deforms excessively and is no longer usable. This is shown as the "Excess Deformation" zone on the graph. It is only in the middle ground that the interfaces will change minimally through use, as the force applied on the interface is just enough to effect a lasting change in the dimensions and/or material properties of the object. This is described as the "Agathonic Zone", as shown in Figure 3.

4.1 Cognition and agathonic design

A definition of cognition from the works of Maturana and Varela is summarized [7] as: "Cognition is effective interaction." Cognition is often defined as thinking, or as intelligence [8], which moves the definition away from the simplest explanation. Thinking or intelligence is limited to living beings with some sort of brain, sensing organs and a complex neurophysiological structure. Perhaps we can consider agathonic designs as products that have a cognitive analog, as they receive inputs and generate a response. There is no thinking, in the classic sense, but there is an accumulation of physical interactions that alter the properties of the object – which is able to change in response to user needs.

Moving beyond the conventional definitions of cognition as “thinking” may provide a useful perspective from which to consider agathonic designs. If cognition is not dependent on the existence of a discrete computer, perhaps the responses from one system to inputs from another are in fact, computational replies. This begins to sound more like parallel distributed processing (PDP) [9] and less like the activity of a central computer with sensors and actuators. The effect of thousands of small "micro interactions" on the object or system is to change many small subsystems directly as a result of the interaction. The changes are not a result of a formal, structured signal processing, computation and actuating mechanism. All of these attributes are present in the agathonic object.

The effect of this upon agathonic design is the realization that a mapping of anticipated inputs can be matched with desired outputs, resulting in an object with increased functionality. One example is a new leather baseball glove, which is shaped, softened and molded to a more desirable shape by the user when the glove is used for its intended purpose. Indeed, owners of new baseball gloves may accelerate this process by artificially increasing their use of the new glove, resulting in a better glove than would be created only through use. A common practice is to place a baseball into the new glove, and wrap the glove with rubber bands, as it speeds the break-in process, and shapes the ball pocket so the glove will have a higher level of functionality in less time. Some people also apply mink oil or similar products to quickly soften the leather, and accelerate changes in the leather’s material properties.

One way to model cognition is to look at it as an interaction between representations, or symbol systems [10]. Another perspective for cognition defines it as the interaction between tangible physical realities. The lack of ambiguity in the physical representation (as compared to virtual representations) clarifies the interactive physical act. If a physical system is the basis of an interaction, then it is free of any representations. In this sense, cognition is achieved completely and solely by way of the interactions between the user and the design object. The following graph depicts the relationship between these components.

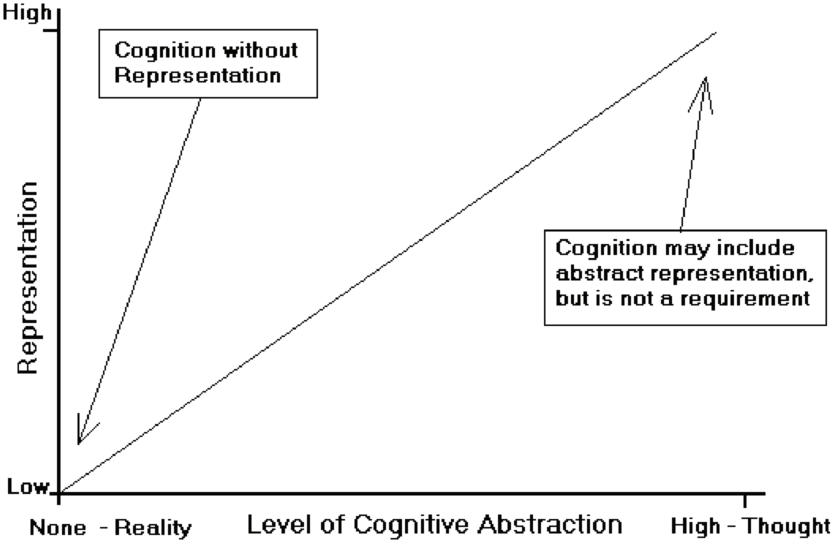


Figure 4

This appears relevant when considering what Maturana and Varela [11] wrote about cognition: "A cognitive system is a system whose organization defines a domain of interactions in which it can act with relevance to the maintenance of itself, and the process of cognition is the acting (inductive) or behaving in this domain. Living systems are cognitive systems, and living as a process is a process of cognition. This statement is valid for all organisms, with and without a nervous system."

