








Conceptual Design of Smart Furniture: A Case Study

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Abstract. Today design industry relies heavily on stylish and feature-rich designs applied to everyday applications. That is especially emphasized in the furniture industry where new trends are rising thus making it, so-called, smart furniture. This paper deals with paradigms and conceptual ideas in the enrichment of furniture with added value but with a stressed focus on furniture longevity and maintainability. The following case study will provide an insight into current smart furniture solutions and key characteristics that ensure the longevity of smart furniture.

Keywords: Furniture design · Industrial design · Maintenance · Smart furniture

1 Introduction

In order to maintain their competitiveness, furniture manufacturers are trying to adapt to the growing desires and needs of users. With the development of IoT technology, artificial intelligence and the desire to stand out from other manufacturers, manufacturers are becoming more innovative, which leads to the emergence of new trends in the furniture industry. As a consequence, the classical concept of furniture has changed from just basic objects that humans use to furniture units that are able to sense, identify and interact with users to meet their needs and desires [1]. Smart furniture with numerous functionalities reduces human effort and increases the quality of life, which is why it is increasingly used in private and business premises. Given the difference in the price of smart furniture and ordinary classic furniture, it is expected that smart furniture will last as long as possible. In order to meet human needs for some time, this paper proposes key characteristics to be considered in the production of smart furniture.

2 Smart Furniture

Given that the idea of “Smart Furniture” is relatively new and still in development, there is no explicit definition of so-called “Smart furniture”. The first patent in which the term “Smart furniture” has occurred dates back to 1998. when innovator proposed integration of computer and card reader into a desk. Since then, technology has advanced

rapidly, so the term “Smart furniture” today has a different meaning. Based on analyzed research projects, studies and patents applications, the authors of the article [2] proposed a description of smart furniture in the context of smart homes, smart devices, smart environments and users as shown in Fig. 1.

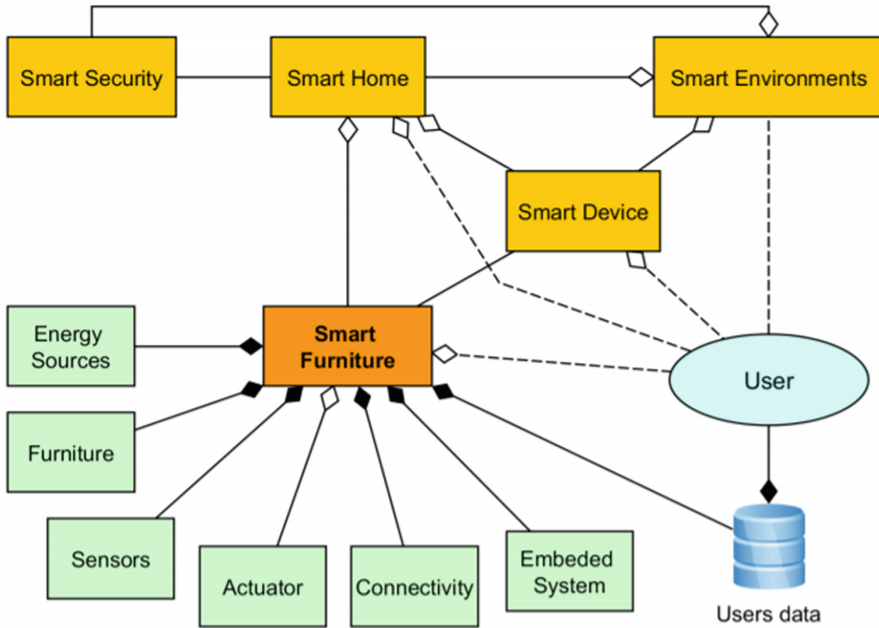


Fig. 1. Role and position of smart furniture within the Smart City [2].

A Smart Home is a house that uses numerous types of information technology to observe the environment, manage electric appliances and communicate with the outer world. Smart devices are described as critical resources that enable the delivery of numerous smart service systems to users [3]. Users should be able to interact with smart furniture, but also with other components of the smart home. By knowing the user’s data and individual user preferences, smart furniture can be customized to the needs and wishes of end-users.

