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EXTENDING THE AFFORDANCE STRUCTURE MATRIX – MAPPING DESIGN STRUCTURE AND REQUIREMENTS TO BEHAVIOR

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1 INTRODUCTION

Affordance Based Design is a recently developed approach to design theory and methodology based on the theory of affordances from perceptual psychology. An affordance is what one system provides or furnishes to another system [1]. For example, a chair affords sitting to a person. A key advantage of the affordance based approach is that affordances are form-dependent, unlike functions which are form-independent. Form-dependence results in a designer being able to analyze concepts with respect to desired and undesired affordances early in the design process, as well as within reverse engineering. The affordance structure matrix is a tool inspired by similar matrix based tools such as Design Structure Matrices (DSMs) and House of Quality (HoQ) matrices.

2 THE AFFORDANCE STRUCTURE MATRIX

The Affordance Structure Matrix is a tool to compare requirements information with physical structure at the conceptual stage. Requirements information is interpreted in terms of affordances following our previous work into Affordance Based Design [2]. Specifically, requirements are organized into four categories: Positive Artifact-User Affordances (+AUA), Negative Artifact-User Affordances (-AUA), Positive Artifact-Artifact Affordances (+AAA), and Negative Artifact-Artifact Affordances (-AAA).
The interior of the ASM is populated by considering whether each component has a helpful (+), harmful (-) or no ( ) relationship to each affordance. The "roof" of the ASM is a Design Structure Matrix (DSM) that captures the relationships between components. The left side of the ASM similarly captures the relationships between affordances. For a detailed description of the ASM and instructions for populating an ASM, refer to [3].
In this paper we extend the original formulation of the ASM by indicating whether relationships are helpful or harmful (+/-), not just existence (x) or non-existence. Based on the identification of helpful and harmful relationships, additional metrics are possible. In particular, the total number of components that are helpful with respect to each affordance can be calculated, as well as the total number of components that are harmful with respect to each affordance.
Similarly, the total number of affordances with which each component has a helpful relationship can be calculated, as well as the total number of affordances with which each component has a harmful relationship can be calculated.
For each component, comparing the relative percentage of helpful to harmful relationships gives a rough indication of whether that component is doing more harm than good. For each affordance, comparing the relative percentage of helpful to harmful relationships gives a rough indication of whether more components are helping to achieve or hurting to achieve that affordance. For the overall product, the total relative percentage of helpful to harmful relationships gives a rough indication of how much room for improvement there is; i.e., compared to an ideal situation where all components are helpful.

3 VACUUM CLEANER EXAMPLE

A vacuum cleaner example is shown here for illustration purposes. A vacuum cleaner is chosen because it is a frequently used consumer product studied in the literature. Otto and Wood [4] show a function structure for a vacuum cleaner. Blackenfelt [5] shows a strategic DSM for a vacuum cleaner. An early version of an Affordance Structure Matrix for a vacuum cleaner was presented by the present authors [3, 6]. A complete extended ASM for a Eureka bagless upright vacuum cleaner is shown in Figure 1.

