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THE STRUCTURE OF THE USE OF ELECTRONIC LABELS IN SMART CLOTHING

Mykola Riabchykov[1], Viktoriia Mytsa[2], Yuri Androshchuk[1] & Liubov Romanenko[2]
[1]Lutsk National Technical University
Lvivska str., 75, Lutsk, Ukraine, 43018, mobile: +380988404276
e-mail: mykola.riabchykov@lntu.edu.ua
[2]Khmelnytskyi National University
Institytska str., 11, Khmelnitsky, Ukraine, 29016, mobile: +380677956771
e-mail: mitsa_vv@ukr.net

Abstract: *The prospects of creating textile smart products with the help of electronic labels are considered. At the same time, such clothing is considered as a complex functional diagnostic system. Discrete cluster circles for the use of labels in smart clothing are proposed. Four groups of smart clothes with the use of labels are highlighted, reflecting qualitative transitions with increasing efficiency of electronic labels. The first level includes clothing for further introduction into the product-service system. Labels are introduced into technological lines with reprogramming at each stage of clothing production. In warehouses of ready-made clothes instant information on all units of goods is provided. The second level allows designing a technological flow for the production of clothes in dynamics, creating clothes with special capabilities for transforming individual movements into signals about real desires. The third level involves the implementation of active labels that can be used as clothing for a group of subordinates, which allows receiving information about their location and behaviour. The fourth level involves the implementation of SIM cards in electronic labels and can provide remote control or recognition. The determined levels are combined into adjacent clusters and compared with existing classification systems.*
Keywords: *electronic label, smart clothing, cluster, product-service.*

1. INTRODUCTION

The processes of creating smart clothing for various purposes are expanding all over the world [5, 6]. In many cases, such products are considered part of diagnostic systems that can record and determine various human parameters. In particular, in [1], photographic methods for designing clothing for motion registration are considered. Some studies suggest determining human health parameters by means of smart clothing. For example, paper [7] describes smart clothing as a complex for conducting such studies as electrocardiography. Study [9] describes the introduction of electronic tags in smart clothing to determine the parameters of arrhythmia. The authors of [10] associate the creation of smart clothing with the use of special electronic devices and the authors of [14] with the introduction of nanotextiles.
In some pilot studies, the creation of smart clothing systems is associated with the use of electronic labels based on NFC and RFID technologies. In particular, the study [8] uses radio frequency identification (RFID) technology to achieve a rational allocation of resources in apparel manufacturing enterprises. Article [12] describes the practice of real implementation of RFID systems in the process of garment production management. This paper identifies the main factors, but this technology is not related to a comprehensive understanding of the implementation of electronic tags in the garment industry.

Article [13] describes the prospects for the introduction of electronic tags in inventory management, which in our opinion is the prospect of creating smart systems. A study [15] suggests the means of using electronic tickets in both trade and clothing production, and an article [11] provides data on the implementation of such technologies.
Study [16] proposes the introduction of electronic tags in the design of clothing to determine the parameters of breathing, which can undoubtedly be considered as an element of smart clothing. Although the authors do not generalize this experience to a wider range of uses.
Article [4] notes the prospects of using electronic labels in the design of clothing, although it is admitted that such technologies are in their infancy.
The study [3] describes RFID technology that provides real-time tracking of clothing items, although the real value of this approach is not indicated.
Article [2] for the first time proposes the use of electronic RFID tags in the fashion industry, although specific implementation methods are provided in fragments.
The purpose of this work is to develop a general concept of the use of electronic tags in the clothing industry, especially in the field of creating modern smart clothing.

2. METHODS

To achieve this goal, this paper uses general methods for analyzing the areas of implementation of electronic labels in clothing, as well as methods for synthesizing general structures.
This study considers the prospects of creating textile smart products using electronic labels. In this case, such clothing is considered as a complex functional diagnostic system. Discrete cluster circles of labels use in smart clothing are proposed.
In the process of cluster analysis, the entire compatibility of sets of promising methods for implementing electronic labels in smart clothing systems is multiplied by multiplications determined by the features of design and use.
In this study, cluster circles are built that determine the qualitative transitions from one cluster to another when introducing electronic labels of the next level (Figure 1).