Different authors propose different definitions, according to one of those proposals, “Smart furniture” is defined as a “Physical structure which is composed of hardware such as computers, sensors, and appliances, and developing software technologies for realizing smart hot-spot services” [4].

According to the article [5], “Smart furniture is furniture which brings added value, functionality, comfort and elegance to fit every personalized requirement issued by the user”.

Smart Furniture can also be defined as furniture which instantaneously changes the legacy non-smart space into a smart space where location-based context-aware services, service roaming, personalized services and connectivity to the Internet are provided.

Since the Smart Furniture is equipped with embedded networked computers, sensors and various I/O devices, it can provide various services in open public and/or private spaces [6].

Given the numerous definitions of “Smart Furniture”, the authors of the article [2] provided an explicit definition of the term “Smart Furniture” based on patent databases and the frequency of keywords used in the literature. They proposed the following: “Smart Furniture is designed, networked furniture which is equipped with an intelligent system or controller operated with the user’s data and energy sources. It can communicate and anticipate the user’s needs using sensors and actuators inside the user’s environment, resulting in a form of user-adapted furniture or an environment that satisfies the user-declared needs and non-declared needs for the aim of improving their quality of life in a smart world”.

3 Current Trends and Characteristics of Longevity

The authors of the article [7] implemented an Arduino-based system in the chair to scan the user ID and check the status of the chair occupancy. As shown in Fig. 2, the data is then sent to a cloud server where it is stored. An authorized user can access this data at any time using a mobile device and thus, for example, check the presence of a student.

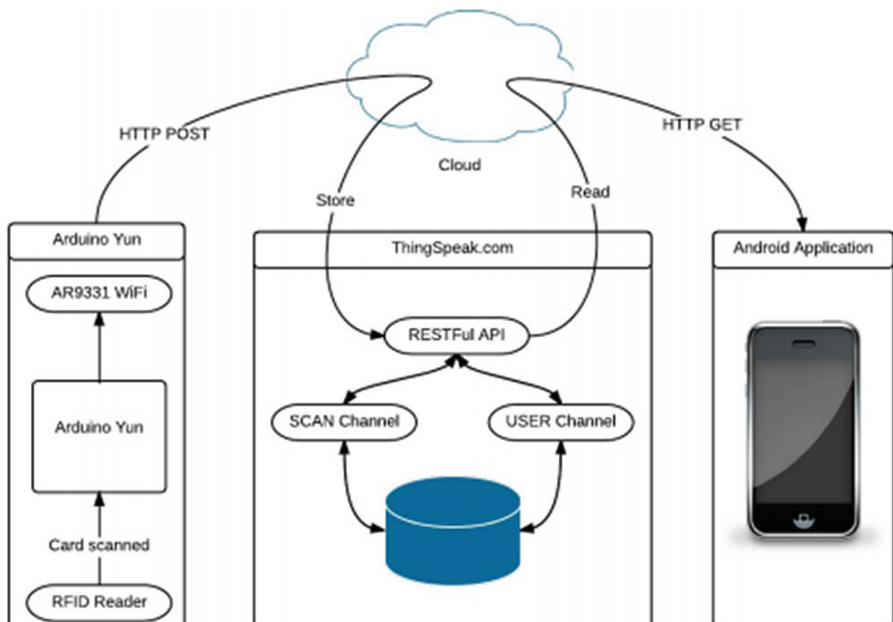


Fig. 2. System architecture of intelligent chair [7].

Office employees perform their work by sitting most of the time. Sitting longer than recommended can lead to serious health problems and musculoskeletal disorders. Smart chairs, equipped with sensors in the seat surface and backrest, monitor the sitting behaviour of the user [8]. If a certain time is exceeded, the user can be provided with a tactile feedback signal. Another solution for providing feedback to users is by sending notifications to a PC, smartphone or smartwatch. Sensors embedded in a smart chair can also be used for the detection of improper posture.

By implementing various sensors in the chair, some vital parameters that are important for human health can be detected. The authors [9] and [10] suggest the implementation of piezoelectric sensors in the chair to obtain heart rate or monitor children who have attention-deficit hyperactivity disorder (ADHD) what would help to determine the required therapy.

