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VäriWig: Interactive Coloring Wig Module

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Figure 1: Embodiments of VäriWig while displaying a single color (left and center) or multiple colors (right).

ABSTRACT

We present the design and prototype of VäriWig, an interactive coloring wig module, which allows traditional synthetic wigs to change colors depending on several factors, such as head movements, music rhythms and other external synchronizations. A large number of customized optical fibers coupled with individually controlled digital tricolor light-emitting diodes are employed to instantly change the colors of specific locks of hair placed all around the head. VäriWig was designed to be seamlessly blended with the traditional wig, even while inactive and is envisioned to be used in art shows and other entertaining social events.

CCS CONCEPTS

• **Human-centered computing** → **Displays and imagers; Mobile devices; Ubiquitous computing.**

KEYWORDS

wearable, wig, hair, color, optical fiber

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1 INTRODUCTION

Human hair has several characteristics (e.g., length, shape), which through history, conveyed a lot of cultural information about its *proprietary*, either social status, age, gender or even health. *Color* is one of the most distinctive characteristics, considered natural (mostly different shades of blond, brown, black, red and white) or artificial from the result of dyeing, going through a wide range of colors. The change of color is intensified in social events or art shows and other related entertainments, for instance, by wearing accessories, such as extensions or even wigs.

In this context, we present VäriWig (from the Finnish word *väri*, meaning color), which allows traditional synthetic wigs to change colors depending on multiple factors, such as head movement, music rhythms or synchronicity with other users. The colors are provided by 25 individually controlled digital tricolor (RGB) light-emitting diodes (LEDs) placed around the user's head. The light is transmitted through a minimum of 100 of optical fibers, which include additional weights for an improved movement.

In the following part, we first present the related work, then, the design and exploration to implement two prototypes of VäriWig. VäriWig is envisioned to be used in art shows or other entertaining and social events.

2 RELATED WORK

Wigs, and more broadly, hair wearable interfaces have already been explored both from an input and output perspective.

First, Martins et al. presented *Headband Hero* [5], a game in which users wear a wireless motion-sensing wig to practice *headbanging* (vigorously shaking the head accordingly with a music rhythm), by giving realtime and post-performance feedback (in the form of graphs). Then, Tobita and Kuzi presented *SmartWig* [7] while emphasizing the aesthetical property of their device. They included several electronic components inside a synthetic wig, in particular, six vibrating motors to help users' navigation and a laser pointer

(mounted onto the forehead) with two buttons (near the sideburns) to assist meeting presentations. Lee [4] presented a set of five wigs combining hair with solid but light and hidden 3D printed structures movable by servo motors. Each wig had a unique hairstyle and flow to explore different interactions between the wearer and the spectators. Following the beauty technology paradigm emphasizing seamless wearable interfaces, Vega et al. presented *Hairware* [8], a chemically metalized hair extensions acting as capacitive touch input, for instance, to control smartphones or other computers by recognizing different kinds of gestures. Dierk et al. presented *HäirÖ* [2], another capacitive touch input hair extension combined with dynamic output through subtle shape and color changes. The latter feature was implemented with thermochromic paint while leaving issues related to power and size. Therefore, the solution offers a very limited number of colors with a slow changing state and a very high consumption of energy for wearable technologies.

VisHair [10] is the closest related work. The authors presented an accessory, called *HairSlice*, to be clipped on the real hair of the wearer. *HairSlice* includes a battery, a Bluetooth module and one light-emitting diode (LED) with a mixture of few side-emitting and end-emitting optical fibers. A mobile application and a custom *Smartband* to be worn on the wrist, allow the user to control one or multiple *HairSlice* parts. However, their work presented some aesthetic, interactive, and functional limitations, some, acknowledged by the authors:

- Aesthetics. First, a small, limited number of *HairSlice* can be worn simultaneously. Second, each *HairSlice* includes redundant components (Bluetooth module and battery) making them bulky, visible, and inefficient when several are involved. Third, the optical fibers alone do not mimic the movement of real hair due to their limited flexibility property.
- Interactive. Input sensors (e.g., accelerometer and gyroscope) are not included to the user's head, limiting the interactive possibilities of such head-oriented wearables.
- Functional. *HairSlice* alone can only be worn while having real (relatively long) hair, excluding short hair, alopecia and other conditions causing complete hair loss (e.g., medical treatment).