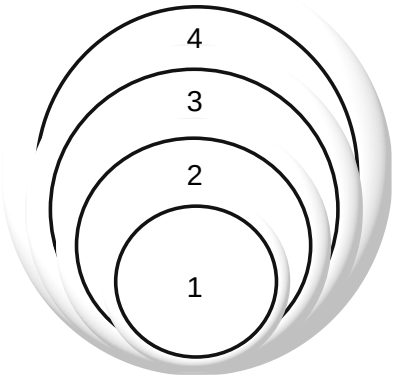

Figure 1. Cluster circles of implementation of electronic labels in smart clothing systems

The smallest circle 1 involves the introduction of electronic labels (transponders) with an external power supply. Today, these are the simplest and cheapest means. More expensive, but also available labels with a range of several meters define circle 2. Circle 3 is active labels with a range of up to 300 meters, which requires its own battery, which, accordingly, increases the size and cost of the device. Circle 4 includes active labels with their own SIM card, which allows you to control this device at any distance.

The described circles in further research are implemented in specific methods of use in smart clothing systems.

3. EXPERIMENTAL

In order to determine the prospects for the introduction of electronic labels, a study of consumer interest in the possible use of smart clothing with the involvement of electronic label systems was conducted.
Online mood boards were used in this study to investigate these factors. Such boards were posted on social networks and presented with a range of restrictions according to existing electronic labels in the design of clothing. For the purposes of this study, our own virtual mood boards were developed, in which users could define their own interpretations. The research was conducted using modern online technologies, in particular using the Instagram network.
Such networks are popular among young people, who are the driving force in the implementation of smart technologies. According to a number of factors, it was found that the number of interested people can reach tens of thousands.
We used an online sample size calculator (Survey Monkey). This calculator has a 95% confidence level and a 5% margin of error as additional features. With the help of a calculator, it was established that the desired number of the sample is 372 respondents. In fact, the Instagram profiles of 400 young women of 20-30 years of age were analyzed. The professions of the respondents were mainly related to photography, modeling, event organization, and design. Ukrainian fashion brands were also analyzed.
According to the results, regressions of the dependence of interest in smart clothes using electronic smart labels of different levels were built.
The results of the analysis made it possible to construct a cluster linear diagram.
Note that the linear diagram can have quite large discrepancies. Therefore, for the abscissa axis, we will note not the absolute value of the distance, but its logarithm. Along the ordinate axis, we note the frequency of use of electronic labels in smart clothing systems (Figure 2).

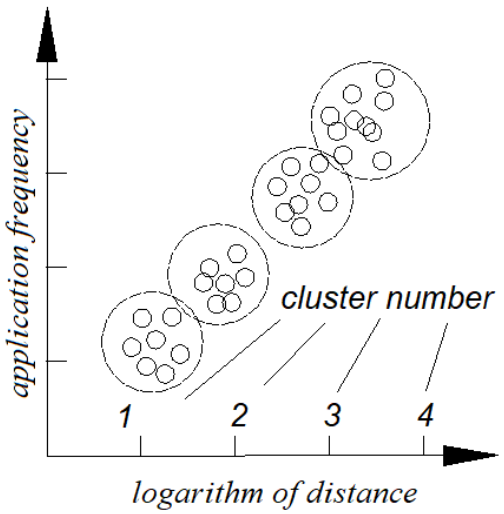

Figure 2. Cluster diagram of label application

The diagram highlights four clusters that function independently but have a compatible trend, while the sets of electronic labels in smart clothing are in many cases independent but have areas of intersection and common regression.
Based on the above analysis, a diagram of clusters was constructed, taking into account the scale of distances for different clusters.

4. RESULTS

According to the results of experimental studies, four groups of smart clothing with the use of labels reflecting qualitative transitions in increasing the efficiency of electronic labels were identified.
The first level (Figure 3) includes clothes for further implementation in the product-service system. It provides constant service, replacement of clothes with a discount for further recycling, and production of clothes with personal information. Labels are introduced into the technological lines with reprogramming at each stage of clothing production. At the warehouses of finished garments, as well as at the warehouses of materials and semi-finished products, instant information about all units of goods is provided.