A large number of companies strive to increase the satisfaction of their employees and improve their work environment. Nowadays, almost every person owns a smartphone, so wireless chargers are being implemented into office desks to reduce the need for each employee to carry their own charger. The further enrichment of the desk could be the possibility of adjusting the slope or height to improve comfort and the health conditions for the eyes and spine [11].

The development of smart furniture can especially contribute to the health of the elderly. With built-in sensors, the smart bed could monitor an individual's health during sleep and automatically notify the central system in the event of a heart attack [11]. The authors of the article [12], propose the concept of a smart paramount bed system as shown in Fig. 3. It would continuously monitor physical conditions such as breathing and heart rate while the user simply lies on the bed with nothing attached to his body. It could also determine a user current state, such as general motion, being away from the bed, sleeping, and awakening. Additionally, the system could read vital signs such as blood pressure and body temperature by linking with measuring. The information measured and acquired in these ways could be shared with a bedside terminal, health care facility and electronic medical record system.

Smart furniture is also widely used in private spaces. The most common features that are smart tables equipped with are charging ports, Bluetooth speakers, LED lights, food and beverage refrigerators. With a touch-sensitive surface and the ability to connect to other devices such as TVs, smart tables make a perfect example of multifunctional smart furniture.

In order to meet the human needs for smart furniture in the long run, it is necessary to consider what are the most important characteristics that end-users expect from smart furniture. According to the research of the authors from the article [5], the five most important characteristics that furniture should have are as follows:

- Functionality,
- Design,
- Safety in Use,
- Customization and
- Structural Design.

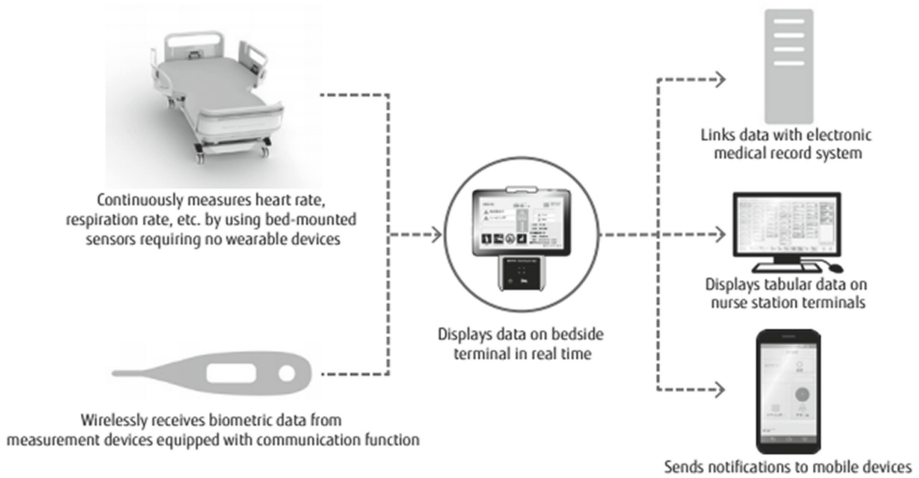


Fig. 3. The basic configuration of smart bed system [12].

The research was conducted according to the relative importance of each individual characteristic for a certain customer profile. The following Table 1 shows the results of research for young single adults.

Table 1. Importance of characteristics for young single adults.

Customer profile	
Young single adult	
Characteristics	Importance
Functionality	13.0%
Space saver	12.6%
Price	12.2%
Multiple functions	11.5%
Modularity	7.3%
Safety in use	6.3%
Design	5.7%
Durability	5.4%
Eco-friendly	5.0%
Structural design	4.9%
Ease of assembly	4.7%
Customization	4.6%
Easy to clean	4.3%
Type of material	2.6%

A graphical representation of results is shown in Fig. 4.

