Internet of Things on the Axis of Design and Technology Interaction: IOT Products as a New Product Paradigm

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ABSTRACT
In recent years, as a result of the fact that technological components have become smaller, cheaper and widespread, information and communication technologies have started to be embedded in all kinds of everyday products. Due to technology integration, products undergo radical changes both in content and form. The Internet of Things (IOT), one of the most important technologies, describes mainly a communication network in which objects are involved, and consumer products constitute an important part of this system. In the scope of this study, which aims to examine the Internet of Things from the product design perspective, firstly, information about the origins, emergence, definition, and development of the concept is compiled, and then the enabling technologies and the application areas in different sectors are examined. Properties and types of IOT objects, as one of the most important components of the system, have been tried to be defined. The main features of IOT products that are separated from existing technological products have been tried to be determined. In order to understand the implications of the integration of IOT technology into everyday products, IOT products introduced to the market were evaluated in terms of design and technology interaction, and the effects of the technological properties of these products on design are discussed in terms of function, form, and interaction.

Keywords: Internet of Things, IOT Products, Product Design, Product Review.

1. INTRODUCTION

For designers, new technologies are important in terms of both providing new product ideas and enabling these ideas to come to life (Nordby, 2010). Today, when the industrial society has evolved into the information society, the boundaries of the design problem have begun to expand with the developments in communication, microelectronics and computer technologies. This has opened the door to innovation opportunities in products through the identification of new functions and the production of new meanings and experiences (Sato,2001). The effect of technology in the context of directing creative activities has been valid in all periods from past to present.Especially in recent years, as a result of the fact that technological components have become smaller, cheaper and widespread, integration of technologies into products has increased. Products that are the objects of design have been undergoing radical transformations both in content and form.As a result of this transformation, products contain integrated systems that are built with electronic hardware and software, and these systems become functional by programming components such as microcontrollers and microprocessors. A new product paradigm emerges as a result of the integration of embedded systems and network technologies into products (Sato,2001). Now, products have become able to interact with each other, their users, other users, various environment and services by means of these technologies.

Recently, the Internet of Things technology, which has attracted the attention of both industry and academy, has enabled the creation of new business models and the creation of new products and services. IOT is considered one of the destructive technologies that have the potential to radically change everyday life (Alkhatib, etal., 2014). Within the scope of this study, which aims to address this technology from a product design perspective; first, information related to the origins, development and the current state of the concept of Internet of Things will be given and then, different application areas, the enabling technologies and the properties of the objects included in this network will be discussed. In the last part of the study, the reflections of IOT technology on consumer products will be examined through product examples with different representativeness.

2. INTERNET OF THINGS

2.1Origin, Definition and Evolution

The origin of the Internet of Things, which can be defined as a worldwide network consisting of interconnected objects that are clearly addressable based on standard communication protocols (INFSO, 2008), goes back to the vision of "ubiquitous computing" put forward by Mark Weiser in 1991 (Kortuem et al., 2010; McEwen and Cassimally, 2014). “Ubicomp” predicted that computers would become indistinguishable and invisible by weaving the fabric of everyday life (Weiser, 1991). Today, as computer components become so small that they can be easily embedded into everyday objects, computing skills are incorporated by microprocessors with a secondary attribute of the content of the objects of their own form, purpose, and function. A new type of object, also known as "computer-augmented objects", emerges that gains added value through digital information processing (Beigl et al.,2001). Donald Norman discusses this phenomenon in his book titled "The Invisible Computer" from the perspective of design and human interface and defines these new generation objects as human-centered “Information Devices” (Norman, 1998). According to the author, the technology of the computer disappears behind the task-specific devices. In the literature, in addition to Ubicomp, there are different concepts that are used to refer to the overlapping or largely intersecting phenomena such as “physical computing”, “pervasive computing”, and “ambient intelligence”. Basically, these approaches, which envision the embedding of computer technology in many objects we use in everyday life, could not foresee that the network connection and the internet will reach today's prevalence (McEwen and Cassimally, 2014). The most important point where the IOT differs from these other concepts is that the network connection is included in the contents of everyday objects.

The first IOT application in history is accepted as a camera system which was established by the academicians of Cambridge University in 1991 in order to monitor the status of the coffee maker (López-de-Armentia et al., 2012). This relatively primitive application, which includes sending the image of the coffee maker to the computer screen 3 times per minute, is considered the first IOT application because it is online and real-time. The term was first used by Kevin Ashton in a presentation on the benefits of using Radio Frequency Identification (RFID) technology in supply chain management at P&G in 1999 (Ashton, 2009). The actual birth date of the concept of the Internet of Things is shown in the years 2008-2009 when the number of connected objects exceeds the number of people connected to the Internet. It is estimated that by 2020 the number of these devices will exceed 50 billion (Evans, 2011).

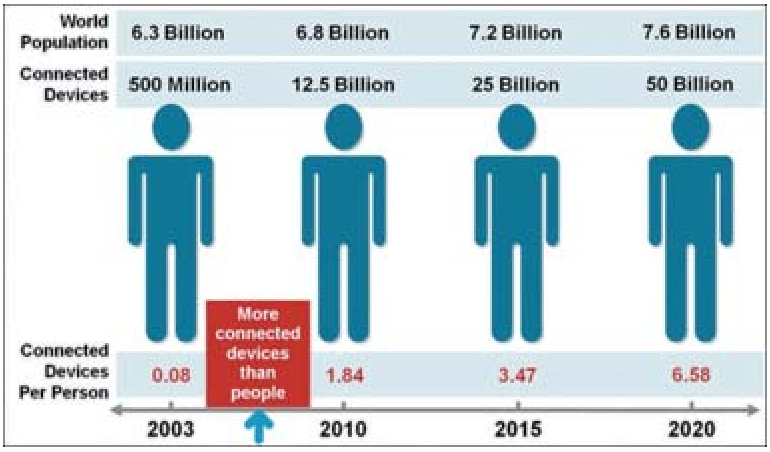


Figure 1. Increase in the number of connected devices(Evans, 2011)

Ashton (2009) has defined a vision where computers can collect data without any human help and can transform the data they collect into useful information, and he pointed out a paradigm shift towards computers that could collect their own data from computers that process data collected by humans.In the present day, the Internet of Things is used to cover a wider range of technologies. In addition to the ability to identify and track objects highlighted by Ashton, objects now have internal processors, network connectivity, and the ability to detect and respond to their physical environment (Rowland, et al., 2015).

The concept has a comprehensive and multi-faceted nature and is still developing, so there is no consensus on the literature related to its' definition. There are many definitions that have different approaches from each other (Ibarra-Esquer, et al., 2017). Atzori et al. (2010) associate this situation with the interest and the fever of the discussions on this subject and they also draw attention to the syntactic structure of the term. That different organizations define it considering their own business and interests is shown as the reason for the difference between the definitions (Atzori et al., 2010). Ibarra-Esquer et al. examined the development of the concept since the emergence of the definition in four different periods: (1) The Early Visions, (2) Establishment Phase, (3) A Shift Towards Data and Services, (4) Things as a Key Element (2017).