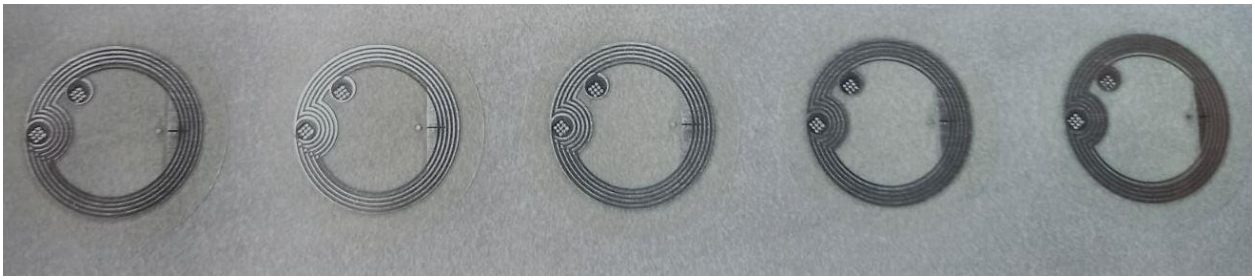

Figure 3. Electronic labels from first cluster

The "product-service" model is becoming widespread in the fashion industry. In this model, the customer, along with the purchased product, gets access to a full range of services that will connect him with the brand for a longer period of time and ensure mainly the quality of the offered product. Under such a system, the brand must provide long-term satisfaction, so it is necessary to connect with the customer on a deeper level. To ensure such a model, the most complete up-to-date information about the product is needed. Modern NFC and RFID tools allow compact and up-to-date information to be recorded on media that can be integrated into the design of clothing items.
The shift towards meeting usage needs through the provision of services will extend the life of the garment as well as cause a longer and more satisfactory experience for the user. For example, product-oriented companies can add value to their product by offering additional services such as maintenance, repair, returns, upgrades, etc. Service-oriented companies can completely abandon personal ownership by offering models such as rent, exchange, and recycling. The main problem in the implementation of such models is to obtain urgent information about an individual item of clothing, which is implemented in the "product-service" system. Electronic tags are able to store information, and in the process of service, this information can be adjusted. Given the compactness of the proposed means and the ability to use them in the design of clothing, the problem of storing information can be solved.
The potential value of the product-service system for the fashion industry lies in the significant reduction of material consumption. The product-service business model in the apparel industry involves the responsibility of the manufacturer for the main result (product), as well as the supporting components of supporting the product to disposal (services). Under

this scheme, each stakeholder works to create shared value for the customer. Electronic NFC and RFID tags in clothing can carry information about the environmental performance of textiles and clothing throughout the life cycle.
The second level, corresponding to cluster circle 2, allows designing a technological flow for the production of clothing in dynamics, taking into account the previous and subsequent steps, the creation of clothing with special capabilities for converting individual movements into signals about real desires.
This cluster level can provide a replacement with significant enrichment of bar code labels for trade. Already today, manufacturers are ready to implement this immediately, provided that retailers are ready. Such systems significantly increase the efficiency of trade technologies.
The second cluster can also provide the production of clothing with personal information (e.g. pass, door key, etc.)
This cluster provides instant information in warehouses about all units of goods (including location). It is possible to display all information or find a product or a group of products by a separate code.
The third level involves the introduction of active labels that can be used as clothing for a group of subordinates, which allows you to get information about their location and behavior. This cluster opens a wide field of fashion projects for the creation of corporate or school clothes.
The fourth level (Figure 4) involves the implementation of SIM cards in electronic labels and can provide remote control or recognition. This cluster implies the creation of special clothing with the ability to be controlled remotely by a group of workers or a combat unit.

Figure 4. Electronic labels from fourth cluster

As a result of the analysis, a general classification can be determined based on the level of the proposed cluster (Table 1).

Table 1. Electronic labels application based on cluster analysis

Cluster	1	2	3	4
Source of energy	Passive	Passive/Semi active	Active/Semi active	Active
Distance	5-10 sm	1-5 m	100-300 m	Any distance
Common aim	Information storage	Logistics inventory control	Location control	Transponders for search
Application in light industry	Implementation of product-service system	Improvement of information for trade	Creation of corporate smart clothing	Professional clothing for individual control
	Active storage of information	Design garment with control elements	Creation of school smart clothing	Professional clothing for collective management

It can be argued that the obtained results allow increasing the effectiveness of the implementation of smart clothing systems using smart labels of different levels.

5. CONCLUSIONS

On the basis of circular cluster analysis, four groups of electronic labels have been identified, which correspond to four growing areas of use in smart clothing items.
The first sphere is created by simpler RFID and NFC systems that can be used effectively in product-service systems. The second area involves advanced electronic labels for use in smart clothing with the ability to control objects. The third area includes active labels for implementation in corporate clothing systems. The fourth area uses labels with an active SIM card, which allows creating smart clothes with the possibility of remote control.
The defined levels are combined into adjacent clusters and are the basis for creating a general classification system. The results of the study make it possible to more effectively implement electronic labels in the process of designing smart clothes, as well as in the creation of smart technologies for the production of clothes.