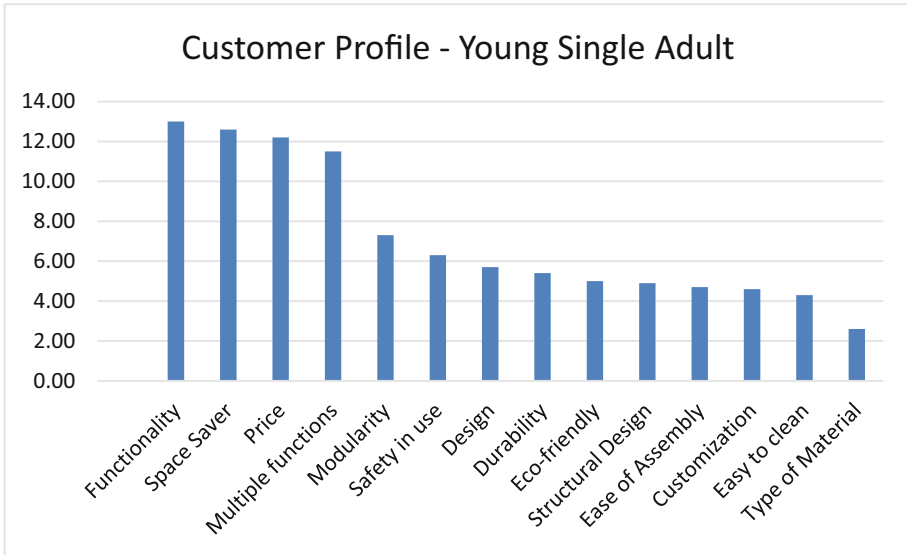


Fig. 4. Importance of characteristics for young single adults – graphical representation.

Due to low incomes, young people want to have as much functionality as possible provided by furniture at the lowest possible price. Low incomes lead to smaller housing spaces where young people live, so space-saving is expected to be another important characteristic of young adults. The following Table 2 shows the results of research for families with small children.

As can be seen in Fig. 5, for families with children the most important feature is Safety in Use. Unlike the results of a survey of young people, families are able to set aside more money for furniture that will meet their needs for a longer period of time. The last group of respondents consisted of wealthy users, the results are given in Table 3.

As can be seen in Fig. 6, for wealthy, upper-class customers the most important furniture features are design, customization and type of material. According to research results, various groups of people have different desires in terms of the possibilities that furniture can provide them, so before production, it would be good to research the market for which the furniture is planned to be produced.

Complex systems like smart homes should consist of different devices that have the ability to communicate with each other, [13] so the possibility of communication is one of the crucial device functionalities for furniture that need to be controlled.

Since the consumer should also be able to communicate with the device, one way of doing this is by voice control which enables a hands-free way to control the device.

When it comes to communication, it is always important to keep in mind possible device compatibility issues as well as security issues, to ensure privacy and safe usage of equipment. With machine learning, intelligence can be added to furniture to learn

Table 2. Importance of characteristics for families with small children.

Customer profile Families with small children	
Characteristics	Importance
Safety in use	14.6%
Functionality	11.7%
Durability	11.2%
Structural design	9.4%
Easy to clean	8.1%
Customization	6.4%
Modularity	5.3%
Design	5.2%
Price	5.2%
Type of material	5.2%
Multiple functions	5.2%
Space saver	4.9%
Eco-friendly	4.4%
Ease of assembly	2.9%

