# Customization tool for people with special needs

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ABSTRACT: There are people with limited skills due to different causes like post-surgical situation as an example. These people are considered people with special needs (PSN). Large number of persons has pain in his body because the contact with support surfaces for long time. This paper aims to design and implement one tool to help design and manufacture customized devices in order to reduce the pain.

UCD (user-centered design) methodology in combination with psychophysical user data generates a 3D geometry that can be produced in a rapid manufacturing environment. One tool is developed in Labview composed by three modules; a) import and treatment of psychophysical data, b) data analysis and reconfiguration into new geometries, and c) build point cloud data that considers materials deflection which can be used by CAD systems for rapid manufacturing. The result obtained after utilizing the tool is a product capable of reducing/delaying the onset of pressure ulcers..

## 1 INTRODUCTION

The evolution of the design methodologies based on the user, expresses the replacement of user needs as the central point of product design.

As response to the boom in technological advances and production supported by the economy and relocation, where more and more mass production manifested a lack of personality and where the competition is increasing, the smaller markets were forced to rediscover new ways of relating with the clients. Customers who are increasingly demanding, become the focus of attention during the design process.

Already in late 90's, Kerckhove (1997) stated that the relationship the user has with a product is a continuous communication process, meanwhile in the computing area, studies were being developed in HCI (Human Computer Interaction), addressing the relationship of graphical interfaces with the computer (often addressing ergonomic issues, or areas likely to have quantitative assessments).

Yong-Ki Lee (2009) in turn, speaks of the products semantic relations as signs of value in a perspective of language domains as a qualitative value. Alison Black (2008) of the Design Council, explores the UCD (User Centered Design) based on the central premise that understanding user needs and having user feedback to the product use, results in better designed products. The product use feedback is obtained by the analysis of a set of exercises in which the user expresses the experience in product interaction.

"The emotional product design introduced a new way of being with the design, as shown by Donald Norman (2005), in a more psychological perspective based on three assumptions relating to our emotional state: "

- a visceral level that makes an immediate judgment;
- a behavioral level that relates to our most rational part, the body control;
- and finally, a reflexive level that reflects our interpretation, comprehension and reasoning part.

Pieter Desmet (2008) addresses the evaluation of tangible and intangible emotional design in the process of product experience from a response to emotional stimuli in a similar case as the Borg CR10 and other works where psychophysical data are used.

Steinar Killi (2007) refers the precious help in customizing products, such as in the case of Adidas and Nike, where the user has the possibility to participate in setting up its own shoes through the Web, for example by choosing color.

In the case of the Freitag (Providência, B. 2008, Santarém, B. At all. 2005) it is studied the bags made from recycled truck canvas, where from the F-Cut application, the user has the possibility to interact / participate in defining, from a set of canvas on display, which look he wants for his bag.

Not less interesting, is the use of rapid prototyping technologies for the production of hearing aids by Siemens that involves the 3D scan of a mold of the hearing cavity for, from the CAD treatment, allowing the construction of a more discreet prosthesis adapted and customized for the user. Or even the exercise done by students who developed a pair of sunglasses based on the 3D scan of their face, contributing to an approach that explores more the emotional relations based in aesthetic factors (Killi, S. 2007).

These cases were the starting point for thinking about design methodologies, not based in what users express, but if possible, in their emotions, enabling solutions where the probability of the products being developed would be more certain both in terms of acceptance as in terms of solving the individual needs of each user.

## 2 PEOPLE WITH SPECIAL NEEDS PRESSURE ULCERS

People having limitations in their motor skills, either consciously or unconsciously, are defined as people with special needs (PSN). This group also comprehends people who have post-surgical situations. A significant number of these persons experience problems concerning the contact of body areas with support surfaces. Due to their lack of capacity for autonomous movements, these persons are subjected to excessive skin pressure and restricted blood circulation, resulting in the development of pressure ulcers (PU).

PUs are cutaneous wounds of ischemic origin and localized usually over a bony prominence, that can vary in intensity being superficial or deep (Blannes, L. at all 2004). The classification of PUs is done by visual assessment of the level of tissue damage in stages ranging from I to IV (Bates-Jensen BM, at all 2008).

The main causes of PU are of extrinsic nature, and among these the most relevant are pressure, humidity, friction and shearing. Pressure is the main factor contributing to PU and the pathological effect on the skin can be attributed to pressure intensity and duration and to the skin tolerance (Providencia, B. & Ciurana, J. 2010).

## 3 METHODOLOGY

The use of a set of tools for acquiring and monitoring psychophysical data has been a practice in the works studying the discomfort often associated with product use. Such is the case of the F-Scan systems (Tekscan Official Web) of the Tekscan company, that allow the mapping and monitoring of foot pressure on the insole of the shoe, or the case of the pressure forces exerted on a bicycle seat during the cycling activity where the crossing of the pressure data with the movement capture during the pedal cycle allows data crossing in a more complete study.(Wilson at all 2007) Similar studies address issues associated with UCD and emotion as the ones already described in the previous chapter.

This paper addresses three psychophysical data tools (Providencia, B. & Ciurana, J. 2010).

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- Tekscan, a tool based on a film with pressure sensors that allows the mapping of pressures in a given area. This technology allows for data acquisition by a set of frames over time.
- Borg CR10, a tool that works with a set of questions posed to a patient during a particular process in time and that are used to measure the evolution of the emotional state.
- Mocap, a tool that allows monitoring a patient movements, from strategic points such as joints where marks are placed to be recorded by a set of six video cameras. The information is then processed by a specific software.

## 4 DEVELOPMENT AND TESTING OF THE CORE SYSTEM

The core system is a software developed in Labview that is part of a solution for the development of a tool to support special needs, in this case people with physical impairment that need to use wheelchairs.

