SEVEN
publicações acadêmicas

TOUCH-SENSITIVE JACQUARD FABRIC FOR HOME INTERFACES: A TECHNICAL STUDY WITH A MULTIDISCIPLINARY APPROACH

TECIDO JACQUARD SENSÍVEL AO TOQUE PARA INTERFACES RESIDENCIAIS: UM ESTUDO TÉCNICO COM ENFOQUE MULTIDISCIPLINAR

TEJIDO JACQUARD SENSIBLE AL TACTO PARA INTERFACES DOMÉSTICAS: UN ESTUDIO TÉCNICO CON UN ENFOQUE MULTIDISCIPLINARIO

https://doi.org/10.56238/sevened2025.036-013

Thais Puccinelli Alves[1], Camilla Borelli[2], Renato Camargo Giacomini[3]

ABSTRACT

This article discusses the design and functional analysis of a touch-sensitive fabric, created with Litz conductive yarns and woven on a Jacquard loom, for home automation applications. The study begins with the following research question: is it possible to design a fabric that maintains its textile properties but functions as a tactile sensor in a smart home system? The hypotheses tested were: (1) the fabric will exhibit electrical conductivity after the weaving process; (2) it can be integrated into electronic systems with efficient Bluetooth response. The methodology consisted of the production of the conductive fabric, its integration with an FPGA board, conductivity testing, practical simulations with electrical circuits, and an interface with a mobile application. The results indicated technical feasibility, good tactile response, and stable functional integration, confirming the potential of e-textiles as active components of environmental automation systems. Furthermore, the study reports on an interdisciplinary learning experience of a Textile Engineering student, who was challenged to acquire skills in electronics, sensors, and digital communication, demonstrating the importance of integrated approaches in higher education technology. Further research is recommended to further explore durability, washability, ergonomics, and energy integration testing to consolidate the system's applicability in real-world contexts.

Keywords: Smart Fabric. E-Textiles. Conductivity. Jacquard. Interdisciplinary Training.

RESUMO

Este artigo trata do projeto e da análise funcional de um tecido sensível ao toque, criado com fios condutores do tipo Litz e confeccionado em tear Jacquard, voltado para aplicações em automação residencial. O estudo parte da seguinte questão de pesquisa: é possível projetar um tecido que mantenha suas propriedades têxteis, mas funcione como sensor tátil em um sistema de casa inteligente? As hipóteses testadas foram: (1) o tecido apresentará condutividade elétrica após o processo de tecelagem; (2) poderá ser integrado a sistemas eletrônicos com resposta eficiente via Bluetooth. A metodologia consistiu na produção do tecido condutor, sua integração com uma placa FPGA, testes de condutividade, simulações

[1] Bachelor of Science in Textile Engineering. Centro Universitário da FEI.São Paulo Brazil.
E-mail: thais.puccinelli@gmail.com
[2] Dr. in Chemical Engineering. Escola de Artes, Ciências e Humanidades da USP. São Paulo Brazil.
E-mail: cborelli@usp.br
[3] Dr. in Electrical Engineering. Centro Universitário da FEI.São Paulo Brazil.
E-mail: renato@fei.edu.br

práticas com circuitos elétricos e interface com aplicativo móvel. Os resultados indicaram viabilidade técnica, boa resposta tátil e integração funcional estável, confirmando o potencial dos e-têxteis como componentes ativos de sistemas de automação ambiental. Além disso, o estudo relata uma experiência de aprendizagem interdisciplinar de uma estudante do curso de Engenharia Têxtil, que foi desafiada a adquirir competências em eletrônica, sensores e comunicação digital, demonstrando a importância de abordagens integradas no ensino superior tecnológico. Como continuidade, recomenda-se o aprofundamento em testes de durabilidade, lavabilidade, ergonomia e integração energética, a fim de consolidar a aplicabilidade do sistema em contextos reais.

Palavras-chave: Tecido Inteligente. E-Textiles. Condutividade. Jacquard. Formação Interdisciplinar.