In the early period from the late 1990s to 2005, IOT has been described as a world where all electronic or non-electronic objects are electronically tagged and all devices are connected together (Sarma et al., 2001). According to the International Telecommunication Union (ITU) report published in 2005, IOT evolves with the vision of “anytime, anywhere, by anyone and anything” (ITU, 2012). ITU portrays the IOT as a virtual world that maps the real world where everything in our physical environment has its own identity in the virtual cyberspace. This world enables human-to-object interactions and object-to-object interactions; real-time monitoring of changes in the physical area. According to the network-oriented definition that emerged towards the end of the early period, the IOT is defined as a worldwide network consisting of interconnected objects that are clearly addressable based on standard communication protocols (INFSO, 2008). The questioning about the concept during in the establishment phase has evolved from what can get connected to the network, to what can be done with things that can be connected to the network (Ibarra-Esquer, et al., 2017). Haller et al. (2009) define IOT as a world where physical objects can become active participants in business processes by seamlessly integrating into the information network. Within the scope of the CASAGRAS project supported by the European Commission, IOT, which is considered as a global network infrastructure that connects physical and virtual objects using its data collection and communication capabilities, is characterized by a high degree of autonomous data capture, event transfer, network connectivity, and interoperability features through object identification, sensor, and connectivity capabilities (CASAGRAS, 2009). In their work on interpreting the definitions related to the concept, Atzori et al. suggest that the IOT paradigm consists of a combination of three different vision: Things-oriented, Internet-oriented, and Semantic-oriented (Atzoriet al., 2010). Accordingly, IOT has three fundamental building blocks: (1) the way objects get connected to the network, (2) the capabilities of interaction and communications provided, and (3) the use and interpretation of the information provided by objects. According to the authors, IOT has the potential to add a new dimension to the interaction process between people and machines through the interaction of intelligent objects with people and with each other. The description offered by Zhang et al. (2010) qualifies IOT as a network that uses embedded sensing and localization devices to connect to the internet for information exchange and communication, to perform intelligent recognition, location, monitoring, and management functions. Coetzee and Eksteen (2011) define a vision where objects become an integral part of the Internet. In this vision, where every object is uniquely identified, can access the network, its location and status can be traced, the internet expands as a result of the inclusion of physical objects. From 2012 onwards, the role of things as data producers and the network as the enabler of new services are emphasized (Ibarra-Esquer, et al., 2017). Miorandi et al. identify objects as providers and/or consumers of physical world data while describing the internet of things as a highly dynamic and radically distributed network of a large number of intelligent objects that produce and consume information (2012). According to the researchers, the focus of the IOT is now shifting from communication to data and contextual information. Gubbi et al. (2013) emphasizing that the definition of objects included in the system has changed with the technological progress and became more comprehensive to cover a wide range of applications, stated that the basic objective (collecting, processing, and sharing of data without human intervention) remains valid.

2.2Enabling Technologies of the Internet of Things

The enabling technologies of the IOT can be examined under the headings of identification, sensing and communication technologies (Atzori et al., 2010). ITU (2012) defined four different technological dimensions of the internet of objects: (1) object identification (tagging things), (2) sensors and wireless sensor networks (feeling things), (3) embedded systems (thinking things), (4) nanotechnology (shrinking things).

Identification technologies are used to provide an identity (ID) to each object in the network. Electronic Product Codes (EPC) and Ubiquitous Codes (uCode) are issued to

RFID tags as unique by the system's manufacturer (Koshizuka and Sakamura, 2010). RFID (Radio Frequency Identification) systems, which are used to identify objects individually and automatically using radio frequency, are the most important elements of identification technologies. An RFID system consists of four main components: a microchip antenna to provide communication, a tag reader, middleware that transfers data, and a transponder tag (Chaouchi, 2010). Near Field Communication (NFC), which is another widely used technology for object identification, uses the same standard as some short-range RFID tags, and an NFC-enabled device, for example, a smartphone can act as both RFID tag and RFID reader. However, devices with this technology can only exchange data with each other within a very short distance (about 4cm). One of the simplest methods of providing a digital identity to a physical object is the QR (Quick Response) codes. These are two-dimensional barcodes that can be read by any imaging device that can extract data encoded in the image, such as a smartphone (Rowland et al., 2015).As a result of the identification of objects with the mentioned technologies, the object is given a name (ID) however the address of the object in the network (IP) must also be defined. Addressing in the IOT system is performed by IPv4 and IPv6 protocols. IPv6 internet protocol has been released due to the rapid growth of the system and the number of IP addresses in the IPv4 protocol will be depleted in the near future (Goth, 2012). The IPv6 protocol using the 128-bit addressing method has an address number of 3.4x1038 (340 decillion) (Weber and Cheng, 2004).

Sensing technologies are one of the most important enabling technologies of IOT. Sensors and actuators operate in collaboration with identification technologies, are the important components of the sensing technologies that act as a bridge between the physical and digital world (Atzori et al., 2010). Wireless Sensor Networks (WSN), which is obtained by combining multiple wireless sensors, provides a high-capacity environment that can perform many tasks (Akbal, et al., 2012). This environment consists of small sensor nodes with very limited energy resources and calculation capabilities (Bandırmalı and Ertürk, 2009). Wireless Sensor Networks cooperate with RFID systems to monitor the status of objects and are actively involved in collecting, processing, analyzing and distributing data on objects (Atzori et al., 2010).

At its most basic, the implementation of the Internet of Things, which relies on objects communicating with each other, is the result of developments in communication technologies. As a result of the evolution of the internet, which was founded in 1969 by ARPANET project, the internet is a network system that connects billions of users around the world by using standard communication protocols (Bolt, et al., 1981). The internet, which started with connecting two computers, continued with the creation of the World

Wide Web by connecting many computers. As a result of the inclusion of mobile devices, mobile internet has emerged and then people have been added through social networks. In the fifth stage, everyday objects have been included on the internet and the internet has evolved to the internet of things (Perera et al., 2014). Many different communication protocols such as WIFI, cellular data (GSM, GPRS, 3G), Bluetooth, BLE (Bluetooth Low Energy), ZigBee, ZWave are used in Internet of Things applications (Rowland, et al., 2015).

