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Wearable Technology Inspired By Nature: Biowear

Biogiyim: Doğadan İlham ile Giyilebilir Teknoloji

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WEARABLE TECHNOLOGY INSPIRED BY NATURE: BIOWEAR

ABSTRACT

In the scientific studies carried out in the poles, the use of the right equipment is of great importance in order to ensure the comfort of the researchers and the high efficiency that can be obtained from the project. In the project, a jacket prototype was developed by focusing on user/environment-friendly wearable technologies that can be used in the poles. In the design and production process, the discipline of inspiration from nature, "biomimicry" and ecological textile concepts were used. The modeling phase of the jacket was carried out using the Blender 3.1 solid modeling program. Changes/improvements have been made on an old jacket by upcycling the jacket in production. In the layer structure of the coat; Three layers were determined as outer fabric, padding and lining. This is because the fat, skin and fur structures of polar bears are taken as examples in the design process. Goose down and hemp fibers were preferred in the filling material, and the middle layer structure of the coat was completed; a natural, insulating middle layer is provided. In the lining part of the coat, 70% hemp and 30% cotton lining structure was chosen. In this way, the hemp plant, which is a local resource, was used and an organic inner layer was formed, eliminating the risk of sweating and allergic reaction of the part that will come into contact with the skin. The body temperature of the individual wearing our jacket, pulse values, location warning in case of sudden fall and an emergency button are available in our jacket. The obtained data will be able to be transferred to the base simultaneously with the LoRa module to the interface created from the Blynk application. The safety and comfort of the individual wearing the protective equipment is ensured outside, and an environmentally friendly alternative has been developed while doing this.

Keywords: Wearable Technology, Protective Equipment, Biomimicry, Textile, Human Health.

Outline

- It is aimed to provide a comfortable working opportunity for scientists working in niche areas such as Antarctica and the Arctic under difficult climatic conditions.
- Wearable technology and textile engineering are brought together and with the help of the design discipline, a safe use is promised to the individual in extreme cold conditions.
- The layer structure inspired by nature (Biomimicry) in the design of the coat is based on the exemplary fat, skin and fur structures of polar bears.

BİOGİYİM: DOĞADAN İLHAM İLE GİYİLEBİLİR TEKNOLOJİ

ÖZ

Kutuplarda sürdürülen bilimsel çalışmalarda araştırmacıların konforu ve yürütülen projeden alınabilecek yüksek verimi sağlamak için doğru ekipman kullanımı büyük önem taşımaktadır. Projede kutuplarda kullanılabilecek kullanıcı/çevre dostu giyilebilir teknolojilere odaklanılmıştır. Tasarım ve üretim sürecinde doğadan ilham alma disiplini "biyomimikri" ve ekolojik tekstil kavramlarından faydalanılmıştır. Modelleme aşaması Blender 3.1 katı modelleme programı üzerinden gerçekleştirilmiştir. Montun üretimde ileri dönüşüm yoluyla eski bir montun üzerinde değişiklikler/iyileştirmeler yapılmıştır. Montun katman yapısında; dış kumaş, dolgu ve astar olmak üzere üç katman belirlenmiştir. Bunun nedeni penguenlerin yağ, deri ve kürk yapılarının tasarım sürecinde örnek alınmasıdır. Dolgu malzemesinde kaz tüyü ve kenevir lifleri tercih edilerek montun orta katman yapısı tamamlanmış; doğal, yalıtkan bir orta katman sağlanmıştır. Montun astar kısmında ise %70 kenevir %30 pamuk astar yapısı seçilmiştir. Bu sayede yerli bir kaynak olan kenevir bitkisinden yararlanılmış ve organik bir iç katman oluşturularak deriyle temas edecek kısmın terleme, alerjik reaksiyon riskini ortadan kaldırılmıştır. Üretmiş olduğumuz montumuzda giyen bireyin mont içi sıcaklığı, nabız değerleri, anlık konum takibi, ani düşme durumunda uyarı verilmesi ve acil durum butonu bulunmaktadır. Elde edilen veriler Blynk uygulamasından oluşturulan arayüz üzerine LoRa modülüyle üsse eş zamanlı veri aktarabilecektir. Koruyucu ekipmanı giyen bireyin dışarıda güvenliği ve konforu sağlanmış, bu yapılırken çevreci bir alternatif geliştirilmiştir.

