

## Functional and Aesthetic Design of Woven Electro-textile Fabrics

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### ABSTRACT

*For developing smart textile design methods and enlarging the assortment, this research has explored weaving methods in order to combine the aesthetics and functional aspects of fabric design in one pattern. Light emitting display in a woven textile fabric was designed with integrated electronic elements. Light emitting provides an interactive design feature in the fabric while the fabric pattern together with the woven optical illusion motif provides an aesthetic function. Integration of conductive yarns into textile structure was realized and specific weave pattern was used to get fabric with possibility to vary brightness of light emitting diode by textile pattern. In the article design process of electro-textile development is described and some of its applications are explained.*

*Keywords: Electro-textile, smart textile, light emitting, interactive design, optical illusions*

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### Introduction

Development of electronic textiles gives opportunities for creation and improvement of new innovative products in different fields related to smart clothes and smart textiles (Kirstein at.al., 2005). Electro-textile structures are the basis for the development of textile sensors, flexible electrode systems, actuators, solar cells, textile transdermal therapeutically systems, heating systems etc. (Janietz at. al., 2012). Luminescent/photonic textiles or flexible displays are one of the fields as well where electrotexiles are important part of the system. Different textile flexible displays can be designed for smart clothing applications, like – LED display, optical fiber display, OLED display etc. (Cochrane at. al., 2011). Replacing

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traditional electronic materials with conductive textile materials it is possible to create flexible light-emitting display substructure using different fabric designing methods, for example – weaving. In woven electro-textile metal yarns or yarns coated with metallic particles (usually silver-coated) are used as conductor (Jeong at. Al., 2010) what can be woven into fabric structure along with non-conductive yarns in warp or / and weft direction. Using different types of weave fabric structure and design can be adjusted to appropriate application. In woven textiles, there are three basic forms of woven structures: plain, twill and satin. If it is necessary to overlap conductive yarn in textile structure, dense plain weave can be used. Interweaving fragile yarn or yarn what

shouldn't be subjected to high bending density (for example, optical fiber) into fabric, twill structure would be suitable (for example twill 2/2 or 4/4). In its turn satin weave provides longer floats on fabric's right or left side, therefore lifting or hiding floats on appropriate fabric side. Using respective fabric weave definite functional properties of electro-textile can be designed as well. It is possible to control the placement of conductive elements in electro-textile using a jacquard shedding system that allows each warp thread to be addressed individually in order to control the order of interlacement of the threads [Ghosh et al., 2006]. Formation of woven conductive networks with cutting of conductive yarns at certain specified points has been reported by Dhawan (2002). Electronic devices can be attached to these electrical networks, which can serve as flexible circuit boards. Similar method was used by Perner-Wilson, H. et al. (2012) for designing jacquard patterns in fabrics with conductive surfaces. Interwoven conductive yarns make weft floats on fabric's right and/or left side. It is possible to cut weft connection on the left or right side of the fabric so surfaces on opposite fabric side can function as individual conductive areas.

In this research, we developed smart textile designing methods and their enlarging assortment by employing weaving methods in order to combine fabric's aesthetic and functional features in one pattern. During study woven LED display was designed with specific weave pattern combination and integrated electronic elements (conductive yarns and light emitting diodes). Light emitting performs interactive (functional) design feature, but fabric pattern with woven optical illusion motif performs aesthetic function. Combining both functions in one pattern, electro-textile in switch-off mode works as a fabric with motion illusion, but in switch-on mode it operates as light emitting display. Depending on the lightening intensity and brightness of light-emitting diodes, human eye can perceive both display functions at the same time as well.

It was necessary to think about both woven pattern design and functionality of system, so for display design several objectives were proposed:

- To design fabric with optical illusion pattern;
- To hide light-emitting diodes (LEDs) under fabric (on left side of fabric);
- To vary intensity of LED emitted light with textile structure.