RESUMEN
Este artículo aborda el diseño y el análisis funcional de un tejido sensible al tacto, creado con hilos conductores Litz y tejido en un telar Jacquard, para aplicaciones de domótica. El estudio parte de la siguiente pregunta de investigación: ¿es posible diseñar un tejido que mantenga sus propiedades textiles, pero que funcione como sensor táctil en un sistema de domótica? Las hipótesis probadas fueron: (1) el tejido exhibirá conductividad eléctrica tras el proceso de tejido; (2) podrá integrarse en sistemas electrónicos con una respuesta Bluetooth eficiente. La metodología consistió en la producción del tejido conductor, su integración con una placa FPGA, pruebas de conductividad, simulaciones prácticas con circuitos eléctricos y una interfaz con una aplicación móvil. Los resultados indicaron viabilidad técnica, buena respuesta táctil e integración funcional estable, lo que confirma el potencial de los textiles electrónicos como componentes activos de sistemas de automatización ambiental. Además, el estudio informa sobre la experiencia de aprendizaje interdisciplinaria de un estudiante de Ingeniería Textil, quien se enfrentó al reto de adquirir habilidades en electrónica, sensores y comunicación digital, lo que demuestra la importancia de los enfoques integrados en la tecnología de la educación superior. Se recomienda realizar más investigaciones para explorar más a fondo la durabilidad, la lavabilidad, la ergonomía y las pruebas de integración energética para consolidar la aplicabilidad del sistema en contextos del mundo real.

Palabras clave: Tejidos Inteligentes. Textiles Electrónicos. Conductividad. Jacquard. Formación Interdisciplinaria.

1 INTRODUCTION

The presence of digital technologies in everyday life has profoundly transformed the way we live and relate to the spaces around us. What was once a traditional house, designed only to house and organize basic functions, is now configured as an intelligent environment, where comfort, practicality and efficiency are amplified by devices that communicate with each other. In this new context of connectivity, e-textiles — fabrics that integrate electronic circuits and functionalities — emerge as innovative solutions, capable of going beyond fashion or technical clothing and assuming interactive, sensory, and even communicational roles.

Initially restricted to academia, e-textiles have been consolidated, in recent decades, as a strategic area of development, where knowledge of textile engineering, embedded electronics and information technology converge. According to Skyrme (2023), in the report *E-textiles and smart clothing markets 2023–2033: technologies, players, and applications*, by the IDTechEx consultancy, there are already more than 200 organizations involved in the creation of smart textile-based products. These products range from heated garments and sensor dressings to touch-sensitive interfaces embedded in vehicle and home interiors. This advance has been made possible by factors such as the miniaturization of components, the evolution of conductive fibers, and the strengthening of connections with mobile devices and the Internet of Things (IoT).

In the field of home automation, this trend gains even more relevance. Houses began to incorporate elements of environmental intelligence that integrate aesthetics, functionality, and technology (Freitas et al., 2012; Muratori, 2015). In this scenario, the so-called smart textiles, also known as *smart textiles*, play an important role in expanding the possibilities of interaction between people and automated systems, as pointed out by Tao (2001) and Van Langenhove & Hertleer (2004). By connecting traditional textile materials with digital solutions, new forms of interface are created that combine design, comfort and technology in a discreet and efficient way.

This article addresses the construction of a conductive fabric responsive to touch, developed with Litz-type copper conductive wires covered by polyester, structured on a Jacquard loom. The fabric is used in the manufacture of a decorative and functional cushion, with a Bluetooth interface aimed at home automation. The research is guided by the following question: is it possible to develop a conductive fabric that maintains aesthetic and structural properties suitable for decorative use?

As a hypothesis, it is assumed that the fabric will maintain electrical conductivity after weaving, be integrated with stability to mobile electronic systems and preserve conventional textile attributes.

In addition to the technical application of the project, this study also represents an interdisciplinary learning experience in the context of training in Textile Engineering. The development of the solution required the author to deepen the contents of basic electronics, conductivity, sensors and digital integration, themes that go beyond the traditional training of the textile area, promoting a practical articulation between different technical knowledge.

General objective: to develop a touch-sensitive fabric applied to residential decoration.

Specific objectives:a) to integrate the fabric with electronic components via Bluetooth;

b) test its electrical conductivity and functionality as a tactile interface.

2 THEORETICAL FRAMEWORK

The integration of electronic functions into textile substrates has been the subject of intensive studies in recent decades, driven by the demand for wearable technologies, flexible interfaces, and integrated solutions for environmental automation. The so-called smart textiles can be classified into three categories: passive, active, and very intelligent, based on their ability to respond and adapt to external stimuli (Wen, 1992; Tao, 2001). This classification guides the development of applications ranging from body sensors to interactive textile panels for device control in smart homes.