Anahtar Kelimeler: Giyilebilir Teknoloji, Koruyucu Ekipman, Biyomimikri, Tekstil, İnsan Sağlığı.

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1. INTRODUCTION

Arctic and Antarctica are the names given to the continents located at the north and south poles of the world. The polar regions hold numerous secrets that are yet to be uncovered, mainly because of the difficulties involved in transportation, accommodation, and exploration compared to other regions. To give an illustration of the significant problem nowadays, it is thought that an increase in temperature values due to global warming may be felt more severely in high-latitude regions, especially in the poles [2]. Therefore, the poles have become the center of significant scientific studies in recent years due to several factors, especially global warming. Every year, researchers from Turkey and around the world, who take the principle of making discoveries and studies at the poles, visit the continent.

The poles, last discovered by humans, are the coldest, driest, highest, and least populated regions on Earth [6]. As might be expected, life is challenging in the polar regions. First, it is important to make sure that the basic needs of those who travel to the poles to do scientific research are met without difficulty. It has been observed that sheltering and nutrition factors, which are among the three fundamental requirements of humans, has been the subject of numerous scientific studies such as building permanent research stations and raising plant in polar regions. It has been observed that the third fundamental requirement, which is clothing, is at least equally important as the other needs.

The poles are the world's driest, windiest, and coldest places [6]. In addition, research has shown that the 25 participants in Turkey's "3rd National Antarctic Science Expedition" were most challenged by the weather conditions at the poles. Therefore, the clothes of the researchers conducting study in polar regions should be appropriate for these extreme conditions. A wearable technology product has been developed to minimize damage in search and rescue operations, natural disasters such as avalanche, or diseases such as hypothermia. It is designed and manufactured as a modular jacket to protect the body.

Humanity has been trying to uncover the mystery of living creatures and has taken inspiration from them from the past to the present [12]. Nature's highly developed systems serve as a model for humanity in terms of innovativeness, productivity, and maintainability [12]. Living creatures have developed various physiological changes depending on the climate and living conditions of the region in which they live [8]. These changes are protecting them from environmental impacts such as hot and cold weather [8]. According to the biomimicry discipline, design in nature evolves based on long and extensive trial-and-error processes. Therefore, it believes that nature needs to be taken as a model in design processes. Additionally, it has been observed that, especially in recent years, the notion of biomimicry has started to appear in the literature more frequently. The main areas in which the discipline of biomimicry is used are given in Figure 1.

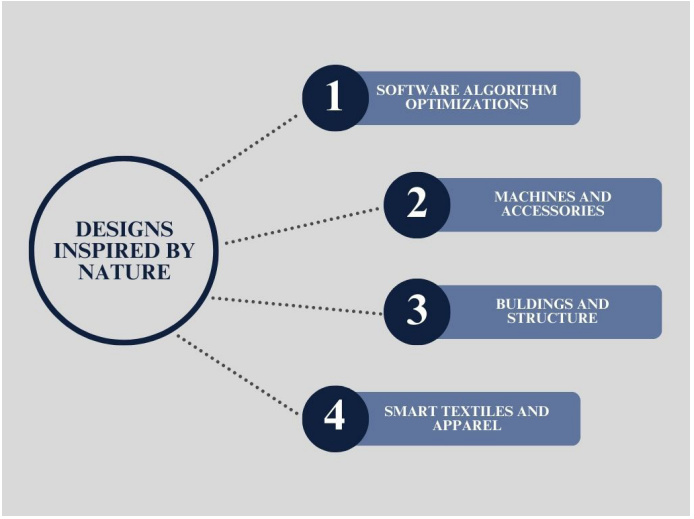

Figure 1. Discipline of Biomimicry

The fabric layer structure of the jacket was designed as a result of inspiration from the fur layer structures of the animals that live on the poles.