The software is subdivided in a set of submodules that perform the processing and interpretation of psychophysical data. On basis of this data a a virtual three-dimensional surface that can be exported to a CAD system.is generated. This surface will provide the desired pressure dustrivution for reduced PU risk.

### 4.1 *Sub-module 1 – Import and treatment of psychophysical data*

In the first sub-module, a text file generated by the Tekscan system, representing a series of measured pressure maps, is imported. Pressure values (mmHg) are given for each of the coordinates of the map. The resolution of the maps is 32x32 cells (fig.1)

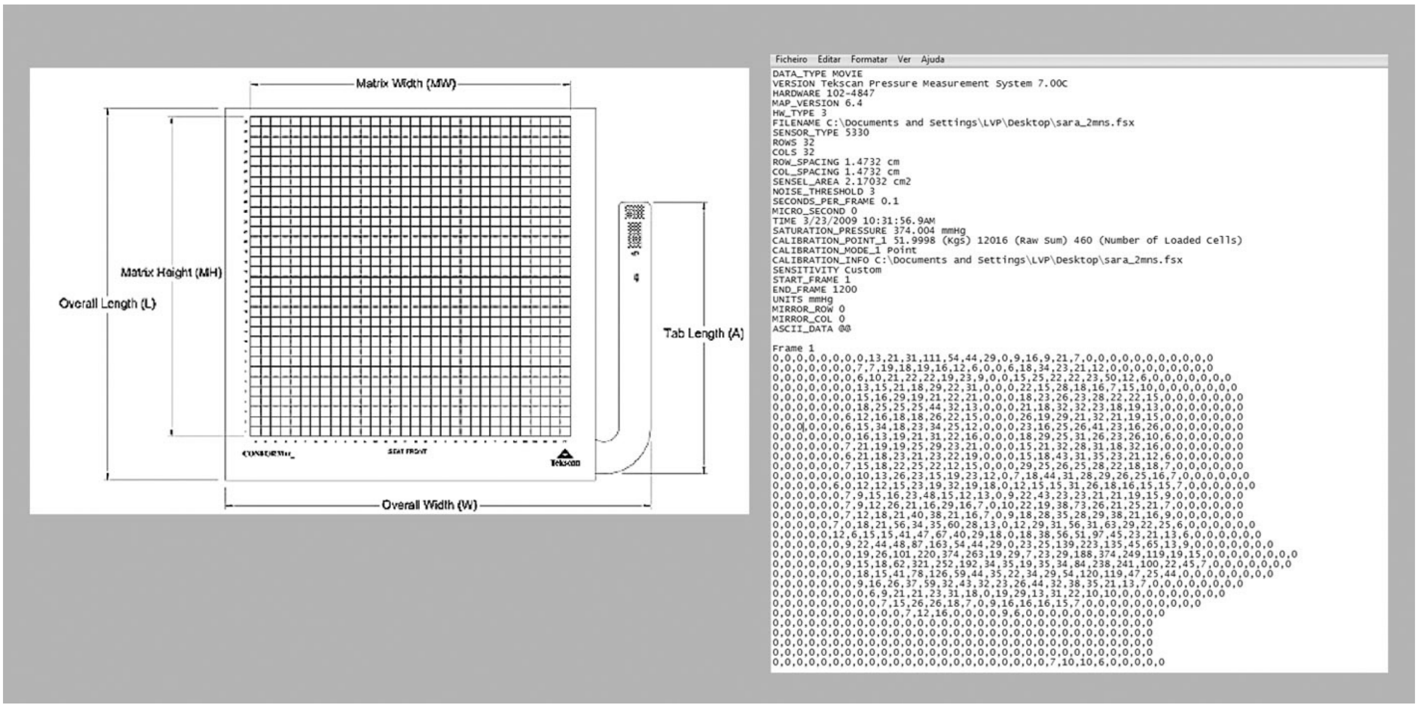


Figure 1 – Distribution of pressure sensors and obtained pressure data.

The pressure values collected refer to values taken perpendicularly to the film, in each grid cell.

The choice of a time interval for averaging of the pressure, or a single frame to be considered in the development process, is based on the choice of a specialized technician who makes the interpretation of the intersection of the pressure data with the Borg CR10 scale (where in function of time the patient is induced to verbally express his feelings regarding discomfort), and the movement interpretation is made from the capture in MOCAP (motion capture).

The software presents in this first phase a set of two graphs figure 2, a 2D-graph using a color scale for representation of the pressure values and a second graph representing the pressure maps in 3D, that allows a more visible interpretation of the pressure values.

At this stage the selection of frame or frames, in the timeline, to be considered during the study, is still possible.

*4.1.1* **Relation between pressure areas and the appearance of pressure ulcers**

Assuming that the highest pressure values are the propitious values to the emergence of UPs, the possibility of reducing the pressure values was studied, especially in the areas where UPs normally arise, through a better pressure distribution.

Reducing the values of higher pressure, would be solving part of the problem, so an approach was developed, that in terms of morphology would create areas of lower contact at critical points and minimize the pressure zones based on a better distribution.

