Multisensory Architectures for Smart Upholstered Furniture: State of the Art and Emerging Trends

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Abstract. Smart upholstered furniture (smart sofas) combines traditional seating with embedded sensors, actuators and connectivity. Beyond comfort, these products are increasingly expected to monitor mechanical loading, usage patterns and indoor conditions, supporting durability, safety and digital services. This paper presents a concise overview of a multisensor smart sofa developed by the authors and situates it within the broader state of the art. The proposed system integrates pressure and weight sensing, inertial and vibration measurements, temperature–humidity monitoring and a local user interface to detect occupancy, posture, shocks, mould-risk conditions and usage intensity. The paper then reviews commercial smart sofas and research prototypes based on discrete sensors, textile arrays and multimodal data fusion, together with recent advances in smart textiles and energy harvesting.Finally, some open challenges and directions for standard-ready, low-maintenance smart sofas for laboratory testing and everyday use are discussed..

Keywords: smart sofa, upholstered furniture, multisensor system, data fusion, smart textiles, energy harvesting, IoT.

1. Introduction

A smart sofa (also termed smart sofa or tech sofa) is an upholstered furniture piece equipped with electronic components and interactive functions such as sensors, actuators, wireless connectivity, USB ports, audio systems, refrigerated cup-holders and LED lighting. These functions aim to improve comfort, ergonomics, energy efficiency and integration with smart-home ecosystems. Recent advances in embedded systems, optical-fiber sensing, FBG-based measurement, IoT connectivity and smart-furniture architectures have enabled more responsive and adaptive furniture systems capable of multimodal sensing, automated actuation and cloud-linked monitoring [1], [2], [3], [4], [5], [6], [7], [8], [9], [10]. Typical building blocks include sensing components for presence, pressure and temperature; actuators for lumbar support, recline and localized heating or cooling; Bluetooth or Wi-Fi connectivity; touch or voice interfaces and mobile applications; local energy sources (rechargeable or energy-harvesting); and an embedded microcontroller that runs the firmware, logs data and issues notifications.

At the same time, the upholstered furniture industry is evolving besides traditional criteria of aesthetics and basic comfort, adding mechanical strength and durability, ergonomics, sustainability and digitalisation. Smart furniture products increasingly integrate sensors and connectivity to collect data on usage, environmental conditions and safety, providing feedback for design optimisation, quality control and user experience. Multisensor approaches are particularly well suited in this context, as they can combine pressure or weight, acceleration or shock, temperature, humidity and vibration measurements to offer a detailed picture of product state and user behaviour. [11], [12]..

2. Smart sofa and multisensor system overview

The multisensor smart sofa developed in the associated research builds on a conventional upholstered frame and adds a compact sensing and processing platform. The goal is to move beyond entertainment-oriented smart sofas towards an instrumented furniture piece that can monitor loading conditions, user presence and posture, shocks and environmental factors over long periods.

At the hardware level, the system integrates global weight measurement via load cells mounted under the frame, pressure or force sensors in the seat and backrest, an inertial measurement unit to detect shocks and movements, a vibration sensor for impact and cyclic loading, and a digital temperature–humidity sensor to monitor the local micro-climate. These sensors are connected to signal conditioning circuits and analogue–digital converters that provide synchronised data streams, in line with typical multisensor seating platforms reported in the literature [13], [14].

Functionally, the system follows a generic multisensor architecture: sensor layer → conditioning and acquisition → synchronisation → fusion (signal, feature and decision level) → analysis and machine learning → presentation on a local LCD and a dashboard [15]. By combining pressure and weight data with acceleration, vibration and T/RH, the sofa can infer presence and number of users, detect shocks and non-compliant usage, estimate mould-risk conditions and correlate them with mechanical stress. Figure 1 illustrates the functional diagram of this multisensor system.