## Materials and methods

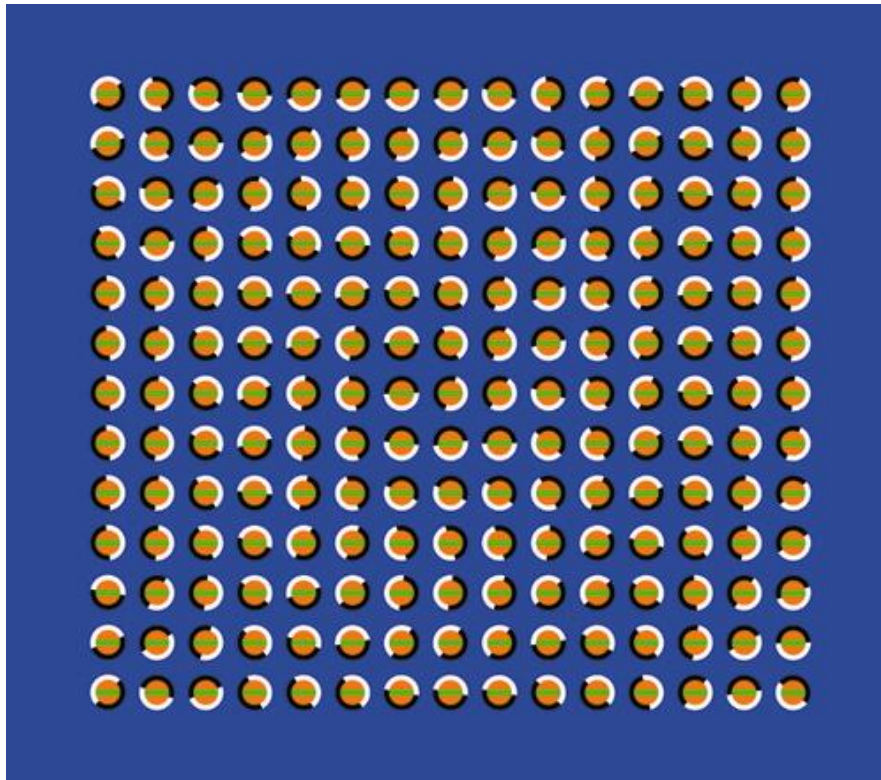
Industrial jacquard weaving machine Vamatex SD 1701 have been used with 1344 hooks, warp density 33 ends/cm and weft density 42 cm/pick. Weave patterns were designed in PC-Edit software. Polyester yarns were used in warp, cotton yarns were used in weft; copper yarns were used in weft for electrical connections. SMD LEDs of size 1206 were attached to the electrotextile after it was woven. For washing test ISO 6330:2012 "Textiles - Domestic washing and drying procedures for textile testing" was used.

Intensity of emitted light was measured with digital environment meter Velleman DVM401 using luxmeter function. Measurements have been done in dark room. As additional tool black mat carton tube with openings in both sides for luxmeter placing and area fixing was used. The diameter openings are 5 cm and 2 cm, and the height of the tube is 8.5 cm.

## Design of optical illusion pattern

The pattern was made influenced by optical motion illusion drawings of Akiyoshi Kitaoka, digital version of pattern design is shown in Fig.1. Motion flow in optical illusion pattern depends on rotation of black and white outlines of objects, what are different for each of them.

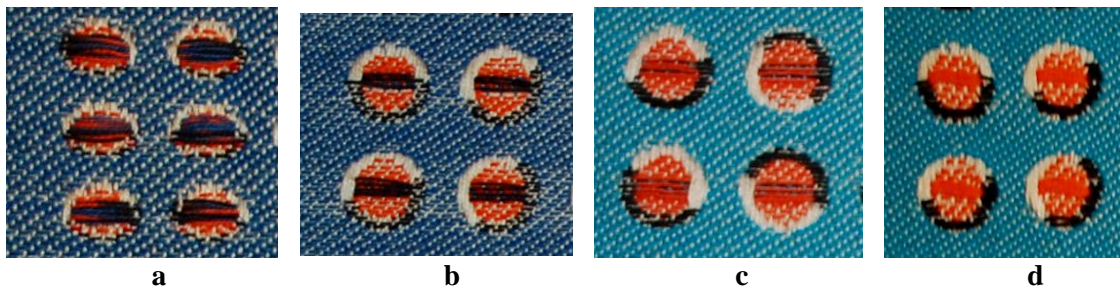
The critical feature for inducing illusory motion is the luminance relationship of the static elements (Conway et al., 2005). Therefore to ensure optical flow, it is necessary to get clear forms and contrast colors of woven structure.



