DEVELOPMENT OF A ROBUST VIBRATION UNIT FOR AN E-TEXTILE HAPTIC FEEDBACK SYSTEM

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Background

Running is one of the most common sporting activities globally and in The Netherlands . However, the sport results in a large portion of sporting activities at around 13% of the total in The Netherlands, (Stam, 2023). Inside of the running population, the numbers are even more severe, with 50% of runners experiencing an injury each year, 92.2% of which occur in the lower extremity, (Kakouris et al., 2021).

To reduce the incidence of lower extremity running injuries, a collaborative research project has been created by Saxion University of Applied Sciences and motion capture company Movella. This project has the objective of designing and demonstrating a running specific e-textile garment system using Movella's DOT IMUs(Inertial Measurement Units) and Saxion's e-textile expertise.

Figure 1: E-Textile Garment Mock up

The intention is that the system will use inertial measurement data to produce a feedback signal which can then be transmitted to the user via a vibrotactile sub-system. The e-textile garment itself serves as both an electrical interface for signaling and power, while simultaneously allowing for the mounting of the IMUs and vibrotactile sub-system. This basic design feature presents a challenge as the device which provides the vibrotactile system is envisioned as using a coin cell vibration motor which necessitates a hard device which creates difficulty when mounted on fabric. This problem is compounded by the need for repositionability due to the individual needs of users and garment washing.

Objective

The unaddressed issues for the design of the e-textile vibration sub-system are, the specific method of attachment mechanism and the manner in which usability and comfort may be incorporated in such a system. This project area provides a challenge as such a device must have a robust mechanical and electrical connection to the e-textile garment while being detachable and user-friendly. The challenge comes from the fact that running occurs in a potentially harsh environment with constant dynamic movement while a garment is flexible and does not provide a stable base for surface-mounted components.The scope of the project is to create a design focused

on robustness and durability but with enough usability and comfort to have a positive perception by users.

Methodology

To conduct this design research, a modified Double Diamond model was implemented as seen in figure 2. This helped to visualize the required design stages of the project while providing a framework for how refined or converged the design should be at each stage.