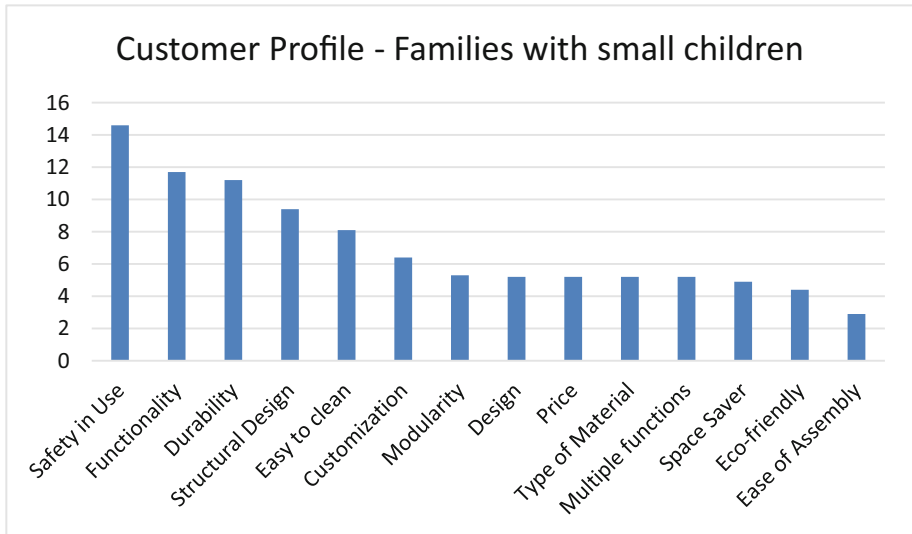


Fig. 5. Importance of characteristics for families with small children – graphical representation.

Table 3. Importance of characteristics for wealthy, upper-class customers.

Customer profile	
Wealthy, upper-class customers	
Characteristics	Importance
Design	16.9%
Customization	12.5%
Type of material	10.7%
Structural design	10.0%
Safety in use	8.0%
Functionality	7.7%
Durability	6.9%
Eco-friendly	6.5%
Easy to clean	4.3%
Modularity	3.8%
Multiple functions	3.7%
Ease of assembly	3.2%
Price	3.0%
Space saver	2.8%

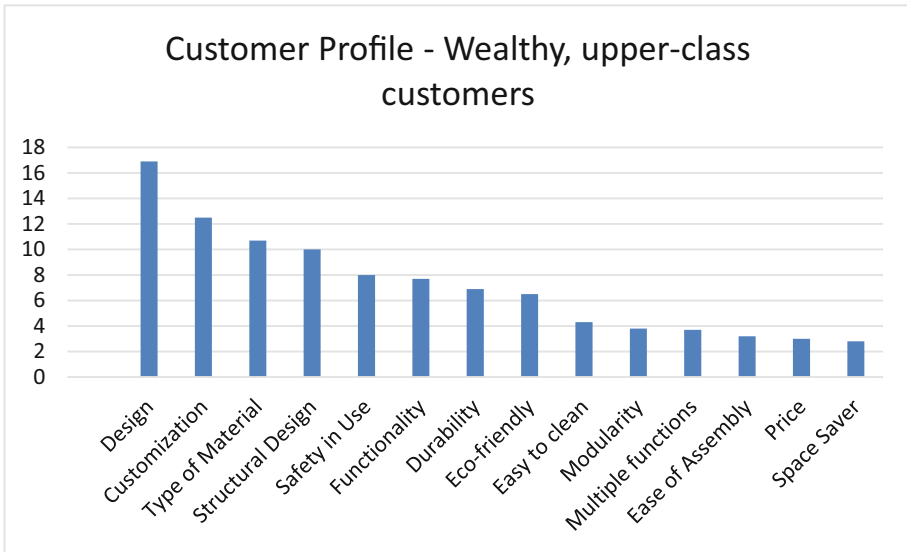


Fig. 6. Importance of characteristics for upper-class customers – graphical representation.

individual user preferences. By knowing individual user preferences, the environment can be personalized and act as an intelligent support system to improve user comfort, health and productivity [14]. Because of population growth and urbanization, the number of small houses and apartments is increasing [15]. To make the best use of space, space-saving design and the possibility of transforming furniture such as wall beds are becoming increasingly important features. Some other key characteristics regarding smart furniture longevity are shown in Fig. 7.