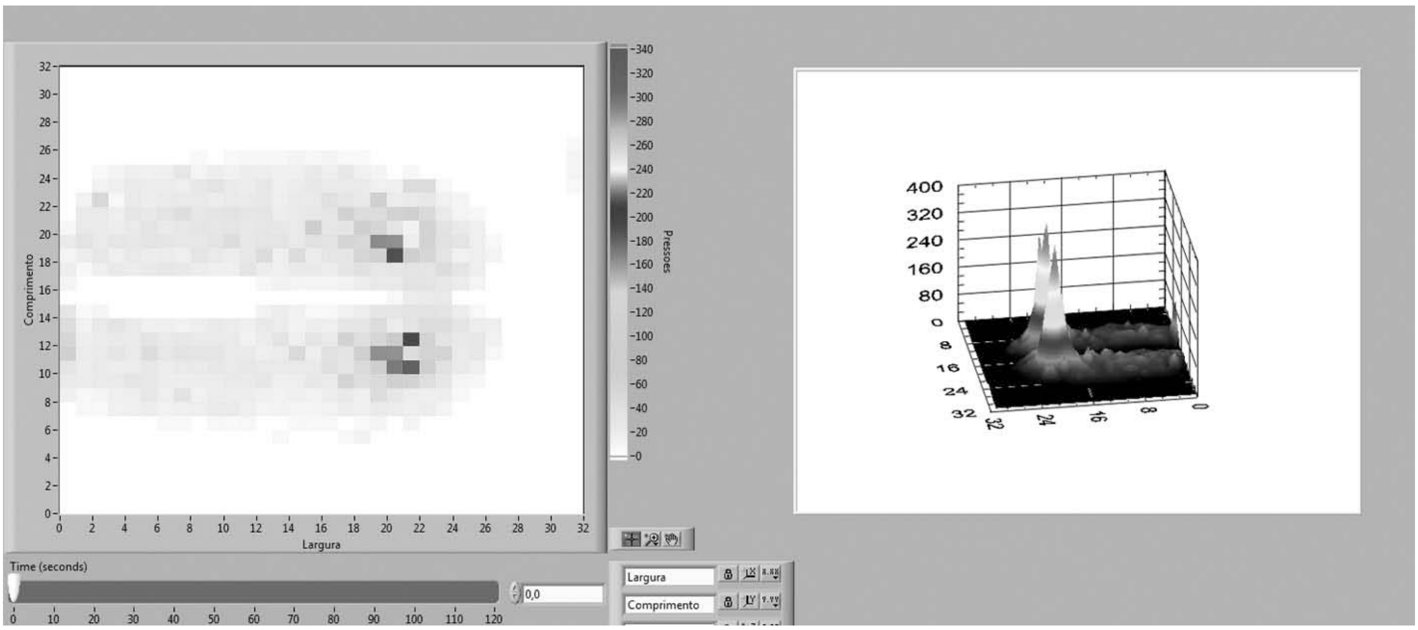


Figure 2 –2D and 3D simulation of the pressure map.

#### *4.1.2* Relation between the pressure areas and the seat base morphology

In an initial stage The pressure values where related with the seat base morphology, creating a direct relationship between pressure values vs. surface cavity values.

A maximum depth for the depressions was defined in basis of the height of the coccyx.

This first approach served as the starting point for studies that would provide the basis for information processing by the application developed, in accordance with the studies of the psychophysics working team.

#### *4.1.3* First prototype

In the first prototype, the values of the pressure were transferred to the CAD (Solidworks) in order to prepare a first test..

Based on the pressure values a set of lines parallel to each other was created. After the application of a loft (solidworks tool to draw surfaces from lines), a virtual surface was created (seat base). The way in which the progression of the loft was drawn, assumed a behaviour based on the vector expression that resulted in a poor morphology. The surface drawn was then explored and a solid was built from a parallelepiped volume, a little longer and wider than the pressure map and with a height of 6 cm (value higher than the desirable value calculated for the difference in depressions).

After the construction of the virtual solid, the data for milling was processed based on the CAM GOELAN tool. This tool allows, based on the CAD file and considering the milling machine, to prepare a numeric code for the milling, including information of drills to use and axial speed and the design that the tools perform during the milling process. This software also allows testing design errors when machining as well as having a process time estimation. After processing all this data, the software generates a code file that can be read by the machine controller.

From the first prototype developed, figure 3, the following conclusions were drawn:

- The methodology used to construct the surface in solidworks (loft), did not allow a continuous smooth surface along the width and length as can be seen in figure 3;
- Although it is not entirely perceptive in the photo of figure 3, the 8 mm diameter spherical head cutter chosen was too small and therefore created marks along the surface.

In conclusion, the morphology found not only had poor surface treatment as the depressions and transitions between areas were too sharp.

