Vital+Morph: A Shape-changing Interface for Remote Biometric Monitoring

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Abstract
In this paper we introduce Vital+Morph, a prototype of a shape-changing interface intended to be used as a media for remote biometric monitoring. Signals measured by a Vital Signs Monitoring Station are *physicalized* into a series of reactive tangible objects with a life-like behavior. Through this interface a person can feel the internal state of an hospitalized patient, as a new form of communication and awareness over distance. We propose a perceptual equivalent of an imaginative material capable of displaying digital information through shape-changing, and start to explore the social impact in complex contexts such as health care. Ultimately, Vital+Morph proposes an unusual viewpoint of the relations between bodies, clinical data and future materials.

Author Keywords
Shape-changing; alternative display; information visualization; presence; health care.

ACM Classification Keywords
H.5.2 [Information interfaces and presentation (e.g., HCI)]: Input devices and strategies.

Introduction
Today large amount of data are being collected about our bodies, environment and social relationships. The increas-

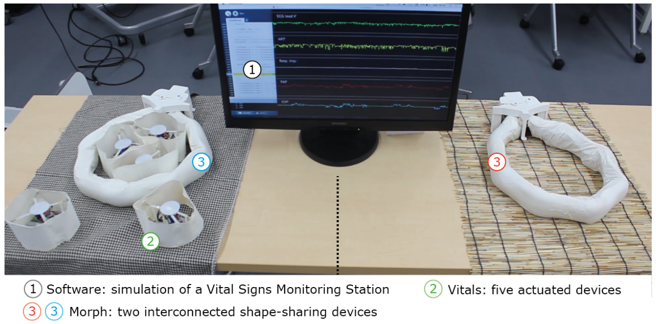

Figure 1: The three main elements that compose Vital+Morph: 1) a software, 2) a series of five *vitals*, 3) two interconnected and synchronized *morphs*

ing availability of Internet of Things devices will enable novel ways to get engaged with digital data in our daily environment. In this paper we introduce Vital+Morph (Fig.1), a prototype of a shape-changing interface designed as a media for remote physical connection and awareness. Data coming from a Vital Signs Monitoring Station (placed in an hospital) are *physicalized* in real-time into a series of five physical devices. These elements are surrounded by an input-output device that helps remote people to share their physical presence by actively deforming it.

We propose Vital+Morph as an interface for remote biometric monitoring. The project is still under development and has gone through a limited series of tests. In this paper we focus the attention on the design process and implementation of the prototype. The interactions and different functions will be briefly presented. Finally, we summarize and discuss the results of a series of preliminary informal evaluations. Through this prototype we aim to contribute to the exploration of novel relations between bodies, clinical data,

Figure 2: An illustration of the possible application of Vital+Morph: (a) an illustration of the main concept; (b) a rendering of an Intensive Care Unit; (c) a *vital* element carried by one of the patient's relatives.

and future 'computational materials': *how to get physically engaged with clinical data* ? *How they can be integrated in our daily life* ? In addition we would like to provoke a discussion on the impact of shape-changing interfaces, their possibilities and limitations in complex contexts such as health care (Fig.2).

Related work

Vital+Morph can be framed into the emerging research area of *data physicalization*, which includes a series of practices and attempts for helping people explore, understand and communicate digital data using computer-supported physical representations [4]. This emerged from recent and anticipated technological advances in digital fabrication, tangible user interfaces and shape-changing displays that will radically change the way how digital data can be made physical. In addition, since the introduction of visions such

Figure 3: A cluster of bubbles. Photo: 🅭🄍 author

as the one of Radical Atoms [3], several researchers have started a systematic reflection on how future *computational materials* can impact and develop novel forms of human-machine interaction.

Several studies have been conducted in the HCI field in order to investigate the usage of bio-signals as a means of communication. Heartbeat, respiration and body heat are the most studied among others because of their symbolic meaning and the availability of reliable and affordable sensors. Most of these systems represent and share bio-signals between distant users through tactile and thermal feedback, in order to promote a more intimate connection and emotional awareness. Some prominent examples are 'Mobile Feelings' [7] and 'Breathing Frame' [5]. Vital+Morph tries to explore a novel territory of communication and awareness, between the hospital and the outside. It is important to mention that a project developed by Kerridge [1] represents an important precursor of "Vital+Morph", even though it employs a more speculative design approach.