**Figure 1. Digital version of optical illusion pattern design**

Type and density of weave as well as size of pattern design elements influence quality and brightness of pattern. In Fig.2

development process of woven pattern is shown.



**Figure 2. Development process of woven pattern: (a) – objects with satin weave; (b) – enlarged objects with satin weave; (c) – enlarged objects with satin weave and floats; (d) – washed enlarged objects with satin weave and floats.**

Double faced satin weave was used to get larger contact area of weft yarns on topside. Since it is possible to process just 4 weft colours in this weaving machine but in pattern 5 colours are required (4 colours + conductive yarn), for white contour floats of

warp yarns were used. Circles with diameter 10 mm were too small and had too thin contour (1mm) to make illusory motion (Fig.2. a). Therefore circles were enlarged till 13 mm, contour was enlarged till 2 mm (Fig.2. b). Black contour still melted into the

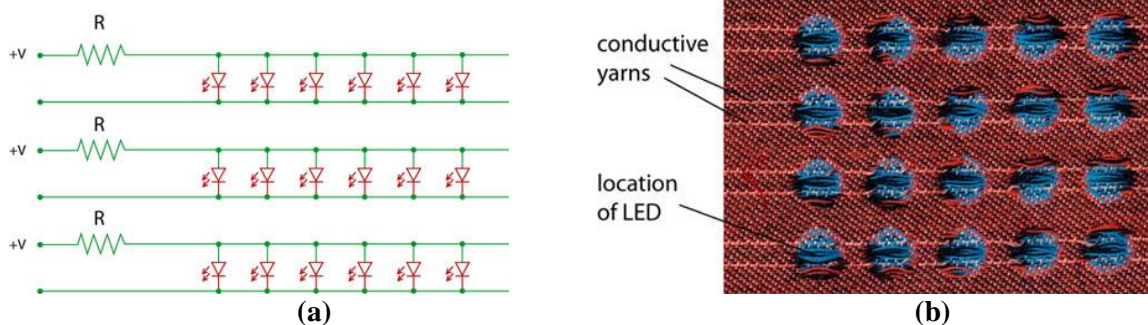
background, so satin weave of black area was changed to floats. Background colour was changed as well to get more contrast between background and black contour (Fig.2. c).

Cotton yarns were used as inserting yarns in weft. It is known that cotton shrinks after hydrothermal processing, so electro-textile was washed to get more dense structure of woven pattern (Fig.2. d). Textile were washed in A type washing machine with temperature of  $60 \pm 3$  °C, 1000 rpm with 20g detergent for 1,40 h. At an average fabric shrank after washing for 8,2% in weft direction and for 3,2% in warp direction. Even though contrast of colours and illusory motion of pattern was better visible in washed sample, it didn't make illusory motion as good as in digital version. To improve the flowing effect probably circles

of pattern should be enlarged more. Increasing pattern elements, total area of pattern increases as well. Efficiency of optical movement reduces and movement flow changes if total area of pattern is trimmed. Since display has size limitation (due to definite application), in this research parameters of pattern weren't enlarged for experiment continuation.

