



Original Research

Development of Fencing Apparel: Integration of Inertial Measurement Unit Sensors for Analysis of Athlete Performance Proposal

Helder Carvalho, University of Minho, Portugal

Daniel Vieira, University of Minho, Portugal

Bernardo Providência, University of Minho, Portugal

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Abstract: This study explores the proposal of a smart fencing garment that integrates inertial measurement units (IMUs) to accurately monitor athletes' movements. A real-time capture of intricate three-dimensional movements was achieved using the Rokoko Smartsuit Pro™, which is equipped with 19 IMUs. Among the exercises conducted, particular emphasis was placed on analyzing correct and incorrect right arm adduction techniques, which provided essential insights for performance enhancement. The meticulous data collection in Rokoko Studio software, which was subsequently exported to CSV files, enabled a comprehensive analysis of the athlete's shoulder, arm, forearm, and hand positions across various axes. This empirical data, coupled with first-hand observations from competitive events and training sessions, formed the basis for the innovative design of the garment, promising enhanced functionality compared to a conventional garment. Integration of IMU technology elevates the garment's capabilities, enabling athletes to fine-tune their performance while providing coaches with valuable insights. Guided by the theory of "kinetic garment construction," the modeling of this new fencing garment lays the groundwork for future prototypes. However, the complete fabrication of advanced prototypes requires interdisciplinary collaboration, considering the complexities involved in prototyping with IMU sensors and real-time signal processing software. Future research endeavors may explore alternative prototyping methodologies and strategies for integrating technology to further revolutionize the field. This study represents a significant stride in fencing garments design and performance monitoring, transcending the boundaries of traditional sports apparel. In summary, this research underscores the transformative potential of integrating cutting-edge technology into sports clothing, propelling advancements in fencing towards greater innovation and performance optimization.

Keywords: E-Textiles, Fencing Gear, IMU Sensors, Smart Garments, Smart Textiles

Introduction

The burgeoning interest in wearable technologies, also known as "Wearable Computing," has been the subject of considerable debate and research in recent years. However, in the specific context of the sport of fencing, there remains a gap in the comprehensive exploration of these technologies and their potential application to enhance athletic performance and ensure athlete safety.

While authors such as Mann (1996), Rambašek (2014), and Kumar et al. (2020) have extensively discussed the potential of wearable technologies, it is essential to acknowledge the need for a deeper, more up-to-date analysis, especially in the context of competitive fencing. Therefore, this article seeks to fill this gap by offering a more detailed and updated analysis of the implications of wearable technologies in the specific context of competitive fencing.

Research on sensors has been expanding, providing new tools for the creation of solutions for smart clothing. Electronic textile technologies are part of a new focus of attention, which discerns between information and communication technologies (ICT) (Ferscha et al. 2014; Buchwald et al. 2018) and Internet of Things (IoT) platforms (Swan 2012; Hiremath et al. 2014; Fernández-Caramés and Fraga-Lamas 2018). According to Post and Orth (1997), the convergence of different fields and industries drives the evolution and creation of new products, as well as the resolution of challenges that open up new business opportunities. These challenges, in turn, require continuous research, development, experimentation, and validation.

From this perspective, smart clothing is boldly positioned between technology and design, with strong connections to the fields of material science, fashion, and user experience in the interdisciplinary sphere of human-computer interaction (Lupton 2014), electronic textile technologies, interaction design, and wearability. Human-computer interaction (HCI) is a multidisciplinary practice that focuses on the interactions between the user and the computer (hardware and software), as well as the design of computer interface, with the aim of creating accessible, functional, efficient, and safe interaction systems. This interaction, in the context of this fencing suit and its attractiveness, was studied in a previous study using the AttrakDiff Mini method (Vieira et al. 2023).

According to Kolko (2011), interaction design is the creation of an interlocution of physical and emotional nature between the user and the product, system, or service; it manifests itself in the interaction between form, function, and technology. Whether in the development of a garment, device, or program, one of the principles is to create empathy with the user. According to Hekkert and McDonagh (2003), experiences are unique and composed of small acts related to contexts, people, and products; these experiences cannot be designed, only the interactions with users. For McLellan (2000), experience design aims to create experiences that are not only functional and objective but also engaging, attractive, memorable, and enjoyable.

The Relationship of Wearable Technology with the User

According to Schifferstein and Hekkert (2008), we live surrounded by artifacts and services created by man to serve various purposes, such as transportation, communication, protection, and entertainment. It is during interactions with these artifacts and services, as well as the information processing that follows, that we experience one or more emotions resulting from

an affective connection to the product. Regardless of how one interacts with an artifact, we use our senses (i.e., sight, hearing, and touch) to perceive it, communicate with it (i.e., touch and voice), and engage our cognitive system in this interaction process. In a scenario of increasing quality of life and consequent rise in user demand, coupled with technological evolution, there is a growing requirement for both performance and design. It is essential to innovate and enhance new concepts to provide clothing with differentiating functions that complement the user experience. The integration of electronic textile technologies in sportswear aims to address these demands by offering solutions that combine performance, comfort, and aesthetics seamlessly.

