IVORY: A Tangible Interface to Perceive Human-Environment Interrelationships

Jessica Broscheit
Hamburg University
of Applied Sciences,
Berliner Tor 7,
D-20099 Hamburg
jessica.broscheit@haw-hamburg.de

Kai von Luck
Hamburg University
of Applied Sciences,
Berliner Tor 7,
D-20099 Hamburg
kai.vonluck@haw-hamburg.de

Susanne Draheim
Hamburg University
of Applied Sciences,
Berliner Tor 7,
D-20099 Hamburg
susanne.draheim@haw-hamburg.de

TEI '19, March 17-20, 2019, Tempe, AZ, USA.

ACM ISBN 978-1-4503-6196-5/19/03.
DOI: https://doi.org/10.1145/3294109.3301266

Abstract
In this paper we explore human-environment interrelationships by utilizing both hybrid materially-oriented approaches and metaphorical representations. Inspired by the 'canary in a coalmine' metaphor we developed a tangible interface to sense the environment and provide a physical experience. The design utilizes life-like characteristics, like shape memory alloys and feathers to illustrate the metaphor. The aim of this approach is to propose a tangible interface as a mediator to provoke empathy for environmental issues. For that, the paper addresses an interdisciplinary field of design, society and technology through an embodied system.

CSS Concepts
• Human-centered computing~Haptic devices
https://dl.acm.org/ccs/ccs_flat.cfm

Author Keywords
Tangible interface; shape-changing material; shape memory alloy; particular matter; environmental-feedback; information visualization, metaphorical representation.

Introduction

Invisible and irreplaceable, air is an essential element which creates a seamless matrix on earth's atmosphere interlinking everything. This invisible matrix of gases, particles, and liquids is in a continuous state of change [1]. Due to its constantly changing nature, air provides a complex system of differing air qualities which also depends on human activities [2]. This research seeks to convey the complexity of anthropogenic impact more comprehensible through a physical experience. Therefore, we introduce a tangible interface for perceiving human-environment interrelationships by utilizing both hybrid materially-oriented approaches and metaphorical representations. First, we consider the background and theoretical concept based on the historical genesis of the canary in a coalmine and the issue of air quality. Second, we discuss related work on shape memory alloy. Third, we describe the implementation details of the prototype. To sum up, this paper presents a design-orientated exploration that reflect on hybrid materials and environmental dimensions.

Background and Theoretical Concept

In the era of the early coal and steel industries, miners were confronted with the danger of hazardous gas mixtures in shafts, caused by underground fires or explosions [3], [4]. The miners could not sense the odorless gases and would pass out without warning. For their protection, canaries were utilized as a bioindicator, to detect gases like carbon monoxide [3]–[7]. For that, the canaries were trained to sing underground [7].

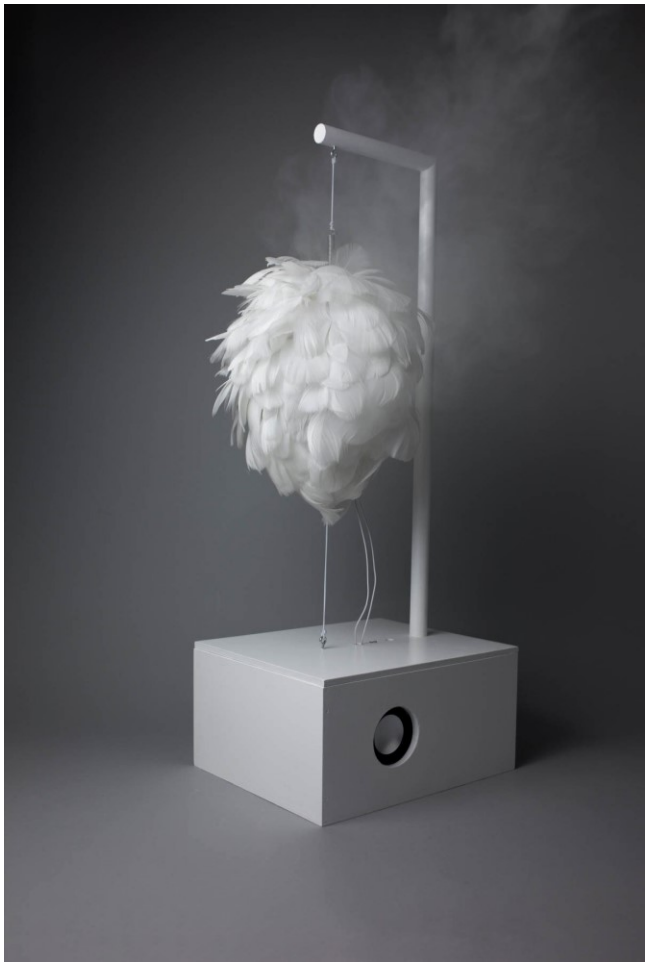

Figure 1: IVORY illustrates the limit values of particulate matter ($PM_{2.5}$) utilizing both hybrid materially-oriented approaches and metaphorical representation.