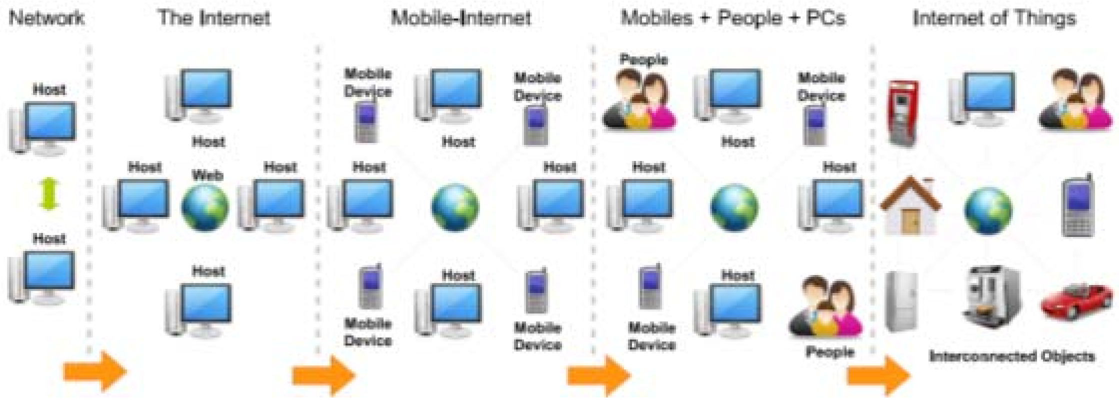


Figure 2.Evolution of the internet in five phases (Perera et al., 2014)

Information processing technologies include two components, hardware and software. Separate hardware components can be integrated into a single chip in embedded systems. Arduino, Raspberry PI, Intel Galileo, WiSense, Gadgeteer, BeagleBone and BeagleBone Black, Cubieboard, UDOO, Z1 and Mulle with processing units such as microcontrollers and microprocessors can be given as the examples of hardware components developed for IOT (Khalil and Özdemir, 2018). Software for embedded systems is designed to ensure efficient use of limited resources.A simple device can only have a program (firmware) that is small enough to keep the system running. More complex devices can have a built-in operating system and run multiple programs. Non-protected software can be upgraded (Rowland et al., 2015).The other method used for information processing in the IOT is cloud computing. Objects can send data to cloud platforms for real-time processing. There are such platforms such as IOT Cloud, Open IOT, NimBits, and Hadoop supporting IOT in the cloud(Al-Fuqaha, et al., 2015).

2.3 Application Areas of the Internet of Things

IOT has application areas in industry, smart home and building systems, energy sector, medical and health sector, transportation and environmental analysis (Kesayak, 2018). IOT technologies are used for real-time optimization, control of production, supply chain networks, logistic management, task planning, production line and monitoring of the condition of machines and detection of risky situations in the industry (Resch and

Blecker, 2012; Hipp, et al., 2012). In smart home and building systems, IOT technologies are used for intelligent lighting that is adapted to ambient conditions or is activated by web and mobile applications; surveillance, security and alarm systems; smoke and gas detection based security systems; home entertainment management such as video, audio, projector, etc. IOT technologies are used to improve the performance of existing security and surveillance solutions in public spaces such as shopping malls, factories, car parks (Miorandi, et al., 2012). In the medical and health sector, it is used in hospital follow-up systems (number of patients, follow-up of drugs, etc.), remote diagnosis and treatment applications, periodically monitoring the health conditions of the patient/elderly, emergency notification systems, real-time baby monitoring applications (Khalil and Özdemir, 2018). IOT, which deals with energy management systems, provides intelligent automation as well as intelligent grid monitoring and control. Applications in the field of transportation include intelligent traffic control, unmanned navigation, inter-vehicle communication, emergency rescue, safety, and road assistance (Kesayak, 2018).Communication between public and private transport vehicles can be used to draw alternative routes to avoid delays and congestion in busy city traffic. Intelligent parking systems that provide drivers with information on empty parking spaces at a given time can contribute to the solution of traffic congestion (Yongjun, et al., 2012). In environmental monitoring; IOT technologies are used in cloud-based air monitoring, noise and air pollution monitoring, precipitation status, dam occupancy, fire detection systems, earthquake and tsunami early warning system applications.While these technologies are used for the purpose of increasing agricultural production, monitoring of soil conditions, monitoring the environmental effects of chemicals used in agriculture, monitoring the status of plants in smart agricultural applications (Kesayak, 2018); in smart animal husbandry, they are used in tracking of parameters such as heat, harmful gas status of animal environments, herd management counting systems, milk efficiency tracking systems, determination of anger period, animal health tracking systems, newborn feeding systems (Gündüz and Akyüz, 2017).

3. IOT OBJECTS AND PRODUCTS

One of the most important components of the internet of things is objects. Researchers in the field have tried to define the properties of objects connected to the network in order to understand the concept of the internet of things. Objects with capabilities such as communication, collaboration, identification, addressing, sensing, actuating, and embedded computing have contributed to the development of the IOT paradigm, which started with the remote identification of objects has evolved into a system in which smart objects communicate with users, internet services and even each other (Ibarra-Esquer, et al., 2017).

In the literature, the objects included in this system are often described as “smart objects”. According to Kuniavsky (2010), the term smart object is used to highlight the difference between objects with embedded information processing and those that are not. Physical objects are classified as smart if they use information and communication technologies or can receive data from other devices and transmit data to other devices. Sterling (2005) describes these objects with the term “SPIME”. They are produced objects which have a very strong relationship with information and are considered as the materialized form of an intangible system. These objects are aware of the position in the world, aware of the changes in the environment, uniquely defined objects that can transfer, log data about itself and its environment. Sterling's approach to intelligent objects emphasizes communication and data exchange. Kopetz also suggests that smart objects that serve as a bridge between the physical world and the digital world are the basic building blocks of the IOT (2011). Smart objects is defined by Kopetz as augmented-everyday physical objects with components that process sensor data and support the wireless connection to the Internet to provide connectivity to the cyberspace established with the internet. These objects collect data, transfer information and content to each other, and operate in collaboration using cloud computing and similar technologies (Chen, 2012).

Ibarra-Esquer, et al. (2010) identified five different capabilities in addition to connectivity in their study aimed to demonstrate the technological capabilities of the IOT objects:

1-Identification capability (IC): Things that can be uniquely and unmistakably identified, either by an electronic tag, hard-coded serial number or printed label that is read by another object.
2-Localization capability (LC): Things that know their precise physical location in the world by their own means, e.g. using embedded geographical devices, and can communicate it to other things and services.
3-Sensing capability (SC): Things equipped with sensors to obtain data from their actual state or the environment. They may or not include temporary storage capabilities or make use of cloud-based storage services.
4-Actuation capability (AC): Things equipped with actuating devices that can be remotely controlled to modify the environment.
5- Processing capability (PC): Things that can process information obtained by themselves or received via the internet.

Figure 3 shows the Euler diagram related to the capabilities of the IOT objects. Accordingly, an object must have at least one of the first four properties to be part of the

IOT system. Any object with any capability in the gray areas of the diagram is considered part of the IOT (Ibarra-Esquer, et al., 2010).