The Market for Wearable Devices

The market for wearable devices is more diversified than one might initially imagine. There is a whole dimension of wearable technologies, both diversified and differentiated by functions and application sectors, ranging from improving business operations, security, medical, wellness, sports, lifestyle, communication, to beauty.

According to the report by Harrop et al. (n.d.), there are two main models of wearable technologies: wearable devices (e.g., smartwatches) and clothing (e.g., smart T-shirts). In smart clothing, integration primarily involves conventional electronics connected to peripherals, such as smartphones or other similar devices. According to Mihaleva and Koh (2016), the human body acts as a biological receptor, and wearable technology serves as an additional interface facilitating interaction between the body, clothing, and environment. Clothing establishes an intimate connection with the human body—physically, socially, and visually—particularly when it incorporates wearable technology. This study aims to explore this connection by integrating Inertial Measurement Units (IMU) sensors in fencing clothing, targeting industries that may be interested in developing new paradigms in sports technology.

The Integration of Electronic Textile Technologies in Sport

The advancement of technology has significantly influenced various aspects of human life, including sports and athletics. Wearable technologies have emerged as an avenue for enhancing athletic performance, monitoring health metrics, and providing real-time feedback to athletes. Therefore, in the realm of fencing sport, where precision, agility, and strategy are paramount, the integration of electronic textile technologies holds immense potential.

In the current context, wearable systems are evolving towards the second generation, described as Wearables 2.0. The first-generation, Wearables 1.0, considered electronic accessories like watches and wristbands as wearable systems. According to Chen et al. (2016), Wearables 2.0 refers to everyday clothing that provides high-performance functions and

services by incorporating sensors and processing modules in their textile structure. According to Stoppa and Chiolerio (2014), electronic textiles, or e-textiles, are fabrics that incorporate electronics and woven interconnections while maintaining physical flexibility, with their components and connections being intrinsic to the fabric itself. This advancement creates new requirements for the detection, communication, and interconnection of sensors and electronic modules, providing a valuable resource for a better understanding and managing context of action. For Köhler (2013), the application of electronic components in textile surfaces can be outlined according to three successive stages of innovation: adoption, integration, and combination.

In the first stage (adoption), electronic devices are incorporated or added to a textile platform, such as pockets (Ridolfi et al. 2010). In the second and current stage of smart textiles (integration), electronic components are physically embedded into the textile material, making them part of the fabric itself. This includes embroidered sensors, integration of conductive threads, and sewn circuit boards. For example, in this stage, inertial measurement units can be attached to clothing to record and transpose the wearer's movements into a digital model (Kang et al. 2017). The third stage (combination) involves transforming textile structures and materials into devices with electronic functions. At this level, technology is integrated as an intrinsic part of the fabric, with components being knitted or woven directly into the textile. Example of this stage include innovations like integrated or yarn-like transistors, fiber-based circuits, photovoltaic fibers, and particularly integrated textile electrodes, which are used to monitor heart activity and perspiration (Lage et al. 2015).

Through engineering, wearable technologies have been developing rapidly, promising discretion, comfort, and adaptation while striving to achieve accuracy, reliability, and effectiveness. Birringer and Danjoux (2009), researchers in the field of interaction design, contribute essays that emphasize interactive and responsive experiences. Their work explores the creation of seamless digital interfaces between user and computer, including the introduction interactive body-tracking systems. However, Lin and Kreifeldt (2001) point out that wearable systems require a sophisticated physical interface, which can be achieved by incorporating ergonomics and industrial design into the design process. This integration leads to products with a pleasant appearance and superior functionality. According to Patel et al. (2012), wearable technologies benefit from advances in several fields, including sensor miniaturization, smart textiles, computing technology, and motion capture technologies. According to Camomilla et al. (2018), these new wearable systems allow continuous monitoring of the physiological state of the user. In sports, these wearable systems enhance training by providing useful, intrinsic, and timely feedback to support the athlete's learning and motivation process, with the aim to address performance gaps. This real-time feedback is provided by the latest generation of portable, accessible, and easy-to-use sensors, which do not impede tasks carried out during physical activity.