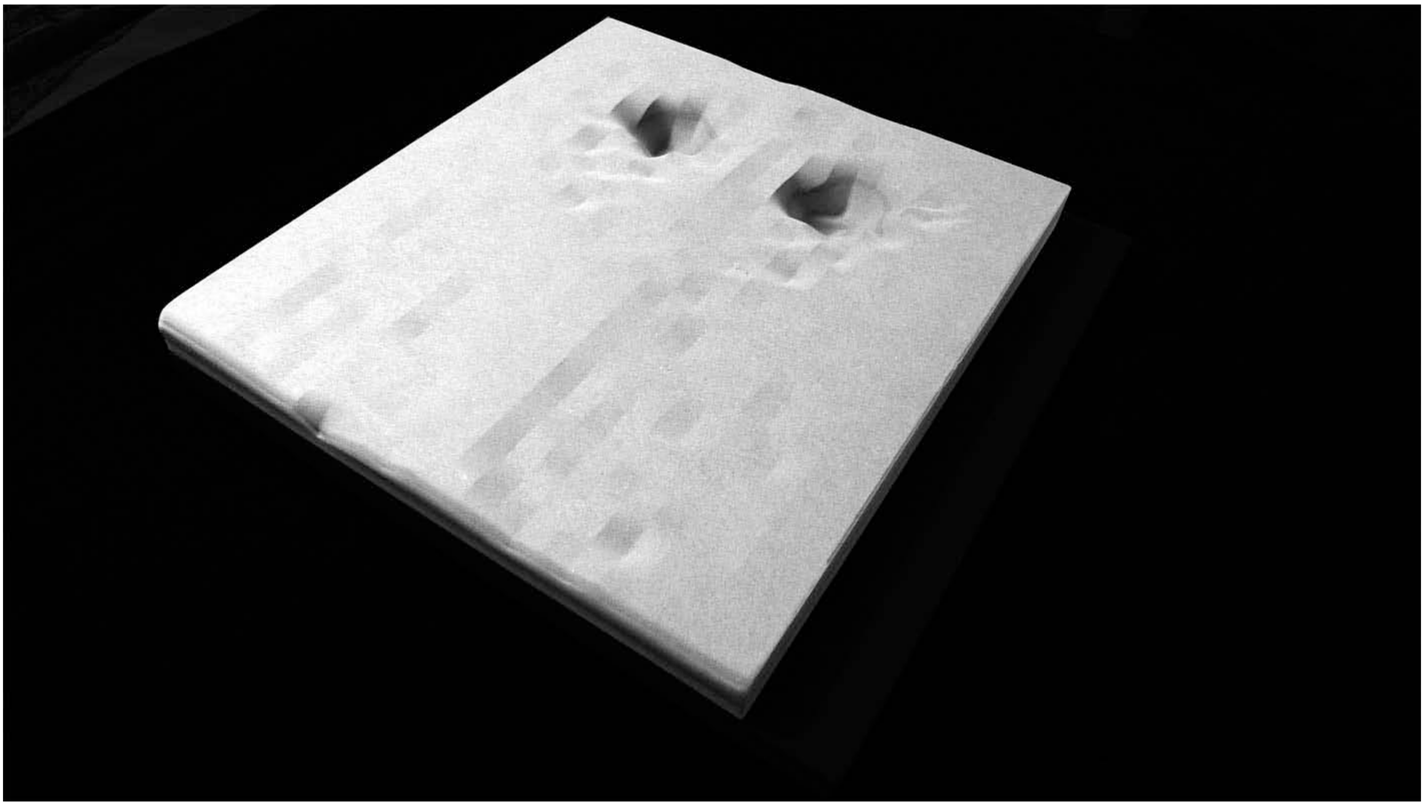

Figure 3 – First prototype developed in MDF

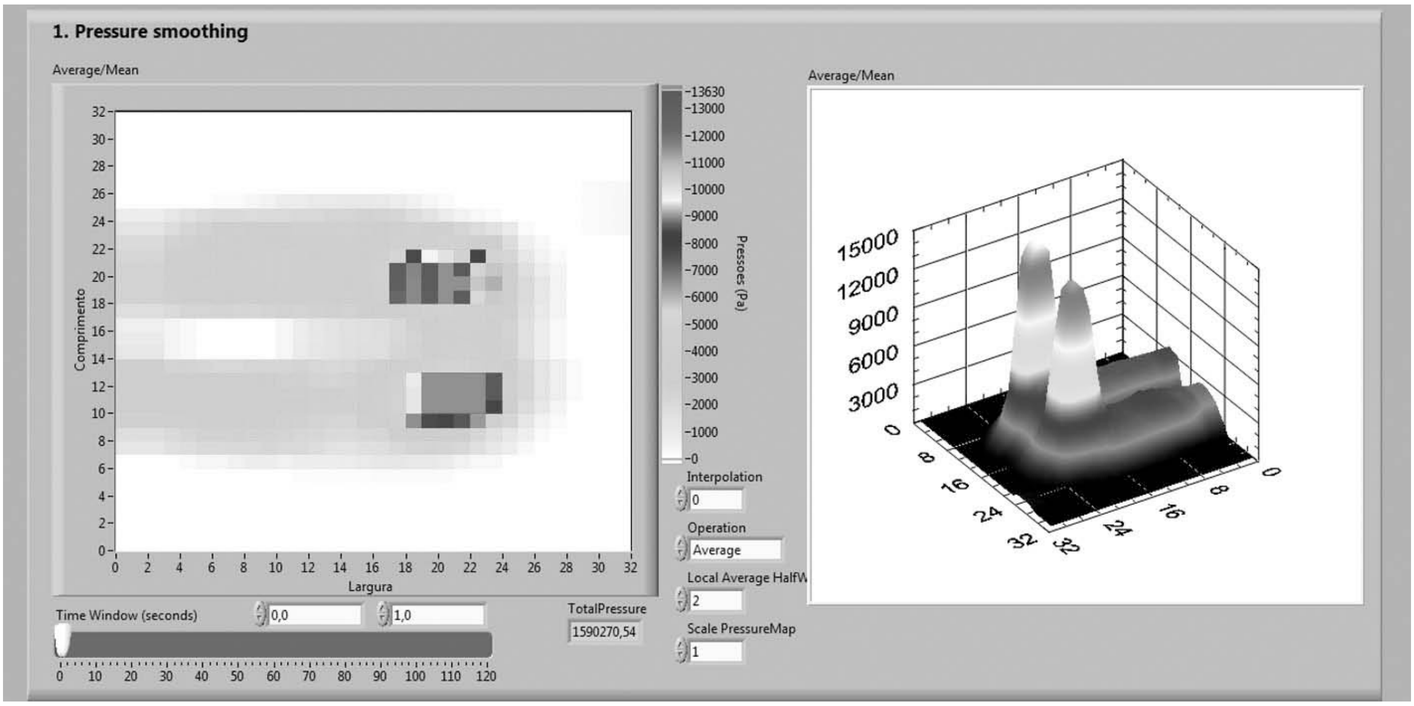


Figure 4 – Pressure smoothing graphs

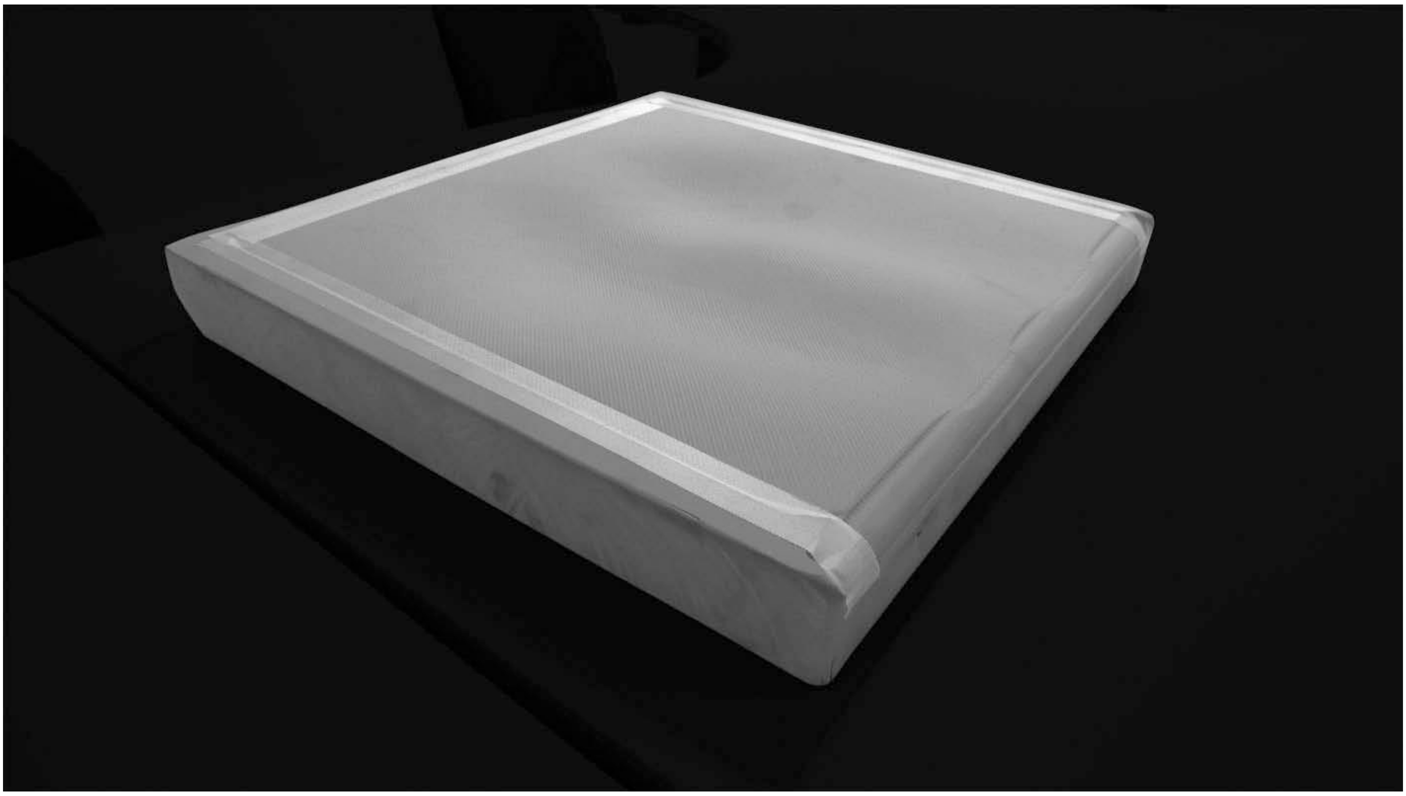

Figure 5 –Prototype evolution made with MDF

The analysis of the first prototype highlighted the following questions:

- How to control the excessively sharp depressions;
- How to control the demarcation by the way in which the loft was processed,
- How to avoid the texture marks caused by the milling.

### 4.2 *Sub-module 2 – Data analysis and reconfiguration*

As a way of answering these questions, the sub-module 2 of the core system was then developed, fallow three steps

Step A): Flattening the pressure map for a more distributed map.