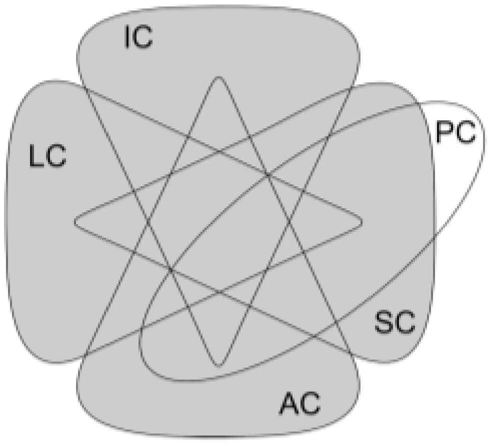


Figure 3.Capabilities of IOT objects(Ibarra-Esquer, et al., 2010)

The objects mentioned in the internet of things refer to a very large universe.IOT objects can be any machine, device, computer, or physical object that can connect to the Internet, generate, consume, transmit or access digital data (Elkhodr, et al., 2013). Rowland et al. (2015) classify this universe by taking into account user interaction, functionality and processing, and accordingly, IOT objects are examined in four classes: multipurpose computers, specialized embedded products, connected sensors, and passively trackable objects (Table 1.). Multi-purpose computers such as PCs, laptops, smartphones, tablets, smart TVs have powerful internal processors, which can run many different applications at the same time, and have built-in interaction capabilities with the user (via a screen, keyboard, mouse or directly touch, with voice or gesture control, etc.). These are important parts of the IOT product universe and it is possible to say that information and networking technologies have developed in the focus of these products.As a result of the spread of the developments in this field, it has become possible to talk about IOT products as a new product class. Due to their complex structures, interaction capabilities, and strong technological components, it is not possible to examine multi-purpose computer which is a field of research in itself, under the title of IOT products. Specialized embedded products are products that are specialized for different functions, typically interact with the physical world, collect data from sensors and produce physical actions. Since these products cover different specialized product definitions and enable IOT technology to be directly involved in the life of end users, they constitute the main object type of the IOT product universe. Connected sensors are small embedded devices used to collect data from the physical world and transfer it to a networked service.There are varieties that can identify a wide variety of data such as motion, light, air quality, contact, location, proximity, humidity, orientation, etc. Passive trackable objects are the kind of object like RFID tags, QR codes, Beacons, etc. that can show a simple presence on the internet. Connected sensors and passively trackable objects normally do not qualify as product and act as embedded components that are only integrated into intelligent systems. However, if they are approached as a product definition, they can be examined under IOT product title.

Table 1.IOT object types(Rowland, et al., 2015)

	MULTIPURPOSE COMPUTER	SPECIALIZED EMBEDDED DATA	CONNECTED SENSOR	PASSIVELY TRACKABLE OBJECT
USER INTERACTION	Rich onboard interaction capabilities (e.g., through screens and keyboards)	May have limited inputs/outputs; advanced interactions handled via web/mobile apps	Via web/mobile apps	Via web/mobile apps
FUNCTIONALITY	Generalized; can run wide range of applications	Specialized for specific functions	Single task	Identity only
PROCESSING	Powerful onboard processor	Onboard processor, with some functions provided by cloud service	Mostly in cloud service	In cloud service

3.1 IOT Products

IOT products constitute an important part of the IOT object universe in terms of their potential to transform everyday life. Within the scope of this study, IOT products are defined as consumer products which have integrated IOT technology (can be connected to the Internet, network-identifiable and addressable, with sensing-actuating and information processing technologies, and can be regarded as a certain level of smartness), have the ability to interact with the user, have specialized functionality, reach the end users.

These products have different properties than current technological products (Chang, et al., 2014). Within the scope of the study, the technology which makes IOT possible has been examined in order to determine the basic technological characteristics of IOT products.When considered in the context of consumer products, these technologies, which are included in the content of the products and the properties of the products resulting from these technologies, are located in different layers of perception for the users. For example, a product's identifiable and addressable nature is not a feature that can be directly perceived, interpreted, and experienced by the end user, however, if the product is identifiable and addressable, it may be present in the network.The connection ability of the product can be evaluated directly as a feature affecting the product, product-user interaction and therefore the user. When the technologies included in the content of the products are considered in terms of the effect to the product, the user-product interaction, and the end user; the properties of these technologies in the products can be grouped under three headings: connectivity, context awareness, and smartness (Figure 4.).

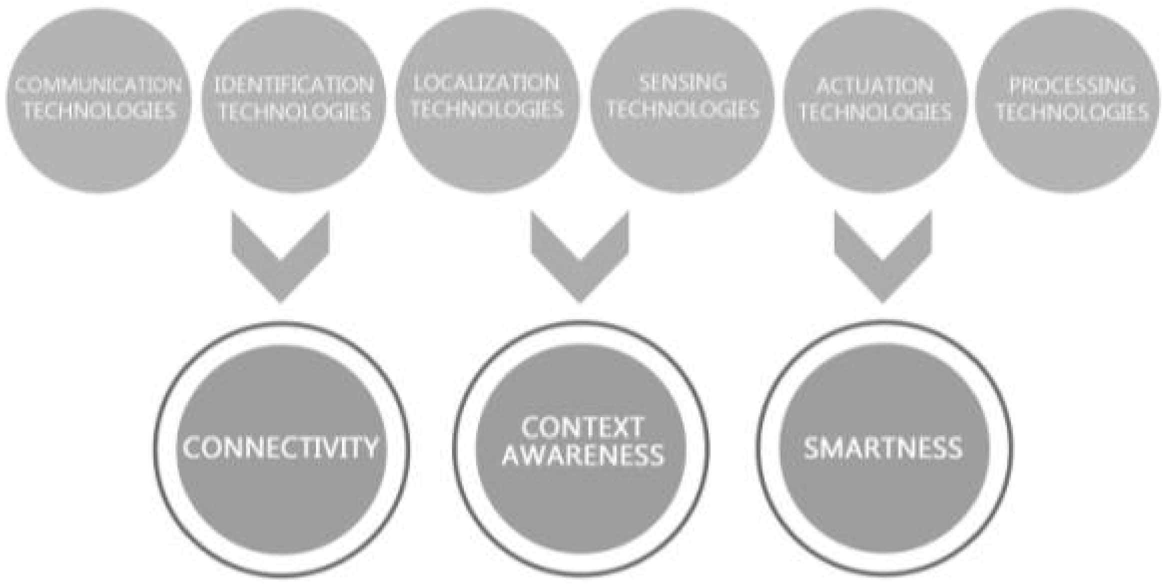


Figure 4.IOT technologies and technology-based key characteristics of products

In order for a product to be included in the IOT universe, it must first be connectable to the network.The reasons for connecting products to the network vary in relation to their use contexts and functionality. A product can be connected to the network for reasons such as monitoring and tracking the user-physical environment, accessing information over the internet, sharing its data with other products or systems, recording the data in the long term, communicating and working with products that are part of the product ecosystem, intervening remotely, assisting the user, sending a reminder and giving notification. It is possible to mention 3 types of connection range in IOT products (Rowland, et al., 2015): (1) long: 3G, WİFİ, cellular data-SIM card; (2) short: Bluetooth; (3) very short: RFID, NFC (Near Field Communication).

Another technology-based characteristic of IOT products is context awareness.In IOT system, the relationship of products with data is of central importance.The ability of products to capture, collect, process, share, and reflect data creates a new layer of information that encompasses the physical world we know of.Data transfer or sharing can be considered the most basic reason for the presence of objects in the network.If the data is not processed, it is non-functional. In order for the data to be meaningful, it must turn into information.In the IOT system, raw data that is collected by the object or shared by the system is processed and converted to meaningful context information for the user (Sanchez, et al., 2006). This makes the object aware of the context in which it is located.For example, in a smart home system, that the room is dark and silent and that the users' position is constant and horizontal are the data collected by sensors. However, the system detects the user's context as a result of analyzing the data simultaneously coming from many sensors and realizes that "the user is sleeping" (Schmidt and Van Laerhoven, 2001).The context can be defined as "any kind of information that can be used to characterize the state of an asset" (Abowd, et al., 1999).Two main approaches are usually followed to create context awareness (Loke, 2006).In the self-supported context awareness approach, designers embed the ability to perceive, reason, and act accordingly into the object with special hardware support.In the context of infrastructure supported context, designers develop contextual awareness by using a hardware software infrastructure outside the device.Although objects do not contain integrated sensors, they serve as service providers using this infrastructure.In infrastructure supported approaches, networked objects can share context awareness results with each other and with the system.Different objects that are part of the same system have the awareness of each other's and each other's operations and they can work together in coordination.