Three functional components are considered for the development and application of wearable technologies. The first component focuses on the implementation and viability of the technology, addressing challenges such as integrating electronics into textiles (Stoppa and Chiolerio 2014). The second component centers on user interaction, where wearable devices are designed to monitor the user's body and provide personalized feedback (Coyle et al. 2010). The third component highlights service and data analysis techniques, which are crucial for enabling effective communication with users, often through human-cloud interaction (Chen et al. 2017; Dias and Paulo Silva Cunha 2018). Together, these components contribute to the holistic development of wearable technologies that are not only functional but also user-centric and data-driven.

This vision of wearable computing anticipates that, in the future, electronic systems will become an integral part of everyday clothing. According to Hughes-Riley et al. (2018), the second-generation Wearables 2.0. will evolve to feature sensors embedded in smart clothing. This evolution will pave the way to third-generation “wearable computers,” where the clothing itself functions as the sensor.

Lemey et al. (2018) state that next-generation wearable systems will need to meet special wearability requirements. These systems will be distinguished by their capabilities to automatically recognize the wearer's activity and behavioral status, as well as the surrounding environment's context. By utilizing this information, they will be able to adjust their configuration and functionality accordingly. The integration of additional functionalities cannot compromise the user's comfort, which translates into the need for discreet, flexible, breathable, and lightweight clothing.

These various interactions encompass the functional requirements driven by the usability objectives, the technical requirements necessary for technological implementation, and the user experience requirements focused on integrating technologies into sportswear. This integration considers the visual dimension while ensuring that the product is wearable, usable, and accurate. Moreover, it aims to create a motivating user experience that is simple, and convenient.

Background

Competitive fencing sport has been one of five activities featured at every modern Olympic Games, along with cycling, athletics, gymnastics, and swimming. It is a combat sport that uses a weapon but without body contact. Considered to be of high physical and psychological demand, fencing must be supported by an adequate psychophysical condition to avoid central and/or peripheral fatigue. It is a game of feints and anticipation of movements, where the objective is to touch the opponent with the tip of the blade and avoid being touched. It is practiced with three different weapons: foil, saber, and epee. Each weapon has different rules, differing not only in the shape of the blade but also in the areas of the body where the

touch is valid. The valid area with the foil is the torso and the belly region; with the saber, it is any part of the body above the waist, including arms and head; and, with the epee, any part of the body is a valid target (Figure 1).



Figure 1: Fencing garment: 1st is foil; 2nd is saber; and 3rd is epee.

Source: Leon Paul London 2019

According to Roi and Bianchedi (2008, 465), a “fencing international tournament may last between 9 and 11 hours. Bouts (game between two fencing opponents) represents only 18 percent of total competition time, with an effective fight time of between 17 and 48 minutes.” Roi and Bianchedi (2008) also explain that the lengthy competition format leads to asymmetries in strength and control, which in turn affect the athlete’s anthropometry, resulting in the progressive development of typical limb asymmetry. All movements are subject to a continuous succession of changes during the game based on the opponent’s behavior, which makes it difficult to identify a significant relationship between any physiological characteristics and performance.

Instead, performance is more probability to be influenced by the athletes’ perceptual skills and neurophysiological aspects. In the game, the athlete is in the *en garde* position, aligning the front foot with the opponent’s position while the left foot placed on the ground at an angle to provide stability (Barth and Beck 2007). To score, the player must push the weapon quickly towards the opponent, which requires an explosive leg extension to perform as it such a substantial charge. These rapid offensive and defensive “propulsion” and “deviation” movements further expose the athlete to impact, energy absorption, displacement, and explosive forces of varying magnitude distributed asymmetrically throughout the body (Sinclair et al. 2010). Injuries are quite prevalent among fencing athletes, with injuries arising from these dynamic and repetitive movements. In addition to

the rare cases of severe trauma caused by blade penetration, most injuries in fencing are caused by excessive exercise (Harmer 2008).

Through the literature review conducted by Roi and Bianchedi (2008), it is also understood that the most frequent injuries are in the lower extremities and the most common types of injuries are ligament sprain and muscle sprain. The upper extremities are the second most common site of injury, followed by the spine/trunk region and the head. So, even if it can be said that fencing is not particularly dangerous, there is still a fine line between a serious injury and a simple blade injury.

Firstly, according to Mihaleva and Koh (2016), a constant pattern of technology improvement is observed and with that, designers tend to make full use of it in their designs. However, the limitations of wearable technologies can still affect the realization of design concepts. Secondly, due to the limitation of fully integrated textile or hybrid technology, it is almost inevitable to use externally coupled devices to integrate intelligent systems into clothing.