E-textiles or electronic textiles are a subcategory of technical fabrics, characterized by built-in electronic functionalities. They integrate electronic components into conventional textile structures, enabling applications ranging from physiological monitoring to interfaces for environmental control (Post; Margaret, 1997; Lind et al., 1997; Rossi; Paradiso, 2011). According to Blecha et al. (2024), this integration can occur superficially — by sewing or printing — or structurally, with the insertion of conductive threads during weaving. The ASTM D8248-20 standard, a reference for classification and standardization of e-textiles, recognizes different levels of complexity and establishes criteria for their validation as functional systems.

From a technical point of view, fundamentals on textile structures and Jacquard weaving processes are well described in classic works such as Araújo (1986), Castelli et al. (2000) and Marks & Robinson (1976). These authors discuss aspects such as warp density, ligaments, and structural parameters that influence the malleability, resistance, and aesthetics of the final fabric, being essential for planning the insertion of functional threads without compromising textile integrity.

Among the most used functional elements are conductive metal wires, such as copper, silver, and stainless steel. Litz yarn, in particular, stands out for its multifilament composition and flexibility, being widely applied in projects that require good conductivity and malleability. Kuzubaşoğlu et al. (2023) point out that the association between metallic yarns and conventional fibers (cotton, viscose, polyester) allows obtaining comfortable and functional substrates, while maintaining desired characteristics such as soft touch, good mechanical strength, and dimensional stability.

Several studies analyze the mechanical and electrical properties of conductive wires. Ashgar et al. (2016) demonstrate that the orientation and type of metallic filament directly impact the tensile strength and conductivity of hybrid yarns. Rajendrakumar and Thilagavathi (2012) complement this, showing how variations in the construction parameters of fabrics with metallic threads interfere with electromagnetic performance. Lou (2012) describes industrial processes for the production of core-spun conductive yarns with application in functional fabrics.

In addition to metals, conductive polymers have also been widely used as viable alternatives. Ding et al. (2010) investigated the behavior of fabrics impregnated with PEDOT:PSS, relating conductivity with electrochromic stability. Varesano et al. (2005), in turn, examined the degradation of electrical conductivity in fabrics impregnated with polypyrrole, highlighting the challenges related to the durability of these materials in the face of continuous use and washing.

As far as practical applications are concerned, smart fabrics have been used in functional clothing, biometric sensors, and touch-sensitive interfaces. Bae and Hong (2013) researched the use of conductive fabrics as substitutes in the control of contact surface screens. Ferreira et al. (2011) demonstrated the application of carbon nanotubes in monofilaments for the development of sensors integrated into technical fabrics.

Andrade, Borelli and Giacomini (2014) developed wide-area textile sensors applicable to clothing, reinforcing the feasibility of integration into large-area garments. Zhang et al. (2021) conducted a review on advances in the engineering of multifunctional fibers, which can simultaneously act as sensors, emitters, actuators, and energy conductors. Materials such as graphene, carbon nanotubes (CNTs) and metallic nanowires have been applied in textile architecture, allowing the incorporation of circuits directly into the fibrous mesh and its integration with Internet of Things (IoT) systems. Sànchez (2006.) contributes with a broad vision of the European textile sector, highlighting the advancement of functional fabrics and the industrial perspectives for e-textiles in technical and decorative contexts. This international vision complements the understanding of the challenges and opportunities of applying smart textile technologies in the contemporary context.

In the context of home automation, the use of functional fabrics represents an innovative approach to creating discreet and comfortable interfaces, replacing or complementing conventional rigid surfaces. The literature indicates that these fabrics can be used to control lighting, temperature, sound, or household appliances through touch or proximity detection. Kirstein et al. (2005) highlight that wearable systems and textile interfaces must combine functionality with essential characteristics such as comfort, washability, mechanical durability and low perceptible interference for the user.

The evolution of manufacturing techniques has contributed to the consolidation of these systems. According to Kuzubaşoğlu et al. (2023), methods such as weaving with hybrid threads, computerized embroidery of conductive tracks, printing circuits with functional inks, and soldering flexible electronic components make it possible to produce e-textiles at scale while maintaining control over physical and electrical properties. Structures are often used to encapsulate the lead wires and protect the circuit from wear, bending, or shorting.

