ActuAir: Exploring Physicalizations of Air Quality at the Workplace

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Research highlights the importance maintaining good air quality (AQ) (CO2:400-600 ppm) to support wellbeing at the workplace. Although AQ is generally monitored in office spaces, it is not always easy to manage e.g. during meetings. Remote work and the domestic workplace have additional complexities; AQ is often not monitored, and people are often unaware of the air quality levels. This project proposes an exploratory design solution to the above, through physicalizing changes in AQ levels through shape-changing silicon and fabric components. These components can be put together and be re-arranged by their users to form soft barriers in the domestic and office workplace. Each operates with a wireless Arduino connected to a local server fetching AQ data (CO2, temperature, humidity); enabling them to act as stand-alone or in coordination with other components. The result is a soft actuating barrier - a biomimetic envelope- which expands and contracts using air pumps and muscle wire based on AQ levels, providing a physicalization of data in place, raising awareness on air quality and supporting wellbeing at the workplace.

CCS CONCEPTS • Human-centered computing → Human computer interaction (HCI) → **Interactive systems and tools**

Additional Keywords and Phrases: Soft robotics, Actuated Materials, Interactive Architecture, Air Quality, Workplace

1 INTRODUCTION

Soft robotics applications have unexplored potentials in the field of human-building-interaction and interactive architecture. As buildings become increasingly sensory- enhanced and data-rich [5, 17], new opportunities emerge for such soft robotic architectures based on based on accumulated occupant and environmental data. Past example projects involve soft robotics in architectural facades [3, 5, 8, 17] e.g. pneumatic elements that actuate based on external environmental data to improve building's microclimate. Breathing Skins Project by Tobias Becker is an example of pneumatic actuators composing the walls of a pavilion, assisting with filtering air in and out of the pavilion and controlling it's temperature (**see Figure 01 A**). Other examples include interior soft installations that physicalize data for awareness and behavior change [6, 19], and soft furniture for wellbeing e.g. adaptive 3D printed seating to assist with posture correction [1]. The concept of biomimicry [3, 16] in these soft architectures e.g. the imitation of organic patterns, features and adaptive processes observed in nature, has empirically associated with wellbeing benefits for the building occupants [16]. Soft material actuations can provide a slow organic feedback and assist with de-scaling cognitive load, enhance connection with nature and bodily processes, acting as data-driven adaptive restorative environments. With the focus on interior workplaces, soft material actuations can enhance the adaptive capacity of indoor spaces e.g. work-desks that support different physiological and psychological needs e.g. breathing regulation and stress and fatigue restoration, and the wider social and environmental wellbeing of the building's occupants.

Figure 01

Covid-19 has imposed major changes in the ways and places we work. Remote work and the home office have been established as a long-term alternative; even post-pandemic [7]. The home office is un-monitored in terms of environmental aspects such as AQ, giving rise to development of varied technologies that support the wellbeing of the remote worker [10]. The pandemic also highlighted the importance of monitoring AQ in workplaces, and the difficulty managing it in shared spaces and at home [20]. Recent HCI research emphasizes in raising awareness for AQ levels and involving the building occupants in managing their spaces– Hilo-wear [20], an example project, supports wearable notifications on indoor and outdoor CO2 levels.

This project is a Research through Design (RtD) exploration addressing the above challenges and opportunities around AQ awareness and restorative spaces through soft actuations in interior architectural elements. Modular room dividers made from felt fabric and silicon actuate physicalizing real time and historic AQ data (CO2, VOC, humidity, temperature) in the workplace, raising awareness on AQ levels while acting as a restorative environment, aiming to support wellbeing through ambient and tangible interactions.

We briefly demonstrate the challenges and opportunities related to the design, fabrication, and installation of a soft robotic room divider for human-data interaction in the built environment. We are going to discuss the making, next steps, challenges and possible extensions to this project to improve material aspects expand it into a wider wellbeing and sustainability agenda.