Currently, the design of fencing clothing is developed according to the standards established by the *Fédération Internationale d'Escrime* (FIE), which translates to “International Fencing Federation.” This design process has evolved to improve athlete protection and safety, in alignment with the protection requirements outlined in British Standard EN 13567: 2007.¹ There are several equipment requirements for fencing: a mask, a glove for holding the weapon, a protective jacket, an electric jacket, trousers to the knees, a plastron, a chest protector, socks, shoes, and the weapon. In addition, there are two levels of penetration resistance: Level 1, with a resistance of 350 Newtons, which is the standard of protection, for use in clubs and national competitions, and Level 2, with 800 Newtons, which is the standard of protection for the Olympic Games, World Championships, and all Series “A” or World Cup events (Leon Paul London 2024). In fully electric fencing with a size five weapon, the 800 Newtons plastron is required for both Levels. Some fencing brands invest more in design than others. Two notable brands of fencing equipment are highlighted: the German brand Allstar International,² which focuses on the visual qualities of its design, and the British brand Leon Paul London, which is known for betting on the quality of its garments and technological innovation (Made in Britain, n.d.). Competing with these two brands are others, such as Absolute Fencing, Blaise Frères, Carmimari, Fence with Fun, Fencing Armor, Gajardoni, Negrini, PBT Fencing, and Uhlmann.

So far, the integration of inertial sensors into fencing garments has not been documented in the literature. This perceived lack represents an opportunity for the design of a new product, which could result in a wearable electronic system integrated into the textile. Similar to camera-based optical systems, inertial motion capture systems already offer precise

¹ <https://knowledge.bsigroup.com/products/protective-clothing-hand-arm-chest-abdomen-leg-genital-and-face-protectors-for-fencers-requirements-and-test-methods/>.

² <https://allstar.de/>.

performance. The literature mentions several brands, including AIQ Synertial, Captiks, Motion Shadow, Nansense, Notch Interfaces, Perception Neuron, Rokoko Electronics, and Xsens Technologies, which offer inertial motion capture systems. The objective of this study is to explore the feasibility and efficacy of integrating electronic textile technologies into fencing garments for performance monitoring and analysis.

Materials and Methods

This study details the development of a conceptual fencing garment that incorporates electronic inertial sensor technology for motion capture. It evaluates performance by recording the three-dimensional motion of the human body in real time, which is then visualized on a digital model and analyzed.

The technology should be able to help the fencing athlete improve his technique, and at the same time provide a robust, accurate, and highly sensitive system without compromising comfort. Among the available brands of motion capture suits, we selected the Smartsuit Pro™ by Rokoko Electronics to assist the design of a smart fencing garment hypothesis and conducted user surveys to inform garment design requirements.

Additionally, the research outlines the testing process and the choice of technology for motion capture. Overall, this immersive research approach provided valuable insights into the practical challenges faced by fencers, allowing us to tailor our design process to address these specific user needs effectively.

Design Process

To specify and identify the design requirements with users, visits were made to fencing schools and surveys were conducted. The information obtained through direct observation and video recordings of fencing matches and training sessions at the visited schools allowed the collection of new data regarding the design features of the garments used. This research was complemented by the creation of an infographic (Figure 2) with relevant notes expressing user concerns such as: uniform susceptibility to dirt; excessive clothing layers; fickle socks and disuse of socks in training; shorts with rubber band loss; shorts that get wrinkled, provoking holds of the knee joint; shorts with weak braces; fickle sleeves; disarticulation between gilet and uniform; electric cable entanglement; overlapping clips of electric gilet and jacket; and, lastly, weapons with constant tip failure.

