Kukkia and Vilkas: Kinetic Electronic Garments

Joanna Berzowska and Marcelo Coelho
XS Labs, Concordia University
joey, marcelo @xslabs.net

Abstract

This paper describes our first experiments in developing kinetic electronic garments, within the context of fashion and personal expression. We have integrated the shape memory alloy Nitinol in textile substrates to create Kukkia and Vilkas, two animated dresses that move or change shape over time, using resistive heating and control electronics. We describe fabrication details, including Nitinol shape setting and felting of the textile substrate. We suggest various models for programming the behavior of such an artifact, including animated, reactive, and interactive models.

1. Introduction

One of the driving forces for fashion has been to seek a continually evolving concept of beauty through the transformation of the body's natural form [4]. At the same time, we have learned to use garments effectively to hide, reveal, and distort the self that we present to the world. We use fashion to express social, cultural, economic, religious, sexual, and professional aspects of our identity, among others [2].

Fashion's growing interest in emerging technologies has given rise to high performance textiles such as Gore-Tex® or KEVLAR® fibers, as well as playful items such as illuminating bras. More recently, designers have been integrating display technologies into garments to allow interactivity and visual output to occur on the body [1,2]. The focus has often been on reactive or interactive clothing that illuminates or changes form according to the wearer's activities. The integration of electronics automatically transforms many of these garments into "functional" items, which need to exhibit some kind of utilitarian purpose.

In contrast, the two garments we describe in this paper are kinetic and animated, but not electronically responsive or interactive. They can be described as uniquely expressive behavioral kinetic sculptures.

Garments are historically versatile insofar as they are soft and adapt to their context of use and to the shape of the body. Garments move with and against the body. They also collect and reflect some of our most intimate moments and are marked by our sweat, food stains, and tears [1]. They become worn and their natural shape changes over time. The two dresses described in this paper develop playful extensions of this natural kinetic behavior, in the form of animated felt flowers and moving hemlines.

2. Kinetic Fashion

All garments can be described as a form of kinetic sculpture through the way that fabric falls on the body and changes shape accordingly to wind, heat, and body language. The term could also be used to describe reconfigurable garments such as Patrick Cox's "Pieces" collection, based on the concept of metamorphic clothing [3]. Each item in the collection allows the construction and deconstruction of numerous garments or accessories, through the use of zippers, snaps, or studs [3].

A more transformative definition of "kinetic" can be illustrated by various examples of garments that inflate to change shape or function. The XS Labs "Inflatables" (2004) explored the idea of inflatable clothing as a way to (1) reclaim private space, (2) distract a perceived enemy, and (3) restrict, or modulate, social interaction. Two early prototypes included the Inflatable Hip Dress (reclaim) and the Inflatable Breast Dress (distract).

Similar garments include a series of raincoats made by CP Company that inflate to become functional artifacts such as chairs, tents, or air mattresses [7]. Similarly, Ixilab in Tokyo has created prototypes for garments that convert into stools, floor mats, or storage units [5]. For comfort in travel, Samsonite created the stylish down-filled Travel Pillow Jacket, whose collar contains a large, inflatable neck pillow, for spur-of-the-moment naps [3].

The word "kinetic" in the context of this paper refers to garments that can be even further reconfigured, whose shape could more fundamentally be altered through the use of some kind of mechanical or electronic process. It also implies an amount of autonomy, so that the shape change need not be activated by the wearer, but instead can be controlled and activated electronically.

One such example is Hussein Chalayan's Airplane Dress, a molded garment that changes shape through the use of a remote control. The dress, created using aviation fiberglass, fits rigidly on the body and moves, shifts, lifts, and opens up like the wings of an airplane [3].

2.1 Nitinol and Textiles

Nitinol, also known as memory metal or muscle wire, is a shape memory alloy (SMA), made of nickel and titanium, that, once treated to acquire a specific shape, has the ability to indefinitely remember its geometry. The range of applications has been increasing in recent years, especially in medicine [8].

The idea of integrating Nitinol wires into textiles is not new, but the process is complex and expensive. The only documented project to date that integrated Nitinol wires into a textile is the Oricalco shirt from Grado Zero Espace. This reactive shirt rolls up its own sleeves as the ambient temperature rises. After it has been wrinkled, it returns to its original shape when heated with a hairdryer [9].

Our work pushes these ideas further by moving away from a utilitarian design and by integrating portable electronics and power to control the shape activation. The seamless coupling of Nitinol, textiles, and soft electronics forms the basis for the shape-changing mechanism and the aesthetics achieved in Kukkia and Vilkas.

