Utilizing from physical computing to support smart product design

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Research introduction

By analyzing the engineering aspects of smart products as one of the technological developments in the field of industrial design and interaction design, we find that there are many developments in the functional aspects of these products that make them more interactive with the user and with other products in their smart environment, which necessarily leads to many aspects of technological knowledge that a designer must be familiar with them, and physical computing is one of those topics that may contribute to supporting the knowledge side of the industrial designer and assist him in integrating these new technologies within the innovative fabric of his design outputs.

Physical computing refers to those interactive systems that enable computers to sense their physical environment and respond to it. Therefore, it is the most comprehensive platform for experiment-based learning for those technological developments and utilizing them in the design and development of smart products in the future.

The research problem is that there is no general framework for benefiting from physical computing in teaching and practicing design in light of technological developments related to smart products.

The importance of the research is represented in:

•Supporting the knowledge side of students and practitioners of industrial design and interaction design.

•Supporting industrial enterprises and providing them with designers with higher technological knowledge.

•Supporting the competitiveness between products because of their new features that support their functional and usage aspects.

•Contribute to making consumers' lives easier by providing a new generation of smart products.

The research assumes that if it is possible to identify what smart products are, to realize the most important functional characteristics and technological aspects of them, and to understand what physical computing and its general features are, then it is possible to develop a general framework to take advantage of physical computing in teaching and practicing industrial design in light of technological developments for the design of smart products.

Smart Products

Smart products are one of the outputs of digital design, which improves the functional aspects of the products in general in terms of performance and interaction with the user, as they provide him with a unique response in terms of action. These products have many

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characteristics that keep them at the top with the largest share of development and improvement efforts, and perhaps the most prominent feature in the characteristics of these products in terms of design are their dependence on participatory design mainly, the characteristics of intelligence and interaction of these products must be woven into the design and development processes, which requires the provision of common areas of interaction between the various disciplines participating in the design and development processes in order to facilitate understanding and cooperation between those disciplines. Physical computing is one of the means that enables the designer to create a common space of understanding with other technical disciplines, and in this part the research sheds light on smart products as one of the topics that stimulate the development of the knowledge aspects of product designers. Definitions vary about what a smart product is, as a result of the multiplicity of disciplines and perspectives associated with the applications of smart products, but in general there is no definitively agreed definition about what a smart product is. Also, the concept of a smart product is related to many other concepts such as the concept of smart environments. In the smart context, and by reviewing the literature related to the definition and characteristics of smart products, we conclude that:

Mühlhäuser and others argue that the definition of a smart product must be done in its context, meaning that the definition of smart environments must first be defined before the definition of a smart product. The definition of Cook and others states that “the smart environment is a small world where all kinds of smart devices work continuously to make the life of the population more comfortable, “and the authors redefined the term as follows:“ A smart environment is an environment that is capable of acquiring and applying knowledge about its environment and adapting to its inhabitants in order to improve their experience in that environment. ”In light of the definition of smart environments, Mühlhäuser defines the smart product as follows: `` A smart product is an entity (a tangible object, program or a service) designed and manufactured that includes a mechanism of self-regulation and integration in various smart environments during its life cycle, which provides improvement in the simplicity and openness of the product through the product's interaction with the user **p2u** and the product's interaction with other products **p2p** by a product's awareness of the surrounding context, its semantic self-description, proactive action, its natural interfaces for multimedia and AI planning and machine learning. " From this definition, we find two types of active knowledge that are related to two types of interaction, namely:

• Product interaction with the user p2u where the product "talks, directs, suggests, and understands"

• The interaction of the product with other products p2p, through which "self-regulation is achieved"

Therefore, it is useful to distinguish between three categories of smart product knowledge, namely:

• Knowing the product, its features and functions, how to use it, and the date on which the product was used ... etc.

• Product knowledge about its potential and actual environments, in particular the perceived potential for adaptation and cooperation with these environments and their components.