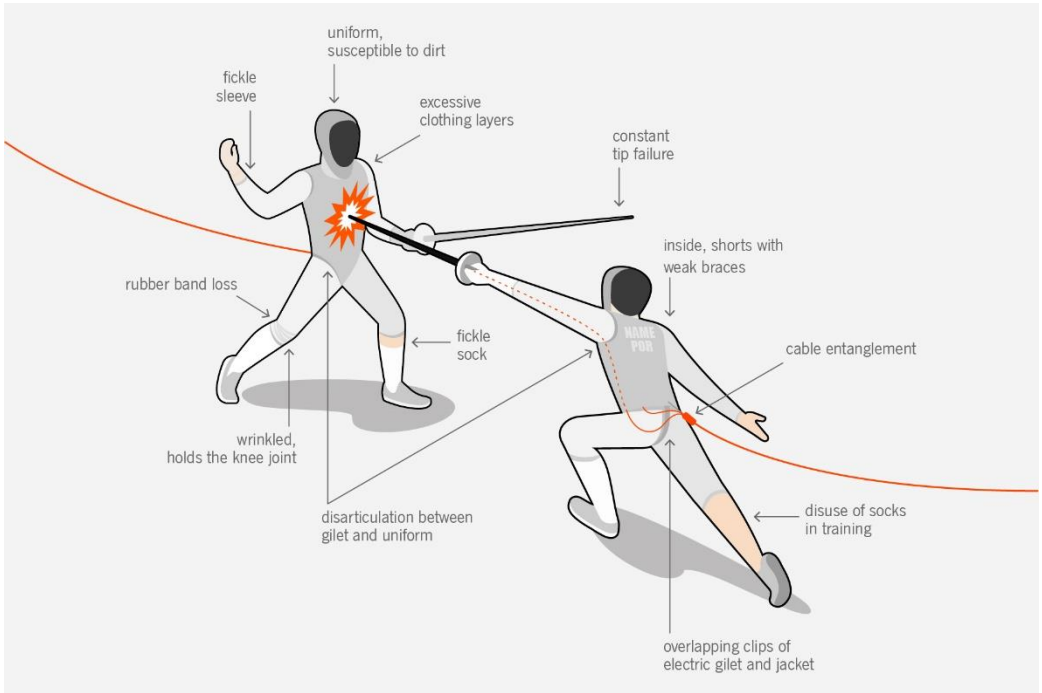


Figure 2: Summary of observation.

Source: Vieira 2022

Based on the type and brand of uniform most used by the observed athletes (Level 1-350N), the decision was made to purchase the main pieces that make up a male foil uniform from the Allstar International brand: Electric Gilet, Ecostar Jacket, Ecoline Glove and Shorts Ecostar. This acquisition initiative made it possible to better understand the observed gaps and thus consolidate the design concept.

Choice of the Technology

Based on the findings from the previous study, “Designing the Future of Smart Fencing Garments” (Providência et al. 2021), this research indicated that the development of fencing apparel could incorporate motion capture using IMU sensors. Specifically, the earlier study highlighted the potential benefits of integrating advanced technologies into fencing garments, paving the way for the development of a new product that aligns with the needs, expectations, and requirements of users. In this context, the current study aims to further explore these possibilities by examining how motion capture can be effectively utilized in fencing clothing.

To support this research, we acquired the Smartsuit Pro™ from Rokoko Electronics. This suit provides an accurate response and is competitively priced compared to other brands, making it an appealing choice for our study. Constructed from nylon and equipped with

nineteen IMUs, the suit includes a configuration cable for connecting to the computer, a 5000 mAh battery, and wireless connectivity.

In testing the Rokoko Smartsuit Pro™ (Figure 3) and the Rokoko Studio software, it was possible to see its high portability and easy setup, with good position accuracy. Setting up the motion capture suit is extremely simple, and calibration requires only a 3-second pose (hands extended down with feet shoulder-width apart and head forward). Once calibrated, it does not need to be recalibrated during use. The system does have one weakness: when doing motion capture, you need to keep your distance from any electromagnetic source, which is sometimes a difficult task while indoors.



Figure 3: Testing the Rokoko Smartsuit Pro™.

Source: Vieira 2022

However, the Rokoko Studio software offers several features to enhance motion capture processes. Firstly, it provides a sensor preview function, highlighting any sensors experiencing magnetic interference in yellow for easy identification. Additionally, users can export their data in various formats, including FBX, BVH, and CSV. The CSV format, specifically, has been optimized for swift data analysis and visualization in Excel, facilitating the creation of graphs depicting parameters such as positions, velocity, and acceleration.

Moreover, the software enables real-time three-dimensional recording of actions, offering a comprehensive view of the performance as it unfolds. Following the recording, users can review and verify the three-dimensional action data and even rewind the recording to identify

and rectify any potential errors in the athlete's movements (Figure 4). This functionality empowers users to refine and perfect motion capture sequences with precision and ease.

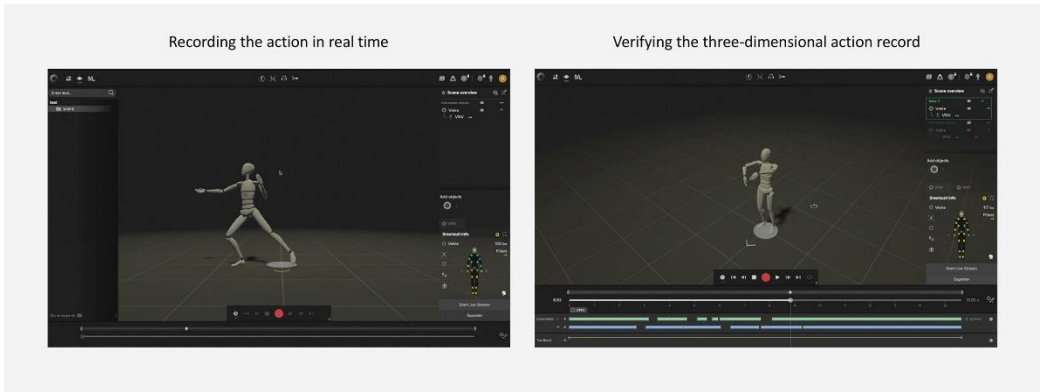


Figure 4: Screenshot while using Rokoko Studio software.