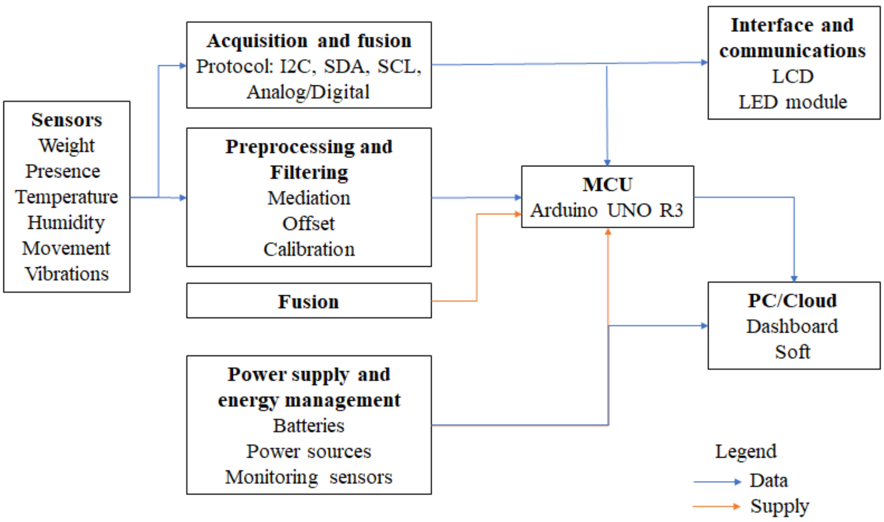

Figure 1 Functional diagram of the multisensor system for a smart sofa.

3. State of the art in smart upholstered furniture

The international market already offers a growing range of smart sofas and recliners, often positioned as home cinema or high-tech relaxation products. Examples include modular systems with integrated surround audio, wireless charging pads, USB ports, refrigerated cup-holders, ambient LED lighting and memory settings for preferred recline positions. Other products feature gesture or voice control, integrated Bluetooth speakers, laptop or tablet tables and concealed storage. Figure 2 shows representative examples of such commercial smart sofas and recliners.

Despite the richness of entertainment and comfort features, most commercial products offer limited sensing beyond simple occupancy switches for safety or control. Monitoring of mechanical loading, posture, shocks and micro-climate is still rare in off-the-shelf smart sofas. This opens a gap between the current generation of feature-rich but weakly instrumented products and research prototypes aimed at comprehensive monitoring and analytics.

Figure 2 Example of a commercial smart sofa with integrated audio, lighting and controls [15]

4. Research on multisensor systems in upholstered furniture

Beyond commercial products, a significant body of research focuses on instrumented beds, chairs and sofas. A first group of studies addresses occupancy detection in foldable beds and seats using capacitive pads and sinusoidal wire networks embedded in the support structure. Related patent US20150137833A1 [16] proposes conductive pads made of metalised foils, conductive textiles or wire meshes placed in the seat or backrest to detect the presence or absence of a user.

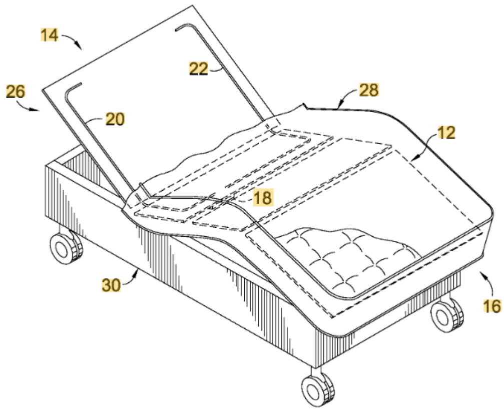

Figure 3 Detection in foldable beds and seats using capacitive pads and sinusoidal wire networks [16]

A second group of solutions focuses on detecting when the user leaves the furniture. A patented system for occupancy detection in chairs and recliners monitors changes in the capacitive or pressure signature of the seat to identify the exact moment when the user stands up and the furniture becomes unoccupied. Such functionality is useful for automatically logging sitting sessions, triggering sedentary-behaviour alerts, switching equipment to a low-power state, or activating security routines (for example, locking controls or disabling actuation when no user is present). The same principle can be applied to smart sofas, where reliable detection of user exit is a key ingredient for meaningful usage analytics and context-aware services.

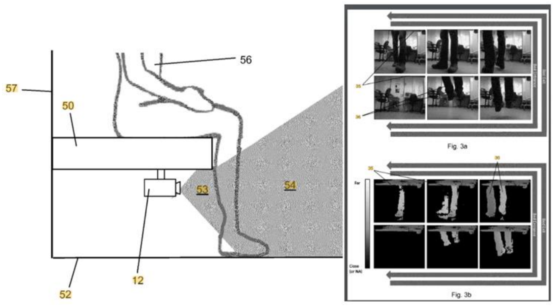

Figure 4 Detection of the moment when the user leaves the chair or recliner [17]

Another group of works investigates posture recognition and comfort using pressure-mapping. Examples include smart quilts and seat toppers with low-cost piezoresistive matrices, removable seat covers equipped with pressure sensors arranged according to biomechanical constraints, and dense pressure matrices in the ischial area for recognising sitting postures with accuracies around 80–90%.