However, the main barriers to large-scale commercial adoption still include:

(1) the degradation of conductive materials in the face of daily use and washing;

(2) the absence of widely accepted technical standards that regulate performance, safety and durability; and

(3) the need for compact and integrable energy sources to the fabric. Strategies such as polymeric encapsulation, development of self-sufficient sensors with triboelectric nanogenerators, and integration with textile solar cells have been proposed as viable solutions (Kuzubaşoğlu et al., 2023).

In view of this panorama, the present work is anchored in the understanding of smart fabrics as hybrid platforms, which combine traditional textile properties with the capacity for digital performance and communication. The proposal for an interactive touch-sensitive cushion, connected to mobile systems via Bluetooth, represents a concrete application of this convergence between textile engineering, functional materials and automation technologies.

3 METHODOLOGY

The methodology adopted in the present study is in line with similar proposals already documented in the literature, such as the research conducted by Guedes, Borelli and Giacomini (2017), who also explored the incorporation of tactile sensors in textile materials with interest in applications aimed at the Internet of Things (IoT), highlighting the challenges related to the integration between textile properties and electronic functionalities.

This study is characterized as an investigation of applied and experimental nature, with a projectual objective, presenting the design, synthesis and functional analysis of an intelligent touch screen fabric for use in home automation systems.

The project was developed based on a project-based learning (*PBL*) approach, which allowed the student to articulate knowledge from different areas in a practical and applied way, as discussed by the active methodologies in technological higher education (Markham, 2008).

The development process involved four main steps:

(1) design and manufacture of conductive fabric;
(2) integration with electronic systems;
(3) performance of physical-functional tests; and
(4) Application of the fabric in a functional decorative item.

3.1 DEVELOPMENT OF TOUCH-SENSITIVE FABRIC

The first stage comprised the structural construction of the touch-sensitive fabric, based on Jacquard technology, which allows precise control of complex ligaments and planned insertion of functional elements. Figure 1 illustrates the structure of the fabric, which was made on a Jacquard loom of the Howa do Brasil brand, using continuous carded cotton threads in the warp, in ecru color, with Ne 20/2 title, and in the weft 90% viscose and 10% metallic yarns, in burgundy color, with 6/2 title.

Figure 1

Jacquard touch-sensitive fabric

Source: authors.

The fabric also has a conductive thread (Litz thread), composed of 4 copper filaments covered by textured polyester, inserted every 2 cm in the direction of the weft and warp. Finally, in the warp, the conductive threads were inserted approximately every 30 cotton threads, and in the weft, a conductive thread was passed for every 14 strokes of the metallized thread, approximately. The wires are shown in figure 2.

Figure 2

Cotton, Litz and metallized yarns

Source: authors.

Electrical functionality was ensured by the insertion of Litz-type conductive wires, composed of four copper filaments covered with textured polyester. In the warp, the conductive threads were positioned every 30 cotton threads, and in the weft, a Litz thread was inserted every 14 passes of the metallized yarn, resulting in a functional distribution pattern every 2 cm in both directions. The chosen pattern was aimed at residential decoration, aiming at the use of fabric as a visual and interactive component of a cushion. The objective was to ensure that the fabric maintained the appearance and texture of a conventional fabric, respecting criteria of comfort, flexibility and aesthetics.

3.2 TESTING AND EXPERIMENTAL DESIGN

With the system assembled, it was planned to carry out technical-functional tests with the objective of validating the effectiveness of the fabric as a capacitive tactile sensor. The tests were divided into three categories:

(a) verification of electrical conductivity of Litz wires: A Minipa ET-2231 digital multimeter was used to measure the resistance between two points of the conductive wire inserted in the fabric. Due to the enamelled coating of the copper wires, it was necessary to carefully scrape the enamel with tin solder to ensure proper electrical contact.

(b) functional test with mini lamp: An acrylic set containing batteries, cables and a mini lamp, illustrated in figure 3, was used to simulate an electrical circuit. The cables were connected to the fabric conductor wires and, upon touch, the mini lamp was activated, confirming the presence of efficient electrical continuity in the fabric.

Figure 3

Set for the Fabric Conductivity Test

Source: authors.