IOT products are also referred to "smart and connected products" in the literature and market. The phrase "smart product" has a vague use.Especially in the market, products that have a certain level of technological content but no conceptual reasoning skills are considered smart.Even for products that do not have any technological content but have a rational solution for design and engineering, the phrase "smart product" can be used as a marketing strategy.Within the scope of this study, smartness is dealt with in relation to the behavioral abilities of the products.In order for the products to be smart, it is first necessary to have context awareness (Mühlhäuser, 2007; Maass and Varshney, 2008). After that, they should develop autonomous behaviors according to the context knowledge they understand.Autonomy, which means that the product operates independently and in a targeted manner without user intervention (Rijsdijk, et al., 2007), is shown as the main characteristic of many smart object-product-system models in the literature (Mühlhäuser, 2007; Maass and Varshney, 2008; Rijsdijk, et al., 2007; Bradshaw, 1997; Jennings and Wooldridge, 1998; Rijsdijk and Hultink, 2003).If we go back to the example of the smart home system, the system that understands the user's context (the user is sleeping) as a result of analyzing the simultaneous data from many sensors, it can be considered as smart if it can perform the behaviors on its own, such as closing the open lights and locking the doors if the doors are not lock.

Loke (2006) discussed objects in terms of their behavioral abilities and concluded that there were three levels of context-aware behaviors.Accordingly, at the first level, there are only reactive objects that react with simple actions to the sensor data, the second level that creates a state model and only those objects that behave when they are aware of the appropriate situation, and at the third level there are objects that not only depend on the state models but plan and operate action on them.Similarly, Bradshaw (1997) and Jennings and Wooldridge (1998) describe three different levels of autonomous behavior: reactive, proactive, and adaptive.Reactive products are capable of reacting to a stimulus/change in their environment. These responses are similar to human reflexes and a specific response is generated in response to a particular input.Proactive products exhibit targeted behavior by anticipating the user's plans and intentions. In addition to the reactive behavior that may give specific responses to the context information, these products can make an assessment of the situation and make recommendations to the user who can choose the most appropriate solution among all possible actions anticipated.Adaptive products have the ability to learn from the environment and improve them over time and can make complex decisions. In these products, context information is used to update internal models of the product's user profile or environmental features. The product can then provide a better performance by adapting itself to changing conditions or producing responses according to user preferences.

In addition to the autonomous behavioral abilities of the products, their ability to have collaborative behavior is considered as a dimension of smartness in the context of product in the literature (Rijsdijk, et al., 2007; Bradshaw, 1997). These products, which are no longer a single product by means of internet and become part of a system, can cooperate and act together for a common purpose, thus enabling machine-machine interaction, which is one of the most important features of the IOT paradigm, to facilitate the life of the end user.

4. IOT PRODUCT REVIEW

The number of connected consumer products in the market is increasing day by day, and many firms from different sectors are developing IOT technology integration strategies for analog or digital products they are currently producing.In order to understand the basics of the new product paradigm as a result of the integration of IOT technology into everyday objects and to understand how this integration is reflected both in content and form in terms of products, IOT products in the market will be examined in this part of the study.

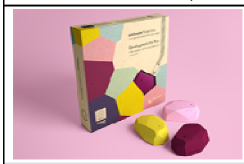
While determining the products to be examined within the scope of the study, a market research was conducted and a product pool was created to define the product universe.When creating the product pool, in addition to general internet browsing, support was received from some special websites which are product database such as "iotlist.co, iot.do/devices, postscapes.com, theconnectedplanet.net".Selection criteria were the fact that the products are not conceptual products and that they are functionally embedded products already reaching the end user. Products with similar functions introduced by different brands were included in the preliminary evaluation.

30 products with different functions and different usage contexts have been determined for product review considering their relationship with data, behavioral smartness, and user interactions. In Table 2, the products are examined within the framework of the technology-based key characteristics and information related to their functionality is provided. In terms of technology-based key characteristics, it has been questioned whether the products can be connected to the network; whether they have context awareness and, if so, whether the context information is accessed by internal sensors or by infrastructure support; whether the products are capable of exhibiting autonomous and cooperative behavior and at which level (reactive, proactive, adaptive). In the continuation of the study, the evaluations of the patterns emerging in Table 2 will be made and the effects of the technological features to the product design will be discussed under the headings of form, function, and interact.

Table2. IOT Product Review

IOT Products	Function	Technology-Based Key Characteristics						
			Context Awareness		Smartness			
					Autonomy			
		Connectivity	Embedded Sensors	Infrastructure Supported	Reactive	Proactive	Adaptive	Abiliyt to Cooperate
 Ambient Umbrella (URL1)	By connecting to the internet, it reflects the data about the weather to its user via its onboard indicator and aims to prevent to leave the house without taking the umbrella in the rainy weather.	✓	-	✓	✓	-	-	-
 Good Night Lamp (URL2)	It is basically a set of lighting elements. In this set of large main elements and small side elements, the small element can be supplied to a distant number of family members or friends. When the main element lights up or goes out, the other elements behave the same way, allowing the product to interact at an emotional level between two different users.	✓	-	✓	✓	-	-	-
 Egg Minder (URL3)	It is an egg tray that tells the user how many eggs are left at home when shopping, which egg is older or which one should not be used anymore. This product is synchronized with mobile devices via its mobile application.	✓	✓	-	✓	-	-	-
 Hydrate Spark 2.0 (URL4)	Following the daily water consumption of the user, the product gives feedback to the user via its built-in interface (shining) to remind the required amount of consumption. It synchronizes with your own mobile app and works with fitness trackers such as Fitbit, Apple Watch, Apple Health Kit, Google Fit, Under Armor Record and Nokia / Withings and integrates with mobile apps such as MyFitnessPal, MapMyFitness, Endomondo.	✓	✓	-	✓	-	-	-
 Quirky Porkfolio (URL5)	Piggy bank connected to the Wink App via WiFi, converts physical data into digital data and keeps track of coins accumulated in it.	✓	✓	-	✓	-	-	-
 Ulo Surveillance Camera (URL6)	Ulo, an interactive security camera, monitors the movements it has detected in the space with its user interacting with eye expressions. When it detects a movement in the alarm mode, it can send notifications to the user via the internet, can broadcast live on its website and take the photos at any time. Ulo services are accessible from the web and from iOS and Android applications.	✓	✓	-	✓	-	-	-
 Blue Smart (URL7)	Connected with the mobile application, Bluesmart has incremental features such as trip tracking, integrated digital weighing, and integrated battery thanks to digital locks, proximity-position sensors. Sends notification when forgotten anywhere. If the suitcase is lost, its position can be tracked.	✓	✓	✓	✓	-	-	-
 Linka Bike Lock (URL8)	The product that works with the mobile application, is locked when be touched. With location awareness, it automatically detects and approaches keyless access by recognizing the user's approach. It detects an undesirable movement and takes precautions by sending notifications to the user. If the smartphone has run out of power, the lock will open by entering the password defined by the application.	✓	✓	✓	✓	-	-	-