Source: Vieira 2022

The evolution of this software has improved errors and, at the same time, the user experience. Even so, quickly changing direction, getting to a point near the magnetic source, or climbing a step creates visual discontinuities in the software. However, these errors can be manually corrected by cleaning up the animation in the recording line. The software also allows the use of filters that can be adjusted to smooth the animation. In contrast, camera-based optical systems provide more accurate positioning data, which means less animation clean-up; however, the systems take longer to set up and require more space.

Pattern Making

A smart fencing garment was designed by leveraging the experience gained from handling inertial sensors technology for motion capture. In accordance with the project specification, the garment was created using 2D vector software modeling, for size M. The flat-pattern method was employed to create a two-dimensional design, which involved disassembling an existing fencing suit. This process translated the actual measurements into a two-dimensional draft, considering the non-elasticity of the fabric. The design concept drew preliminary inspiration from the “kinetic garment construction” theory proposed by Lindqvist (2016). This theory emphasizes enhancing the dynamic interaction between the fabric and the body, which contrasts with traditional approaches that focus solely on measurements of an upright body. The theory is visualized through a series of directional lines, suggesting the places on the body where the fabric “falls” without restricting movement, translating into a more dynamic approach to the body.

Finally, after verifying the measurements to understand the garment's construction, a flat-pattern model of the entire piece was created. In addition to considering clearance

requirements for a good ergonomic result, all assembly details were also taken into account. This approach provides a guideline for the development of a future advanced prototype (Figure 5).

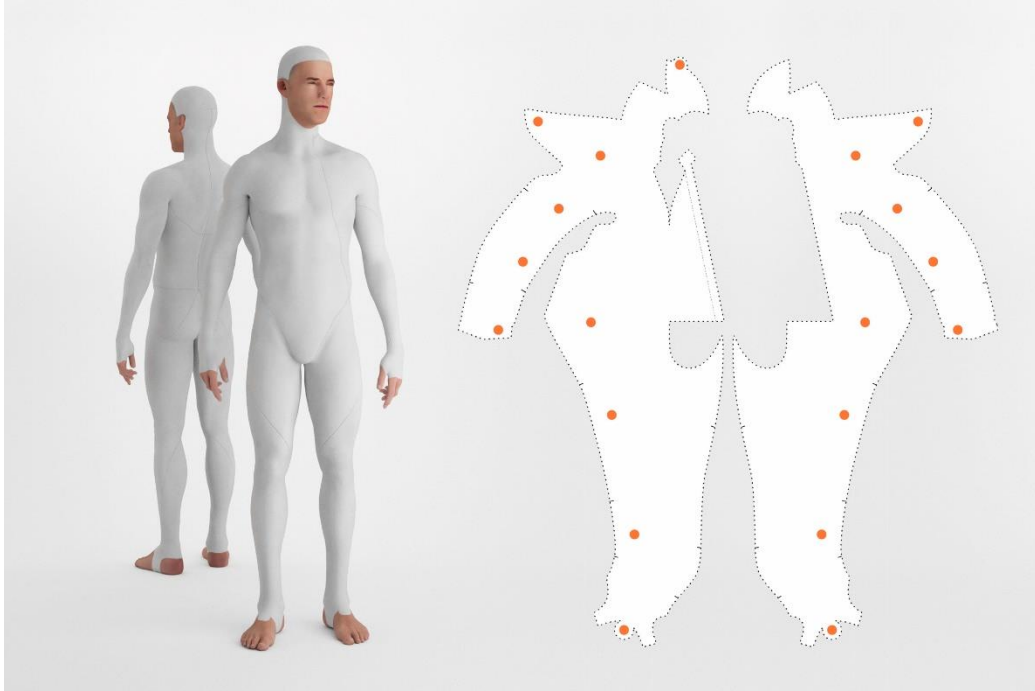


Figure 5: Guideline for the prototype of a smart fencing garment with inertial sensor units.

Source: Vieira 2022

Results and Discussion

Computer software provided synchronous feedback regarding the movement of the different body parts. Several real-time action recording exercises were performed with the motion capture suit from Rokoko. The data obtained was exported from the Rokoko Studio software in CSV format, analyzed in Excel, and converted to a JPG file. One of the exercises was a comparison of right arm adduction in both the correct and incorrect way. This exercise evaluated the positions in the X, Y, and Z axes of the shoulder, arm, forearm, and hand during the movement (Figure 6).

A substantial change was observed in the X position of the hand and slight differences in the shoulder, arm, and forearm. In the Y position there were slight differences in the hand, shoulder, arm, and forearm. On the other hand, in position Z, there was a substantial change in the forearm and hand, and slight differences in the shoulder and arm.

