THE USE OF THERMOGRAPHY AND MOTION CAPTURE TO IDENTIFY ASSISTIVE TECHNOLOGY OPPORTUNITIES: A CASE STUDY

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1. Context

Technology is the knowledge and application of tools, techniques, and sciences with the purpose to shape the world (Best, 2012). The design process embraces technologies to support different project phases; one of the phases is the data collection where one can use technological instruments to gather objective and quantifiable data to tailor the project to the needs of users (Merino et al., 2017; Merino et al., 2018).

During data collection with disabled people, technological instruments assume a critical role (Merino et al., 2017; Speck et al., 2016); for instance, one can obtain accurate data with subjects that have communication problems due to physical and psychic limitations (Merino et al., 2017). The instrumentation allows in-depth exploration of the subjects and objects to bridge the gap between the project team and the capabilities and limitations of users (Forcelini, Varnier & Merino, 2019; Merino et al., 2018; Varnier & Merino, 2018).

Merino et al. (2018) highlighted that motion capture and infrared thermography (IRT) are viable methods for the development of assistive technologies (AT), enabling more efficient, comfortable and safe solutions. These technologies assist the development of new projects, adaptations of existing products, identification of problems and ergonomic analysis (Forcelini, Varnier & Merino, 2019). Therefore, this article aims to identify opportunities for assistive technology projects for a subject with motor disabilities through the use of data from infrared thermography and motion capture (Xsens).

2. Method

This study was divided into three steps (i) Data gathering; (ii) Data analysis and; (iii) New project opportunities identification.

- Data gathering – we captured data via infrared thermography and motion capture, picture-taking, video records, and unsystematic observations.
- Data analysis – we described and analyzed the collected data.
- New project opportunities identification – through our study new opportunities for the development of AT projects for the research subject were identified.

The data gathering was performed with a disabled subject (paraplegia, tendon shortening and sensitivity on the left side of the body), female, 24 years old, a wheelchair user.

A preliminary version of the Thermos protocol was used to guide and maintain the accuracy of the thermography data collection process (Forcelini, 2019). The motion capture used a preliminary version of the Motion Capture protocol; which proposes guidelines to data collection through Xsens' MVN Biomech (Varnier, 2019).

3. Results and Discussion

The research subject is characterized as semi-dependent, performing some of her activities autonomously and others with help. To seat, she assumes the posture in W. She uses the knees to walk in her residence and nearby areas. To leave home she uses a wheelchair.

She has difficulties to move between the floor and the wheelchair and vice versa, which requires a person to provide assistance. To assume the walk position she is required to be put on the floor that might be dirty and uncomfortable. This situation causes embarrassment and risk of injury to the subject. Therefore, we stress the need to develop **a device that allows the transfer of the subject autonomously and safely, removing the need of other people**.

The subject needs bilateral internal rotation of the hips to walk and to stay in a resting position, which is a risk factor for the development of arthrosis and labral lesions due to accentuation of the joints degenerative process. Thermographic evaluation of the posterior region of the subject demonstrates a temperature increase in the coxofemoral joints, which corroborates these risk factors.

The analysis of the gluteal region (after using the wheelchair) presented hyper radiant points (points with high temperature) with 33.1ºC on the left side and 32.8ºC on the right side. These temperatures increased substantially from the average temperature at rest, 23.8ºC on the left side and 23.9ºC on the right side.

Brioschi et al. (2009) reported that thermographic data demonstrates the degree of vasoconstriction or vasodilation of the skin, which may reflect the function, dysfunction or trauma. Therefore, we suggest the development of **a device to reduce the observed coxofemoral pressure, which allows the stabilization and mobility of the subject**.

Thermographic data also demonstrated a temperature increase on the right arm, right deltoid, and trapezoids. The right arm presented an increase of 1.9ºC in the hyper radiant point, from 33ºC to 34.9ºC. That might be related to the deviation of the subject's spine, which causes an uneven stress when moving the wheelchair. For this reason, it is vital the development of a **propulsion system to reduce the need for force to move the wheelchair**.