IOT Products	Function	Technology-Based Key Characteristics						
			Context Awareness		Smartness			
					Autonomy			
		Connectivity	Embedded Sensors	Infrastructure Supported	Reactive	Proactive	Adaptive	Abiliyt to Cooperate
 Aether Cone (URL9)	Aether Cone, a music player with an artificial intelligence infrastructure, learns what kind of music users like to listen to from their preferences and can make its own suggestions. It has speech recognition feature. A simple interface with 3 buttons and one dial makes it easy to use without interacting with any display. With Bluetooth and WiFi connection, it can connect to music stored on the phone, tablet or laptop, as well as to services like Spotify, Deezer and Apple Music.	✓	✓	✓	✓	✓	✓	-
 Nest Termostat (URL10)	"NEST Learning Thermostat" learns by following the user's preferences and behavior patterns and reduces energy consumption by making autonomous decisions for air conditioning. The product with both wifi and Bluetooth connection can connect to the internet, cloud, mobile devices, other products, and can work with other products (lights, locks, detectors, assistants, etc.). For example, the Nest Protect smoke detector warns the thermostat when it detects any problems and stops the operation.	✓	✓	✓	✓	✓	✓	✓
 Nest Protect (URL11)	NEST Protect warns by sending notifications in different ways at the time when it detects smoke or CO in the environment. Through its sensors, it can see which part of the space is in danger. In case of an imminent danger, it calls the fire department. The product with wifi and Bluetooth connectivity can work with other products. When it detects any danger, it stops the thermostat, the security camera automatically takes the video of the danger area, sends video to the user over the internet and stores it in the cloud.	✓	✓	✓	✓	-	-	✓
 Philips Hue (URL12)	The personal lighting system, which consists of smart light bulbs that can be controlled remotely via the Hue App, and internet modems exhibits context-sensitive autonomous behavior. When it realizes that the user is approaching the house with the help of location awareness, it illuminates the house. It illuminates the space in the colors and values appropriate to the atmosphere of the music played or the film being watched and helps the user wake up. It works with Amazon Alexa, Apple HomeKit and Google Home Assistant and can be controlled by voice.	✓	✓	✓	✓	✓	-	✓
 MAID Oven (URL13)	MAID Oven is a smart kitchen assistant and a multifunctional oven. The MAID is connected to a recipe store on the Internet and can be accessed from its integrated screen. It adjusts cooking time and temperature depending on the number of servings, personal preferences, and smart personalization variables. It has a personalization engine that learns continuously. It uses the basic information that users enter through the MAID App, follows the activities using the data in the phone and smartwatches, makes calorie calculations, offers suggestions for healthy eating, offers exercise. It can be controlled by touch, voice, gesture, and app.	✓	✓	✓	✓	✓	✓	-
 August Smart Lock Pro (URL14)	The product can be controlled by Wi-Fi, Bluetooth, Z-Wave connection. The location-aware product via Bluetooth detects the user approaching the door and opens the door automatically. Allowing the user opens the lock with the mobile app for guests remotely. It allows the doors to be checked and locked remotely. Works with Goole Home and other August products. It can be controlled via voice over Google.	✓	✓	✓	✓	-	-	✓
 SmartMat (URL15)	SmartMat is a smart yoga product that detects the user's exposure and gives real-time feedback on how to correct if not correct. At first use, the user has a range of movements to calibrate his body shape, size, and personal limitations. It detects data on the position of the hands and feet, balance and weight distribution, and offers suggestions for achieving perfect personal yoga poses. It provides real-time support and long-term process and development tracking via iOS and Android compatible application.	✓	✓	✓	✓	✓	-	-

IOT Products	Function	Technology-Based Key Characteristics						
			Context Awareness		Smartness			
					Autonomy			
		Connectivity	Embedded Sensors	Infrastructure Supported	Reactive	Proactive	Adaptive	Abiliyt to Cooperate
 Smiirl Counter (URL16)	Designed to increase the visibility of local businesses, the product reflects the likes on a real-time mechanical flip-board display by connecting to Facebook and Instagram pages, the product aims to attract customers' attention by physicalizing the digital data.	✓	-	✓	✓	-	-	-
 Owlet Care (URL17)	Developed for baby tracking, Owlet Care monitors the data on the heart rate and oxygen level of the infants via their sensors and transmits the collected-interpreted data to the parents via the mobile app. It is an example of a mobile app-connected wearable technology product in which connected sensors are turned into product definition.	✓	✓	-	✓	-	-	-
 Little Riot Pillow Talk (URL18)	"Little Riot, Pillow Talk" is a new product definition developed for remote partners. In the product set consisting of two wristbands and two mini-speakers, the wristbands transmit the heartbeats of the people to the mutual speakers and aim to connect the two users who are away from each other.	✓	✓	-	✓	-	-	-
 Estimote Beacon (URL19)	Beacon is a technology that provides location information using low energy Bluetooth (BLE) technology. Products with Beacon technology emit passive signals to interact with smartphones near them. Thanks to location awareness, beacon that can undertake different tasks in different scenarios has been made possible by product technology as a result of IOT technology.	✓	✓	✓	✓	-	-	-
 Toddler Monitor (URL20)	The product developed for child safety is hanged on the door of the children's room, if the door is opened, it detects the movement and sends a warning to the parent via the mobile application.	✓	✓	-	✓	-	-	-
 Iswimband (URL21)	Iswinband, which can be attached to the wrist and head, is a drowning detection product that warns the user via the mobile application when the non-swimmer enters the water or when the swimmer is in the water for too long.	✓	✓	-	✓	-	-	-
 Lapka(URL22)	Consisting of four units measuring radiation, electromagnetic fields, humidity and how organic the food is, Lapka's personal perimeter monitor, connects to smartphones and transfers all environmental factors to the user via Lapka application in an easy and fun way.	✓	✓	-	✓	-	-	-
 Tile Mate (URL23)	Tile Mate is an advanced Bluetooth tracker to prevent the loss of important items. When the item connected to the Tile Mate is lost, the product gives an audible warning or the location of the lost item can be tracked on the map.	✓	✓	-	✓	-	-	-
 Hiku (URL24)	The shopping button that can scan barcodes and recognize speech can add barcodes or voice items to a shareable shopping list. The shopping list is constantly updated via the Hiku mobile app. It can also be connected directly to online shopping services.	✓	✓	-	✓	-	-	-