The development of the prototype for the presented concept is outside the scope of this work. In addition to the complexity of prototyping the various inertial sensors, it is necessary

to develop appropriate software that enables real-time analysis of the athlete’s movements. This type of software development requires close interdisciplinary cooperation, involving advanced signal processing and programming skills that cannot be handled solely by a product or fashion designer. For the modeling and planning of this fencing garment, the theory of “kinetic garment construction” was utilized. This theory provides guidance for developing a future functional prototype, allowing faster progress in both technological advancements and ergonomic development.

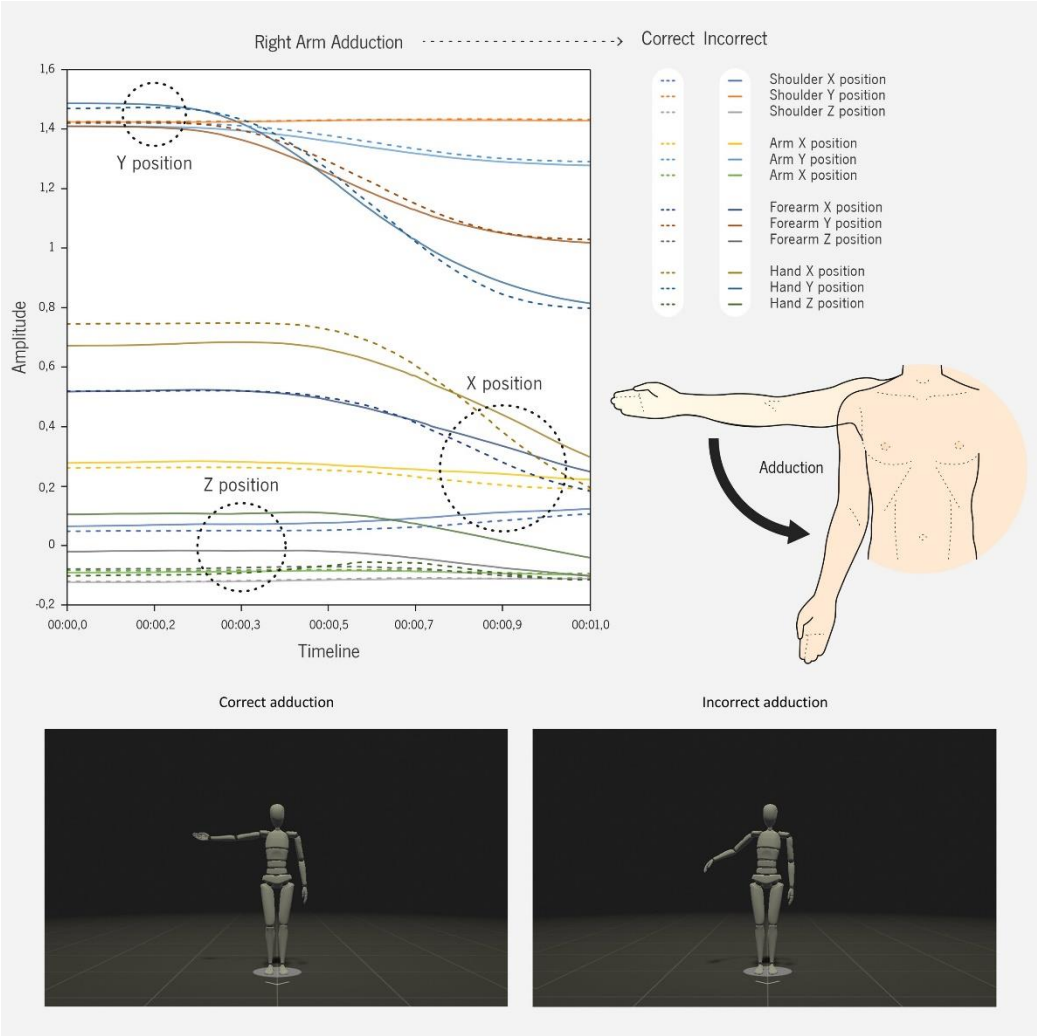


Figure 6: Information acquired from Rokoko Studio, right arm adduction recording.
Source: Vieira 2022

A concept was presented that offers useful feedback based on the knowledge gained from handling this technology and observing the wearing conditions of the fencing garment. We believe that the simpler, more practical, and more discreet the application of sensors or electronic components on the wearable textile surface, whether through adoption, integration, or combination, the more natural the product design becomes. Additionally, the electronics of the devices should be invisible and non-intrusive to the user. The integration of wearable technologies in the field of competitive fencing represents a path to revolutionize training methodologies, improve performance results, and understand athletic biomechanics. Through this study, we sought to explore the feasibility and effectiveness of smart fencing garments in providing real-time performance feedback and optimizing training regimes. By closing this gap, we aim to empower fencers with cutting-edge tools and knowledge to excel in their sport. While the integration of electronics into textiles is promising for improving of athlete performance, it is imperative to address concerns regarding the inclusive, sustainable, and ethical implementation of these technologies.

