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# Auto-adjustable Bra for Women with a Pronounced Alteration in Breast Volume

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## Abstract

The auto-adjustable bra combines new technologies such as soft robotics, computational design, and e-textiles to develop a bra which uses a pneumatic system to compensate severe asymmetries in breast volume (Anisomastia). In the present work, the bra aims to adjust to the measurements of a woman's breasts through air channels which are located in the internal mesh of the bra cup. This inflatable structure gives a balance in the breasts' volume while holding them. Furthermore, the conductive fabric which covers the bra cup works as a sensor to control the air injection system by comparing the fabric's resistance in both bra cups to send a signal to the air pump to stop the air injection. Thus, the bra keeps in shape and the air pump is disengaged. The project could have a global impact on women with Anisomastia by raising their self-esteem, recovering their emotional balance, and possibly enhancing their social and sexual relationships.

## Author Keywords

Anisomastia; breast asymmetry; auto-adjustable bra; computational design; e-textiles; pneumatics; soft robotics.

## CCS Concepts

•Human-centered computing → Human computer interaction (HCI); Interaction design; User studies;

## Introduction

Ideals and stereotypes of body's image started in the earliest 1990s, gaining momentum in 1998. However, still in the 21st century, woman's body image, breast size, and their social implications remain in our cultural consciousness, so that, this topic becomes more significant in women with pronounced breast asymmetry condition (Anisomastia)[4][11].

This project faces this cultural thought of perfect breast perception, where breast has a significant impact on woman's shapes, and may, therefore, play an important role in body image. In this way, if the breasts differ substantially between them, it is possible a woman suffers an alteration of her body image. Consequently, it is not uncommon to find women who develop a withdrawn and introverted personality seeing their safety and self-esteem diminished [2].

### *Frequency of occurrence*

Breast asymmetry is found in the vast majority of women to a more or less visible extent (more than 90%, by some estimates). Asymmetry can manifest in different ways such as the size of the breast, the position of the nipple and areola, the angle of the breast or the position of the breast fold/root (where the breast meets the chest) [10], [6], (Fig.1).

Breast sizes can vary for different reasons including an indication of breast cancer risk. Furthermore, around 25% of women have asymmetry in breast volume of at least one cup size, approximately 10% of which, breast asymmetry is greater than that [3].

There are responsive technologies that shape-shift interfaces for people to interact with their computers or objects. Others help to program physical materials as were used in this project. This project's main contribution is to combine different digital fabrication techniques to develop a bra prototype that adapts to different breasts' size, thanks to



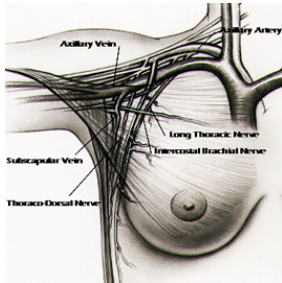
**Figure 1:** (From left to right) Types of breast asymmetry: degree of sagging, position on chest wall, nipple placement and shape. Image CC-BY-SA 2.0 rebecca\_verde on Flickr.

the parametric design used in the internal structure of the bra cup which includes the air channels. Now, women with Anisomastia can feel comfortable when wearing a daily bra that fits any breast measurement.

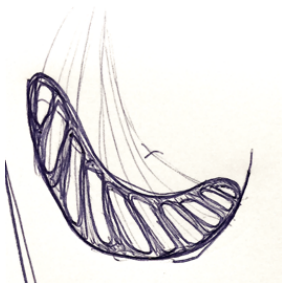
## Related Work

During the last years, the wearable technology industry related to smart bras has started increasing, and most of the projects developed in that field applied technology for biomedical purposes. The OMbra, which was introduced at "Consumer Electronics Show (CES)" 2016, aims to give women real-time biometric data while using sensors and textile technology to get an accurate electrocardiogram signal [9]. Another approach to this field is VITALI, presented at CES 2017 as a sports bra that has fabric sensors to track the breathing, and heart rate variability (HRV) with key physiological indicators of the balance between stress and wellbeing to train the nervous system to be more resilient.

Some projects' approach to shape-changing interfaces in the field of HCI is the Skinmorph, which was presented in the "International Symposium on Wearable Computers (ISWC)" 2018. This is an on-skin interface which can selectively transition between soft and rigid states to serve as a texture-tunable wearable skin output. The texture change is made possible through the material design of smart hy-



**Figure 2:** Anatomy of the Thoracic Wall, Axilla and Breast [7].



**Figure 3:** First sketch of the inflatable piece.

drophilic gels which are soft in resting state but when activated by heat ( $>36^{\circ}\text{C}$ ), they generate a micro-level structural change which results in observable stiffening [5]. Line-Form is another Shape-Changing Mobile Device that can be used as a wearable. This device can physically display expressive 2D and 3D shapes, both for information representation and for dynamic affordances. Users can interact with LineFORM through direct deformation and via touch to provide haptic feedback through variable stiffness joints to enable such interactions as physical snap to grid [8].