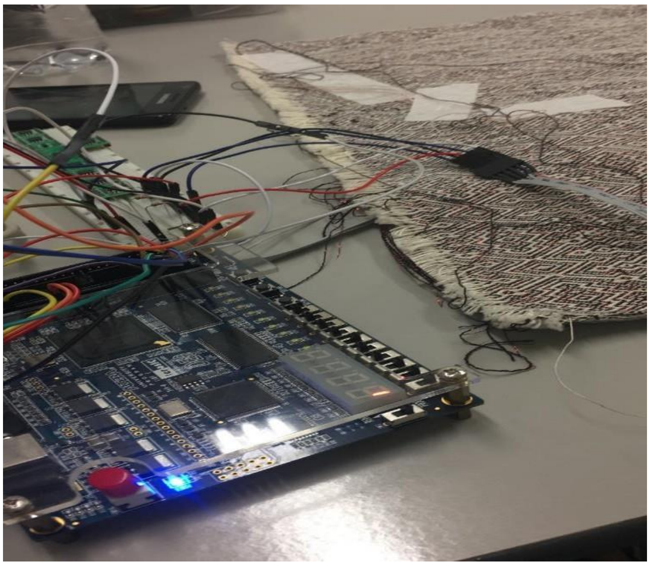
(c) tactile response tests and communication via Bluetooth with mobile device: After assembling the system, the tissue was subjected to tactile stimuli with real-time response monitoring in the Android application. Communication latency, signal reading accuracy, and interface stability during prolonged operation were evaluated.

3.3 ELECTRONIC INTEGRATION AND INTERACTIVE SYSTEM DEVELOPMENT

In the second stage, the fabric was integrated into a responsive electronic system, based on an Altera DE0 (Terasic) development board, equipped with FPGA (Field Programmable Gate Array) architecture, programmed to interpret touch signals (Figure 4). To make the electrical connection viable, the Litz wires had their coating removed at strategic points with the help of heated tin, exposing the copper filaments for later soldering to flat cables. These cables were connected directly to the DE0 board, ensuring the reading of tactile signals in an individualized way (Figure 5).

Figure 4

Electronic board system connected to the touch-sensitive fabric



Source: authors.

Figure 5

DE0 electronic board and cell phone, integrated via Bluetooth

Source: authors.

The circuit was powered by a PowerBank, offering mobility and energy independence of the system in relation to the conventional power grid. Data transmission between the fabric and the mobile device was carried out through a Bluetooth module integrated into the board. The interface application was developed using the Bluetooth Electronics platform, compatible with Android devices, allowing the creation of configurable responsive input buttons. Each button in the app was linked to a conductive thread of the fabric, simulating different touch-sensitive activation channels.

3.4 MAKING THE DECORATIVE ITEM

The final stage consisted of the practical application of the developed tissue. A piece was sewn, in the form of a decorative cushion, as shown in figure 6, with dimensions of 40 x 40 cm, allowing the insertion of the electronic components and their integrated operation. Thinking about maintaining the aesthetic and functional character of the article, the piece was filled with textile fibers.

Figure 6

Jacquard touch-sensitive fabric sewn in the shape of a cushion

Source: authors.

4 RESULTS AND DISCUSSIONS

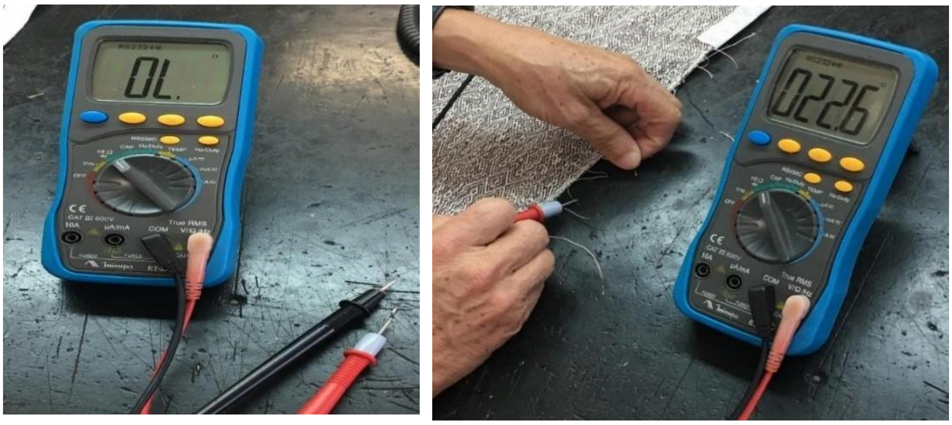
The evaluation of the developed fabric was carried out based on the planned tests, focusing on functional validation and the feasibility of using the material in home automation contexts.