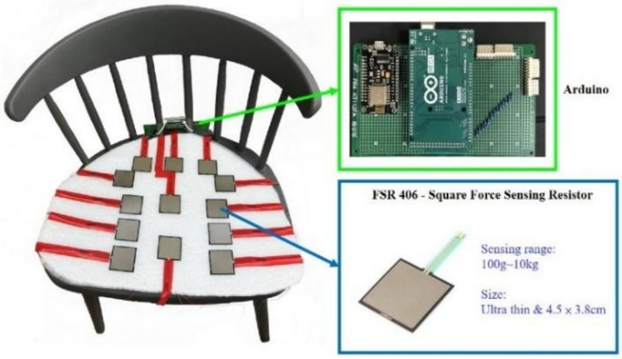

Figure 5 Posture recognition and comfort using pressure-mapping [18]

Another relevant contribution focuses on a soft "smart quilt" (seat topper) that integrates a low-cost piezoresistive pressure matrix mounted on a laboratory chair. The topper generates a pressure map with sufficient spatial resolution to feed a posture-classification model in real time, enabling discrimination between several sitting postures based on the pressure distribution under the pelvis and thighs. The solution is thin, compliant and comfortable, and can be integrated either directly into the upholstery or as an additional layer on top of the seat surface, which makes it directly transferable to smart-sofa applications.

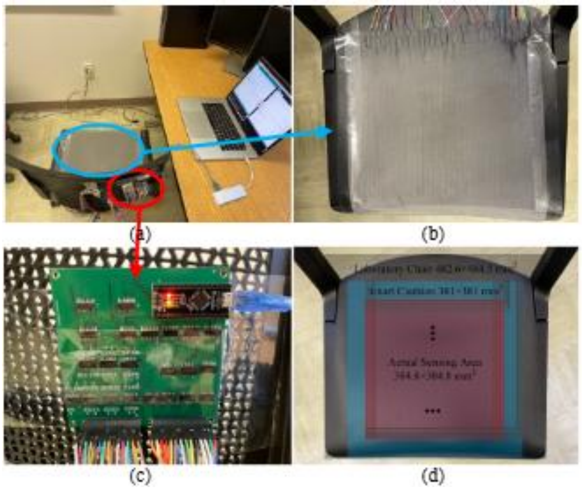

Figure 6 Smart quilt (seat topper) with low-cost piezoresistive pressure matrix for posture recognition [19]

Another study investigates a removable seat cover with integrated pressure sensors. The authors propose a dedicated hardware architecture and a sensor layout specifically designed to follow the biomechanics of sitting, with higher spatial resolution in the ischial and thigh regions and lower resolution in peripheral areas. The cover can be mounted and replaced without modifying the underlying chair, acting as a modular sensing layer. This approach is highly relevant for smart-sofa applications, where a similar removable cover can be adapted to the geometry of the seat surface and used as a replaceable, serviceable sensing module.

Figure 7 Removable seat cover with integrated pressure sensors [19]

Other studies explore textile-based sensing systems for recognising social behaviours on shared seating surfaces [20]. Industrial practice already uses pressure maps to assess comfort and reduce peak pressures under the pelvis in seating products, a methodology that extends naturally to sofas.


Figure 8 Representative textile and pressure-mapping solutions from this line of research [20].

Industrial practice also relies increasingly on pressure mapping for the assessment of seating comfort. SATRA and several chair manufacturers routinely use pressure maps to identify and optimise the distribution of pressure under the pelvis, thighs and back, with particular attention to peak values under the ischial tuberosities and to how the load spreads over the thighs and lumbar area. These measurements support the comparison of different foam constructions, spring layouts and upholstery designs, and provide objective criteria for comfort tuning. The same methodology can be transferred to upholstered sofas, where pressure mapping can help balance comfort, support and durability across the entire seating surface. [21]

Figure 9 Industrial practice in comfort evaluation using pressure mapping [21].