A non-living organism with no nervous system can be defined by the interactions it has outside of the boundaries of the system. The significance for agathonic design is that autopoietic (living) systems perceive interactions, and store a representation of the historical interaction event. Agathonic (non-living) systems store the actual history of the interaction event within the design object. The objects do not require a nervous system, a brain, or a computer, and they are not subject to potential impreciseness of bias or loss of memory. The lack of representation in cognition is not a barrier to effective cognition by agathonic objects and systems, and is an essential element of agathonic design theory. Agathonic objects experience cognition via interaction, not by way of an information processing overlay dealing with abstractions or representations.

4.2 Autopoiesis and allopoiesis

This line of thought has implications beyond mechanical systems, as Maturana and Varela vacillated in their definition of autopoiesis [12]. They wrote about their definition for autopoiesis, and whether it applied strictly to living systems, or had some applicability to systems that are usually classified as non-living. They reached an agreement for a definition that described an organization with many conditions, and finally chose to use it to define living systems. It appears likely that similar mechanisms in other non-living objects and systems (in addition to strictly mechanical constructs) can have interaction results similar to the examples of agathonic design described earlier in this paper.

By comparison, allopoiesis describes a system that produces something other than itself. As an agathonic design is implied if a non-living system modifies itself as it is used, with the result being increased functionality. A new systems level definition may be required to describe this distinction.

4.3 Structural coupling

The concept of structural coupling applied to the domain of agathonic design is intriguing. As Mingers [13] points out, "Structural coupling is a reformulation of the idea of adaptation, but with the important proviso that the environment does not specify the changes that will occur." In autopoiesis, a living system may realize changes due to the interactions, but the integrity of the system is maintained. In a non-living, agathonic design, similar results may come from user-object interactions.

An agathonic design will likely change due to interactions with the user, but the difference is that system is non-living, and the integrity of the system is maintained. This line of thought suggests that designers should thoroughly understand the design object environment and all interactions, such that the function of the object or system is unaffected by its environment. The user interactions will then determine the changes to be made to the object or system, make them in the process of interaction, and result in increased functionality. Negative changes to an agathonic system are unwelcome and undesired.

The goal is to direct entropic wear to improve the object or system. The 2nd Law of Thermodynamics reminds us that globally, entropy will increase over time. Keeping that constraint in mind, it is entirely possible to use entropy to increase functionality.

5 EXAMPLE – AGATHONIC DESIGN THEORY APPLIED TO SHOES

Consider the design of shoes as a typical application of agathonic design theory. Shoes are generally designed for individuals. It’s less common to design shoes to be shared amongst different people, so we’ll limit this discussion to shoes worn by a single individual. We will stipulate that the shoes are new when purchased, and are designed to provide different types of functionality for the user. In this example, the three examples of shoes are widely known; hiking boots, running shoes, and ballet pointe shoes agathonic or system.

In the case of hiking boots, the lifespan is unknown, and may be anywhere from several months (if the boots are heavily used), to several years – if the boots are used less frequently. Many of the design issues involve making the shoe comfortable, and responsive, while protecting the foot and ankle from injury. Hiking boots are routinely considered “not quite ready for use” when they are new, as some “breaking-in” is needed before the boots shape themselves to the user’s foot. Knowing that feet vary in size and physical characteristics, it may be possible to account for the breaking in process such that an improved fit is achieved. Knowing that hikers wear socks is important, for the ability of the foot in use to modify the boot will likely be directly related to the system dynamic of foot, sock and boot. Which parts of the boot are modified during the break-in process, and could those be redesigned to improve the overall functionality?