4.1 CONDUCTIVE PROPERTIES OF TOUCH SENSITIVE FABRIC

The electrical conductivity tests, performed with a Minipa ET-2231 digital multimeter illustrated in figure 7, indicated an average resistance of less than 2 ohms per tested segment of the Litz type conductive wires. Due to the insulating enamel of the wires, it was necessary to manually remove the coating in specific areas to ensure direct contact of the multimeter terminals with the copper filaments. The electrical continuity was maintained even after the weaving process and the manipulation of the fabric, proving that the yarns preserved their functional properties in the Jacquard structure.

Figure 7

Results regarding tissue measurement with the multimeter



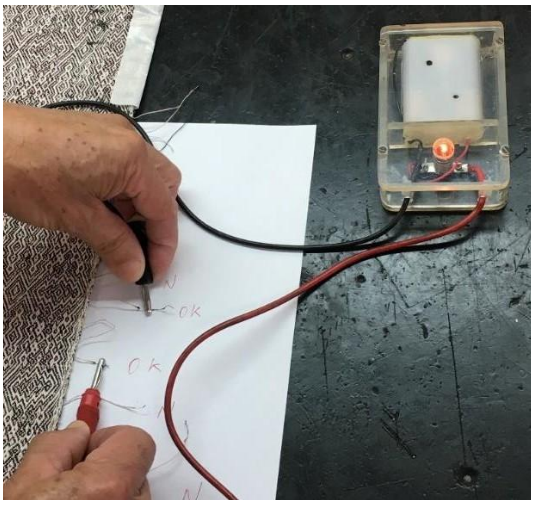
Source: authors.

4.2 PRACTICAL TESTS WITH ELECTRICAL CIRCUIT

In the test with a mini lamp connected to batteries, all 20 tests performed showed immediate activation on the conductive wires, evidencing the ability of the fabric to act as a circuit closing element. Figure 8, with the device's light on, confirms its operation as a practical and direct tactile interface.

Figure 8

Electrical circuit with the mini lamp lit through the conductive wires of the touch-sensitive fabric



Source: authors.

4.3 CONNECTIVITY AND INTEGRATION VIA BLUETOOTH

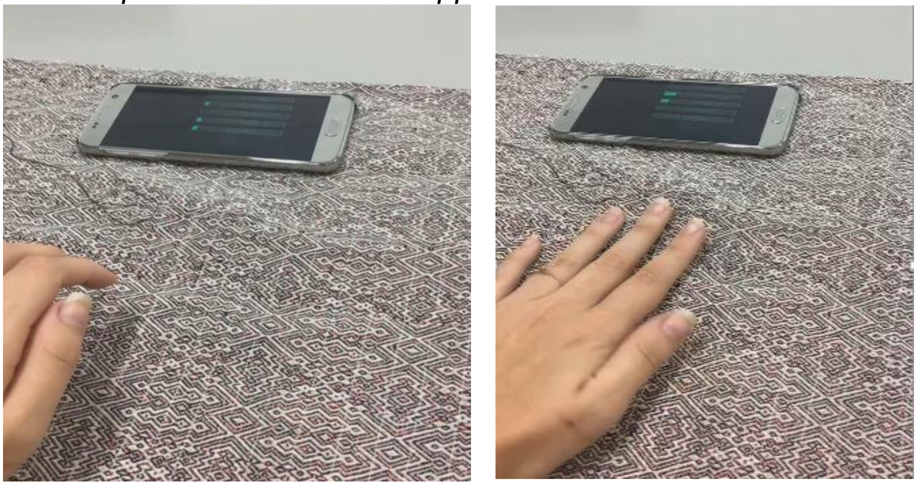
During the testing phase with the mobile application, the system's immediate response to tactile interactions was observed. The signals were read by the DE0 board and transmitted via Bluetooth, with latency of less than 200 milliseconds and stability for 10 consecutive cycles.

This result proves that the developed touch-sensitive fabric is functional as a capacitive contact sensor and that its integration into mobile digital systems is technically feasible. This extends the potential of its application in home automation solutions, where the activation of devices by touch can be done discreetly, without the need for rigid interfaces.

In addition, the visual response offered by the app enables an intuitive and accessible user experience, paving the way for applications that involve accessibility, comfort, and smart interior design.