Finally, in other contexts of wearable technology, many works have explored optical fibers, but mostly by integrating them through synthetic or natural textile fibers, such as cotton, using different weaving or knitting techniques. Two literature review papers [3, 6] gave an overview of these works, in addition to valuable mechanical properties of the optical fiber, yet, remaining textile-oriented only.

3 VÄRIWIG

In this section, we first present the overall architecture of *Väriwig*, then, we report on the processes and results encountered while exploring the components and design to implement prototypes of this wearable, in particular, the structure and the optical fibers.

3.1 Architecture

Väriwig consists of wearing a regular synthetic wig above an interactive colorful module (Figure 2). This separation allows an additional customization of the hair color and shape based on the choice

of the synthetic wig. The interactive colorful module comprises essentially five kinds of components:

- (1) *Microcontroller board*, an Arduino Nano 33 BLE Sense integrating a wireless module (Bluetooth) and a wide range of different sensors (gyroscope, accelerometer, microphone, and less common, such as temperature, humidity, pressure, color, brightness or proximity sensors) for possible input/output control in a small form factor (18 x 45 x 4 mm, 5 gr).
- (2) *Light source*, 25 individually controlled digital tricolor (RGB) light-emitting diodes (LEDs) connected through a flexible strip. Compactness (144 LED per meter) has been selected to have a high number of controlled lights in a small form factor. The strip is positioned vertically along one side (perpendicularly to the centered top surface of the head) and curved to form an elliptical shape with a 17.5 cm circumference (equivalent to the strip's length, and thus, defining the number of LEDs), representing a 22 cm² surface, large enough to secure the placement of the microcontroller board inside, while being small enough to be wearable by most humans. For instance, Chinese and Caucasian adult male head circumferences are about 56.5 (SD=1.6) and 57.7 (SD=1.7) [1].
- (3) *Battery*, placed on the back of the head for two reasons: (1) to minimize the overall height of the structure on top of the head and (2) to simplify its access, for instance to change (and charge) the battery. A standard 9-volt battery was used (17.5 x 26.5 x 48.5 mm), however, the slot (pocket) dedicated to the battery is made to receive different kinds and sizes (with a greater capacity or more compact).
- (4) *Light diffuser*, different kinds of optical fibers are usable and presented in the last subsection.
- (5) *Structure*, with the aim to attach all previous components together while offering wearability. The structure is made from different materials (e.g., plastic, fabric, foam) and techniques (e.g., 3D printing and sewing) detailed in the next subsection.

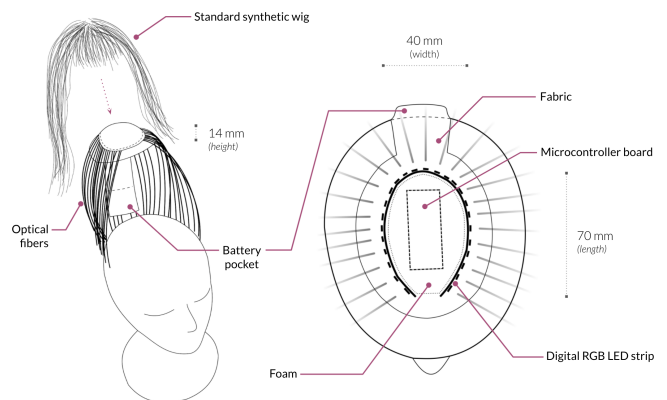


Figure 2: Drawing of the overall architecture.

3.2 Structure

The structure is mostly flexible to adapt to the diversity of head shape and it comprises a piece of non-elastic fabric from which a

flexible (semi-rigid) 3D printed strip support (Figure 3, bottom) is sewed. A piece of foam is placed in the center, to increase comfort and secure the microcontroller board in it. Another 3D printed support structure was made to create locks of optical fibers (Figure 3, top), by joining them (at least 4, for a minimum of 100 per VäriWig module, depending on their thickness). Each lock is clipped on the main strip support. Finally, additional fabric is added for the battery pocket and on the top to prevent undesired light emission.

