Design by Prototyping in Hardware Start-ups

This PhD thesis focuses on physical prototyping in hardware start-ups that develop consumer products, and is conducted within the field of engineering design research.

Prototyping is not a new thing in product development, but to effectively make use of prototypes throughout the development process is a complex and interwoven challenge for designers. Emerging desktop digital fabrication tools for prototyping and increased globalization are contributes to this complexity, and the designer’s role in product development is getting more omniscient. Surprisingly, researchers have identified that despite its importance, prototyping is currently one of the least understood aspects of product development.

In this light this project has three objectives; The first is to expand the existing understanding of product development in hardware start-ups, and provide a particular focus at prototyping. Second, the project investigates how digital fabrication tools can be applied to collect feedback from users in the early stages of product development. Finally, as the third objective, the project provides a holistic prototyping framework, Prototyping Planner. The objective is, that the framework can support novice designers in better comprehending opportunities in prototyping.

The project has been conducted as a collaboration between DTU Skylab and DTU Mechanical Engineering. Exceeding the academic contributions, a central motivation for the project is to support the growing population of young entrepreneurs, who are dedicated to develop new hardware products for the benefit of society.

We assess the first objective, focused at understanding design in hardware start-ups, through studying the existing body of literature. This provides overview of how prototypes are defined, and what different roles and purposes of prototypes have been described. With offset in insights obtained from literature, we use both qualitative and quantitative research methods to further develop our understanding of prototyping activities, and also the product development challenges that hinders success of hardware start-ups.

The second objective, explores how digital fabrication tools can be utilized for prototyping activities with test users. Through two studies conducted with hardware-start-ups, we propose respectively four design heuristics for prototyping with digital fabrication and a seven-step data-driven approach for interlacing the known concept of ‘Design of Experiments’ and prototyping of hardware products.

Different studies have documented how novice designers are lacking the competencies to fully comprehend the potentials of prototyping. The third objective is hereby approached through the accumulated insights of the project, which supported the conceptualization of Prototyping Planner. The tool is evaluated though a controlled experiment with 20 design teams working on an identical design challenge. Results reveal that the framework is successful in nurturing ‘prototyping mindsets’ among the participants, but also identify a range of opportunities for further improving the framework. Such opportunities are to be seized in future research activities on the topic of prototyping.