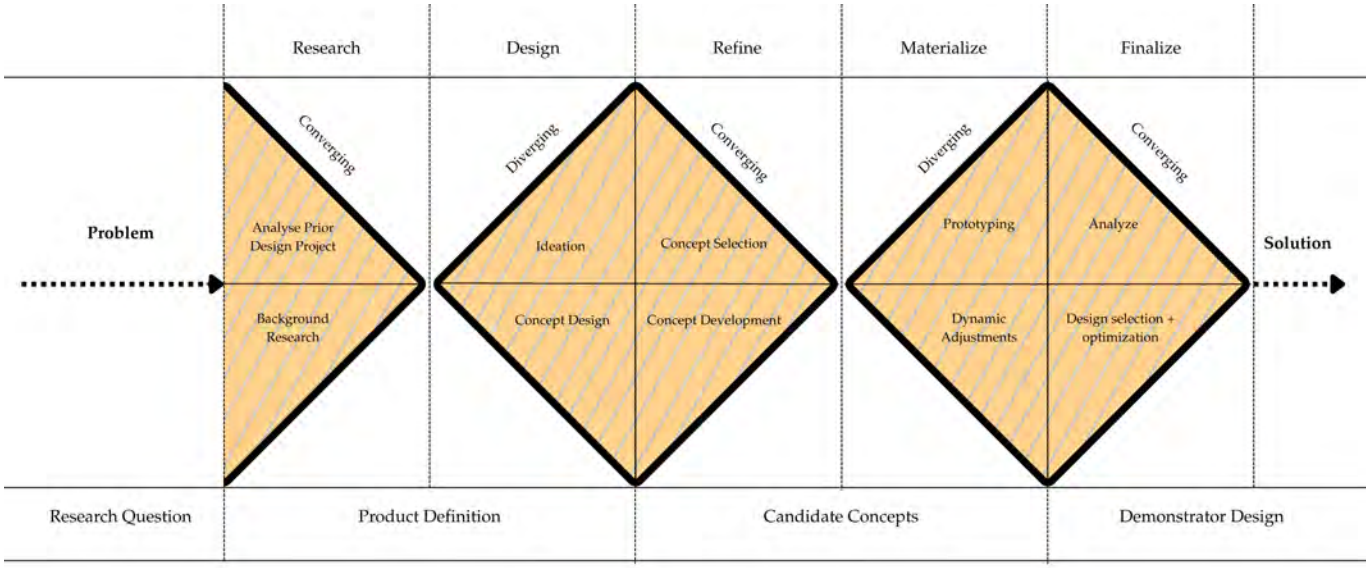

Figure 2: Double Diamond Research Model

To further focus the design process, the designs were left as abstract at each stage as possible to allow a combination of research and experimentation to develop and cull the designs. Therefore, at each stage, the concepts became clearer and had their numbers reduced based on increasingly stringent criteria.

Results

The design process took on several different stages in order to verify and achieve a suitable result. Emphasis first must be placed on parameterizing robustness, usability, and comfort through extensive literary research. Key design elements emerged from this research, such as: device positioning, ingress protection, cognitive ergonomics, physical ergonomics, and crucially the mechanical interface. The key design decision was to decouple the mechanical and electrical connections to improve design flexibility and the effectiveness of both interfaces. In order to understand how these design elements mapped onto the system, a Product Breakdown Structure was used, as seen in figure 3.