Figure 4: A paper mock-up of the Vital+Morph bi-directional communication. Photo: 🅭🄍 author

Design process

Materials and information

The continuous production of data is usually expressed through the use of verbs such as "flow"and "stream". They mark a strong analogy between information technologies, natural elements (such as water and air), and physiological process like blood circulation or respiration. Ultimately, streams are associated with the idea of life, representing a living entity. In order to design a novel shape-changing interface we started to think about a material that can embody the idea of flow and stream, but can also be directly touched, and carried around without using any sort of containers. This led us to imagine a novel material capable of displaying digital information by shifting from a stable shape into an unstable shape, like from a "solid"to 'liquid' state and vice versa. Since this kind of material does not exist, we have designed a perceptually equivalent one. The following section summarizes the design process of such imaginative material.

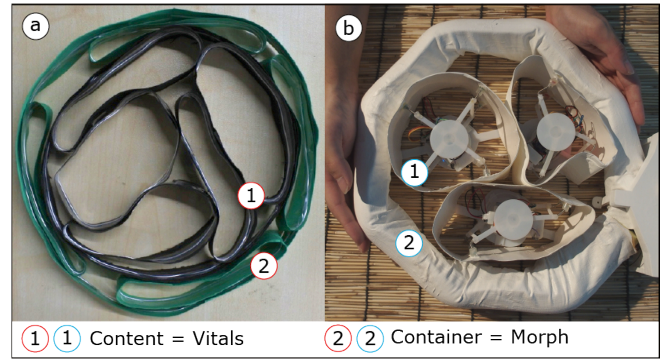

Figure 5: The paper mock-up (a) and the final prototype (b).

Paper prototype

In order to prototype our new material we looked at existing natural elements such as soap bubbles (Fig.3). By observing the process of formation and aggregation of bubbles we derived our design (Fig.5). We started to explore these forms by transferring them to a tangible realm through some stylized paper models. These have been used as probes for discussing and refining the overall shape and the functions of the display. We have identified two important elements : 1) five elements that act as display for the data, 2) a container. We named the former as *vitals* and the latter as *morph*. Each stream of data is displayed through a single surface that changes shape accordingly. We have decided to use five elements because there are five fundamental vital signs. The configuration presented in Fig.5 enables dif-

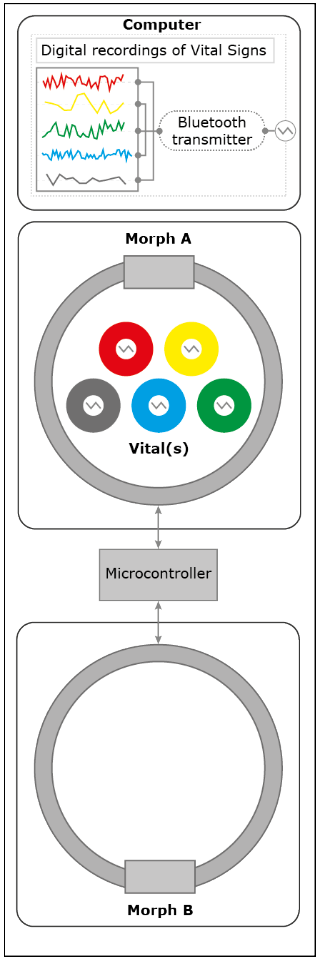

Figure 6: A schematic representation of the system. Photo: ⓒⓘ author

ferent interactions between a user, the material and data. In this way each data stream can be perceived individually and taken to an intimate level. Being independent, the *vitals* can be moved in different places. Distributing them to different users can lead to a novel form of "co-monitoring"of data: each user can shares the responsibility of monitoring a piece of information. In addition, by placing the *vitals* inside the circular contour (the *morphs*), differences between data streams can be detected easily by comparing the deformations of their surfaces. If the *vitals* are used for displaying the vital signs coming from the hospital, the *morph* is conceived as a shape-sharing interface. Through this system, distant located users can communicate and interact with each other by exchanging the shape and motion of the physical element (Fig.4).