Conclusion

The performance gap between top athletes is becoming increasingly narrow, making even small advantages crucial. The use of smart clothing in sports can provide a competitive edge by integrating electronics into textiles, enabling real-time monitoring, control, and supervision. This technology can support athletes and coaches during physical activity, whether in competition, training, or rehabilitation.

In this work, we present the design of a smart fencing garment. The requirements for this garment were defined by prospective users via surveys conducted during a visit to fencing schools. Additionally, information obtained by direct observation and video recording of fencing matches and training sessions held in the visited schools was used to identify problems in the standard garment. This data made it possible to present a new hypothesis for a smart fencing garment, specifically through the development of a flat model and 3D rendering. The motion capture suit allows the athlete to improve his performance and the coach to obtain more information about the athlete by recording the action in real time and verifying the three-dimensional action record. Compared to the design of the standard garment, this approach may allow for a more interactive and informative design. Considering these factors, the integration of this technology adds new functionality to the fencing suit.

However, along with these benefits come several considerations and counterarguments that deserve attention. Firstly, there are concerns regarding the accessibility and price of the product, as implementing advanced technology may not be feasible for all athletes. Additionally, questions arise about comfort, durability, and maintenance, underscoring the need to address practical challenges. To overcome these obstacles, interdisciplinary collaboration is essential, requiring effective coordination between designers, engineers, and

athletes to ensure the successful development and integration of the technology. Ethical and privacy concerns also arise regarding the continuous collection of athletes' movement data, emphasizing the need for robust consent mechanisms and data security measures.

To evaluate this hypothesis and address such concerns, the fencing garment explored in this article needs to be transformed into an advanced prototype. Although the tested technology and the developed concept may be suitable for user validation, an advanced prototype will enable more accurate information to be obtained about ergonomic aspects such as comfort, wearability, breathability, and protection. User tests with an advanced prototype will provide essential information for the finalization of the uniform. These tests will also provide important information about the athlete's behavior, especially in relation to possible conditioning caused by long periods of use. For example, if the electronic components affect the athlete's performance, a new way of adopting, integrating, or combining the sensors in the textile will have to be thought out.

Equally important is how the information collected by the sensors is communicated to the user. Analyzing the best output devices for displaying data and results during or after sporting activities is crucial. Examples of such devices include video monitors, smartphones, computers, and wearables. The visual, audible, or vibrating feedback provided by these devices should be further developed and analyzed according to the user's needs.

Additionally, there is also the possibility that the fencing uniform may not be commercially viable due to the cost of production. New prototyping, manufacturing methods, and techniques could improve the process, possibly making it more affordable. The integration of these inertial sensors in garments must also ensure flexibility and washability. Effective management of manufacturing costs is fundamental in guaranteeing the success of sensor integration into textiles and ensuring the viability of their production and marketing.

Integrating electronic textile technologies into fencing garments is expected to offer several benefits. These include enhanced performance monitoring and analysis, which can lead to more informed coaching and training decisions. Additionally, the technology will improve feedback mechanisms for athletes, aiding in skill refinement and technique optimization. It will also increase engagement and motivation among fencers by creating more interactive and data-driven training experiences. Moreover, this integration could drive advancements in sports science and technology, opening new avenues for innovations in athletic performance enhancement. Future work regarding the fencing uniform proposed in this article may include exploring other ways to integrate inertial sensor technologies for motion capture.

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AI Acknowledgment

The authors declare that generative AI or AI-assisted technologies were not used in any way to prepare, write, or complete this manuscript.

Informed Consent

The authors have obtained informed consent from all participants.

Conflict of Interest

The author declares that there is no conflict of interest.

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ABOUT THE AUTHORS

Helder Carvalho: Professor at School of Engineering - Department of Textile Engineering (DET); Researcher at Centre for Textile Science and Technology (2C2T), University of Minho, Guimarães, Braga, Portugal
Corresponding Author's Email: helder@det.uminho.pt

Daniel Vieira: Professor and Researcher at Centre for Textile Science and Technology (2C2T) and Landscape, Heritage and Territory Laboratory (Lab2PT), University of Minho, Guimarães, Braga, Portugal
Email: mail@danielvieira.pt

Bernardo Providência: Professor at School of Architecture, Art and Design (EAAD); Researcher at Landscape, Heritage and Territory Laboratory (Lab2PT), University of Minho, Guimarães, Braga, Portugal
Email: providencia@eaad.uminho.pt