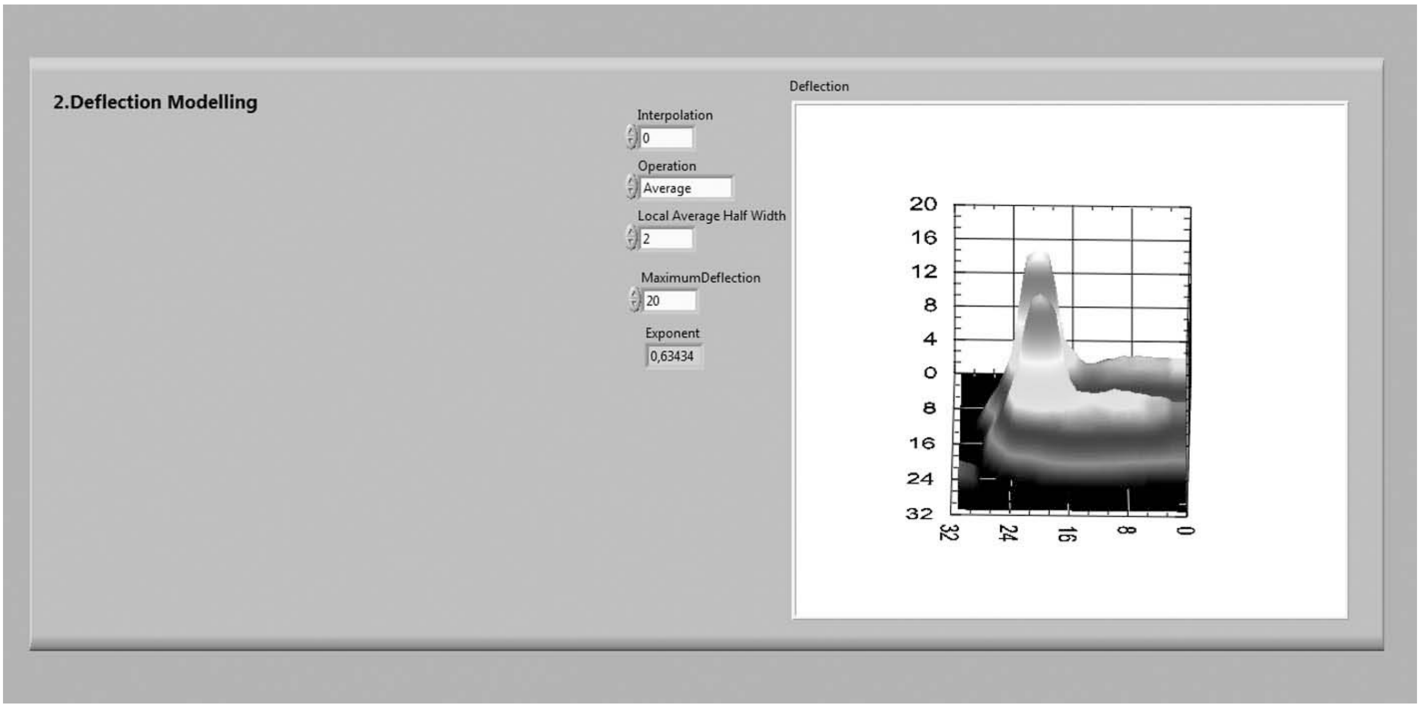


Figure 6 – Deflection Modelling

In a first step, a new pressure map is created, which represents the original map, but smoothed.This is achieved through an average or local median in each point. Each point is replaced by the average/median between itself and N of its neighbors in x and y-direction. The number of neighbouring points N allows controlling the degree of surface smoothness..

The operation of local averaging results in a sum of pressures that is different from the original sum. To correct this (because the sum of all pressures must be equal to the original, for it results of body weight) a scale factor must be used.

Step B): Smoothing of the surface produced from a loft

In order to improve the surface, a tool was used for the conversion of a point cloud into a surface.

This tool permitted to ensure that the morphological relation between points was identical regardless of the points acquisition order.

Step C): to avoid the texture marks made by the milling process, a spherical cutter of 12 mm diameter was used.

In step A, illustrated in figure 4, "pressure smoothing", we can see on the left side the mean pressure values. These values can be averaged or median and the values of the neighborhood can be calculated, thereby controlling the degree of surface smoothness.

The graph on the right side of figure 4 illustrates the smoothing in 3D giving a better perception of the results.

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In Point 2, "deflection modelling", the deflection maps are generated for the given desired maximum deflection (fig. 6).

For this purpose, the maximum desired deflection is imputed by the user. This value is related to physical factors , namely the height of the coccyx. The program applies an exponential to the original pressure map in order to fit the pressures between 0 and the maximum deflection desired. Then a smoothing is applied to the deflection map., Normally the same degree of smoothing used for pressure smoothing is applied.

4.3 Sub-module 3 – Build point cloud data that considers materials deflection

This sub-module aims to incorporate issues of material deflection, since the objective is to build a seat base in two layers, a rigid bottom layer and a top layer of a flexible material. To do so, it became necessary to study the foam behavior and the shape of the surface when using a flexible material (fig. 7).

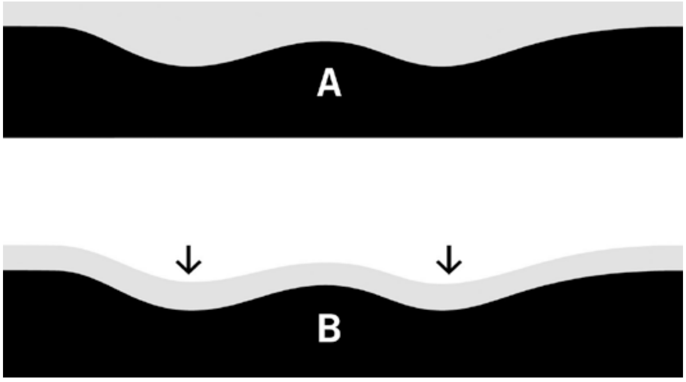


Figure 7 – Schematic representation of the two layers of the seat base. A) Initial state of the cushion; B) Cushion representation when in use.