### Design of electro-textiles

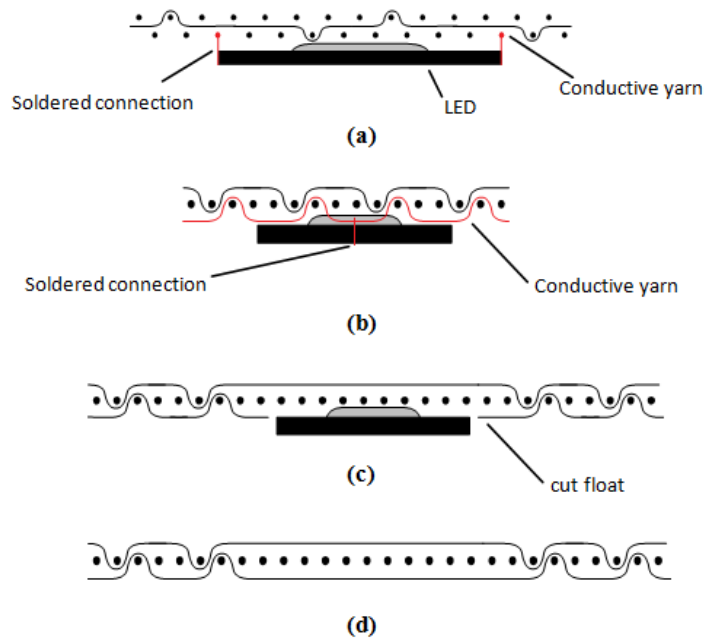
In the pattern parallel port controlled LED display construction has been used, so light emitting diodes can be controlled by rows or by columns (depending from orientation of fabric). LED display electrical scheme is shown as examples in Fig.3.a to demonstrate working principle of display. For such working principle electrotextile is prepared (Fig.3.b).



**Figure 3. LED display: (a) – display electrical scheme; (b) – interwoven conductive yarns**

Conductive yarns were placed in parallel as weft inserted yarns on fabric's backside using warp faced satin weave (Fig.3.b). LEDs are attached to the electro-active fabric from backside therefore electronic system isn't visible on fabric's front side. LED can be placed in every circle. Connection of conductive yarn and LED is done by soldering what in this case is the handiest solution. Fig.4. demonstrates schematic picture of fabric intersection in different parts, conductive yarn position and connection to LED.

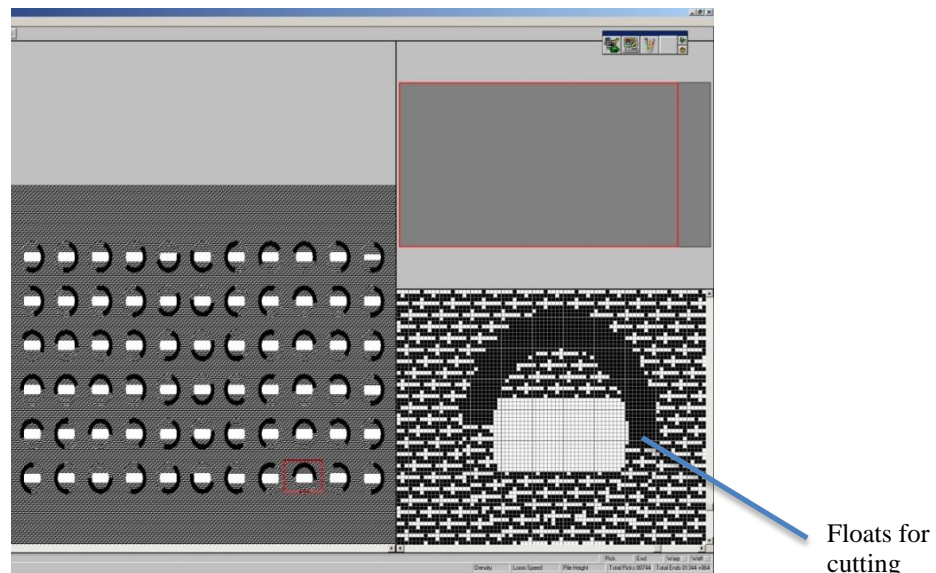
It is important to take into consideration shrinking behavior of yarns compared to conductive yarns while designing electro-textile, especially if longer floats are used in the weave. After wash test conductive yarns didn't shrink, therefore they made loops in places where longer floats were located. Length of loop depends of rotation of pattern circle. Distance between conductive traces of cathode and anode contact is 5 mm. In this case 5 mm distance is enough to avoid connection of both. If distance is smaller and floats are longer, short circuit is possible.