3. Design

The design of garments we wear usually integrates social, psychological, and physical functions [3]. Each garment presents a variable combination of functionality, from the purely aesthetic to highly task-driven. With these projects, instead of focusing on an application that might increase our physical comfort or increase our productivity, we focus on playful scenarios that develop a behavioral model for the garments themselves and encourage a sense of wonder and delight.

Figure 1: The rising hem line of the Vilkas dress. Photo by Shermine Sawalha.

Vilkas is a dress with a kinetic hemline on the right side that rises over a 30 second interval to reveal the knee and lower thigh (see Figure 1). It is constructed of heavy hand-made felt with a very light yellow cotton element that contracts through the use of hand-stitched Nitinol wires. Once heated, the Nitinol easily pulls the cloth together, creating a wrinkling effect. This movement is slowly countered by gravity and the weight of the felt.

The hemline is programmed to rise autonomously, not in response to any external or internal input. This creates a kinetic dress whose behavior can be playful and even desirable, but can also be embarrassing in the wrong social situation. The wearer can wait for the hemline to fall, which can take several minutes, or can actively pull it back down. This initiates a physical conversation between the wearer and the garment, as they fight over control of the body's real estate.

Figure 2: Hanna attempts to immobilize the kinetic flower in the Kukkia Dress, with a close-up of the movement of one of the flowers. Photos by Shermine Sawalha.

The Kukkia dress is decorated with three animated flowers that frame the neckline. Each flower opens and closes over (on average) a 15 second interval (Figure 2). The flowers are constructed out of felt and silk petals that provide relative rigidity and conceal the Nitinol wire stitched onto the back. When heated, the wire shrinks and pulls the petals together, closing the flower. As it cools down, the rigidity of the felt counteracts the shape of the wire, allowing the flower to open.

4. Implementation

Our initial approach was to simultaneously consider aesthetics, functionality, comfort, and behavior. Our work involves a very hands-on approach to materials. XS Labs research includes the weaving, knitting, and felting of electronic textile substrates with specific parameters for each application. We knew that we would need to fabricate and shape-set not only the Nitinol, but also create a custom textile. Parameters such as thickness of material, weight, translucency, and structure would affect the behavior (movement) of the textile.

4.1 Nitinol fabrication

The transformation temperature of off-the-shelf Nitinol is too high for use in clothing. By varying the elemental ratios of the nickel and titanium combination, the alloy can be tuned to change shape at different temperatures [8]. By custom fabricating our Nitinol wire, we were able to control the specific shape and the transformation temperature. We decided to use 0.2 mm Nitinol wire with a 60º C Af and ratio of Nickel 54.5 wt %, Oxygen 0.05 wt %, Carbon 0.02 wt % and balancing Titanium.

The material needs to be constrained in the desired shape and heat-treated. Typically for superelastic material, a heat treatment in the 500°C range is adequate. We experimented with different shapes such as curves and zigzags but found that a coil or spring shape (see Figure 3) was by far the most successful. It provided the greatest amount of change, as well as the necessary strength to move or distort the garment. In its relaxed (or martensite) state, the coil becomes a straight wire, allowing us to easily weave, stitch, or felt it into fabric.

Figure 3: Shaping the Nitinol wire and final shape memory (or austenite) state. Photos by Jacques Teisen.

4.2 Nitinol Integration Tests

Because Nitinol needs to be shape-set at 500ºC, it is impossible to shape it after integration into fabric (unless we use heat-resistant materials like Kevlar). This limits design and fabrication possibilities. On the other hand, Nitinol wire that has been previous shape-set can be stitched onto a surface, woven into a textile, or knit into wool.

In its martensite state, Nitinol is extremely malleable; it can be integrated into a soft fabric substrate without causing any disruption in its natural movement and flexibility. On the other hand, once heated to its shape memory (or austenite) state, a Nitinol wire becomes stiff and returns to its original shape with enough force to lift its own weight several times.

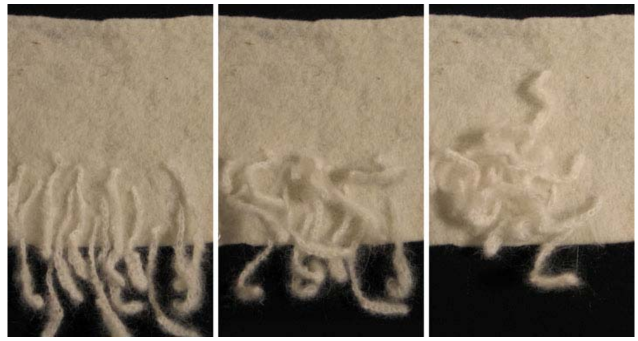

Figure 4: Nitinol thread is knit directly into wool. Photo by Shermine Sawalha.

