Make-A-Morph: Exploring the design space of inflatable devices made from planar fabric

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Abstract
Developing inflatable devices from planar fabric is a new versatile fabrication process that allows the development of complex geometric shapes with a beneficial mass to robustness ratio. However, designing and fabricating with this matter is complex, and the existing design primitives for shape change can constrain designers' creativity. We present a pipeline that allows users and designers to explore and compose with various shape-change primitives. To this extent, we rely on digital simulation combined with a simple digital fabrication tool. This pipeline allows to explore and visualize deformation and develop new application cases for shape-changing interfaces. We propose a workshop around manipulating these tools to foster discussion between designers and researchers around the future of shape-changing interface fabrication.

Keywords
Inflatable, Tangible Interface, Shape Changing, Computer Assisted Design (CAD), Digital Fabrication

1. Introduction

Previous works on shape-changing interfaces have demonstrated that inflatable devices made from planar fabric are doted of various advantageous features, from robustness [1] to versatility [2, 3]. The principle in those examples is to seal (most of the time using heat-sealing technology) two sheets of airproof fabric in a specific pattern to obtain a specific deformation when inflated. In aeronautics, where heavy mechanical devices are traditionally used [4], portability can be used as an advantage: deflated devices can be rolled up and are not submitted to breakage as other extra-light materials such as Styrofoam or aerogel silica can. It is also relevant in interaction since shape-changing interfaces can offer new dimensions for tangible interaction by providing dedicated form constraints or specific feedback.

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Programming the controlled deformation of an inflatable shape-changing interface remains challenging. As of now, the design of such devices is complex, and the design primitives defined in previous works [2, 3] exploring shape-changing behavior are either created with vast knowledge in mathematics and material science or rely on a long trial-and-error process. Furthermore, the fabrication is often performed manually, involves iterations, and is challenging to reproduce.

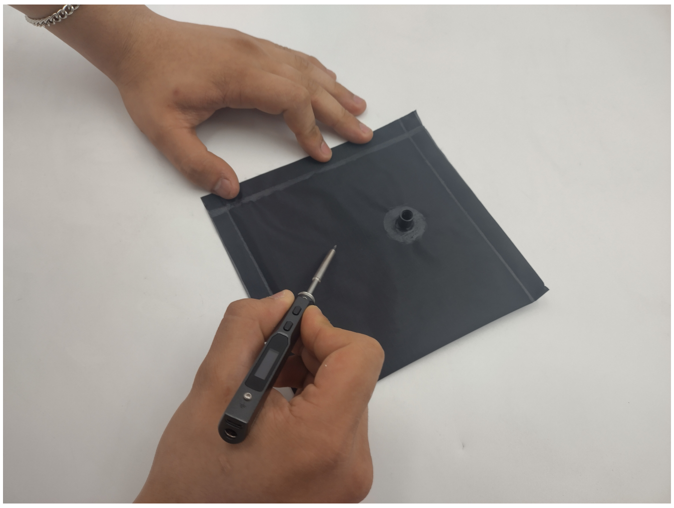


Figure 1: Figure 1: Pre-sealed pocket used to start the exploration with a soldering iron

We developed a pipeline that addresses these challenges. It relies on a modeling software simulating the result of any given sealing pattern and generating the files necessary to realize it depending on the chosen fabrication method. The fabrication can be done with equipment accessible in most maker spaces, such as soldering iron or laser plotter, as presented in [2]. Moreover, it does not require complex assembly like screws or nails and uses off-the-shelves or up-cycled materials from nylon fabric to chips bag [5].

We propose to conduct a workshop that explores this technique. We will rely on a set of computational tools that enable users to experiment with a set of primitives and allow easy fabrication. This exploration allows the creation of custom patterns and variations in a free-form workspace and simulates the resulting deformation.

We argue that manual fabrication is a great way to be familiar with the design opportunities, constraints, and capabilities of a process or a fabrication method. The users will manipulate and play with the identified primitives on pre-sealed pocked (Figure 1). Through this workshop, we aim to understand better this technique's opportunities and limitations and foster discussion among the HCI researchers.

2. Workshop

This workshop is part of a more extensive study aiming at developing new tools for creating shape-changing devices. It intends to deepen our comprehension of the previous results concerning the limitation of the fabrication technique, the process, and the expected outcome and to gather valuable feedback from the HCI community.