Now contrast hiking boots with running shoes, which are smaller, lighter, and have a lifespan that is much less than that of hiking boots. The shoes move differently than hiking boots, and the purpose of the shoes is similar – yet much different. The mechanics of the foot have to be understood along with the kinematics of a leg in motion. Runners wear their footwear differently than hikers, so an examination of how the shoe is used may indicate several rich areas for interface improvement. Could the sole be made of a material that improved with use? Could shock absorbing material in the ball and heel areas of the shoe change with use, such that the runner has fewer injuries? And could the shoe strength and flexibility be tuned to support the runner and improve running performance? There are likely dozens of ways that the various features and attributes of running shoes could be reviewed with an eye towards not just making them work well, but making them improve with use.

And finally, consider the design of ballet pointe shoes – a complicated shoe that usually has a lifespan measured in hours. Some high performance dancers may break down their shoes in just a few hours, but typical users may get 10 to 20 hours of use from a pair of new shoes. These specialized shoes are highly personalized, as dancers adapt their shoes to work to their demanding standards. Subtle nuances in shoe response, feel, flex and performance are known to the dancers, so they strive for total control of their shoes not only to prevent mishaps, but to provide a fit that will improve their dancing. Ballet dancers are serious athletes, such that their shoes and feet are often performing at the boundaries of physical possibilities. Could a review of box design, shank design, and other components of a pointe shoe be reviewed to improve a design that is ready to be improved? As dancers seek the best equipment possible, it is reasonable to expect that redesign of pointe shoe components and subsystems would lead to improved pointe shoes.

6 DISCUSSION AND CONCLUSION

The interactions between the user and object are the basis of agathonic design theo. And a design theory will also have to address the end of object or system functionality. All of the physical examples discussed will at some point degrade to the point of failure, such that their cycle of improving performance is interrupted or ended. The user then must decide to replace, repair or retire the agathonic object or system.

This discussion of agathonic design theory suggests that there are many avenues to explore, continuing with the role of "cognition as interaction" in modifying the object. For example, what happens to the information that is passed along in the interaction between the user and the object? Agathonic design recognizes and directs entropy in the design. In the best case of directed entropy, an object wears (moves to a lower energy state) as it is used, but in a predictive manner that increases its functionality and/or value to the user. A useful theory of agathonic design may result when the way objects and systems are used is combined with an improved understanding of material properties.

Agathonic design is a new technique that designers may want to consider in their work. It channels entropy to create an object or system with improved functionality. It makes use of cognition without representation to process new information and revise the design. The design itself facilitates and uses interactions to improve functionality by using the material, the design geometry, kinematics (movement constraints), user interfaces, and design goals.

Many commercial benefits are available to businesses interested in pursuing agathonic designs. There are apparently many existing materials that are suitable for use in agathonic designs, and entrepreneurial ventures may discover or create new materials that are well suited for agathonic designs. Designers may want to explore the benefits of introducing agathonic features into their products, as increased user value may result, allowing for greater profitability and/or reduced product liability costs.

The potential for using agathonic design for virtual products is intriguing, as perhaps something as widespread as computer software could benefit from a redesign using agathonic principles. The buttons on a screen might modify themselves – but as stated earlier – anything with a computer is by definition, not agathonic. There may be a way to embrace agathonic principles separate from the computer controlled feedback model, and do it in a way that improves the product. And other virtual designs are intriguing – like organizations or institutions. While the actual changes may be a result of programming and computer controls - could these same feedback controls be redesigned using agathonic principles, to emulate a non-computer driven wear pattern, using an agathonic model?

Many future research questions are now apparent as the fundamentals of agathonic design are explained. Possible avenues of exploration include: refinements to user interface heuristics, characterizing agathonic material properties, agathonic feedback cycle optimization, design for progressive product end-of-life functions, and intelligent user-object systems performance optimization. Agathonic design may prove to be a useful addition to the designer’s toolbox. Designers can utilize entropy to improve the functionality of a product, and improve the relationship between the user and the design object. When this practice becomes more widespread, both the art and science of design will have advanced.

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