Modular Robotic Wearable

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Abstract

In this concept paper we trace the contours and define a new approach to robotic systems, composed of interactive robotic modules which are somehow worn on the body. We label such a field as *Modular Robotic Wearable* (MRW). We describe how, by using modular robotics for creating wearable, it is possible to obtain a flexible wearable processing system, where freely inter-changeable input/output modules can be positioned on the body suit in accordance with the task at hand. We describe the first rough prototypes and show an artistic application, as well as some drawing of future works and projects. Finally, by focusing on the intersection of the combination modular robotic systems, wearability, and bodymind we attempt to explore the theoretical characteristics of such approach and exploit the possible playware application fields.

Introduction

The Modular Robotic Wearable (MRW) thought was born in 2007 from both the research line in electronic and robotic art – called *The SuperAvatars*. This work was based upon our research tradition on *modular robotics* since the mid 1990's with the development of LEGO robots, embodied AI humanoids, intelligent robotic building blocks such as I-Blocks, African I-Blocks, robotic playground tiles and robotic therapy tiles.

Fig.1. Fatherboard, The SuperAvatar *(The mask, 2007)*

Besides that, the concept derives, somehow, from both artistic and scientific-technological fields.

Indeed, MRW inherits the knowledge coming from either the old *Wearable Electronic Art* works (see *Gutai Bijutsu Kyokai*, Gutai Art Association), such as Atsuko Tanaka's Electricdress (Fig. 2), and the old Steampunk and Cyberpunk [2] lines of thinking.

These, indeed, are consistent electronic art branches that are expressed in different styles (cyborgs, humanoids, exoskeletons, etc.) and through prestigious authors (Stelarc, Marcel.li Antúnez Roca, Bill Vorn, Chico MacMurtrie, Martin Spanjaard, Ulrike Gabriel, etc.). In the last few decades, they have explored the possibility of augmenting the body through modern digital technologies.

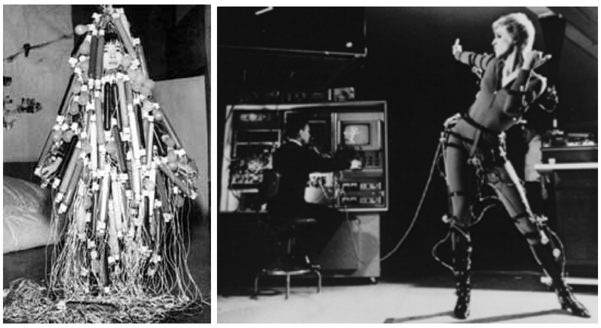

Fig. 2. Classical examples of wearable for artistic performance. Left: Atsuko Tanaka *(Electricdress, 1956)*, Right: The Steampunk.

Under the scientific point of view, MRW is inspired by and related to *Wearable Computing* or *WearComp* – a branch of research on forms of human-computer interaction comprising a small body-worn computer (e.g. user programmable device) that is always on and always ready and accessible, as defined by Steve Mann in 1997 [3].

Despite of these evident similarities, MRW approach proposes alternative and innovative paths, also thanks to the close relation established with modular robotics.

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Towards Modular Robotic Wearable

Differently from the above mentioned works, MRW aim at making no use of mechatronic devices (as, for example, in Cyberpunk and related research branches) and mostly relies on "simple" plug-and-play circuits, ranging from pure sensors-actuators schemes to artefacts with a smaller level of elaboration complexity. Indeed, MRW focuses on enhancing the body perception and proprioperception by trying to substitute all of the traditional exoskeletons perceptive functions - in most of the cases strongly rigid, cabled and centralized - through the use of local sensing circuits. In MRW we do so keeping the weight load as light as possible, while preserving a high level of modules interchangeability, as well as efficiency and flexibility.

Indeed, the MRW concept that derives from the *Polymorphic Intelligence* theory [4] has as a major goal

to focus on human-machine interaction pushing it to such an extreme in which interaction can be called and considered (human-machine) interrelation. This is because it takes into deep consideration certain aspects of body action/reaction which might be partially or fully unconscious. Therefore, although the MRW is thought as a non-invasive technology, the goal of such a research approach is to push the borders of machine mediated movements and sensing to unknown limits, and develop tools for investigating psychological and psychosomatic aspects, such as gestural and postural persons' attitudes and body automatisms.
Therefore, besides being an excellent method for expressing multimedia art aesthetics, MRW might represent a fascinating instrument for exploring such fields as neural robotics, and playware, as well. In fact, the MRW approach focuses both on pre-existing and well known psychosomatic aspects - a body re/appropriation [5] - and on body/hi-tech relationship, bringing along new discoveries and potential research fields on exploring body action and reaction, limits and capabilities.
Evidently, and more simply, MRW can also be seen as a means for augmenting human interfaces both from virtual realities to the body and from the physical body to virtual realities.