In this workshop, we will explore shapes and functions developed by novice users in shape-change. As such, the goal is to:

- have finished shape
- having feature oriented device
- share knowledge in fabrication process among participants
- explore and discuss a new tool with participants

2.1. Steps

The Workshop will be articulated in the following phases:

- Introduction to the workshop, the design principle behind baromorphic object and problem statement *(20 min)*
- Group creation (ensure mixed background) and theme choice *(10 min)*
- Hands on manipulation, application of the design principle and first iterations *(45 min)*
- First feedback break and discussion *(10 min)*
- Introduction to the software *(10 min)*
- Conception and Iteration through the software *(45 min)*
- Second feedback break and discussion *(10 min)*
- Presentation of our pipeline to produce inflatables from start to finish (10 min)
- Fabrication and test of each group concept *(60 min)*
- Feedback and open talk about possible future application of the technology *(20 min)*

2.2. Participant

This workshop aims to host between 8 to 15 participants to cover comprehensive application cases while offering each one the possibility to experiment with the technique manually. No knowledge in fabrication processes is needed. Depending on attendance, the participant will be paired in groups of two to three.

2.3. Apparatus

Digital tools and materials used will be brought by the workshop organizer. It consists of soldering irons for the hands-on manipulation time and a custom-built machine to draw more accurate shapes and materials in the form of:

- Pre-made pocket to explore manually the design primitives
- various material from nylon fabric TPU coated to mylar and other up-cycled materials from diverse sources.

Participants are required to bring their computer with a running rhino 7 software [6] the free demo version is sufficient.

3. Results

The thirteen participants were divided into four groups of three to four. They were introduced to the design principle behind inflatable and left free to discuss what kind of device they wanted to develop during the workshop.

3.1. Intention definition

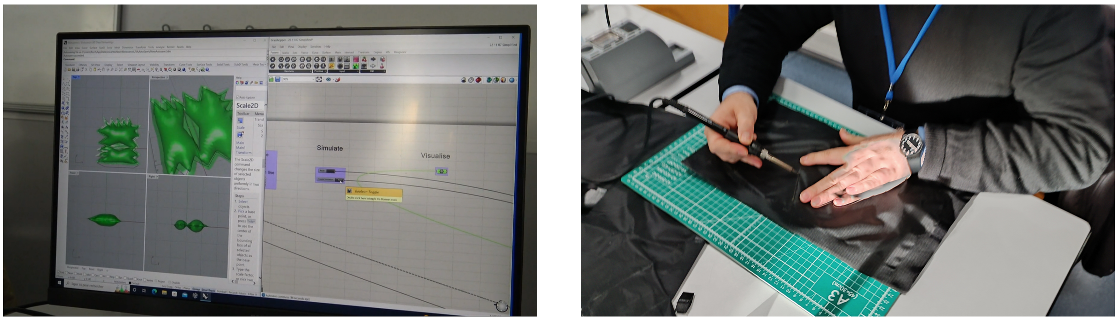
Each group came up with ideas exploiting different particularities of inflatable devices.

- One active scarecrow monster: a device that deploys violently to scare birds or other incommodities using inflation-induced movement.
- One inflatable cushion: an inflatable cushion that can deploy everywhere, taking advantage of the device's two states (inflated and deflated).
- One breathing/distress aid: the group used the slowness of the airflow as an advantage to press and relax while the user feel the air pass through a tight seam from one pouch to another.
- Exploration of the textures changes through inflation. The group focused on the change in shape and feel of the material when inflated.

3.2. Digital and physical prototyping

The participants reported an interest in simulating and visualizing their prototype on a computer however it was pulled back by the work-in-progress state of the software.

On the other hand, the physical manipulation did not come as a difficulty for the participants, who rapidly used their newly developed knowledge of the material to realize the prototype of their intended design.



(a) Simulation of inflation of a digital prototype

(b) Fabrication of a physical prototype

Figure 2: Prototyping of the design ideas

3.3. Testing

At the same time as the physical prototyping part, the participants took on themselves to try and test their prototype, evaluating the success of their first intention. They graded their results on an average of three and a half on five, with nine out of ten evaluating it at three or higher.

(a) Test of the cushion prototype regarding resistance and comfort

(b) Scarecrow prototype before inflation

(c) Scarecrow prototype after inflation

Figure 3: Participants testing their design ideas

4. Future works

Previous workshops were preliminary works oriented toward the field of aeronautics. In contrast, this one aims to extend it to a larger audience and explore the synergy possible with other fields. The goal was to grasp opportunities for HCI tangible interaction. Results of these workshops may have relevance in future paper publications.

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