IOT Products	Function	Technology-Based Key Characteristics						
			Context Awareness		Smartness			
					Autonomy			
		Connectivity	Embedded Sensors	Infrastructure Supported	Reactive	Proactive	Adaptive	Abiliyt to Cooperate
 Mother and the Motion Cookies (URL25)	In the set consisting of 1 mother and 4 cookie units, the mother unit is connected to the internet router via an ethernet cable. The account is taken over the website and the mother is saved. Mobile application is downloaded and cookies are introduced. One of the 10 available applications (walk, door, sleep, teeth, medicine, coffee, cartoon, secrets, status, temperature) is assigned to the cookies and cookies are placed in relevant places. Cookies function according to the needs of the user. For instance, the user can count the distance he walked, the number of steps, the number of calories burned, along with a cookie in his pocket and walking application or the user can find out if his child has come home along with a cookie attached in his/her bag and case application.	✓	✓	-	✓	-	-	-
 Kyon Pet Tracker (URL26)	KYON is a pet collar with embedded GPS technology. With the technology of KYON Sense, it detects the mood of the animal and reflects the owner with LED display. It has features such as temperature sensor, drowning water sensor, passivation technology preventing dog fights. If the pet moves away from the safe area defined by its owner, the 3D GPS tracking feature that identifies the 3-axis animal in the product is activated and gives immediate information. Works with the mobile application.	✓	✓	-	✓	-	-	-
 Moov Now (URL27)	Moov Now, developed for different sports such as running, swimming, cycling, cardio, boxing etc., is a personal wearable sports coach that monitors the user's movements in real time and in 3D and makes suggestions by speaking. Synchronizes with the smartphone and saves the data for the training with the connected mobile app.	✓	✓	-	✓	✓	-	-
 Elliq (URL28)	Launched as an active aging companion, ElliQ is an emotionally intelligent personal assistant specialized for the elderly. It was designed to encourage an active and engaged lifestyle by suggesting activities and making it simple to connect with loved ones. The product includes speech recognition, a rotatable head, removable tablet, and camera; that allows human-like interactions.	✓	✓	✓	✓	✓	-	-
 Samsung SleepSense (URL29)	The sleep monitoring product placed under the pillow monitors the heart rate, breath and movements of the user during sleep with an accuracy of 97 percent. The information he collects (total sleep time, percentage of REM sleep, etc.) is transmitted to a smartphone application based on seven factors. The application provides "expert advice" on how to improve sleep quality by changing nutrition, exercise and other factors. SleepSense also works in collaboration with Samsung's SmartThings IOT home automation system. When it detects that the user is asleep, he can turn off the lights or the TV and reduce the temperature.	✓	✓	✓	✓	✓	-	✓
 Amazon Echo (URL30)	Amazon Echo is a smart speaker supported by a cloud-based intelligent assistant, Alexa. It is controlled by speaking, answers the questions asked and performs the given commands. In addition to playing music, preparing to-do lists, setting alarms, streaming podcasts, listening to audio books, weather, traffic, sports, and news, etc., provides real-time information on the internet. The product that connects to the internet via WiFi continues to learn continuously by making automatic updates. Can control other IOT-based products at home by voice command.	✓	✓	✓	✓	✓	✓	✓

As a result of the review, it was seen that all 30 products are networked. Wi-Fi and Bluetooth are the most commonly used types of connection in the context of consumer products. Different connection types such as cable connection (URL: 25), SIM card (URL: 2), and BLE (Bluetooth Low Energy) (URL: 19) have also been encountered. In addition to being able to connect directly to the Internet, it was observed that the products can also be connected to mobile devices (URL: 3, 4, 5, 7, 8, 15, 17), other products, their product ecosystems (URL: 10, 11, 12, 14, 29, 30), their own modems in product ecosystems (URL: 10, 11, 12, 14, 29, 30) and their own products (URL: 2, 18).

All products constituting the sample have a certain level of awareness of the context in which they exist. Access to raw data used in the production of context information is usually carried out by means of embedded sensors. Three products (URL: 1, 2, 16) with only infrastructure-supported context awareness were encountered. It was observed that the products (URL: 7-15, 19, 28-30) that use both embedded sensors and infrastructure relate to data in more complex contexts. There is no product which is not associated with data. The contexts associated with a wide variety of data types from location data (proximity, presence, position, orientation) to motion data (motion, speed, acceleration, inertia) from environmental data (temperature, humidity, light, radiation, gas, electromagnetic field, air) to biological data (heartbeat, respiration, oxygen) level, temperature) have been identified. It was observed that the products have different roles related to data, including data producer, consumer, visualizer, processor, and archive. The reason for the existence of certain products (URL: 16) and the reason for many products to be connected to the network is related to the data. Products connect to the network to access data, process data, and transfer data to mobile applications, web services, and other products.

The products were evaluated in terms of whether they have autonomous and cooperative behavior abilities under the title of smartness. It was observed that all of the products, most of which were at the reactive level, had the ability to exhibit autonomous behavior, but only 6 of the 30 products (URL: 10, 11, 12, 14, 29, 30) were found to have the ability to cooperate. Within the scope of the study, the work of a product synchronized with smart mobile devices through mobile application was not considered as a collaborative behavior. Only cases where the product cooperates with another product together were examined under this heading. Autonomy, which can be explained as self-determination and operation of the product according to changing conditions without any user intervention, had been handled by taking into account 3 levels: reactive, proactive, adaptive. It was observed that 21 of 30 products remained at the reactive level of autonomy. The reactive products exhibit a particular behavioral pattern encoded in response to a particular stimulus. The fact that an umbrella (URL: 1) reflects the context information related to weather received from the internet; that a security cam (URL:6) sends a notification to the user when detects a motion in the alarm mode; and that a suitcase (URL:7),that is aware of the location information of the user, sends a notification when the user moves away from it, can be given as the examples of autonomous behaviors exhibited at reactive level.

It was observed that 9 of 30 products were at the proactive level of autonomy.These products are products that can evaluate the current situation, select the most suitable solution among possible actions and make recommendations to the user.The fact that an IOT oven (URL:13), which monitors the calorie and exercise of the user over other devices during the day, recommends low calories for dinner; that a yoga mat (URL:15) that senses the user's poses, provides real-time recommendations on the position of the hands and feet, the distribution of balance and weight, to achieve the most accurate exercise; that a personal assistant (URL:28) that specializes for elderly recommends activities to assess leisure time at home can be given as the examples of autonomous behaviors exhibited at proactive level. Only 4 products (URL: 9, 10, 13, 30) with adaptive autonomous behavior were found in the sample.All of these products have a certain level of artificial intelligence infrastructure and have the ability to learn from their users' preferences and environment over time, adapt to changing conditions.For example, Nest Thermostat (URL: 10), by following the user's preferences and behavior patterns, learns users' preferred air conditioning and acts accordingly.

When the products are evaluated in terms of their functionality, it is possible to talk about two types of IOT products.The first is IOT products that are the result of the integration of these technologies into existing product definitions (oven, thermostat, speakers, lighting, security camera, etc.) (URL:1-15). In addition to their main function, these products gain the incremental functions by IOT technologies. If they are not connected to the network, they can continue to perform their main functions. The second type is new product definitions that gain functionality by means of IOT technologies (URL:16-30). These products cannot perform their functions if they do not have IOT technologies. It is possible to qualify these products as data-driven products. These products make sense of data that cannot be captured and processed without technological infrastructure. As a result, it is possible to say that every IOT product which is not a replica has an inherent incremental innovation.