**Figure 4. Schematic picture of fabric intersection: (a) - intersection of warp yarns in part where LED is connected; (b) – intersection of weft yarns in part where LED is connected; (c) –intersection of weft yarns in part where long floats for cutting are designed with cut left side floats; (d) – intersection of weft yarns in part where long floats for cutting are designed (not cut, without LED)**

Fabric has been designed with possibility to vary brightness of LED light by textile pattern. For this purpose floats in the middle of circles have been made – in the part

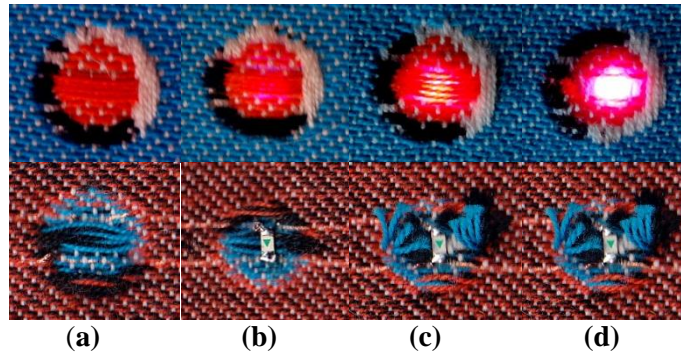
where LED will be located. Detail of pattern design in PC-Edit software is shown in Fig.5.



**Figure 5. Detail of pattern design in PC-Edit software**

Floats are placed both in the front and on the back and it is possible to cut floats to make pattern more transparent for LED emitted light illumination. In Fig.6, different light

illumination is shown when floats aren't cut and when they are cut on front side, and also cut on both front and back sides.



**Figure 6. Light illumination through different textile structure: (a) – textile with floats on right and left side of fabric without LED; (b) – textile with floats on right and left side of fabric with LED; (c) – textile with floats on right side and cut floats on left side of fabric with LED; (d) – textile with cut floats on right and left sides of fabric with LED**

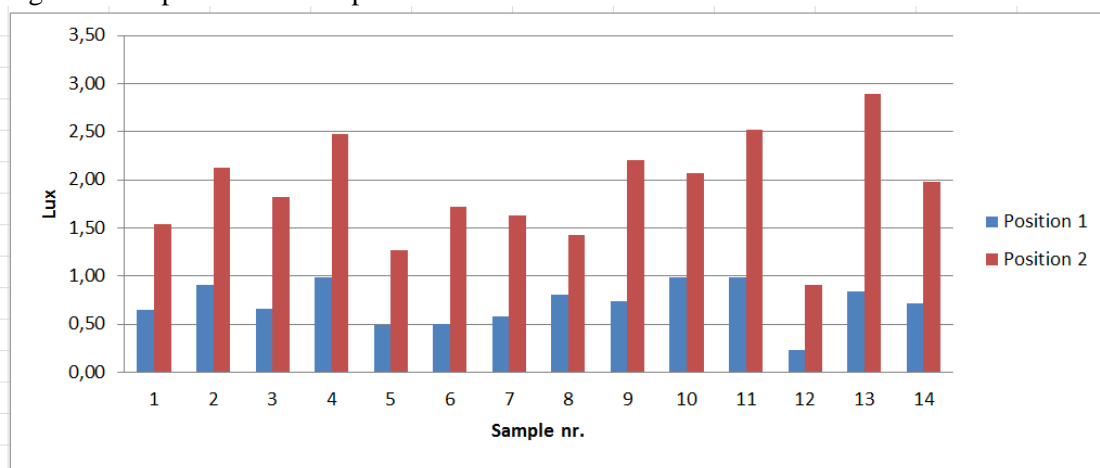
To describe light illumination of display in different positions, light intensity of display LEDs in each position was measured with environment meter, using luxmeter function. Intensity of emitted light for different positions is shown in Fig.7.

makes optical motion vision in static textile. Turning on electro-textile it fulfills its interactive function as well by illuminating light.