6. REFERENCES

[1] Avellar L., Stefano Filho C., Delgado G., Frizera A., Rocon E. & Leal-Junior A. (2022). AI-enabled photonic smart garment for movement analysis. Scientific reports, 12, 4067. https://doi.org/10.1038/s41598-022-08048-9.
[2] Chan H.-L. (2016). 3-Using radiofrequency identification (RFID) technologies to improve decision-making in apparel supply chains. Information Systems for the Fashion and Apparel Industry, Woodhead Publishing Series in Textiles, pp. 41-62. https://doi.org/10.1016/B978-0-08-100571-2.00003-8.
[3] Choy K.L., Chow K.H., Moon K.L., Zeng X., Lau H.C.W., Chan F.T.S. & Ho G.T.S. (2009). A RFID-case-based sample management system for fashion product development. Engineering Applications of Artificial Intelligence, Vol. 22, Iss. 6, pp. 882-896. https://doi.org/10.1016/j.engappai.2008.10.011.
[4] Costaa F., Genovesia S., Borgeseb M., Michela A. & Dicandiac F.A. (2022). Radio Frequency Identification (RFID) for Sensing. Encyclopedia of Sensors and Biosensors, Vol.3, pp.375-390, https://doi.org/10.1016/B978-0-12-822548-6.00089-3.
[5] De Fazio R., Al-Hinnawi A.-R., De Vittorio M. & Visconti P. (2022). An Energy-Autonomous Smart Shirt Employing Wearable Sensors for Users' Safety and Protection in Hazardous Workplaces. Applied Sciences (Switzerland), Vol. 12, Iss. 6, 2926. DOI: 10.3390/app12062926.
[6] Gaillard S.D.M. & Visser J. (2022). Pockets, dresses and suppression – A philosophical reflection on clothing, agency, and identity. Technology in Society, Vol. 62, 101972. DOI: 10.1016/j.techsoc.2022.101972.
[7] Kim, J.K., Park, S., Cho, H.-S., Lee, S.-H., Lee, J.-W. (2022). Conditions for Textile Electrode Sensors to Monitor Cardiac Activity in Daily Life. Journal of Electrical Engineering and Technology. 17(5), pp. 3045-3055. DOI 10.1007/s42835-022-01156-6
[8] Lee C.K.H., Choy K.L., Ho G.T.S. & Law K.M.Y. (2013). A RFID-based Resource Allocation System for garment manufacturing. Expert Systems with Applications**,** Vol. 40, Iss. 2,1, pp. 784-799. https://doi.org/10.1016/j.eswa.2012.08.033.
[9] Malek A.S., Elnahrawy A., Anwar H. & Naeem M. (2021). From fabric to smart T-shirt: fine tuning an improved robust system to detect arrhythmia. Textile Research Journal, Vol. 92, Iss. 17-18, pp. 3204-3220. https://doi.org/10.1177/00405175211060887.

[10] Meena J.S., Choi S.B., Jung S.-B. & Kim J.-W. (2022). Recent progress of $Ti_3C_2T_x$-based MXenes for fabrication of multifunctional smart textiles. Applied Materials Today, Vol. 29, 101612. https://doi.org/10.1016/j.apmt.2022.101612.
[11] Ngai E.W.T., Chau D.C.K., Poon J.K.L., Chan A.Y.M., Chan B.C.M. & Wu W.W.S. (2012). Implementing an RFID-based manufacturing process management system: Lessons learned and success factors. Journal of Engineering and Technology Management, Vol. 29, Iss. 1, pp. 112-130. https://doi.org/10.1016/j.jengtecman.2011.09.009.
[12] Ngai E.W.T., Chau D.C.K., Poon J.K.L., Chan A.Y.M., Chan B.C.M. & Wu W.W.S. (2014). 4-The role of radio frequency identification (RFID) technologies in improving garment manufacturing operations. Fashion Supply Chain Management Using Radio Frequency Identification (Rfid) Technologies, pp. 70-98. https://doi.org/10.1533/9780857098115.70.
[13] Ovezmyradov B. & Kurata H. (2022). Omnichannel fulfillment and item-level RFID tracking in fashion retailing. Computers & Industrial Engineering, Vol. 168, 108108. https://doi.org/10.1016/j.cie.2022.108108.
[14] Riabchykov M., Alexandrov A., Nikulina A. & Korolyova N. (2022). Prospects for the Development of Smart Clothing with the Use of Textile Materials with Magnetic Properties. Tekstilec, Vol. 65(1), pp.36-43. DOI: 10.14502/tekstilec.65.2021050.
[15] Tu Y.J. & Piramuthu S. (2022). Models to address RFID-based ticket-switching in retailing. Decision Support Systems, Vol. 153, 113666. https://doi.org/10.1016/j.dss.2021.113666.
[16] Wang Q., Zhao J., Xu S., Zhang K., Li D., Bai R. & Alenezi F. (2022). ExHIBit: Breath-based augmentative and alternative communication solution using commercial RFID devices. Information Sciences, Vol. 608, pp. 28-46. https://doi.org/10.1016/j.ins.2022.06.066.