Technical implementation

The basic framework of Vital+Morph is presented in Figure 6. In this section we introduce the implementation of the prototype by describing its main components: the software, the *vitals* and the *morph*.

Software

A software written in Processing reads a text file containing the recordings of five different physiological signals, and plot them on a monitor. Each signal is transmitted to its corresponding vital using via Bluetooth.

Data selection

Instead of measuring vital signs from a real patient we have used a set of data obtained through Physio Data Bank[1], a public database of physiologic data. For this prototype we choose 24 hours recordings of a 80 years old woman hospitalized after a surgery. We select five signals: heart rate (pulse), arterial pressure, respiratory rate, pulmonary arterial pressure, and central venous pressure. At this stage we implemented a simple direct mapping between each signal and actuators.

[1] https://physionet.org/physiobank/

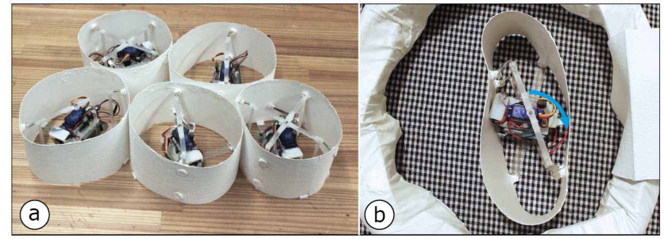

Figure 7: *Vitals*: the five different elements (a). When actuated a *vital* element will present the received signal through physical deformation (b).

Vitals

In order to implement the shape-changing material described above, we have designed the surface of the *vitals* to be deformed by a single internal actuator. Already some work has been done in the area of soft robotics to explore similar solutions for design deformable robots. Sugiyama and Hirai [8] proposed a circular robot modeled as a rheological object, which consists of a series of SMA actuators attached to the inside of a rubber shell. When voltage is applied to a wire, it causes a contraction resulting in a deformation of the shell. We started from this example, but with a single actuator only. As shown in Figure 7 each *vital* is composed of a paper cylindrical surface that surrounds the actuated mechanism, an Arduino Pro Mini 328, a Bluetooth receiver module, and a lythium-ion polymer battery hosted in a custom made container (Fig.8). In order to increase the deformation effect the paper surface is coated with few layers of latex paint. The actuation is provided by a mechanism driven by a micro servo motor (Tower Pro SG90)

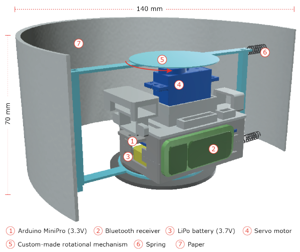

Figure 8: The different parts of a *vital* element. Photo: ⓒⓞ author

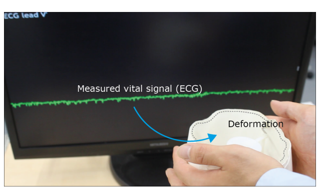

Figure 9: The relation between the signal measured by the VSMS and a *vital* element. Photo: ⓒⓞ author

that actuates at a speed of 0.1 sec/60 deg. The servo is connected to the paper surface with small springs (radius: 2mm, length: 100mm). When the shaft of the servo motor rotates the spring pulls the paper, which causes a deformation of the surface. Such solution helps to smooth the effect of the motor rotation and provides a simple form of indirect haptic feedback. Since the deformation is caused by a single motor, a series of customized horns for the servo have been developed. Each configuration gives a different deformation. The horns on the top of the motor are then vertically linked to a passive rotational element on the bottom of the structure. Then the paper surface is connected with the bottom of the module through a plastic stand. This prevents the cylinder from moving freely and at the same time improves the quality of the shape-changing effect.