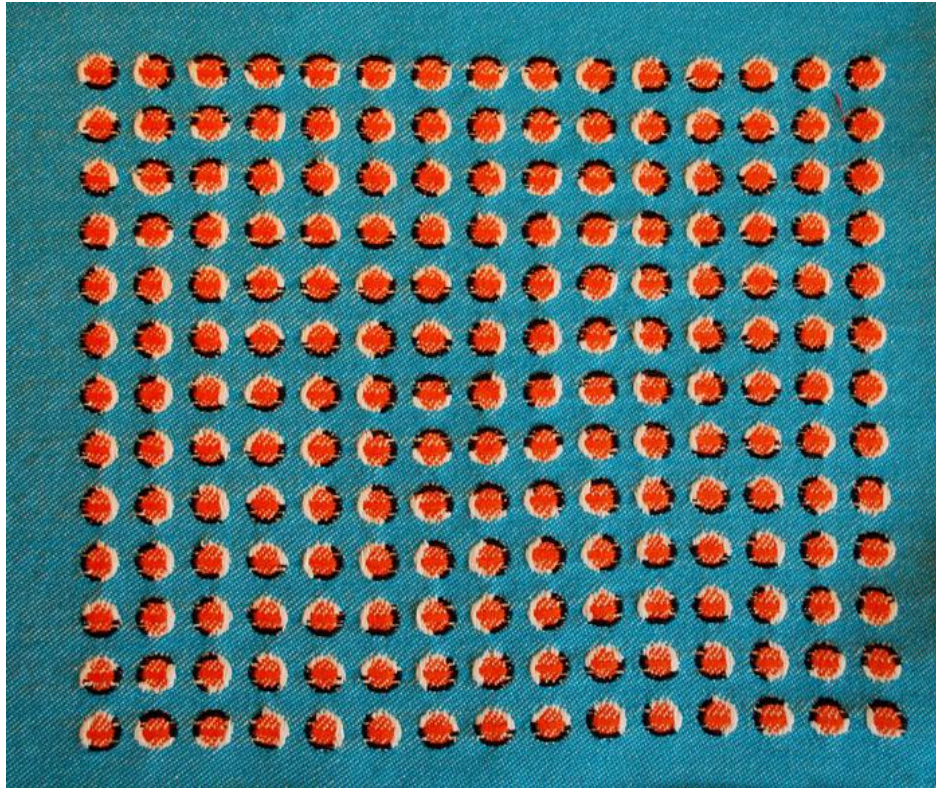
### Results and discussions

Woven LED display in switch-off mode is shown in Fig.8. Visual interface of display is designed as optical illusion pattern what

For measurements row of LEDs (14 LEDs/row) in display was connected to 5V power using 10 ohm resistor. Graph in Fig.7 shows measurements of two positions – emitted light intensity when floats are cut just on left side (position 1) and when floats are cut on left and right side (position 2).



**Figure 7. Intensity of emitted light for different positions**

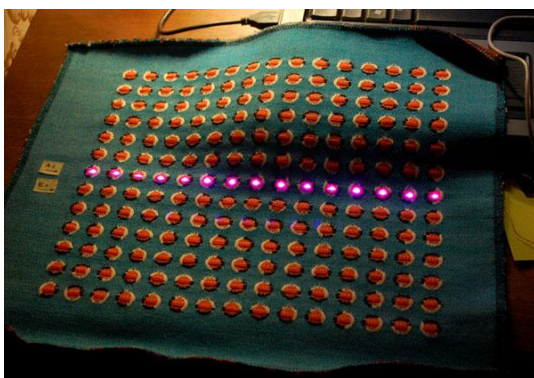


**Figure 8. Digital version of optical illusion pattern design**

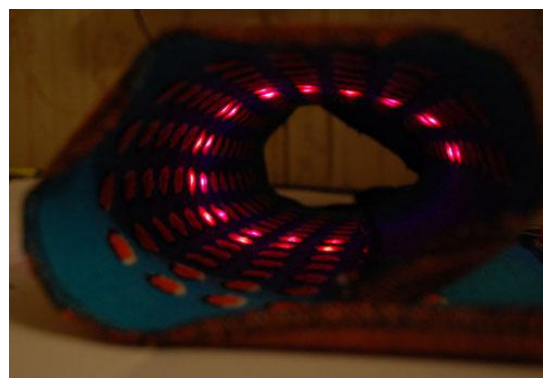
For experiment middle-bright LEDs were used (350 mcd), therefore LED light intensity is low with floats in both sides of fabric. With cut floats on left side of fabric LED light intensity in average is 0,72 lux. With cut floats on left side and right side of fabric LED light intensity in average is 1,90 lux or on 163% brighter light illumination.