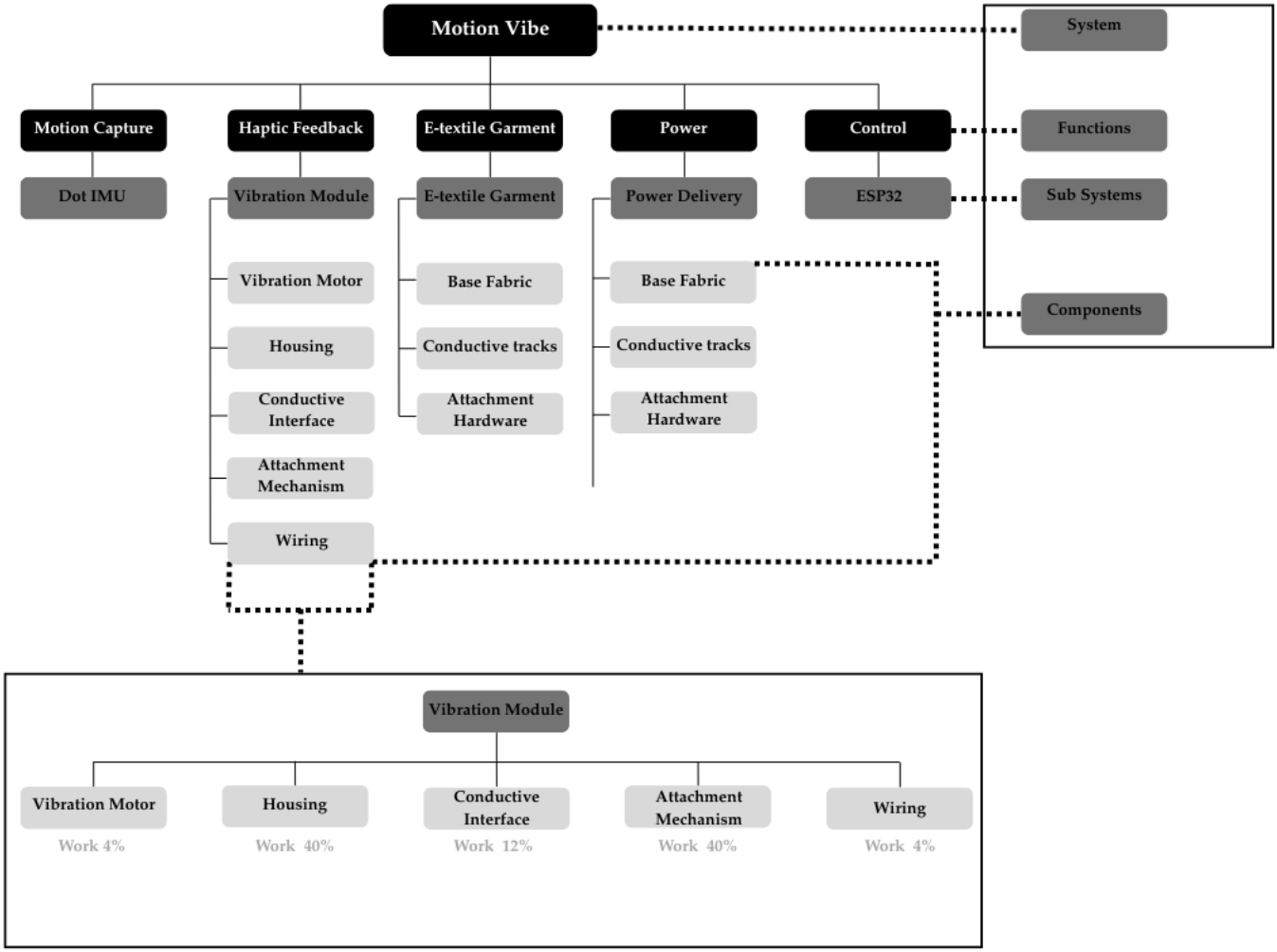

Figure 3: Product breakdown Structure MotionVibe

Following the research stage, four novel attachment systems were ideated. In addition, one underdeveloped design from a previous project was selected to increase design variety. From this cohort of designs, two variants were selected as the final candidates for development and prototyping, the clip-on and magnetic options, shown in figure 4.

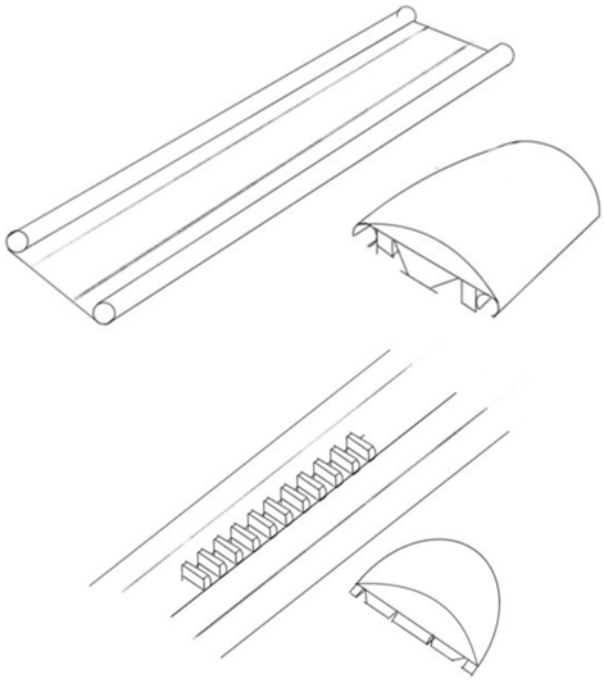

Figure 4: Candidate Concepts Ideated

The two designs which were selected were the clip-on and magnetic track options. Both designs were developed and optimized in Solidworks, using a rapid development, rapid prototyping model with four parallel design stages. After all desired design features were incorporated in a sufficiently optimal package, i.e. low volume, 3d-prints were used to demonstrate component and garment compatibility as seen in figure 5.

Figure 5: Rapid Prototyping of Concept Designs

These designs were then prototyped at a high quality level using SLA 3d-printing for use in testing and as a constituent part of a demonstrator model of the system, as shown in figure 6.

Figure 6: Final Prototypes

In addition, sample garments with a prototype attachment interface were produced to carry out comparative testing on the two prototype models of the device, shown in figure 7.

Figure 7: Test garments and their production

Several mechanical tests and measurements were performed

Following testing, the better performing, clip-on design was further developed based on production type manufacturing and assembly processes. This resulted in a fully optimized design which could be further integrated and adapted to a final system, shown in figure 8.

Figure 8: Final Concept Render

After the conclusion of the design process a suitable attachment system was developed This design presents several challenges in terms of garment design however several promising technologies such as 3d knitting and/or the use of plastic inserts were determined to be suitable solutions. The resulting vibrotactile unit was deemed to be suitable for use in a demonstrator system and several more units are to be produced.

References

Kakouris, N., Yener, N., & Fong, D. T. (2021). A systematic review of running-related musculoskeletal injuries in runners. *Journal of Sport and Health Science*, *10*(5), 513–522. https://doi.org/10.1016/j.jshs.2021.04.001

Stam, C. (2023). Sportblessures in Nederland Cijfers 2022. *VeiligheidNL*.