Morph

The concept of shape-sharing using paired remote robotic systems was previously introduced by Sekiguchi et al. [6]. We employed this idea for implementing the *morph* elements. The current version is composed of two synchronized elements composed of a group of eight actuators (for each *morph*) linked together and enclosed in a soft cover (Fig. 10). In order to provide an input-output mechanism we have used an analog feedback type of servo motors (Adafruit LLC 1450), where position sensing and actuation are provided in a single element. The motors are then connected with a custom made linear type of linkage (Fig. 11). The two devices are then connected and synchronized through an Arduino Mega board, which implements a direct mapping between the position sensor of a motor to the opposite one, and backwards. Finally the motor chain was covered with a handmade soft cover composed of an elastic surface, and reinforced internally with a sponge-like material. This helps to enrich the tactile qualities of the device by making it more soft.

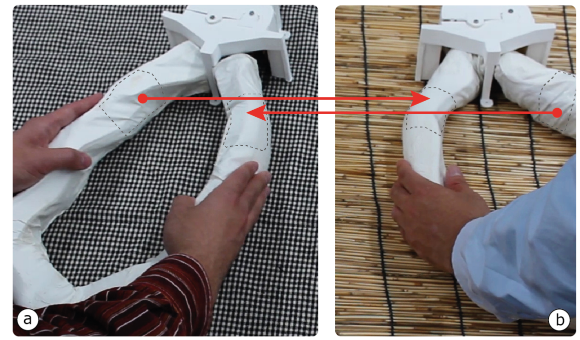

Figure 10: *Morphs*: the two synchronized devices.

Preliminary evaluation: issues and limitations

In order to understand the limitations and potential of this prototype we have organized a series of informal meetings and presentations with colleagues, students and the general public. We recorded a general appreciation of the aesthetics and feel of the interface. Many users said that the global interface "*looks like a living organism*", and "*feels good in my hands*". These comments support the idea that designing shape-changing interfaces with a life-like behavior can help people to relate more strongly with the digital content displayed through them. In addition, many users expressed an interest regarding the applications scenario of Vital+Morph: "*I never thought about this possibility*", others said that "*it will be useful for the aging society*". However some of them pointed out some personal concerns: "*it is a creepy perspective* [...] *I don't want to have such kind of device in my house*". Even if informal evaluations underline the power of *physicalizations*, as a very effective but also intrusive way for displaying data in daily environments. In spite of this a critical point many participants noted the diffi-

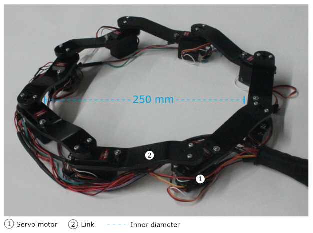

Figure 11: One *Morph* element opened to reveal its content. Photo: 🅭🄍 author

culty of clearly understanding the correlation between data and deformations.

Future work

Future development will focus both on improving the technical properties of the current prototype, and enhancing the capability of displaying data through shape-changing, such as:

- improving the *vitals* : testing different materials (silicone, gels) in order to give better durability and appearance in combination with a faster and precise actuation.
- Developing a novel vocabulary for the *morph*: establishing a lexicon of shape-sharing for remote physical presence.
- Investigating more appropriate and expressive mapping strategies for representing data through shape-changing. The methodology proposed by Houben et al. [2] represents a promising starting point.
- Exploring potential interactions between the *morphs* and the *vitals*, since at the moment there are no explicit relations.

The implementation of all these features requires, however, a consistent evaluation on how effectively the relation between data and shape-changing can be actually communicated and recognized by the users, and more specifically an understanding of how people would relate and interact with such system. There are many important questions to answer in order to improve the design and the use in real life scenarios. Regarding the design, they imply the investigation on more general open questions shared within the research field of *data physicalization* and shape-changing interfaces. Therefore testing this interface in a real scenario (the hospital and outside) represent a very critical step for our research.

Conclusion

In this paper we presented a work in progress of a system that allows clinical data to be *physicalized* in real-time through a novel shape-changing display. We described the design process, the possible interactions, and the implementation of each single element. A preliminary evaluation was also reported, but more structured user testing will help us refine the current prototype and proving its effectiveness in real-life scenario.

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