Figure 5: Marcelo connects the power supply to the woven sample and watches it contract. Photo by Tracey Doyle.

To develop the kinetic mechanisms, it was necessary to explore several custom shaped Nitinol wires and their integration with textile techniques such as knitting, weaving, hand stitching, and embroidery. We did not use Nitinol in the sewing machine, because it is thicker and more rigid than standard sewing thread. After experimenting with the different methods, it became evident that two methods, (1) felting Nitinol wire directly into wool and (2) hand-stitching Nitinol onto felt, were superior to knitting or weaving (shown in figures 4 and 5). Overall weight was an issue, as we had to consider thickness (strength) of Nitinol wire, resistance of the wire (which determines the power needed to produce heat), and the weight of the material to be moved or distorted.

4.3 Felting

Felting is one of the earliest forms of textile processing. It renders wool windproof and water-resistant, as well as fire-resistant insofar as it will not start a flame and it extinguishes itself. We use resistive heating to activate the Nitinol and the fire-resistant qualities of felt are important for safety reasons. In addition, felt is thicker than most woven fabrics, so we can stitch conductive threads on both sides, effectively insulating one side from the other. Moreover, a wire or conductive thread can be completely embedded into felt, creating a seamless soft circuit that is insulated from the outside and from the wearer's skin.

By pairing coil-shaped wire with felt, we achieved the most versatile and fruitful results. Felt has the rigidity and thickness necessary to house strings of Nitinol and conductive threads. The coil shape provides enough force to move the felt, despite its weight. On the other hand, felt offers enough physical resilience and rigidity to slowly force the coil to straighten, so as to counteract the motion. This creates a fluid, organic, continuous movement, different from the kinetic feel of mechanisms controlled by motors, piezoelectric strips, and more traditional actuators.

4.4 Electronics

Nitinol is not only used as the scaffold for the desired shape change, but it also produces the heat necessary for its own actuation through resistive heating. The Kukkia flowers, for instance, are each outfitted with a 40cm wire with 35 Ohms/meter resistance that draw an average of 0.52 Amps. A PIC16F88 microcontroller triggers TC4432 MOSFET drivers that send power to the Nitinol. We use small rechargeable lithium polymer cells that can power the dress for two hours. The PIC16F88 was chosen because it integrates pulse width modulation (PWM), in-circuit programming, and analog inputs for thermistors to ensure that the temperature on the surface of the dress will never exceed the felt's combustion temperature.

We use the term "soft computation" to refer to electronic circuits composed of soft materials such as threads and predicated on traditional textile construction methods. We use conductive yarns, fibers, and fabrics to enable the construction of working electronic circuits on soft substrates [2]. The control electronics are connected to the Nitinol coils through decorative stitching with conductive threads. The use of snaps allows a durable and seamless connection between the flexible threads and the rigid PCB. The male snaps are soldered to the PCB, while the female are sewn into the dress and connected to the conductive thread by knots reinforced with conductive epoxy. A small inside pocket holds the circuit board and insulates it from the skin. This modular assembly allows the board to be removed when necessary, separating soft from hard electronics for cleaning or debugging.

5. Behavior Model

We chose a simple approach that emphasizes form, aesthetic experience, and fashion rather than utility and interaction. Kukkia and Vilkas do not respond to proximity, mood, or the stock market. They are simply behavioral kinetic sculptures worn on the body that exploit characteristics such as control, expectation, and unpredictability to challenge expectations and provide a playful space for expression [6]. Kukkia and Vilkas can be viewed as personal and poetic extensions of the body. Their motion in turn contradicts and reinforces natural body movements. The flowers "pulse" around the neck, hinting at natural rhythms such as breath or a heart beat. Vilkas works like a curtain that reveals and hides, protects and exposes. At the same time, a conversation takes place between the dress and the wearer.

6. Conclusions and Future Work

We have constructed two electronic, animated dresses that exploit the integration of Nitinol into textiles in order to produce abstract kinetic behavior on the body. Even though they were designed mainly as sculptural fashion artifacts, these dresses can also be considered as substrates or output devices that can potentially connect into any interactive system. In the future, we will explore different models and the potential of the dresses to function as (1) purely kinetic artifacts, (2) reactive garments that react to ambient or variables, or (3) fully interactive physical display devices that can communicate specific data and respond to input.

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