• Knowledge of the product about its users, based on detailed user models that take into account the dynamics of changing user knowledge (learning / forgetting) and distinguishing the difference reflected from the categories of users in the life cycle in addition to the difference in the characteristics of an individual user.

Maass and S. Janzen have identified three basic requirements for smart products:

- (R1) Adaptation to situational contexts.
- (R2) Adaptation of actors interacting with products or packaging.
- (R3) Adjustment to basic business limitations.

Mühlhäuser refined these requirements with the following operational requirements:

- Location: learning about situational and societal contexts (R1).
- Personalization: tailoring products according to the needs of the buyer and the consumer (R2).
- Adaptability: Change product behavior according to buyer and consumer (R2).
- Responses and tasks. Proactive action: anticipates the user's plans and intentions (R2).
- Commercial Awareness: Consider Commercial and Legal Restrictions (R3).
- Network capability: the ability to communicate and interconnect with other products (R3).

The Smart Products Consortium has improved the definition presented by Mühlhäuser, while introducing the following definition: “A smart product is an independent organism designed for integration and self-regulation in different environments during its life cycle, which allows it to have a natural interaction between the product and the human. Pro-active is being able to proactively approach the user using the sensing, input and output capabilities of the environment, thus it is subjective, situational, context-aware, and can share and distribute related knowledge and functions among many smart products that emerge over time. " Sabou and others compared the different features suggested by Janzen and Mas, Mühlhäuser and the Smart Products Consortium, it was found that a smart product should feature awareness of the surrounding context, pro-activism, and self-regulation, and Gutierrez added to those characteristics life cycle support and ability.

Zaeh et al. Also found that the trait of intelligence can be conferred on products and systems that have the following characteristics:

- "Continuous observing of their condition and environment."
- "Interacting and adapting to environment and operating conditions."
- "Maintaining optimum performance in changing circumstances, and in exceptional cases."
- "Communicate actively with the user, the environment, or other products and systems.

"Smart products are real-world objects, devices, or software services that bring together knowledge about themselves and others and include them together. Mühlhäuser has separated this knowledge in three layers according to the level of abstraction it deals with in order to integrate the different vendors who offer their own technology, hence, such a scenario is extremely important, especially at the hardware level where changes to the embedded systems must be kept to a minimum to keep their cost viable. Adopting this approach also allows for increased hardware functionality and user adaptation capabilities to meet the minimum requirements for the embedded infrastructure. Smart product accessories may include external hardware or software. Or both, and the knowledge layers for the smart product are as follows:

- The first layer is the Smart Product Device layer and it is found in the embedded systems. This is where the operating time driver or firmware resides. The processing power available at this level powers the actuators, sensors, I / O and User Interface (usually LCD screens, LEDs, and buttons), the knowledge embedded in this layer defines a set of events and valid states and a set of event state procedures (ECA) also includes rules governing transitions between different states, and these rules define device functions, and implement intelligent behavior current, and ensure the required operating conditions to maintain the devices' integrity and safe operation.

• The second layer is the Smart Product layer, and it consists of four main parts, which are the control unit, the physical body of the device, and the elements of integration or embedding with the context and the user model.

• The third layer includes other extended services that enable the user to increase the functionality of the smart product, for example, by subscribing to the smart product manufacturer or any third party service provider. From the foregoing, it is clear that the knowledge of the smart product is linked to three layers, where the first layer is considered only integrated within the structure of the device and it guarantees a minimum of functionality and usability of the device, while the second and third layers are related to the infrastructure of the usage context of the product and they are working to push the functional limits of the smart product.