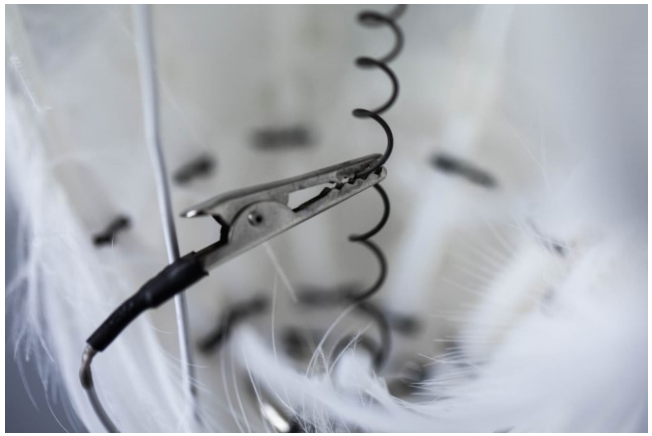

Figure 2: The shape memory alloy spring is placed in the center of the construction to generate the kinesis of the prototype.

If the air reached high concentrations of carbon monoxide, the canaries would drop from their perches. The collapse of these sensitive organisms provided the miners with the necessary time to initiate security procedures [3]. Nowadays, these birds no longer act as indicators for carbon monoxide in underground environments, but the 'canary in a coalmine' metaphor still exist to describe warning of some danger. As alternative to bioindicators, there are various sensor technologies to monitor the environment ubiquitously [8], [9]. These technologies not only gathers data about environmental conditions, but also about human activities [10]. Hence, they are capable of recognizing both the change of air quality and the impact of human activities. Thus this complex system provides differing air qualities for human respiration [1]. This is especially true for the air pollution provoked by particulate matter. Particulate matter (PM) is a complex mixture of solid and liquid concentrations, measured in mass per volume of air (µm/m3). These particles are categorized according to their aerodynamic diameter as follows [11], [12]:

- PM10 are particles with a diameter <10 µm;
- PM2.5 are particles with a diameter <2.5 µm;
- UFP are ultrafine particles with a diameter <0.1µm.

Moreover, particulate matter consists of gaseous air pollutants—like nitrogen oxides, carbon monoxide, sulfur dioxide, and ozone—and has an impact on the environment and affect human health on a global scale [12], [11]. For instance, particulate matter ($PM_{2.5}$) and UFP are not only capable of entering the respiratory tract, but also the bloodstream, and can cause respiratory and cardiovascular health problems [11], [12]. Due to significant environmental changes caused by anthropogenic impact, this research utilizes the 'canary in a coalmine' metaphor as aesthetic mediator to evoke empathy for environmental issues.

Related Work

With the vision of ubiquitous computing, referring to Mark Weiser, the third era of computing is characterized by a world of connected and imbedded interfaces through a network of low-power computers [8]. These interfaces require novel communication approaches between human and computer to fit technology into everyday live [8], [13]. In particular, tangible user interfaces (TUI) provide a communication system that embody digital information and enrich the physical space for human interaction through both thoughtful designs and haptic materials [14]. As an example, various TUIs utilized shape changing materials to represent digital information as dynamic stimuli [14]. Additionally, the potential of shape changing approaches has been explored in various studies on tangible interfaces and electronic garments [15]–[19]. *'Surflex'* is a soft interface to enable physical computing interaction. For that, shape memory alloy springs deforms the surface to provide a programmable system for embedded computing [15]. *'Shutters'* is a curtain composed of actuated louvers. These louvers utilize shape memory alloy for environmental control [18]. *'Caress of Gaze'* is an interactive garment, that utilized eye gaze tracking technology to control a 3D printed body architecture via shape memory alloy [20]. These different approaches

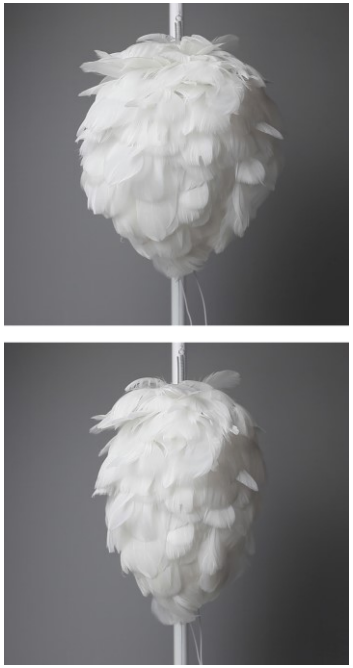

Figure 3: On-and-off state of the prototype.

rethink interacting with the environment through shape changing dynamics [17]. For example, shape memory alloy (SMA) is made of thermomechanical material that can be addressed through an electrical stimulus [19]. The thermomechanical material memorizes its original shape and provides a life-like transformational potential through heat control. Thus it provides a dual process between malleable and definite state, as well as silent and life-like dynamics [19]. This study combines the abovementioned approaches with metaphorical representations to enhance the potential of human-computer interaction.