The jacket includes an electronic system on the inside. The system has a mainboard called Raspberry Pi Pico. Furthermore, the jacket includes a pulse sensor, temperature sensor, an accelerometer, a GPS module, an emergency button, a battery, and a Lora module that provides wireless communication.

2. MATERIALS AND METHODS

2.1 Sketch and Modeling

Before designing the project to be realized through the solid modeling program, many sketches were made on paper and the details of the design were created. The design process of the jacket is divided into two: modeling and texture shading. The modeling of the jacket was carried out through the solid modeling program Blender, which is a free three-dimensional modeling and animation program. To show the three-layer fabric structure of the jacket, the inner filling consisting of goose down and hemp fibers, hemp fabric as the lining material, and polyester texture for the outer layer are shown by assigning texture to the models via Blender. Renders that are taken from Blender are shown in Figure 2.

Figure 2. Renders Image Taken From Blender

2.2 Fabric Selections and Sewing of the Coat

The fabric selections for the multi-layered structure of the coat were searched in the literature and the most useful and environmentally friendly products were decided. Afterwards, the sewing phase of the coat was started with the products provided.

2.3 Fabric Selections

While choosing the fabric of the designed and produced coat, the parts of the coat were examined under three main headings. These headings consist of lining, filling and outer structure parts. There are detailed explanations of the layers at the upcoming parts.

2.4 Lining Structure of the Coat

As the fabric of the innermost layer lining part, hemp fabric got selected. The hemp fabric is produced in an organic way, it does not harm the skin of the coat's consumer, has a non-perspiring texture and maintains its existence in harmony with ecology. The fabric chosen for the mentioned part contains 30% hemp structurally, the rest of the fabric contains cotton material. Hemp fabric that is selected for the lining part of the coat is shown in Figure 3.

Figure 3. Hemp Fabric Selected for the Lining Part of the Coat

2.5 The Filling Structure of the Coat

Goose down is one of the most preferred materials in coats with its fullness performance and insulation ability. At the same time, the down structure is quite voluminous and shows a high return against deformation [9]. For these reasons, it was decided to include goose down in the filling layer of the coat. In order to adapt to the changing and developing world conditions and to exhibit a more environmentally friendly approach in the inner filling part of the jacket, hemp fibers were used in addition to goose feathers in the filling part of the jacket. Images taken from the filling part are located in Figure 4 and 5.

Figure 4. Filling Part

Figure 5. Filling Part

2.6 External Structure

Polyester fabric was preferred in the outermost layer of the coat because of its ability to cut the cold air coming from outside. The lotus flower leaf and surface have an essential place in the literature in order to show the hydrophobic and dirt-repellent properties of fabrics [12]. Parachute fabric is used in sections such as the neck and pockets, where the need for waterproofing is at a different level due to

the placement of the electronic components of the coat. Choosing the color of the parachute fabric as sax blue, separate from the color of the general outer structure, made the coat more seeable in an all white environment. In the Figure 6 and 7 outside view of the coat is shown.

Figure 6. Front View of the Coat

Figure 7. Back View of the Coat

2.7 Connecting Parts of the Coat

Velcro fasteners were used in the connection parts of the Biomont, since it was aimed to be inspired by the velcro plant and to ease of use. Velcro straps are preferred over the use of zippers on the neck of the coat and when putting on and taking off the coat.

2.8 The Sewing Phase of the Coat

After the study on the layer structure and fabric choices of the coat reached a conclusion, ideas were shared with a tailor in our region, and then the sewing stage was started. The sewing phase of the coat is shown in Figure 8.

Figure 8. The Sewing Phase of the Coat

2.9 Creation of Electronic Circuit

The circuit's mainboard is a device called Raspberry Pi Pico. The mainboard is powered by the battery. Sensors included as circuit components are a temperature sensor, a GPS module, a heart rate sensor, and an accelerometer. Also, a button is used as a circuit component. The person wearing the jacket can press this emergency button to alert the base in case of an emergency. The data received from the sensors is transmitted to the mobile application via the LoRa module and can be viewed from the interface. Cables are used to connect the components of the circuit. The working principle algorithm of the jacket is shown in Figure 9.