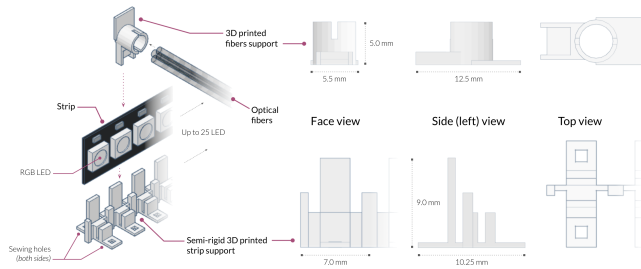


Figure 3: 3D models of the printed structure.

3.3 Optical fibers

3.3.1 Light. Thin optical fibers (such as 0.25 mm) are considered end-glow optical fibers. To produce side-emission, we performed micro perforations by handmade mechanical treatment, using utility knife to abrade and slightly cut the optical fiber’s cladding surface at different places. However, industrial-grade processes could be used for quicker and consistent results, such as projection of microparticles with different velocities or by contact with chemical solvents. An example of the result is presented in Figure 4 (top) and compared to commercialized side-emitting optical fibers obtained with a dedicated coating for a more diffuse light-emission. We proceeded with the latter one (from subjective visual selection); however, the coating implies a greater overall thickness of the optical fiber (in this case, 1.5 mm), and thus a change to the mechanical property, in particular flexibility, affecting its movement, usually more rigid than a real or synthetic hair.

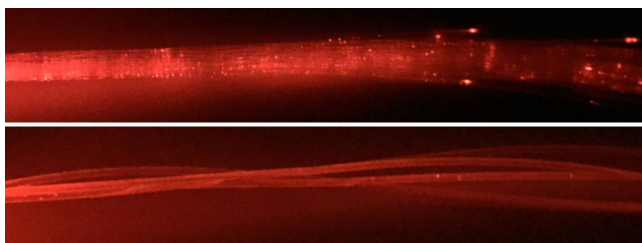


Figure 4: Side-emission with micro perforations (top) and dedicated coating (below).

3.3.2 Movement. To adapt and obtain a movement closer to the one of real or synthetic hair, we added a weight at the end of the optical fibers by using adhesive and metallic parts (Figure 5). Since the additional weights lack interactivity, different thicknesses (1.2 to 2.0 mm) and materials (iron and copper) were tested to reduce

its length. Iron and copper elements have a respective density of 7.87 and 8.96 g/cm³, thus, by using heavier (and more precious) materials, such as gold (19.3 g/cm³), the length of the additional weight could be more than halved. Finally, a targeted weight of 1 gr has been chosen empirically to suit an optical fiber of at least 25 cm length and 1.5 mm diameter. It was obtained with iron wire (4.3 mm length and 2 mm diameter).

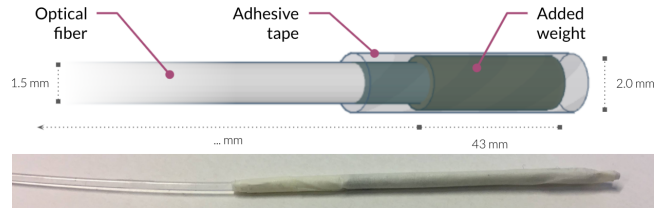


Figure 5: Added weight to the optical fiber.

For a seamless integration, the adhesive tape covering the weight should be the same color as the synthetic hair of the wig. However, dark-colored (black) adhesive tape could also be favored, since VäriWig is intended to be used in dark environments. In this context, we also tested a strategy of double coloring by dyeing in another color only the tips of the hair from the wig, making the weight unnoticeable even in a bright environment (Figure 6).



Figure 6: Double coloring, dyeing the tips of the wig hair.

3.3.3 Shaping. By default, optical fibers are relatively straight, representing only a subset of the different hair types. We refer to the Andre Walker Hair Typing System™ introduced in 1997 [9], the most widely spread and accepted system by cosmetologists, to class hair into four numbered categories (each of them having slight variations defined by a letter varying from A to C):

- (1) Straight hair. Fine and fragile to coarse and thin (curl resistant).
- (2) Wavy hair. Fine and thin to coarse and frizzy.
- (3) Curly hair. Loose curls to corkscrew curls.
- (4) Kinky Hair. Tight coils to Z-Angled coils.