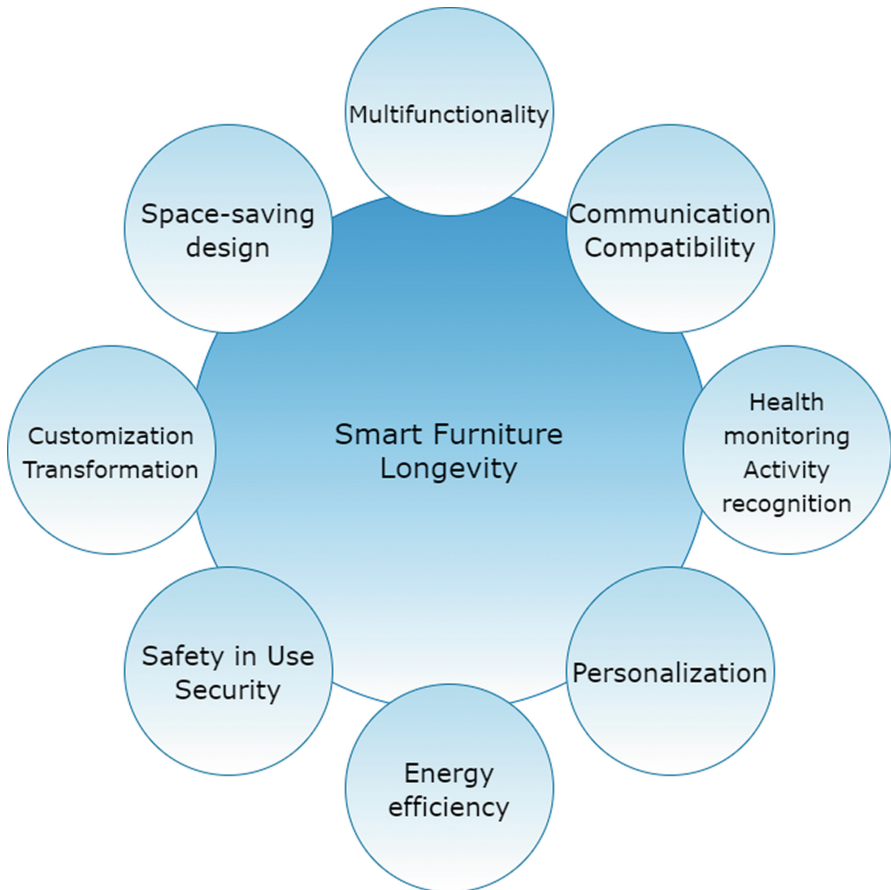


Fig. 7. Key characteristics for smart furniture longevity.

As mentioned earlier, smart devices should be able to communicate with each other. This interconnection of devices as well as the connection of the physical and virtual environment can be wired or wireless. Wired systems are more reliable concerning interference because of shielded cables, but wireless systems are generally more prevalent due to lower costs. Another advantage is the ability for devices that use this method of communication to be easily transferred from location to location. The most common wireless communication standards are shown in Table 4, [11].

Table 4. Some key smart home communication technologies.

Wireless technology	Range	Data rate	Power (mW)	Max nodes	Security
RFID	0–3 m	64 kbps	200	1 at a time	N/A
Bluetooth	1–100 m	1–3 Mbps	2.5–100	1 M + 7 S	56–128 bit key
BLE	1–100 m	1 Mbps	10	1 M + 7 S	128-bit AES
ANT	30 m	20–60 kbps	0.01–1	65533 in one channel	64-bit key
ZigBee	10–100 m	250 kbps	50	65533	128-bit key
NFC	5 cm	424 kbps	15	1 at a time	AES
WiFi	150–200 m	54 Mbps	1000	255	WEP, WPA, WPA2
6LoWPAN	25–50 m	250 kbps	2.23	-	128-bit key
Sigfox	10–50 km	10–1000 bps	0.01–100	-	No default encryption
HomePlug GP	100 m	4–10 Mbps	500	-	128-bit AES
Z-Wave	100 m	9.6–100 kbps	100	232	128-bit AES
Insteon	40–50 m	38 kbps	-	64000 nodes per network	256-bit AES
EnOcean	30–300 m	125 kbps	0.05	-	128-bit AES

4 Conclusions

Based on current changes and trends, such as IoT technology and artificial intelligence, the furniture industry is enriching its products with new features. The purpose of such products is to increase the quality of life, reduce human effort and ensure that human needs are met for some time. To ensure requested longevity, the study listed some basic functionalities and characteristics that smart furniture should possess. Due to individual differences among consumers, it is difficult to satisfy everyone's needs with one product. And while some characteristics such as energy efficiency and safety are desirable to all, other characteristics, such as design that vary from person to person, should be able to be customized to each individual. With all this in mind, the production of smart furniture should take into account the characteristics that will affect its longevity, maintainability, and thus consumer satisfaction.