Fig. 3. *Fatherboard*, performing [13] (*The suite, 2007).*

MRW Definition

We define *Modular Robotic Wearable* (MRW) as a robotic system composed of interactive robotic modules which is worn on the body.

- By wearable we intend that the system has to be worn on the body and interact with the body as part of the surrounding environment of the system.
- By a robotic module we intend an entity with a physical expression which is able to process and communicate with its surroundings. The communication can be directed towards neighbouring modules and/or via sensory input and actuation output to the surroundings (i.e. interactive robotic modules). A modular robotic system is constructed from many such robotic modules.

Modular Robotic Wearable combines the wearable with the modular robotics and exploits the intersection of this combination.
By exploiting modular robotics for creating wearable, it is possible to obtain a flexible wearable processing system, where input/output modules (robotic modules) are freely interchangeable and freely can be positioned on the body suit in accordance with the task at hand. As with any modular robotic system, the design of the individual module is crucial for the performance of the modular robotic wearable. Design issues include attachment mechanism, communication method, size, form, material, and energy as well as the definition of processing, input and output capabilities.

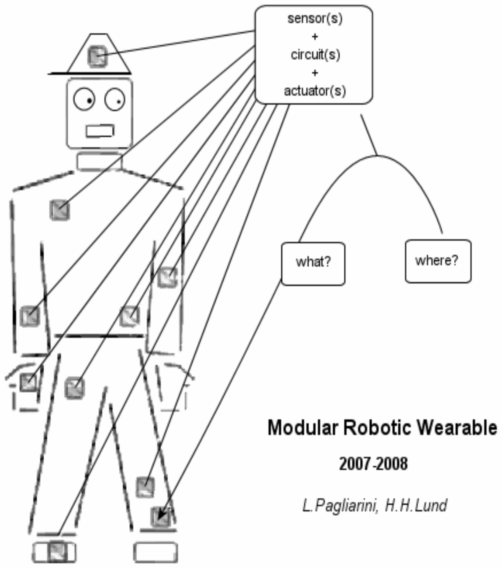

Fig. 5 Modular Robotic Wearable
(original schemata, 2007)

There are two categories of module attachment in modular robotic wearable, namely

- Direct attachment, where modules attach and communicate directly to each other;
- Indirect attachment, where modules attach to, and communicate to each other through, the body (suit).

The direct attachment is similar to most modern modular robotic systems, where the modules can attach directly to each other, whereas the indirect attachment resembles the use of discrete grid systems in some early modular robotic systems and simulations. In traditional modular robotic systems most research strives towards developing a connection as free as possible with no constraints imposed from the surrounding environment.
However, in wearable the situation is often somewhat different, and there may be advantages in developing modular robotic wearable with indirect attachment through a predefined grid system. Often, for full-body

wearable, a body suit is needed in order to create the wearable system and this body suit may form the grid system. Hence, in such a system, the modules attach directly to the body suit in any position formed by the grid system on the body suit.
Communication between modules in the modular robotic wearable can be categorised into:

- Local neighbour-to-neighbour communication (wired or wireless)
- Global communication from one module to a module further away (wireless)

And the way to perform the communication can be either wired (e.g. by direct connection or through the body suit) or wireless (e.g. by IR or radio). So, for instance, the communication possibilities in a modular robotic wearable may be as enlisted in Table 1.

Communication	**Wired**	**Wireless**
Local	Physical connection	IR or radio
Global	Body suit	Radio

Table 1. Communication possibilities in modular robotic wearable.

Several experiences with human – modular robot interaction [6,7,8,9,10] tell that the design of the individual modules is crucial for the easy understanding and manipulation with the modular robotic system. For instance, development of African i-BLOCKS showed the need for particular module attachment design to facilitate 3D building possibilities needed by users in the local context of schools and hospitals in rural areas of Tanzania [11], and strength of magnetic attachment in modular robotic therapy tiles were defined by the capabilities of autistic children in the therapy use [12].

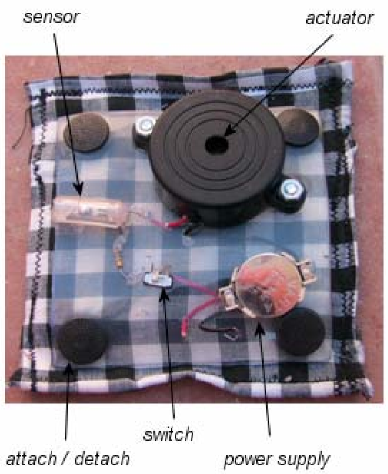

Fig. 6 MRW Module example
(early prototype, 2008)

Similarly, for modular robotic wearable, it is important to understand the use and use context when designing the individual modules. With wearable as the context, the modules must be designed to be flexible in order to fit the body and the free body motion. For instance, in one of our early prototypes we experimented the use of pure electronic circuits (with no PIC or digitalization, see Fig. 6) in order to run quick and inexpensive tests while optimizing on the input-output reaction time. In synthesis, we allow any possible input (sensors of acceleration, temperature, movement, vibration, and etc.) to mediate body actions and reaction directly activating (either in a discrete or analogical fashion), a given actuator (sound, light, etc.), as in a shortcut.