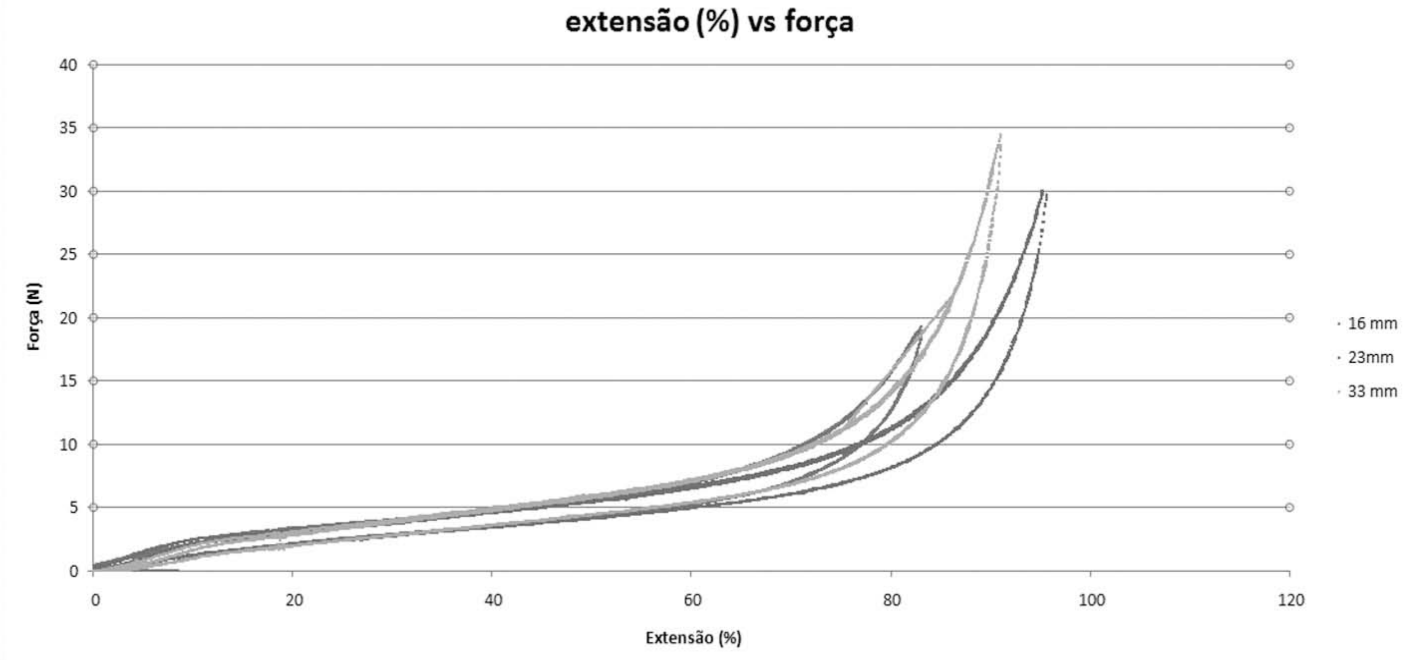

Figure 8 - Graph of extension (%) vs. force (N)

In Point 3, the viscoelastic foam to be used in the cushion is characterized by compression tests using a dynamometer, in order to determine the force/deflection curves.. Three different thicknesses of the same foam were tested and it was found that the relation between percentual deflection and force applied is equal for all thicknesses, up to about 75% of compression (fig. 8). At this point the foam starts to saturate. A polynomial interpolation is performed on the measured points and the resulting coefficients are input into the core system, that generates the pressure/deflection curve (fig. 9).

At this point the system has three pieces of information:

- The desired smoothed pressure map
- The desired smoothed deflection map
- The properties of the foam

For each pressure value of the smoothed map, and assuming that the behavior of each cell of the cushion is independent of the neighbours, it is now possible to compute the percentual deflection that the foam exhibits at the pressure applied. Considering that the desired absolute deflection is also known, it is possible to compute the height of the foam that should be used to match the percentual deflection..1. The system is now able to generate a surface representing the height of the cushion that will approximate the desired behavior best (fig.10). This method is an approximate method and the success of the end product depends on the choice of the foam. If the foam is too soft, for instance, the system will compute values of percenttual deflection exceeding 100%, The software limits the maximum deflection, but in practice this means that at those points the foam will be excessively compressed and pressure values will be higher than those computed form the pressure/deflection curve. This means that the desired smoothed pressure map will not be achieved.

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The choice of the viscoelastic foam was based on its good elastic recovery, allowing the non-deformation of the seat base; the fact that this type of material is being used in medical areas due to its antibacterial characteristics; and also due to the fact that it is an open-cell foam allowing better breathing of the skin when in contact with it.