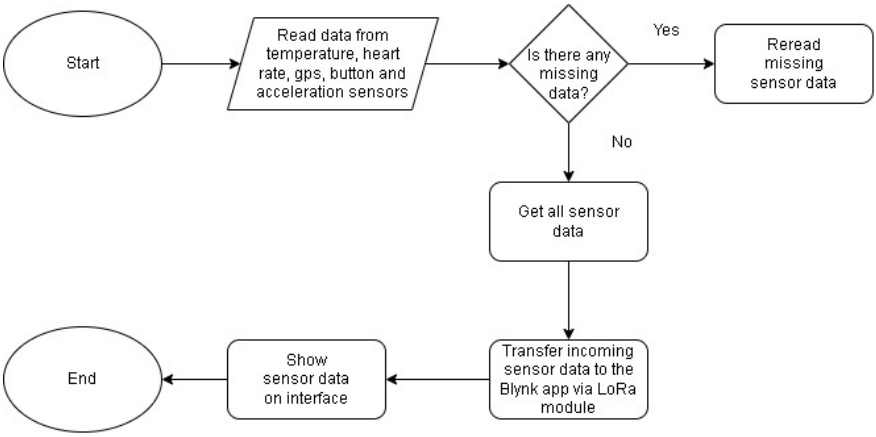

Figure 9. Jacket Working Principle Algorithm

2.10 Software

The project's codes were written and tested in C++ languages. The data that the sensors need to collect is integrated into the codes. The communication system of the LoRa module, which is used to transfer all the data that will come to the jacket later to the interface, is paired with the application so that the snapshot of the data is reflected.

2.11 Designing the Interface

The data collected by the sensors, such as the temperature sensor, GPS module, heart rate sensor, and accelerometer in the jacket, from the researcher who was wearing the jacket during the activity was transmitted to the science base simultaneously. The Blynk software was used to create an interface. Blynk is a program designed for IOT systems. We were able to develop an interface using the Blynk program that can simultaneously communicate with the LoRa module, store data, and receive sensor data, allowing us to get up-to-date information. As a result, the study was supported by the use of the mentioned program in the development of the project's interface. The important element of the developed interface is that it is not complicated and has an aesthetic and remarkable structure. At the same time, it is to transmit the current data received from the person wearing the coat to the researchers in a fixed position, quickly and with its usual simplicity.

The "LoRa module" is responsible for wirelessly transmitting data from sensors to the interface of the mobile application via radio waves. The design of the interface is given in Figure 10.