2 MAKING PROCESS

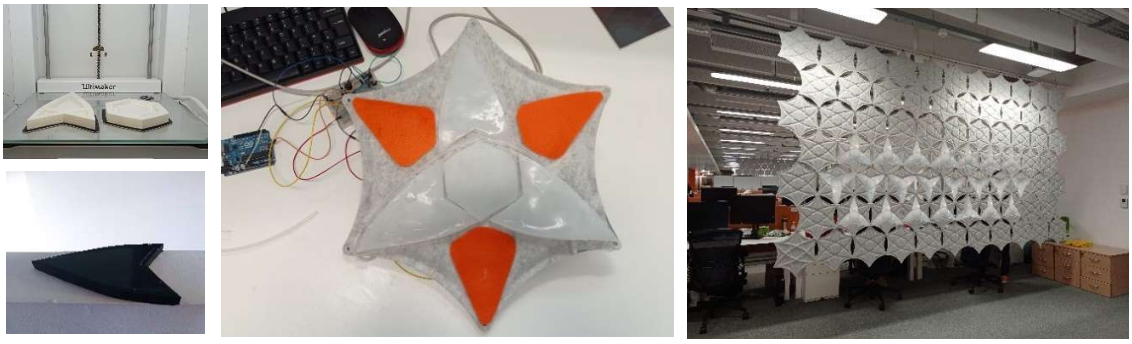
2.1 Design and Material Exploration

The project physicalizes changes in AQ levels through shape-changing silicon and fabric components (**see Figure 02 B**). These components can be put together and be re-arranged by their users to form soft barriers in the domestic and office workplace. Each component operates with a wireless Arduino connected to a local server built on Raspberry pi. The server is fetching AQ data (CO2, VOC, temperature, humidity) and wirelessly communicates with the Arduinos which control the air-pumps and valves for each component e.g. the amount of air pumped in and out, and the time they stay inflated or pulsing. All hardware (Arduinos, air -pumps and valves) are integrated in each component, enabling them to act as stand-alone and in coordination with other components. AQ data is made available through an open API provided by the building, which includes real time and historical (24-hour timeframe) sensory readings (CO2, temperature, humidity) of the building's rooms. We use BME680 AQ break out to enrich the data stream when needed (using VOC measurements). Additionally, we use Luftio's API (see https://luftio.cz/) to be able to use the components at home or at a remote desk.

The fabrication process (ongoing) involves experimentation with form-finding, materials and shape changing capacity, as well as with testing different workarounds to achieve the best result. We chose to 3D design (Rhino 3D software) and 3D print molds which are then used to create silicon pouches using EcoFlex-0030, following the patterns in prefabricated felt components (**see Figure 02 A**). At the stage, the silicon components that are created are expanding and contracting using air pumps. The silicon is glued to the felt fabric using Sil-Poxy. We experiment with thermochromic pigments mixed with silicon and muscle wire embedded in felt and in silicon to maximize shape change effects [11, 13, 16, 18].

2.2 Ambient Feedback and Tangible interaction

The component pulse when there is a change in the data; and stay inflated in proportion with the actual AQ levels. The users will be able to move around these modules and experience AQ in different parts of the workplace. The users will be able set the 'data sensitivity' of each component by pressing the middle part on each, deciding how much and how fast they can expand based on what AQ levels e.g. initiated shape change when a small change occurs, or only a critical change occurs. The desired result is a soft actuating barrier which expands and contracts using air pumps and muscle wire based on AQ levels, providing a physicalization of data in place, raising awareness on air quality and supporting wellbeing at the workplace (**see Figure 02 C**).



A B C

Figure 02

3 CHALLENGES AND OPPORTUNITIES

Challenges of expanding the soft robotics agenda for the workplace are infrastructural constraints to support the function of robotics in interior spaces. Soft robotics usually operate with motoric actuators and air pumps, which produce noise. Voiding air pumps and noise has been achieved through electrohydraulic actuators [14, 15], which have a different fabrication process (e.g. using air-sealed soft pouches filled with dielectric silicon oil) but can potentially be combined with other materials such as silicon pouches to produce different shape changing effect. Alternatively, ways to noise-seal the air pumps while maintaining the system's portability and adjustability will be an ongoing challenge.

3.1 Next steps

This is a work-in-progress which we hope to strengthen through the participation in this workshop. Next steps in making experimentation include:

- Further experimentation with electronics and fabrication processes e.g. blending electrohydraulic actuation with silicon modular systems.
- Thermochromic change in silicon using pigments e.g. filling up silicon pouches with electricity-heated air or liquids.

- Further examination of form factors in silicon architectures with adaptive openings and heated parts to assist with indoor air circulation through stack effect.
- Combination of the above silicon structures with air filtering fabrics (e.g. Fiberglass) enhanced with color changing capacity.

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