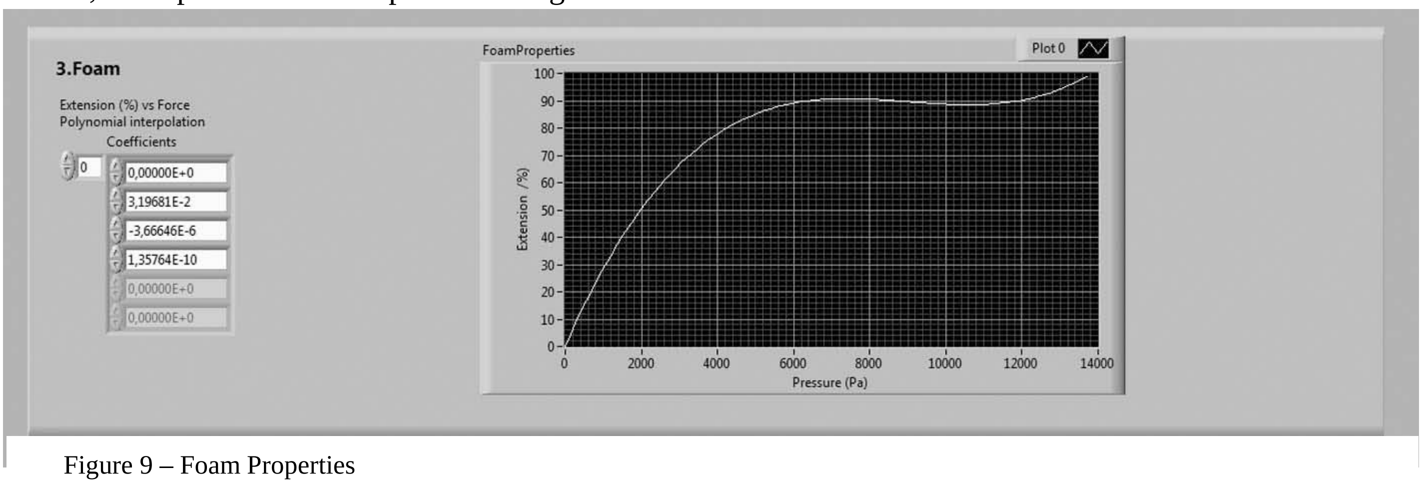

Figure 9 – Foam Properties

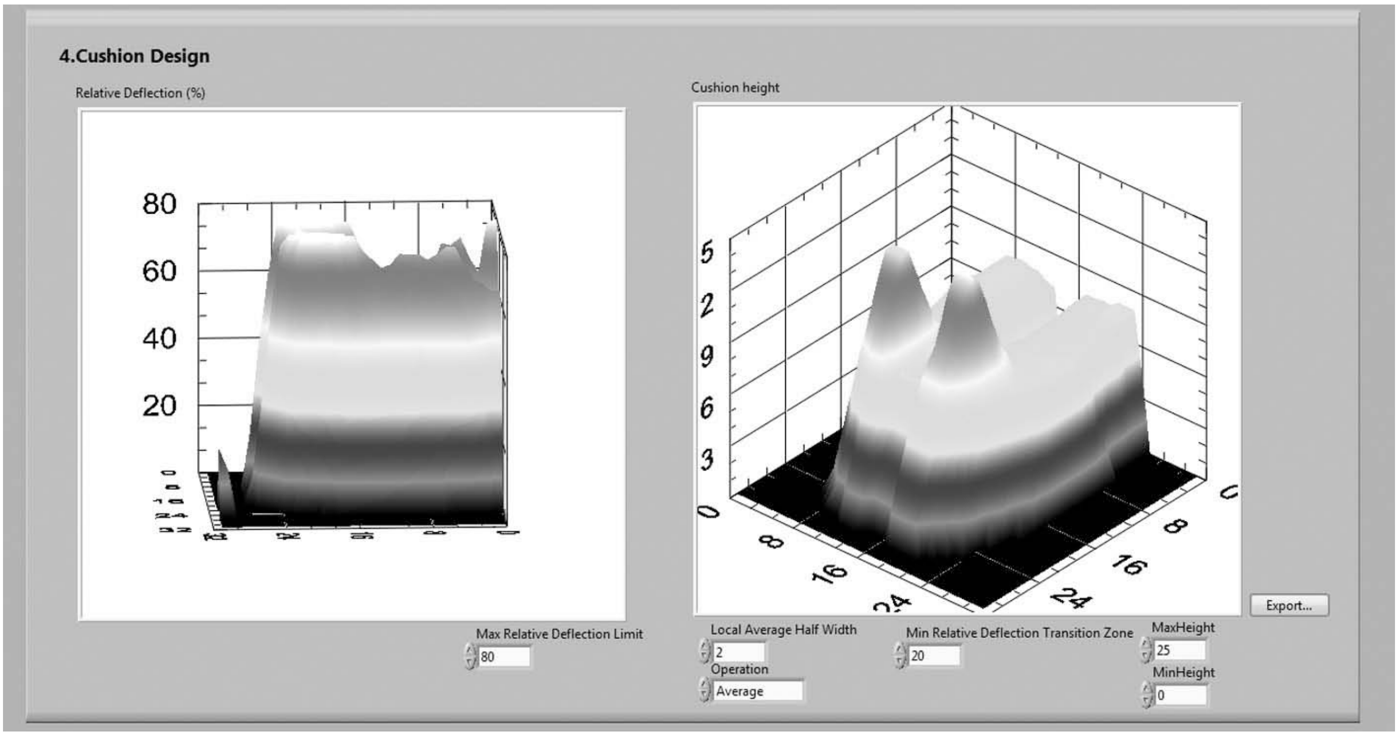


Figure 10 – Relative deflection computed on basis of the desired pressure map, cushion height map that matches the computed percentual deflection for the desired absolute deflection

On the left and right sides of the figure 9 the results of the final shape of the cushion can be visualized, considering the maximum and minimum thickness of foam.

The values obtained at the time of the data exportation are automatically converted to obtain not the pressure values but the final shape of the desired foam, where a better distribution of contact zones, minimizing the pressure in the critical points, is achieved.

The exported file, then results in a seat base which can be machined or printed from the rapid prototyping tools.

From the knowledge of materials, including the deflection behavior that was considered previously, the file downloaded to the CAD system considers the design of the base depending on its the thickness in view of the expected deflection, so that when under load the best desired shape is obtained for the patient.

## 5 CONCLUSION

The work presented here was designed based on two premises:

- to study a methodology based on the user, that would allow the development of product design in order to meet user needs;
- to develop a methodology based on the rapid prototyping or rapid manufacturing technologies to produce a customized product, responding to user needs.

Analysis and evaluation techniques, in combination with teams of psychophysics technicians, allowed during the evolution of the process to refine the model as well as the technologies designed.

This interaction gave an increasingly broad perception of the relationship of the user with the product experience, especially based on the emotional and discomfort relation.

As a final result we present the "core system" a tool for aiding people with special needs, which allows from the work with a collection of psychophysical data to create a txt file that can be read by a CAD system and in turn use these data on building a customized product.

In the tests that were done, according to the psychophysical teams, the result was quite interesting, with a better distribution of pressure and thus an expectable minimization of pressure ulcers and consequently a better quality of life of patients.

In future work, it seems that there is a large field study in the area of perception and interpretation of psychophysical data and in the development of more effective technology in supporting patients with special needs, either as an aid in the interpretation of data as in creating custom manufacturing solutions.

Similarly the technological developments and their democratization by an increasingly bigger offer by the industry, as well as ever more accessible values due to the competition, can be studied in order to understand which technologies to choose in response to custom fabrication solutions similar to these.

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