System Implementation

The intention of this design research is to explore human-environment interrelationships by utilizing sensor technologies, shape memory alloys and metaphorical representations (Figure 1). Therefore, the process of system implementation contains three sections. First, it illustrates the fabrication process to convey the concept of visual rhetoric. Second, it specifies the human-computer interaction according to the bird behavior. Third, it describes the details of the hardware-module.

Fabrication:
To convey the 'canary in the coal mine' metaphor, the design seeks organic materials and life-like characteristics. For this, the artefact utilizes feathers as bird reference. These feathers are attached to a kinetic construction to simulate the dynamics of respiration (Figure 3, 4). For that, a shape memory alloy spring was installed in the center of the kinetic construction, to provide a malleable and life-like dynamic of the artefact.

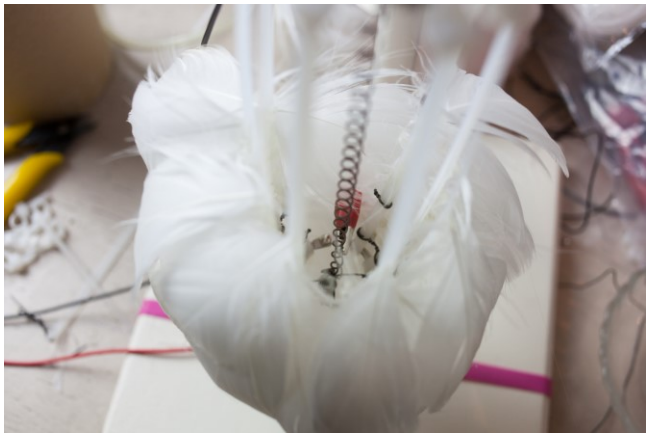

Figure 4: Fabrication of the kinetic construction.

Interaction:
Similarly, for the behavior of the canary, the prototype 'sings', 'breathes' and 'sleeps', depending on the environmental conditions. For that, three different interaction modes were designed to perceive particulate matter through the tangible interface:

- Convenient mode: If the values of particulate matter ($PM_{2.5}$) are good or moderate, IVORY 'sings' and 'breathes'.
- Threshold mode: If values of particulate matter ($PM_{2.5}$) are above the threshold value, IVORY stops 'singing' and 'breathing'.
- Sleeping mode: If IVORY has to 'sleep', it can be covered with a blanket, then it stops 'singing' and 'breathing'.

Hardware-Module:
To implement the interaction, a hardware module was developed. The module consists of a microcontroller

Arduino Mini [21], particle sensor SDS011 [22], shape memory alloy spring [19], photoresistor, soundboard and speakers. The sensor SDS011 measures the optical density of air and transmits the $PM_{2.5}$ data to the microcontroller Arduino. The program on the microcontroller Arduino maps the data to control both shape memory alloy (SMA) and soundboard. Technically, the shape memory alloy spring simulates the 'breathing' of the tangible interface and synchronizes the sound (Figure 4). To activate the 'sleeping-mode' the photoresistor measures the ambient light. If the tangible interface is covered under a blanket, the process of 'singing' and 'breathing' stops.

Conclusion

This paper introduced a tangible interface that reflects on human-environment interrelationships by utilizing both hybrid materially-oriented approaches and metaphorical representations. Our intension was to develop a tangible interface as a mediator to provoke empathy for environmental issues through the 'canary in a coalmine' metaphor. The tangible interface senses particulate matter ($PM_{2.5}$) and transforms the data into kinetic dynamics supported by sound. For that, the shape memory alloy provides a life-like characteristic and illustrates the abstract representation of 'the canary in a coalmine' metaphor. By presenting the tangible interface in the CSTI lab, the tangible interface aroused immediate interests from the audience. Further work is required to evaluate the impact of IVORY as information system in smart environments. In addition, it is important to realize that shape memory alloys have a limited ability to convey information. Due to the on-and-off state, the dynamic is restricted and provides a limited range of information.

Future Work

In the future, our aim is to develop various applications of tangible interfaces by using 'the canary in a coalmine' metaphor. Promising future research directions stem from, for instance, developing embodied interaction through electronic garment. Additionally, these devises have to connect with other systems, to measure the environment for personal requirements. Moreover, our intension is to provide more detailed information through sonification, as the physical dynamic of the shape memory alloy is limited.