Display is designed as one layer fabric

and using proper weave electronic system isn't visible on fabric right side and electro-textile keeps small thickness (without LED – 1,7 mm, with LED – 1,94 mm) and weight (with partly attached LEDs - 480 g/m<sup>2</sup>), as well as good flexibility what is important in textile and clothing designing. Display with one and two switch-on LED rows is shown in Fig.9 and Fig.10.



(a)



(b)

**Figure 9. Textile LED displays: (a) - with one switch-on LED row; (b) - with two switch-on LED rows**

## Conclusions

Weaving methods can be used as a tool to build and enhance electro-textile properties. By exploring various weaving techniques and perceiving electronic light emitting schemes as weave patterns, a new way of developing electro-textile designs can be explored. Experimenting the interaction between light and textile structure can be an important research and development topic in the future of aesthetics research in textiles.

The main aim of this research was to explore the possibilities in aesthetic electro-textile creation through applications of various materials and colors of yarns together with weave patterns and fabric density. In this study, woven light emitting electro-textile was created by combining aesthetic and functional designs in one fabric pattern. Optical illusion the pattern provided an optical illusion of motion in the fabrics that can be applied to different designs. The fabrics integrated with electronic elements (LEDs) provide interactive property in textiles but do not decrease the comfort properties in the fabrics. Textile display can be used as an output interface for different electronic systems, for clothing, accessories, room and auto interior.

In order to ensure electro-textile protection from environmental conditions such as humidity, the display mechanism may be insulated. For example, the lamination can be formed with PU film or coating with elastomer to provide dehumidification.

## Summary

Development of electronic textiles provides an opportunity to create innovative products in different fields related to smart clothes and smart textiles. Developing smart textile designing methods and enlarging their assortments, a weaving method was used in this research to find out how to combine the fabric's aesthetic and functional properties in one pattern. Using different types of woven fabric structures, various

designs can be explored for appropriate applications.

During this study, a woven LED display method was developed with integrated electronic elements (conductive yarns and light emitting diodes). Light-emitting methods rendered an interactive design feature in the fabric pattern creating optical illusion motif which performed an aesthetic function. In addition, the structure of electro-textiles has been demonstrated with a discussion on a possibility to vary brightness of LED light in the textile pattern.

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## References

- Akiyoshi's illusion pages. Retrieved March 20, 2013, from <http://www.ritsumei.ac.jp>
- Cochrane, C., Meunier, L., Kelly, F., Koncar, V. (2011, December). Flexible displays for smart clothing: *Part I—Overview. Indian journal of fiber and textile research. Vol 36, 422-428.*
- Conway, B. R., Kitaoka A., Yazdanbakhsh, A., Pack, C. C., Livingstone, M. S. (2005, June). Neural Basis for a Powerful Static Motion Illusion. *The Journal of Neuroscience, Vol 25(23), 5651-5656*
- Dhawan A., Ghosh, T. K., Seyam, A. M., Mutha J. (2002) Development of Woven Fabric-based Electrical Circuits. *Proceedings of Materials Research Society Symposium, Vol. 736, 67-72*



Ghosh, T.K., Dhawan, A., Muth, J.F. (2006, July) Formation of electrical circuits in textile structures. *Intelligent textiles and clothing*, 242

Janietz, S., Gruber, B., Schattauer, S., Schulze, K. (2012, September). Integration of OLEDs in Textiles. *Journal Advances in Science and Technology*, Vol 80, 14-21,

Jeong, K.S., Yoo, S.K. (2010). Electro-Textile Interfaces: Textile-Based Sensors and Actuators. *Smart Clothing Technology and Applications*, 98-113

Kirstein, T., Cottet, D., Grzyb, J., Tröster, G (2005 March). *Wearable computing systems – electronic textiles*. *Wearable Electronics and Photonics*, 177-197

Perner-Wilson, H., Worbin, L., Satomi, M. Involving the machines. Retrieved March 20, 2013, from <http://www.stdl.se/?p=202>