The form-related evaluation of the products focuses on whether the products have familiar shapes, and whether they have affordance in terms of function and technology.Accordingly, in the first type of products where IOT technologies are integrated into existing product definitions, familiar formal qualities were generally encountered. It can be said that these products have shape affordance but do not have technology affordance. In other words, these products cannot transfer their technological characteristics (i.e. connectivity, context awareness, and smartness) directly to the user. In the second type of products, it was observed that there are unusual forms that are weak in terms of expressing the function of the product and giving clues about the way of use of the product. (Figure 5.).

Figure 5. Examples of Weak Affordances [77, 79, 80, 84]

IOT technologies have a direct impact on the interactions between user and product, leading to the emergence of new interaction patterns. As a result of the review, 5 different interaction patterns were found in addition to the physical interaction established directly between the product and the user (Figure 6.).In the User-Product-Internet pattern, there is no differentiation in the physical interaction that the user establishes with the product, but the product connects to the internet to access information that it cannot normally have.In the User-Product-Product-User pattern, the interconnection of products enables different users of these products to connect to each other.Usually communication-related products have this interaction pattern.User-Product-App is the most common form of interaction. The way mobile applications are involved in interaction varies. Data visualization can be done through the mobile application; the product can be controlled remotely, reminder/notification can be sent to the user; the archive of the related data can be kept.In the User-App-Product-User pattern, there are two different users and one user is in direct contact with the product and the other is informed via the mobile application.The final pattern, the User-Product-Product pattern, was usually found in smart home systems and product ecosystems.The user only interacts directly with a product. The product communicates with other products to which it is connected, gives commands, shares information and intervenes autonomously.As a result of the integration of IOT technologies into products, in addition to the different interaction patterns, different forms of interaction were observed. Products that mimic human gestures and mimics, has speech recognition and speaking ability, can be controlled by gesture/voice were encountered.

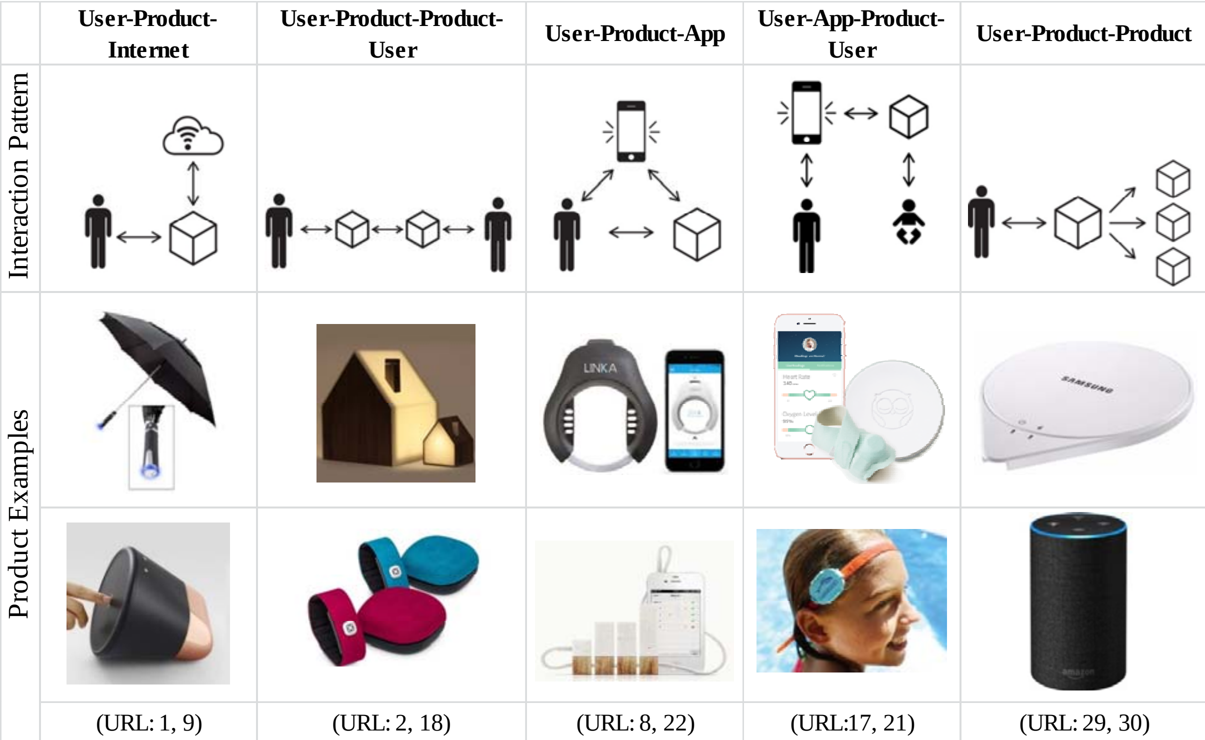


Figure 6. User-product interaction patterns

5. CONCLUSION

Today, when the industrial society has evolved into the information society, developments in communication, microelectronics and computer technologies affects product design discipline in many ways.That technological components have become smaller, cheaper and wide spread, make it easier and feasible to integrate technologies into everyday products. As a result of the integration of IOT technologies into products, products have been undergoing major transformations in terms of form, function and interaction. The internet of things, described as one of the destructive technologies that have the potential to transform everyday life, defines new possibilities and contributes to new product ideas and allows for incremental innovations in existing products.These products, which exist between the digital and physical world due to their software and hardware content, allow us to capture, collect and process the kind of data we did not have before.

This study aimed to investigate the subject of the Internet of Things, which is mostly addressed by engineering and computer sciences in the literature, from a product design focused perspective. Within the scope of this study, first information about the emergence and the history of the concept was given, the origins of the concept were tried to be traced and the different terminologies used to express the similar phenomenon were discussed.It was determined that there is no consensus on the definition of concept in the literature due to its comprehensive and multifaceted nature. The evolution of the definitions since the emergence of the concept was examined.The enabling technologies of IOT and the application areas of the internet of things in different sectors were investigated. Properties and types of objects which are one of the most important components of IOT system tries to identify and the location of IOT products in the IOT object universe was tried to be determined.

IOT products were defined as consumer products which have integrated IOT technology, have the ability to interact with the user, have specialized functionality, and reach the end users. The main technology-based features, which distinguish IOT products from existing technological products, were determined as connectivity, context awareness, and smartness.In the product review which was carried out about 30 commercial consumer products, the products first were examined under these headings and the different patterns were interpreted considering the functionality of the products.The reflections of the technology-based basic characteristics of the products on the design were discussed under the headings of function, form, and interaction.Accordingly, in terms of functionality, there are two types of IOT products, namely the existing product definitions and the new product definitions.IOT technologies lead to the emergence of a new visual product language in products of the second type in particular.It is possible to say that in many of these products with different and unconventional forms, the function-form integrity cannot be established and the products do not have shape affordance but a new product aesthetics has emerged using simple and courageous forms.As a result of the evaluation, it has been seen that IOT technologies cause new interaction patterns and new forms of interaction which directly affect the interactions between user and product.Finally, it is possible to conclude that the focus of the user experience on IOT products shifted towards services. The services configured around the IOT products, which have many mobile applications, have become almost as important as the product while offering the intended user experience.

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