Finally, pneumatic systems have also been used as a shape changer. PneuUI is a project that enables technology to build shape-changing interfaces through pneumatically-actuated soft composite materials. It uses elastomer as a material that deforms uniformly under stress; however, by compositing different structural layers with various mechanical properties, the orientation of deformation can be pre-defined [12]. This last technology was incorporated in the project to control the air channels injection to shape and bring consistency to the internal mesh of the bra design.

### Implementation

The auto-adjustable bra focuses in developing a bra that can be worn by women with visible breast asymmetry not only for aesthetics but also for a functional purpose since the project efficiently incorporates different technologies during the prototyping process. Research and analysis of the breast physiology were crucial in this project in order to understand which tissues are part of the woman's breast and how they are arranged to bring natural support (Fig.2). After this analysis, sketches of the inflatable piece started coming out following the shape of the muscular tissue located in the woman's breast (Fig.3). Finally, a woman with Anisomastia was the case of study of this project, and the technologies applied on it went from scanning the woman's

breast, to work on a real 3D model, to incorporate e-textiles and pneumatics on the bra to achieve the project purpose which is to homogenize woman's breast volume.

### 3D Scanning & Laser Cutting

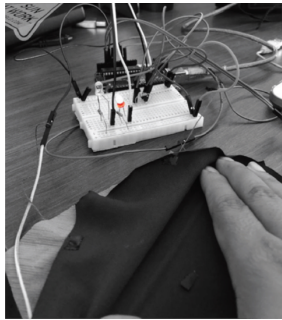
New digital tools that complement hand tools are necessary to design, represent, make and modify the human figure to be used as a canvas for creation later. The challenge in this project is to step away from a simple copy of the human figure as support of this work but start the creative process from the very beginning instead. The process of breast scanning was made with a 3D Systems Sense - 3D scanner. Then the file was edited to create a 1:1 scale mannequin where the bra prototype was tested as many times as necessary. The program Slicer for Fusion 360 was used to turn the digital 3D model into 2D patterns that can be cut out of any flat material, in this case, cardboard 4mm. This program exports EPS, PDF or DXF file format and they can be used to laser cut on any laser cutting machine. Finally, it was possible to make a 3D model mannequin using a press-fit technique (Fig.4).



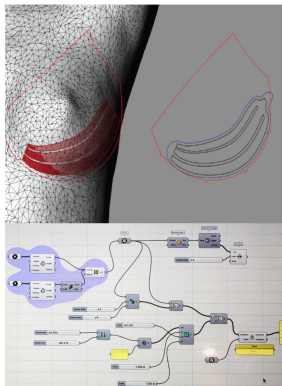
**Figure 4:** The process of making a 3D mannequin consisted of making and using 2D slices of cardboard.

### E-textiles & Wearables

Within the relatively new industry around electronic textiles, projects are pursued based on various kinds of functionality. Some electronic textile products may only be built for data storage, while others provide physical interfaces through



**Figure 5:** Conductive fabric: resistance tests.



**Figure 6:** Computational design using Rhinoceros and Grasshopper programs.

control elements in the garment design. In some cases, power sources such as batteries can also be integrated into clothing or fabrics. Some experts talk about the difference between embedding electronic devices in fabric, or actually layering conductive electronics into textiles to "make the fabric into the computer". This project is an example of using e-textiles as an interface to obtain data that let us control the bra's pneumatic system.

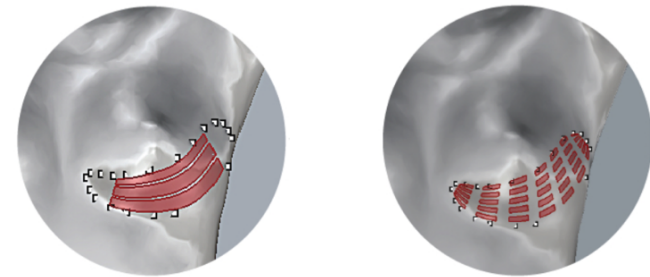
There are different techniques for making soft/flexible fabric circuits and the EonTex LTT-SLPA-2K fabric was very useful for this project. This fabric is a bidirectionally stretchy nylon/spandex, elastic fabric coated with a long-lasting conductive formulation and highly conductive with a tunable surface resistivity in the range of  $10E4$  to  $10E7$  ohm/square. Additionally, it is extremely flexible with a mass per unit area of 4.8 oz./sq.yd. and a warp of 198-248 with an 85% warp recovery [1].

The conductive fabric was used as a sensor in both bra cups, taking the fabric resistance data to send a signal to stop the air injection coming from the air pump when the conductive fabric located in the smaller breast reaches the resistance of the bigger one (Fig.5).