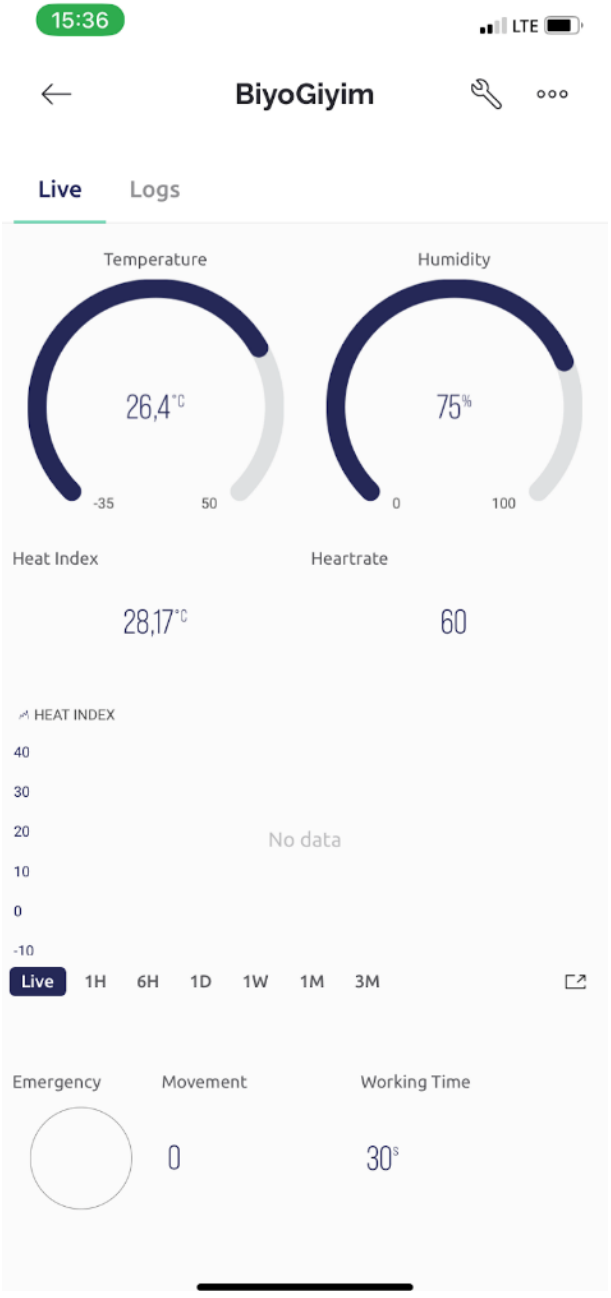

Figure 10. The Design of the Interface

3. RESULT AND DISCUSSION

3.1 Physical Outputs of the Jacket

The reason for choosing a three-layered structure in the designed and produced Biomont is inspired by the layer structure of polar bears, which consists of layers of fat, epithelium (skin), and fur. These layers can be referred to as the lining, filler, and outer structure. In the lining part, a fabric made of 70% hemp and 30% cotton, both of which are naturally produced, biodegradable, environmentally friendly, and harmless to the skin, is used. In the filler section, hemp fibers obtained with special permission from the Hemp Research Institute and goose feathers are preferred due to their insulation capabilities. When looking at the outermost fabric of the coat, it is observed that parachute/polyester fabric is chosen because it is inspired by the hydrophobic structure of lotus flowers. In the Figure 11 hydrophobic feature of parachute fabric is shown.

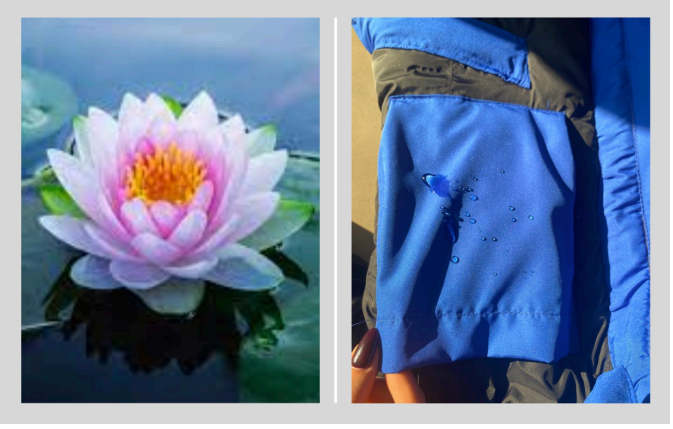

Figure 11. Hydrophobic Feature of Parachute Fabric

In order to provide statistical results to the physical output of the coat, a textile company was contacted and Biomont was tested for color fastness to washing, rubbing, water, sweat, water repellency and strength. When the fabric weight values are examined, it is determined that it is quite low, and considering the thick structure of the coat, it already has the weight of a thin fabric. The water repellency of the jacket resulted in an ISO 3 value, which shows that the water repellency value of the jacket is at a good value. When the literature is examined, this feature of the coat can be supported by the use of a main membrane structure. The tensile and tear strength of the coat; It is located at a high level in the outer layer compared to a low-weight structure. There is a comparison of the layer structure in Figure 12. The table containing the test results explained is in Table 1 and 2.