References

[1] D. Suzuki, A. McConnell, und A. Mason, *The Sacred Balance: Rediscovering Our Place in Nature*, Updated. Vancouver B.C.: Greystone Books, 2007.

[2] P. J. Crutzen, "The "Anthropocene"," in *Earth System Science in the Anthropocene*, Springer, Berlin, Heidelberg, 2006, S. 13–18.

[3] T. D. Spencer, "Effects of Carbon Monoxide on Man and Canaries," *Ann. Occup. Hyg.*, Bd. 5, Nr. 4, S. 231–240, Jan. 1962.

[4] J. S. Reif, "Animal Sentinels for Environmental and Public Health," *Public Health Rep.*, Bd. 126, Nr. 1_suppl, S. 50–57, Mai 2011.

[5] G. A. Burrell und F. M. Seibert, "Experiments with Small Animals and Carbon Monoxide," *J. Ind. Eng. Chem.*, Bd. 6, Nr. 3, S. 241–244, März 1914.

[6] J. S. Haldane, *Respiration*. New Haven, Yale University Press, 1922.

[7] J. Klähn, *Bemerkungen über den Kanarienvogel*, Bd. 1. Auflage. Sankt Andreasberg: Harzer Roller-Kanarien-Museum, 2006.

[8] M. Weiser, "The Computer for the 21st Century," *SIGMOBILE Mob Comput Commun Rev*, Bd. 3, Nr. 3, S. 3–11, Juli 1999.

[9] F. Mattern und C. Flörkemeier, "Vom Internet der Computer zum Internet der Dinge," *Inform.-Spektrum*, Bd. 33, Nr. 2, S. 107–121, Apr. 2010.

[10] J. Gabrys, "Programmieren von Umgebungen," in *Internet der Dinge*, F. Sprenger und C. Engemann, Hrsg. Transcript, 2015.

[11] R. D. Brook *u. a.*, "Particulate Matter Air Pollution and Cardiovascular Disease: An Update to the Scientific Statement From the American Heart Association," *Circulation*, Bd. 121, Nr. 21, S. 2331–2378, Juni 2010.

[12] U. Lahl und W. Steven, "Feinstaub - eine gesundheitspolitische Herausforderung," *Pneumologie*, Bd. 59, Nr. 10, S. 704–714, Okt. 2005.

[13] M. Weiser und J. S. Brown, *The Coming Age of Calm Technology*. 1996.

[14] H. Ishii, D. Lakatos, L. Bonanni, und J.-B. Labrune, "Radical Atoms: Beyond Tangible Bits, Toward Transformable Materials," *interactions*, Bd. 19, Nr. 1, S. 38–51, Jan. 2012.

[15] M. Coelho, H. Ishii, und P. Maes, "Surflex: A Programmable Surface for the Design of Tangible Interfaces," in *CHI '08 Extended Abstracts on Human Factors in Computing Systems*, New York, NY, USA, 2008, S. 3429–3434.

[16] J. Berzowska und M. Coelho, "Kukkia and Vilkas: Kinetic Electronic Garments," in *Ninth IEEE International Symposium on Wearable Computers (ISWC'05)*, Osaka, Japan, 2005, S. 82–85.

[17] M. Coelho und P. Maes, "Sprout I/O: A Texturally Rich Interface," in *Proceedings of the 2Nd International Conference on Tangible and Embedded Interaction*, New York, NY, USA, 2008, S. 221–222.

[18] M. Coelho und P. Maes, "Shutters: A Permeable Surface for Environmental Control and Communication," in *Proceedings of the 3rd International Conference on Tangible and Embedded Interaction*, New York, NY, USA, 2009, S. 13–18.

[19] M. Coelho und J. Zigelbaum, "Shape-changing Interfaces," *Pers. Ubiquitous Comput*, Bd. 15, Nr. 2, S. 161–173, Feb. 2011.

[20] B. Farahi, "Caress of the Gaze: A Gaze Actuated 3D Printed Body Architecture," in *ACADIA 2016 POSTHUMAN FRONTIERS: Data, Designers, and Cognitive Machines: Projects Catalog of the 36th Annual Conference of the Association for Computer Aided Design in Architecture*, K. Velikov, S. Manninger, und M. del Campo, Hrsg. ACADIA, 2016, S. 352–361.

[21] S. F. Barrett, *Arduino Microcontroller Processing for Everyone!: Third Edition*. Morgan & Claypool, 2013.

[22] „Messungen mit dem Feinstaubsensor SDS011," *LUBW Landesanstalt für Umwelt, Messungen und Naturschutz Baden-Württemberg*, Juni-2017. [Online]. Verfügbar unter: http://www4.lubw.baden-wuerttemberg.de/servlet/is/268831/. [Zugegriffen: 15-Feb-2018].