Clinical and ergonomic studies have also validated the use of pressure-mapping on seating surfaces. Several works show that real-time feedback of the pressure map in wheelchairs or transport trolleys used by patients with spinal cord injury helps clinicians and caregivers identify hazardous peak pressures, adjust cushions and postures, and train users in better pressure management. This evidence supports the idea that pressure maps are not only a research tool, but a clinically relevant instrument for preventing pressure ulcers and optimising long-term comfort. By analogy, integrating similar pressure-mapping feedback into smart sofas could support self-management of posture and load distribution for users at risk or for prolonged sitting in domestic environments. [22]

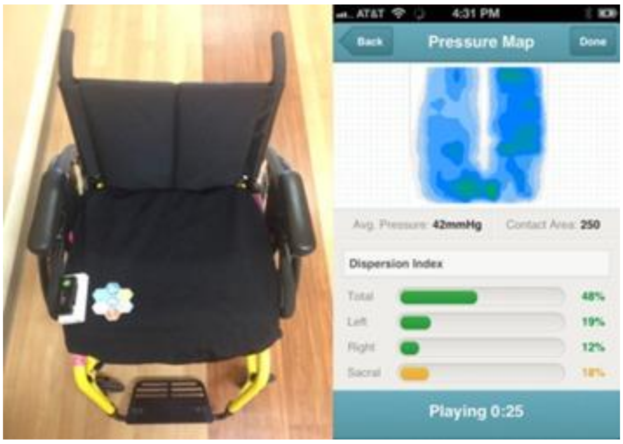

Figure 10 Pressure maps used on wheelchairs and transport trolleys for patients with spinal cord injury [22].

Additional contributions focus on sensor durability and scalability, proposing textile pressure arrays that remain stable under repeated loading and can be integrated as a permanent sensory layer in upholstery. Parallel efforts address posture monitoring in office chairs using capacitive textile sensors and validate the ergonomic relevance of pressure-mapping for users with limited mobility.

Figure 11 Examples of textile-based pressure arrays and posture-mapping systems for seating [23].

A further line of research addresses textile-based pressure sensor matrices designed for long-term durability and industrial scalability. These solutions integrate conductive or piezoresistive elements directly into fabrics, resulting in flexible, washable and mechanically robust pressure-sensing layers that remain stable under repeated loading and constant pressure over extended periods. Thanks to their sheet-like form factor, such textile matrices can cover large areas and be cut or shaped to match specific seat geometries. This makes them strong candidates for permanent sensory layers embedded in upholstery, where the sensing structure can be integrated during manufacturing and remain hidden, while still providing high-resolution pressure maps for smart-sofa applications.

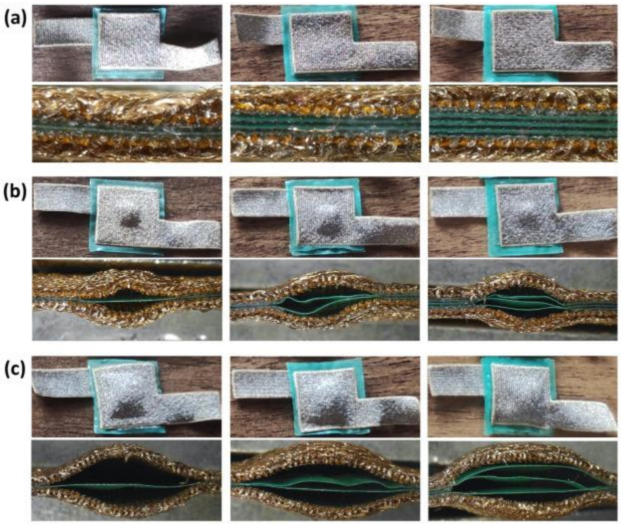

Figure 12 Textile-based pressure sensor matrix integrated into upholstery materials [24].

A relevant direction for smart sofas is represented by “upholstery electro-fabrics” developed specifically for seating furniture upholstery. Coskun and Oner [25] propose an intelligent fabric in which capacitive sensors and conductors are integrated directly into the material, so that the upholstery surface becomes a sensing layer capable of generating 3D pressure maps for different sitting positions. The results show that these textiles are sufficiently robust for real use in chairs and armchairs, and are, in principle, transferable to smart sofas as a permanent sensing layer hidden inside the upholstery.