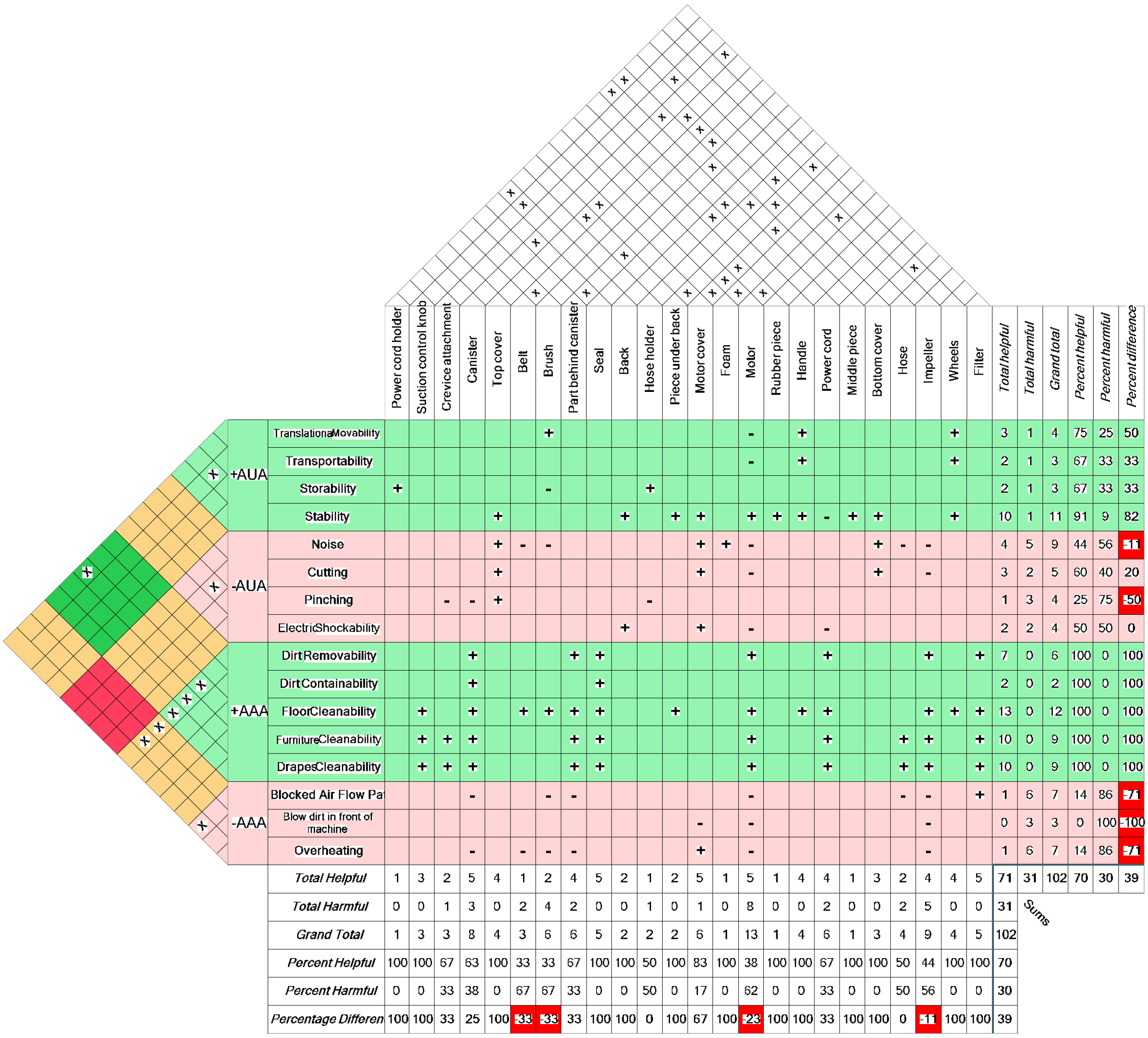

Figure 1. Affordance Structure Matrix for a Eureka bagless upright vacuum cleaner

Turning our attention first to the bottom of the ASM in Figure 1, several parts, such as the power cord holder and suction control knob, are seen which have 100 for the "Percentage Difference" in the bottom row. This indicates that all of their relationships with the affordances are helpful in nature. Note however, that the suction control knob is related to 3 affordances whereas the power cord holder is related to only one affordance, indicating that the suction control knob may be more critical or more sensitive to change than the power cord holder. Other components have negative percentage differences (marked with red backgrounds), such as the belt, with -33 percentage difference. A negative percentage difference for a component indicates a potentially troublesome component that is an opportunity for future improvement.

Looking now at the right side of the ASM in Figure 1, again several affordances (such as *dirt removability*) have 100 percentage difference, which indicates that all the components related to those affordances are helpful. However, again several affordances have negative percentage differences (again marked with red backgrounds), such as *noise* and *blow dirt in front of machine*. The vacuum cleaner is in fact relatively noisy, and does tend to blow dirt in front of the machine due to the exhaust air flow path as directed by the motor cover. The negative percentage differences indicate that these are flaws with the current design that are opportunities for redesign. This observation leads to the following method for improving existing products using an extended ASM:

1) Focus on the large negative percent differences, which is where problems are likely to occur.
2) To remedy the situation, either new parts can be added to mitigate the negative percent difference or existing parts can be modified so they are no longer harmful.

For the vacuum cleaner example, this method would direct us toward redesigning the motor cover such that it would no longer blow dirt off the floor in front of the machine. We would likewise be directed to redesigning several parts such as the motor and air paths in order to reduce the noise of the machine and susceptibility to blocked air flow paths.

However, whenever any component is modified to improve one affordance, any changes can affect other components that the original component is related to. This information is captured in the top (or "roof") of the ASM, which is a conventional DSM. Similarly, changing one affordance can have an effect on other affordances. This information is captured on the left side of the ASM. For example, if we try to improve the +AUA of *translational movability*, we are likely to simultaneously improve the +AAA of *floor cleanability* (a win-win situation, as denoted by the strong green background). However, if we try to improve the +AAA of dirt removability, perhaps by using a more powerful motor, we risk degrading the –AAAs of *blocked air flow path* and *blow dirt in front of machine* (a win-lose situation, as denoted by the orange background).

Finally we note that for the whole product, the ratio of "percent helpful" to "percent harmful" relationships is 70:30. This ratio is on par for other products that have been analyzed using the extended ASM.

3 CONCLUSION

The extended ASM augments traditional DSM tools by mapping design structure to requirements which are interpreted as affordances. As an attention directing tool this allows designers to recognize opportunities for improvement and trade-offs to be considered. Our on-going research focuses on integrating affordance based and function based approaches to design under Grant #CMMI-0826441 from the National Science Foundation.

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