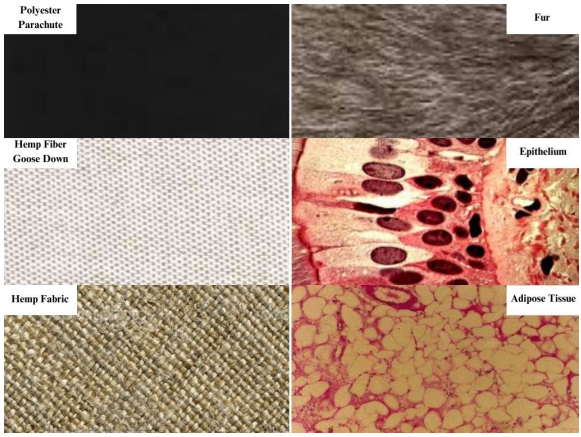

Figure 12. Comparison of the Layer Structure

Table 1. Test Data Results of Fabrics

Fabrics's Name	Thread Analysis	Color	Basis Weight TS 251	Thickness	Color Fastness to Washing ISO 105 C06	Color Fastness to Rubbing ISO 105 X12	Color Fastness to Water ISO 105 E01	Color Fastness to Sweat ISO 105 E04-Acidic	Color Fastness to Sweat ISO 105 E04-Basic
Outer Layer Fabric	% 100 PES	Blue	87 g/m²	Warp: 29 fiber/cm Weft: 36 fiber/cm	Acetate: 4/5 Cotton: 4/5 Nylon: 4 Poliester: 4/5 Acrylic: 4/5 Wool: 4/5	Wet: 5 Dry: 4/5	Acetate: 4/5 Cotton: 5 Nylon: 4/5 Poliester: 5 Acrylic: 5 Wool: 4/5	Acetate: 4/5 Cotton: 5 Nylon: 4/5 Poliester: 5 Acrylic: 5 Wool: 4/5	Acetate: 4/5 Cotton: 5 Nylon: 4/5 Poliester: 4/5 Acrylic: 5 Wool: 4/5
Inner Lining Fabric	%30 Hemp %70 Cotton	White	114 g/m²	Warp: 15 fiber/cm Weft: 20 fiber/cm	-	-	-	-	-
Product (Three layers)	% 100 PES- Goose Down and Linen Fiber- %20 Hemp- %80 Cotton	Blue-White	Product Weight: 42,90 g Insu-lation Material Weight: 12 g	-	-	-	-	-	-

Table 2. Test Data Results of Fabrics

Fabric's Name	Thermal Resistance ISO 11092	Water Vapor Resistance ISO 11092	Water Repellency ISO 4920	Thickness Determination ASTM D 1777	Air Permeability ISO 9237	Breaking Strength ISO 13934-1	Tear Strength ISO 13937-2	Pilling Resistance (ICI Pilling Box) ISO 12945-1
Outer Layer Fabric	0,0005 m^2.K/W	0,93 m^2. Pa/W	ISO 3	0,2 mm	0,0 mm/sn	Warp: Fmax 785,221 N Weft: Fmax 468,64 N	Warp: F tear growth 37,51 N Weft: F tear growth 33,44 N	–
Inner Lining Fabric	0,011 m^2.K/W	2,37 m^2. Pa/W	ISO 3	0,5 mm	1324.3 mm/sn	Warp: Fmax 228 N Weft: Fmax 773,85 N	Warp: F tear growth 23.50 N Weft: F tear growth 25.77 N	1000 cycle 4/5 2000 cycle 4 3000 cycle 4 4000-10.000 cycle 3/4
Product (Three Layers)	0,196 m^2.K/W	28 m^2.Pa/W	ISO 3	11,67 mm	367.12 L/ m2/sn	-	-	-

A neck section has been added to allow the attachment of circuit elements associated with the coat, and the large front pockets of the coat have increased its storage space. Parachute fabric is used in the sections added to the outer structure of the coat. The main reason for choosing parachute fabric is its water-resistant properties. Hook and loop fasteners are used at the connection points of the coat for ease of use. The connecting parts of the coat are shown in Figure 13, 14 and 15.