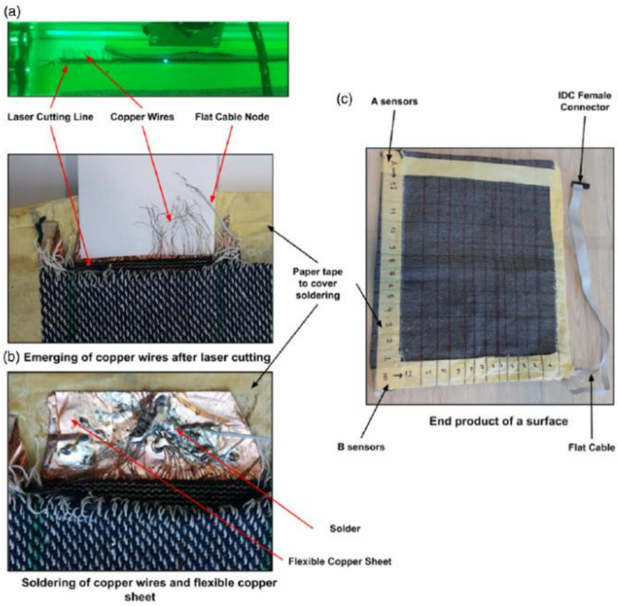

Figure 13 Upholstery electro-fabric with integrated sensing elements for seating furniture [26].

From a systems perspective, many of these prototypes implement multimodal fusion and, increasingly, machine learning or TinyML to combine pressure signals with inertial measurements or other modalities. Reported results demonstrate high accuracy for chair-usage detection and posture classification using compact models suitable for microcontroller deployment. At the same time, recent reviews on energy harvesting for IoT nodes highlight thermoelectric generators and piezoelectric or kinetic harvesters as promising options for powering such sensing systems, especially in low-power, duty-cycled operation. [14], [26]

Finally, updates to seating standards and regional innovation strategies in the furniture sector point towards test protocols and industrial practices where instrumented prototypes, digital key performance indicators and data-driven validation become standard tools. In this context, multisensor smart sofas can serve both as laboratory platforms for standardised testing and as pilot products for real-world, in-situ monitoring. [27]

5. Conclusion

This paper gives a short description of a multisensor smart sofa and a synthesis of the current state of the art in intelligent upholstered furniture. The proposed system combines weight and pressure sensing, inertial and vibration measurements and temperature–humidity monitoring within a layered multisensor architecture, enabling detection of occupancy, posture, shocks, mould-risk conditions and usage intensity. At the same time, the literature and market review highlight a clear separation between commercial smart sofas focused on entertainment features and research prototypes that emphasise sensing, data fusion and analytics.

Emerging trends in smart textiles, multimodal fusion with machine learning, energy harvesting and standardisation create favourable conditions for the next generation of smart sofas: instrumented, connected and partially energy-autonomous, yet compatible with existing testing standards and industrial workflows. Future work should aim at fully integrated, standard-ready platforms that combine robust hardware, explainable alert algorithms, user-friendly interfaces and low-maintenance power solutions, supporting both laboratory testing and everyday use in homes and public spaces.

6. References

[1] Y. Zhao, Internet of Things Technology in Smart Furniture: An Overview. Clausius Scientific Press, 2024.

[2] Mimoso, I. et al. (2025). Exploring Smart Furniture: A Systematic Review of Integrated Technologies, Functionalities, and Applications. Sensors, 25(22), 6900.

[3] Moldovan, A.O., Tarca, R.C., Moldovan, O.G. and Ghincu V.R., 2021. Review Of Optical Fiber Technology Measurement Systems and Application. Revista de Tehnologii Neconventionale, 25(1), pp.44-52.

[4] Moldovan, O.G., Moldovan, A.O., Tarca, R.C. and Craciun, D., 2021. Determination of the Calibration Equation for FBG Temperature Sensors. Recent Innovations in Mechatronics, 8(1), pp.1-6.

[5] Zhao, Y. (2024). Internet of Things Technology in Smart Furniture: An Overview. Journal of Electrotechnology Electrical Engineering and Management.

[6] Feng, K. & Su, Y. (2025). IoT-driven smart furniture system design and user experience optimization. Preprint.

[7] Noje, D.C., Moldovan, O.G., Novac, O.C., Novac, M.C. and Ţarcă, R.C., 2024, June. Flexible system architecture used to collect and store signals acquired by IoT devices. In 2024 16th International Conference on Electronics, Computers and Artificial Intelligence (ECAI) (pp. 1-5). IEEE.

[8] Campos, P., Ehrenberg, N. & Campos, M. (2018). Designing Interactions with Furniture: Towards Multi-Sensorial Interaction Design Processes for Interactive Furniture. arXiv:1803.01145.

[9] Krejcar, O. et al. (2019). Smart furniture as a component of a smart city — Definition based on key technologies specification. (cit. în Mimoso et al., 2025).