MRW Modules and Playfield characteristics
A further important aspect concerning a good MRW prototype is conceiving wearable robotic modules that are as "flexible" as possible in terms of functionality or displacement (on the bodysuit) , as well as the proper "*playfield*" (surface) for such modules.
As mentioned above, MRW easily allows to explore and study existing relationship amongst psyche (mental states, wishes and wills) and body (movements and parameters), as well as it easily enhance body language capabilities. Therefore, in the MRW a central part of the research is focused on catching (experimenting) relationships between routinary, as well as unusual body movements and possible robotic circuits, in which the input-output flow highlight, improve or detect special characteristics of human body (or body-movement) in space. Such an achievement (i.e. high level of experimentation and exploitation of MRW technology) can only be reached by building modules that follows certain rules:

- each circuit is fully autonomous energetically and electronically, although a circuit can be thought as 'eventually' connected to others MRW modules or any other computer interface;
- although there can be exceptions, each single circuit is conceived independently from the body-part (either suits or accessories) where it will be positioned;
- a MRW circuit applies to the whole body host and should not be limited to any single and specific application.

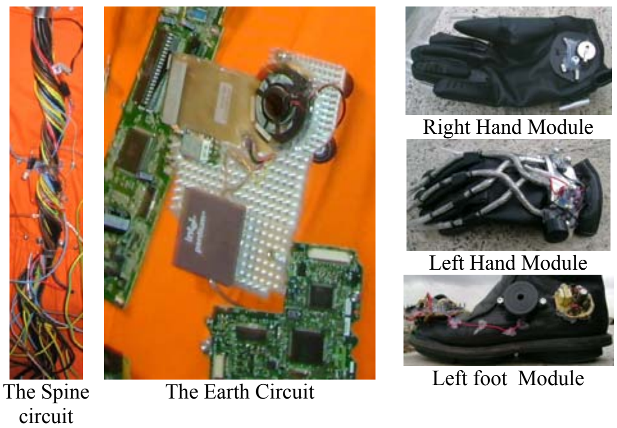

Fig. 7 Few Fatherboard Modules

Although, when building the first prototypes, we become aware that the development of a good MRW bodysuit or "playfield" is crucial to achieve the best results out of a MRW system, at the present, we only ran a couple tests.

The first one was produced for the very initial prototype, Fatherboard (Fig. 3) and was basically a rough start point with all circuits fixed on the tissue or the suite accessories (see Fig. 3 and Fig. 7).

Indeed, the pilot project run on the "*Fatherboard, The Superavatar*" art project [13] was the β-version for MRW - that has been successfully exhibit in different prestigious locations, as the Fondazione Bevilacqua La Masa in Venice [14], Palazzo Strozzi in Florence [15], Piemonte Share Festival in Turin [16], Expocoruña, La Coruña [17], Fondazione D'Ars XXV Oscar Signorini Pize, "Robotic Art", Milan [18], and etc. In the Fatherboard costume we installed about 15 different circuits made out of sound (buzzers, beepers, etc.) and visual (led, digits, etc.) outputs. Since the intention was to run a preliminary study on basic wearable robotics, the circuits were fixed on the suit (or accessories) and although most of them were energetically autonomous, some shared a central battery.

The second prototype (i.e.: Phonotron), still under development, represents a much better approach and, somehow, foresee what will be the basis of future MRW playfield and applications. As shown in Fig. 6, in this prototype the modules are becoming fully autonomous in terms of power supply and functionality and - thanks to a (females) spring buttons system - easily attachable-detachable. In this second prototype we are building a suit that, as for a chessboard, contains all the matching spring buttons (males).

With this new system we plan to test the MRW concept with a wider and more complex set of situations trying to exploit all the following potential interfaces:

1. Body-reality;
2. Body – Virtual Reality (Avatars, SL, any VW);
3. VR - Body

and apply the concept to different potential application fields, such as:

1. Sport
2. Health
3. Entertainment

Indeed, we believe that further than the artistic performances use, the MRW concept with its tight body coupling holds promise for new uses of *playware* (intelligent hardware and software that create play and playful experiences [8]) where the body motions are used to create feedback that motivates playful interactions in several application domains, e.g. for sports training, health rehabilitation and its documentation, and in entertaining play and games.

Conclusion

This concept paper presented the Modular Robotics Wearable technique as a new approach to robotic systems to wear on the body. By using the basic principles of modular robotics, the MRW method creates a large variety of flexible wearable artefacts with freely inter-changeable input/output modules that can be positioned all over the body suit (and accessories). We described a couple prototypes and tried to depict a line of research and the potentiality of the method. Finally, we focused on the intersection of the combination modular robotic systems, wearability, and body-mind theory to highlight the theoretical characteristics of such approach.

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