Figure 9

Touch-sensitive Jacquard fabric – mobile app demo



Source: authors.

In addition to the functional performance, the fabric has retained its flexibility and aesthetic appearance after the insertion of the conductive threads and the assembly procedures. The regular distribution of the Litz wires, with a spacing of 2 cm, was effective both to ensure capacitive activation and to maintain the aesthetics of the product. The developed cushion operated as a sensitive, discreet and comfortable interface, demonstrating practical applicability for interior design and accessibility and automation solutions.

Although the developed fabric does not use cutting-edge materials such as graphene or printed sensors, it represents a technically feasible and affordable solution for tactile automation in homes. The simplicity of the system and the possibility of customization in conventional textile structures expand its application potential. However, the absence of washability, mechanical durability and ergonomics tests limit its commercial validation.

From a pedagogical point of view, the development of this interactive fabric provided a practical and interdisciplinary experience to the author, an undergraduate student in Textile Engineering. The project required not only the mastery of textile and structural aspects, but also the active search for knowledge of electronics, capacitive sensors, wireless communication and FPGA board programming. This experience demonstrates the potential of project-based approaches *(Project based learning)* to promote integration between areas of technical knowledge and prepare the student for real challenges.

5 CONCLUSION

The present study aimed at the development and functional evaluation of a touch-sensitive fabric, made on a Jacquard loom with Litz-type conductive threads, applied to home automation systems. The results obtained demonstrated the technical feasibility of the proposal: the fabric preserved its essential textile properties, such as flexibility and aesthetics, even after the insertion of conductive threads, in addition to presenting stable electrical conductivity and functional integration with electronic systems via Bluetooth.

The practical application in the form of a decorative cushion reinforces the potential of smart fabrics as discreet and functional interfaces for residential environments. Communication with mobile devices occurred responsively and without noticeable latency, validating the system as an integrated capacitive tactile sensor.

In addition to its technical character, this work also stands out as a significant pedagogical experience. Developed by a Textile Engineering student, the project required the articulation of knowledge from different areas — such as electronics, sensors, programming, and wireless communication — traditionally absent in conventional textile training. It is, therefore, an example of active and interdisciplinary learning, in which knowledge is built from real and complex challenges, in line with pedagogical proposals such as project-based teaching and integrated technological education.

It is concluded that the developed touch fabric is a promising solution for applications in home automation and smart interior design, and a powerful training tool. For future research, it is recommended to carry out durability tests (washability, abrasion, use cycles), usability analysis with different user profiles, and the study of integration with autonomous energy sources. Such actions can expand the practical and educational applicability of e-textiles in multiple contexts of contemporary society.

REFERENCES

Andrade, G. M., Borelli, C., & Giacomini, R. C. (2014). A new textile tactile wide-area sensor for clothing. In 14th AUTEX World Textile Conference (pp. 1–10). Uludag University.

Araújo, M. (1986). Manual de engenharia têxtil. Fundação Calouste Gulbenkian.

Asghar, A., Ahmad, M., & Yahya, M. F. (2016). Effects of metal filament's alignment on tensile and electrical properties of conductive hybrid cover yarns. Fashion and Textiles, 3(1), Article 3. https://doi.org/10.1186/s40691-015-0055-4

ASTM International. (2020). Standard guide for characterization and testing of moisture management properties of textile fabrics (ASTM D8248-20). ASTM International.

Bae, J., & Hong, K. H. (2013). Electrical properties of conductive fabrics for operating capacitive touch screen displays. Textile Research Journal, 83(3), 329–336. https://doi.org/10.1177/0040517512464298

Blecha, F., Zhang, Z., & Ren, X. (2024). Electronic textiles. In Z. Zhang & X. Ren (Eds.), Advances in chemical engineering (pp. 1–35). Academic Press.

Castelli, G., Risso, A., & Scuri, M. (2000). Reference books of textile technology. Acmit.

Ding, Y., Invernale, M. A., & Sotzing, G. A. (2010). Conductivity trends of PEDOT-PSS impregnated fabric and the effect of conductivity on electrochromic textile. ACS Applied Materials & Interfaces, 2(6), 1588–1593. https://doi.org/10.1021/am100036n

Ferreira, A., Ferreira, F., & Oliveira, F. (2011). Monofilament composites with carbon nanotubes for textile sensor applications. In 11th World Textile Conference (pp. 1–8). AUTEX.