Figure 13. Neck Part of the Coat

Figure 14. Pocket Compartment

Figure 15. Velcro Tapes

3.2 Electronic Outputs of the Jacket

The temperature sensor, one of the circuit components, was used to measure the temperature inside the wearer's jacket. The heart rate sensor tracked the person's heartbeat. The accelerometer allows the movement of the individual to be detected and even transmits a warning to the base when they fall to the ground. The GPS module provides accurate location determination and tracking of the person on Earth. The button served as an emergency button and was positioned so the person wearing the jacket could immediately reach it. Each sensor's data is instantly reflected to the interface by the LoRa module utilized for wireless communication. Cables are used in the connection of electrical components. The circuit is powered by the battery to operate properly. The representation of the sensors on the jacket is given in Figure 16.

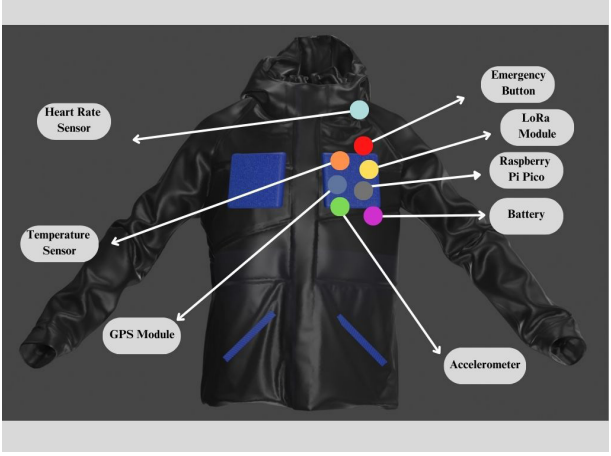

Figure 16. The Placement of the Circuit Elements on the Coat

4. CONCLUSION

The structure of the Biomont is inspired by the fat, epithelium, and fur texture of polar bears and has three layers: hemp fabric on the lining, goose feather, and hemp fiber on the filling, and polyester and parachute fabric on the outside. A fabric consisting of 30% hemp and 70% cotton was used in the lining of the coat. When the fabric weight values are examined, it is determined that it is quite low, and considering the thick structure of the coat, it already weighs a thin fabric. This adds additional value in terms of increasing the comfort of the user. Using velcro tapes instead of zippers in the connection parts of the coat, inspired by the catnip plant, has made the coat easier to use. Storage space has been strengthened by increasing the number of pockets of the coat.

In the part of the jacket that will come into contact with the skin, naturally produced, biodegradable raw materials that do not harm health are used. Goose down and hemp fiber were used in the filling section of the coat. Goose down supports the coat thanks to its high filling performance and insulation ability. Hemp fibers increase the insulation and environmental features of the jacket. The polyester fabric was used in the outer structure of the jacket, and parachute fabric was used in sections such as the pocket and neck sections of the jacket. With the help of polyester fabric, the coat keeps the wearer warm and, inspired by the lotus flower, the waterproof feature of the parachute fabric was utilized. This feature of the coat can be supported by.

Using the Raspberry Pi Pico main board as the motherboard in the electronic circuit of the jacket is important because this main board is produced for wearable technology products. The presence of emergency buttons in addition to sensors such as temperature, pulse, instant location tracking, and acceleration in the jacket enabled urgent news to reach the base easily. With the LoRa module, the data received from the circuit is understandably transmitted to the interface and the base is informed.

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Addings

A. Budget Cost Table

Product Name	**Amount Of Usage**	**Total Cost**
Parachute Fabric	1 meter	76 TL
Hemp Fabric	2 meter	350 TL
Hemp Fiber	250 grams	-
Raspberry Pi Pico	1 piece	130 TL
Battery	1 piece	250 TL
MPU6050 Accelerometer	1 piece	60 TL
Push Button	1 piece	2 TL
Temperature Sensor	1 piece	35 TL
Heart Rate Sensor – MAX30102	1 piece	75 TL
LoRa Module	1 piece	200 TL

Author Contribution Rates

Design of Study: EK(%30), DÖ(%30), ZNT(%30), ÖT(%10)

Sketching and Solid Modelling: EK(%20), DÖ(%20), ZNT(60)

Writing Up: EK(%40), DÖ(%25), ZNT(%35)

Design of Electronics: EK(%25), DÖ(%30), ÖT(%45)

Software: EK(%20), DÖ(%30), ZNT(%10), ÖT(%40)

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