[10] Stolojescu-Crisan, C., Crisan, C. & Butunoi, B.-P. (2021). An IoT-Based Smart Home Automation System. Sensors, 21(11), 3784.

[11] A. Baserga, F. Grandi, A. Masciadri, S. Comai, and F. Salice, “High-efficiency multisensor system for chair usage detection,” Sensors, vol. 21, no. 22, p. 7580, 2021.

[12] F. Castanedo, “A review of data fusion techniques,” The Scientific World Journal, vol. 2013, article 704504, 2013.

[13] Tarca R. C., "Advanced mechatronics." Publisher: University of Debrecen, 2012.

[14] Kovacs, Fr, Ţarcă, R., Blaga, Fl., and Tripe V.A., "Sisteme de fabricaţie flexibilă." Oradea: Editura Universitatii din Oradea, 1999.

[15] Jubilee Furniture, “Grando Modern Sectional with Speaker & Wireless Charger & LED Lights (SKU L6026),” Jubilee Furniture [Online]. Available: https://jubileefurniturelv.com/products/grando-modern-sectional-with-speaker-and-led-lights?srsltid=AfmBOopnoaceLDg0SlLjfZYl7xusCNrFYwwmYClEIFlhZ5gXoXolbjLs. Accessed: Nov. 27, 2025.

[16] R. E. Chacon, W. R. Rohr, A. Madadi, and G. M. Lawson, “Occupancy detection for automated recliner furniture,” U.S. Patent Appl. US2015/0137833 A1, 2015.

[17] I. O. Kirenko and M. J. Rocque, "Occupancy detection," U.S. Patent 10,509,967 B2, Dec. 17, 2019, assignee: Koninklijke Philips N.V.

[18] M.-C. Tsai, E. T.-H. Chu, and C.-R. Lee, "An Automated Sitting Posture Recognition System Utilizing Pressure Sensors," Sensors, vol. 23, no. 13, Art. no. 5894, Jun. 2023, doi: 10.3390/s23135894.

[19] L. Yuan and J. Li, "Smart Cushion Based on Pressure Sensor Array for Human Sitting Posture Recognition," in 2021 IEEE Sensors, 2021, doi: 10.1109/SENSORS47087.2021.9639463.

[20] S. Skach, “Strike A Pose: Capturing Non-Verbal Behaviour with Textile Sensors,” in Proc. 20th ACM Int. Conf. on Multimodal Interaction (ICMI ’18), Boulder, CO, USA, 2018, pp. 534–537.

[21] "Using pressure mapping to create better furniture," SATRA Spotlight, SATRA Technology Centre, 2023. [Online]. Available: https://www.satra.com/spotlight/article.php?id=430 Accessed: 24-Sep-2025.

[22] T. L. Vos-Draper, M. M. B. Morrow, J. E. Ferguson, and V. G. Mathiowetz, "Effects of Real-Time Pressure Map Feedback on Confidence in Pressure Management in Wheelchair Users With Spinal Cord Injury: Pilot Intervention Study," JMIR Rehabil. Assist. Technol., vol. 10, Art. no. e49813, Oct. 2023, doi: 10.2196/49813.

[23] M. Martínez-Estrada, T. Vuohijoki, A. Poberznik, A. Shaikh, J. Virkki, I. Gil, and R. Fernández-García, “A smart chair to monitor sitting posture by capacitive textile sensors,” Materials, vol. 16, no. 13, p. 4838, 2023.

[24] C. Gumus, K. Ozlem, F. Khalilbayli, O. F. Erzurumluoglu, G. Ince, O. Atalay, and A. T. Atalay, "Textile-based pressure sensor arrays: A novel scalable manufacturing technique," Micro and Nano Engineering, vol. 15, Art. no. 100140, Jun. 2022, doi: 10.1016/j.mne.2022.100140.

[25] H. Coskun and E. Oner, “Development of upholstery electro-fabric for smart textile applications,” Journal of Industrial Textiles, vol. 51, no. 2S, pp. 2306S–2329S, 2022, doi: 10.1177/15280837211048157. [Online]. Available: https://www.researchgate.net/publication/355043983_Development_of_upholstery_electro-fabric_for_smart_textile_applications (accessed: Nov. 28, 2025).

[26] C. Covaci and A. Gontean, “Energy harvesting with piezoelectric materials for IoT—Review,” ITM Web of Conferences, vol. 29, art. 03010, 2019.

[27] CEN, EN 1728:2012 – Furniture – Seating – Test methods for the determination of strength and durability, 2012.