Figure 7 represents our attempt at inclusivity and addressing human diversity, by modifying the shape of optical fibers regarding various hair types.

To reproduce each hair type, in particular, type 2, 3 and 4, we used heat to reshape the optical fibers. One grill and two wood cylinders with varying diameter (15 and 5 mm) have been selected to attach the optical fibers (Figure 8) before being placed inside an oven for 3 minutes at 150 degrees Celsius. We did not reproduce each subtle

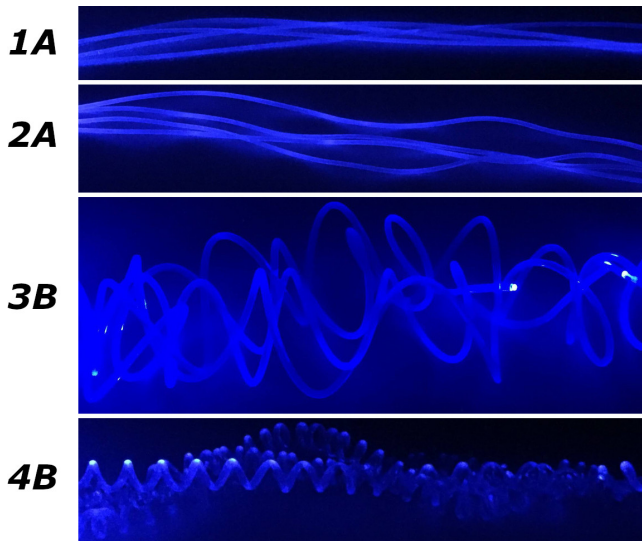


Figure 7: Attempt at diversity among hair types.

variation among the different hair types, we are confident that all of them are reproducible, using the same technique, for instance by adapting the spacing and rolling diameter.

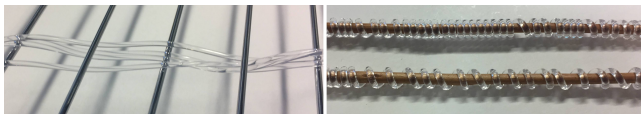


Figure 8: Set of tools to reproduce variation of hair type.

Curling the hair also means that they are longer than they appear, and thus are heavier. For instance, in the case of type 4B, the additional weight might not be required as shown in Figure 9.

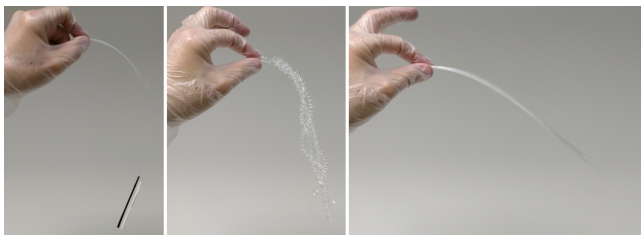


Figure 9: Flexibility comparative illustration (from left-to-right) of type 1A with additional weight, type 4B and thin (0.25 mm) end-emitting optical fibers.

Finally, we produced two VäreiWig prototypes (Figure 1), both with 1A hair type, 1.5 mm diameter side-emitting optical fiber at 25 and 40 cm length to test the benefit of additional weights. The longer one, use a slightly gray colored wig for an elven-inspired hairstyle. Besides, such non-interactive colors allow a seamless integration of the optical fibers (Figure 10, left), however, as with the adhesive tape of the additional weights, since the VäreiWig is meant to be used in the dark, other colors could be used.



Figure 10: Optical fibers through gray and pink synthetic hairs.

4 FUTURE WORK & CONCLUSION

Design and prototype of VäreiWig was a first attempt at producing interactive hair color changing for the full user's head. However, there is still improvement opportunities, for instance, the additional weight could be integrated with a unique metallic piece (Figure 11) including reflective surfaces to increase optical fiber side-emission intensity. Finally, convinced by the visual end result, we intend to conduct formal user studies with amateur and professional dancers.

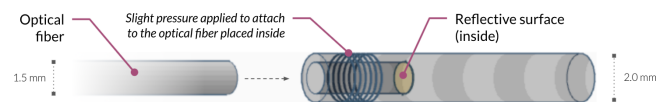


Figure 11: Concept of an additional weight using a unique piece of metal with an inside reflective polished surface.

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