#### *Parametric Design*

Clothes can be considered as the very first form of mediators between body, space, and events. They aesthetically comprise not only the evolution of its relation to the physical functions of the body (movement, protection, temperature regulation) but also the evolution of cultural expression. Computational couture looks at the creation of exclusive custom-fitted clothing through the lens of a systemic approach, extending the sartorial techniques with 3D modeling and computation-based approaches developed in Rhinoceros and the visual programming environment Grasshopper (Fig.6).

The aim of this bra design is to perform, train and expand the sartorial sensibilities to body proportions and dress-making into an algorithmic approach that loops through design and digital fabrication. Exploring computational design methods towards a new reinterpretation of clothes, garments, and accessories for fashion design was the approach to use parametric design programs to develop not only the bra itself but also the bra's internal inflatable channels (Fig.7).

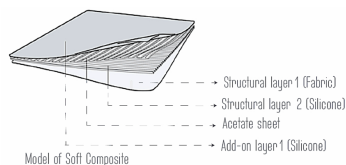


**Figure 7:** Iterations in the parametric design of the inflatable channels in the internal bra cup.

#### *Soft Robotics & Pneumatics*

Soft robotics is an emerging domain that is dedicated to robots comprised of soft components including soft actuators, flexible sensor/circuits, and soft bodies. This field often focuses on pneumatic actuation of elastomeric channels and bladders. Pneumatic actuation is chosen because air is a lightweight, compressible and environmentally benign energy source [12]. Thus, there is a large space to introduce soft robotic technology in constructing shape-changing interfaces as in this project since the elastomer itself deforms uniformly under stress.

The process of making the inflatable piece attached to the



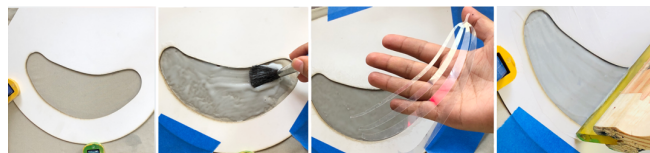
**Figure 8:** Model composition of the internal mesh of the bra cup.



**Figure 9:** View of the inflatable channels in the internal part of the bra cup.

interior side of the bra cup, started by pouring silicone and spreading evenly over a mesh of fabric. This action happened inside of a mold, which was previously defined by the parametric design. Finally, an acetate sheet laser cut in the shape of the air channels was located over the first layer of silicone when it was still sticky. Finally, the last layer of silicone was poured over the acetate piece and spread out evenly using a hand tool (Fig.10). The thickness of the material used as a mold is something to have in consideration in order to have enough space to put the acetate sheet in between the two layers of silicone. For this project, the mold piece had 2mm. thickness.

The acetate sheet main function is to be a path where the air flows to take the form that was defined previously in the parametric design. This is possible because it works as an insulating material since it does not get attached to the silicone. The following figures show the composition of the inflatable piece and how it looks like with some air injected (Fig.8), (Fig.9).



**Figure 10:** Process of making the inflatable piece.

### User Experience Evaluation

The auto-adjustable bra was tested on 3 personas with different types of breast asymmetry. The users described the experience as comfortable and no invasive, even though they could fill the inflatable piece growing when injecting air (Fig.11), (Fig.12).

Persona 1: She is 28 years old and she has a shape breast

asymmetry which means that both breasts do not fit the regular bra cup sizes, leaving a gap between the breast and the bra cup. This user described the experience as comfortable and problem-solving. She also was surprised because the inflatable structure helped to lift up both breasts.

Persona 2: She is 29 years old and she has degree of sagging breast asymmetry which involves a lack of fullness in the lower portion of the breast. She has this condition in the left breast and she described the experience as amazing. She said she can't wait this project to be a product because the bra helped to look her breast symmetric.

Persona 3: She is 27 years old and she has a shape breast asymmetry. She described the experience as incredible because the bra design adjusts to her breasts' measurements and also it looks nice. She also liked that no wire supports were included in this bra prototype.

### Acknowledgments

Thanks to Katia Vega for her guidance, advice, and support, and Sarah Reboloso for the great talk we had about women in society and how to address a topic like woman's breast asymmetry in a pre-established cultural context.

### Conclusion

The auto-adjustable bra project combines various digital fabrication techniques and new technologies such as soft robotics, computational design, and e-textiles to develop a bra that adapts to any breasts shape in women with Anisomastia. The bra uses a pneumatic system to compensates the severe asymmetries in breast volume through air channels situated in the internal mesh of the bra cup. This approach would help women with Anisomastia to feel more comfortable and look good wearing a bra that fits any breast measurement.





**Figure 12:** Internal and external view of the bra prototype.



**Figure 11:** Women with different breast asymmetry testing the auto-adjustable bra.

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