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References

1. Mohamed, A.M.S., Ibrahim, N.F., Hassan, M.R.: The impact of smart furniture design on meeting the needs of a limited-space housing. *J. Archit. Art Hum. Sci.* **6**, 25 (2021). <https://doi.org/10.21608/mjaf.2020.23392.1499>
2. Krejcar, O., et al.: Smart furniture as a component of a smart city-definition based on key technologies specification. *IEEE Access* **1** (2019). <https://doi.org/10.1109/ACCESS.2019.2927778>
3. Lim, C., Maglio, P.P.: Data-driven understanding of smart service systems through text mining. *Serv. Sci.* **10**(2), 154–180 (2018). <https://doi.org/10.1287/serv.2018.0208>
4. Ito, M.: Smart furniture: improvising ubiquitous hot-spot environment. In: 23rd International Conference on Distributed Computing Systems Workshops, pp. 248–253. IEEE, Rhode Island, USA (2003). <https://doi.org/10.1109/ICDCSW.2003.1203562>
5. Vaida, C., Gherman, B., Dragomir, M., Iamandi, O., Banyai, D.: Smart furniture -Quo Vadis. In: 3rd International Conference on Quality and Innovation in Engineering and Management (2014)
6. Tokuda, H.: Smart furniture: a platform for creating context-aware ubiquitous applications everywhere. In: Yang, L.T., Guo, M., Gao, G.R., Jha, N.K. (eds.) EUC 2004. LNCS, vol. 3207, pp. 1112–1112. Springer, Heidelberg (2004). https://doi.org/10.1007/978-3-540-30121-9_108
7. He, J., Atabekov, A., Haddad, H.M.: Internet-of-things based smart resource management system: a case study intelligent chair system, In: Proceedings of the 2016 25th International Conference on Computer Communication and Networks (ICCCN), pp. 1–6, Waikoloa, HI, USA (2016). <https://doi.org/10.1109/ICCCN.2016.7568533>
8. Roossien, C.C., et al.: Can a smart chair improve the sitting behavior of office workers? *Appl. Ergon.* **65**, 355–361 (2017). <https://doi.org/10.1016/j.apergo.2017.07.012>
9. He, Z., et al.: A heart rate measurement system based on Ballistocardiogram for smart furniture. In: 2018 IEEE Asia Pacific Conference on Circuits and Systems (APCCAS), pp. 151–154 (2018). <https://doi.org/10.1109/APCCAS.2018.8605567>
10. Yang, R.C., et al.: Objective evaluation of therapeutic effects of ADHD medication by analyzing movements using a smart chair with piezoelectric material. *Appl. Sci.* **11**(12), 5478 (2021). <https://doi.org/10.3390/app11125478>
11. Shidiq, D.D., Chico Hermanu, B.A., Fauzan, A.M., Ubaidillah, A.: Development of adjustable desk with wireless charging features. *AIP Conf. Proc.* **2097**, 030021 (2019). <https://doi.org/10.1063/1.5098196>
12. Majumder, S., et al.: Smart homes for elderly healthcare-recent advances and research challenges. *Sensors* **17**(11), 2496 (2017). <https://doi.org/10.3390/s17112496>. PMID: 29088123; PMCID: PMC5712846
13. Nakajima, R., Sakaguchi, K.: Service vision design for Smart Bed System™ of paramount bed. *Fujitsu Sci. Tech. J.* **54**, 9–14 (2018)
14. Zdankin, P., Weis, T.: Longevity of smart homes. In: 2020 IEEE International Conference on Pervasive Computing and Communications Workshops, Austin, USA (2020). <https://doi.org/10.1109/PerComWorkshops48775.2020.9156155>
15. Aryal, A., Becerik-Gerber, B., Anselmo, F., Roll, S.C., Lucas, G.M.: Smart desks to promote comfort, health, and productivity in offices: a vision for future workplaces. *Front. Built Environ.* **5**, 76 (2019). <https://doi.org/10.3389/fbuil.2019.00076>
16. Husein, H.A.: Multifunctional furniture as a smart solution for small spaces for the case of Zaniary towers apartments in Erbil City. *Int. Trans. J. Eng. Manag. Appl. Sci. Technol.* **12**, 1–11, (2020). <https://doi.org/10.14456/ITJEMAST.2021.8>