The trapezoid thermograms indicated a bilateral temperature increase, which may be related to the head protrusion discovered by the motion capture data (T1-C7 and C1-Read joints) during the walk. The head protrusion presented extension angles between 20º and 30º above the comfort zone; Tilley & Henry Dreyfuss Associates (2005) established the comfort zone between 0º and 15º degrees. As shown by Bonney & Corlett (2002), this issue can increase compressive loads on the cervical spine and cause tissue deformation.

The trapezoid and right deltoid heat up may be associated with shoulder flexion and abduction. The range of shoulder movement presented extension angles above 60º, which is outside the comfort zone. Palmer & Epler (2000) and Marques (2003) defined the comfort zone between 0° and 45°. Therefore, we highlight the need for **a device to stabilize and move the subject; thus, reducing the shoulders extension and injuries in the knees and T1-C7/C1- Head joints**.

The hand's temperature increased after the wheelchair propulsion; 1.1ºC on the right hand and 1.7ºC on the left. This increase may be related to the excessive pressure applied to the tissue of the hands during propulsion.

The hyper radiant point of the right hand was found in the thenar region (at rest and after activity). On the left hand, it migrated from the thenar region (at rest) to the joint between the hand and wrist (after activity). This fact may be associated with atrophy of the left hand that creates difficulty to handle the propulsion system of the wheelchair. For this reason, to reduce the pressure on the tissues and joints, we suggest **a new propulsion system for the wheelchair, which facilitates its handling and reduces friction with the user's hands**.

The lower temperatures of the legs are associated with the reduction of blood circulation caused by muscle atrophy. The knees presented a temperature decrease because of the contact with the cold floor during the walking. The temperature decreased 0.9ºC on the right leg and 1.2ºC on the left. Based on these measurements, we can identify the contact regions with the floor. This information is useful to guide the development of **a device for the protection of knees and other regions that have contact with the floor.** This device should have a comfortable internal coating and resistant external material.

The thermographic data of the wheelchair demonstrated an increase in the temperatures of the seat and backrest after the subject movement (2.9ºC in the backrest and 4ºC in the seat). As a consequence of that, we foresee the necessity for the **development and test of different covering materials to the seat and the back of the wheelchair to reduce heating and improve the thermal comfort of the user**.

The thermal asymmetry observed on the right and left side of the seat can be associated with the posture issues of the subject. Therefore, we identified the possibility of **developing a custom seat and backrest, based on anthropometric data of the wheelchair user, which would make the contact area with the body homogeneous, relieving pressures on the skin**.

4. Conclusion

This study demonstrated the subject's postures and movements issues with and without a wheelchair. As a result of the analyses performed by design and health professionals, it was identified new project opportunities, such as: (i) a device that allows the transfer autonomously and securely (ii) an assistive device for stabilization and mobility, that reduces the coxofemoral pressure; (iii) a new wheelchair propulsion system that facilitates handling and reduces friction with the user's hands; (iv) a device for protection of knees and other regions of contact with the ground during walking; (v) new covering materials to the seat and the backrest of the wheelchair that reduce heating and improve the thermal comfort of the user; (vi) a custom wheelchair seat based on anthropometric data from the user.

These opportunities can help the subject to perform her daily life activities, increasing her comfort and safety, while reducing the risk of injury and improving her quality of life. However, we emphasize the need for a detailed and multidisciplinary analysis of the subject (physiotherapists, physicians, occupational therapists, designers, and others) to develop them.

The proposed method was satisfactory to the data collection and analysis. The observations contributed to visualize the subject's interactions and limitations. The thermography was efficient for data collection with a disabled subject for its noninvasive characteristic which allows analysis without direct contact. The motion capture was suitable for the real simulation of movements, contributing to the understanding of the subject's limitations and needs. Moreover, health professionals were essential for data analysis.

5. References

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