Ferreira, A., Ferreira, F., & Oliveira, F. (2014). Têxteis inteligentes – Uma breve revisão da literatura. REDIGE, 5(1), 1–10.

Freitas, C. C. S., Silva, R. M., & Oliveira, J. P. (2012). Automação residencial: Cenário atual e perspectivas futuras. Revista Ciência e Tecnologia, 15(26), 45–56.

Guedes, C. E. S., Borelli, C., & Giacomini, R. C. (2017). Desenvolvimento de um sensor táctil incorporado a um tecido aplicável à internet das coisas-IoT. In Pesquisas em design, gestão e tecnologia de têxtil e moda: 2º semestre de 2017 (Vol. 1, pp. 60–64). Escola de Artes, Ciências e Humanidades – EACH/USP.

Kirstein, T., Lawrence, M., & Tröster, G. (2005). Wearable computing systems – Electronic textiles. In X. Tao (Ed.), Wearable electronics and photonics (pp. 1–57). Woodhead Publishing.

Kuzubaşoğlu, B. A., Tekçin, M., & Bahadir, S. K. (2023). Electronic textiles (e-textiles): Fabric sensors and material-integrated wearable intelligent systems. In R. Narayan (Ed.), Encyclopedia of sensors and biosensors (Vol. 1–4, pp. 80–100). Elsevier. https://doi.org/10.1016/B978-0-12-822548-6.00085-6

Lind, E. J., Eisler, R., & Burghart, G. (1997). A sensate liner for personnel monitoring applications. In 1997 First International Symposium on Wearable Computers (pp. 98–105). IEEE. https://doi.org/10.1109/ISWC.1997.629924

Lou, C. (2005). Process of complex core spun yarn containing a metal wire. Textile Research Journal, 75(6), 466–473. https://doi.org/10.1177/0040517505053871

Markham, T., & Larmer, J. (2008). Aprendizagem baseada em projetos. Artmed Editora.

Marks, R., & Robinson, A. T. C. (1976). Principles of weaving. The Textile Institute.

Muratori, J. R. (2015). O mercado de automação residencial no Brasil. AURESIDE.

Post, E. R., & Orth, M. (1997). Smart fabric, or wearable clothing. In 1997 First International Symposium on Wearable Computers (p. 167). IEEE. https://doi.org/10.1109/ISWC.1997.629937

Rajendrakumar, K., & Thilagavathi, G. (2012). A study on the effect of construction parameters of metallic wire/core spun yarn based knitted fabrics on electromagnetic shielding. Journal of Industrial Textiles, 42(4), 400–416. https://doi.org/10.1177/1528083712441960

Rossi, D., & Paradiso, R. (2011). Future direction: E-textiles. In A. Bonfiglio & D. De Rossi (Eds.), Wearable monitoring systems (pp. 1–20). Springer.

Sánchez, J. C. (2006). Têxteis inteligentes. Química Têxtil, 4(82), 58–77.

Skyrme, T. (2023). E-textiles and smart clothing markets 2023–2033: Technologies, players, and applications. IDTechEx. https://www.idtechex.com/en/research-report/e-textiles-and-smart-clothing-markets-2023-2033-technologies-players-and-applications/925

Tao, X. (2001). Smart fibres, fabrics and clothing. Woodhead Publishing.

Van Langenhove, L., & Hertleer, C. (2004). Smart clothing: A new life. International Journal of Clothing Science and Technology, 16(1/2), 63–72. https://doi.org/10.1108/09556220410520360

Varesano, A., Aluigi, A., & Ferrero, F. (2005). A study on the electrical conductivity decay of polypyrrole coated wool textiles. Polymer Degradation and Stability, 90(3), 451–456. https://doi.org/10.1016/j.polymdegradstab.2005.03.017

Wen, X. (1992). Smart materials and structures: An overview. Journal of Intelligent Material Systems and Structures, 3(4), 502–511. https://doi.org/10.1177/1045389X9200300402

Wen, Y. K. (1992). Intelligent structures 2: Monitoring and control. Elsevier Applied Science.

Zhang, Y., Wang, H., Lu, H., Li, S., & Zhang, Y. (2021). Electronic fibers and textiles: Recent progress and perspective. iScience, 24(7), Article 102716. https://doi.org/10.1016/j.isci.2021.102716