Physical Computing

Physical computing is a specialty developed from interactive design where artists and designers take advantage of technology to create art pieces and spatial processing works that can interact with the audience, they work to connect the virtual and real world, and help create new intuitive interfaces between interactive objects and humans, during the past decade physical computing is becoming increasingly popular among Makers and Hobbyists, driven by the fact that more and more devices and inexpensive and easy-to-use programming environments are becoming available to all. Physical computing is characterized by prototyping using technological media, especially electronics, as it promises to develop and improve existing software and hardware in an experimental manner driven by curiosity, imagination and creativity. Part of the nature of physical computing processes is that they are driven by ideas. Physical computing includes the creative arts and design processes and combines physical components and software.

Resulting systems from physical computing include: Transducers from sensors such as sound, light or temperature sensors and actuators such as LEDs, machines, or amplifiers - to achieve continuous interaction with its external environment, as for the prototyping tools used in physical computing, it includes microcontrollers and small computers.

The resulting interactive objects and physical media are programmed, which can be part of networks of interactive structures. Physical computing projects are of a repetitive nature and quickly produce prototypes that can work and interact with the audience of users. Physical computing is the process of creating a conversation between the physical world and the virtual world of computer; it is the process of converting one form of energy into another form, and the task of the designer with it. Finding the transducers and learn how to use them in converting between the physical energy suitable for the project and the electrical energy using computer.

Devising a general framework for utilizing physical computing to support the design of smart products

Before discussing how to benefit from physical computing to support smart product design, the overlapping area between smart product design and physical computing must first be defined, and to achieve this, what we might call layers or levels of smart product design must be explored and then determine the level that allows the benefit from knowledge and the skills acquired through physical computing in building smart products, and follow researches that are discussing those levels.

Levels of smart product design

The complex nature of the functions of smart products is what dictates the multiplicity of the design layers of those products, so the functions of the smart product from the point of view of interaction can be classified into functions related to the interaction of the product with the user P2U, and functions related to the interaction of the product with the product P2P, which Mühlhäuser referred to, which includes product interaction with the product, there are two types of interaction, which are the interaction of the smart product with another product within the smart environment, and the interaction of the product with the service provider or manufacturer. Mühlhäuser has indicated that it is not essential or binding in many cases, and to differentiate between these two types of interaction between products, the research suggests assigning a label of this last one by calling it the interaction of the product with the service provider P2S, and by taking the complex nature of the functional aspects of the smart product, and in light of the multiplicity of interaction and information exchange aspects, it is possible to divide the design levels of the smart product into three levels as follows:

- The first level: It is the design of the smart product device, which includes direct interaction with the user, and this level works to achieve the main function of the product with the user's intervention in the control and operation settings, and this level is related to the three types of interaction mentioned above, where the product interacts with the user directly, it also interacts with other products in the smart environment, in addition to the possibility of interacting with the service provider directly.
- The second level: It is the design of the smart product environment, or the design of the smart environment that provides interaction between the smart products in it, and works to improve their responses and reduce user intervention due to perception and understanding of behavior and its use pattern and re-configuring the smart products in it to fit this usage pattern in the best way.

A possible picture, which requires a kind of artificial intelligence to understand patterns, learn user behavior, and improve the functional aspects of different products. This level is related to two types of interaction, which are the interaction of the product with the product P2P and the interaction of the product with the service provider P2S. The third level: It is the design of the smart product service, and this level includes all the services related to the smart product that the factory or service providers can provide, and it includes maintenance services, product update, supply of operating materials and tools, remote operation and monitoring, and this level aims to transfer the burdens of operation and maintenance and updating the smart product from the user to the service providers, which generally helps in improving the usability and functional aspects of smart products, and it is noted here that this level is not mandatory when designing the smart product and can only be taken into account to achieve it at a later level, and in general, this level is related to type one of the interactions which is the product's interaction with the P2S service provider. To summarize the general picture of the levels of smart product design, one can rely on the illustration in figure (1). It is noted from this drawing that the types of interaction of the smart product reflect the flow of information between its design levels. Table (1) shows the relationship between levels of smart product design and functions of each level, the types of interaction and information flow, the elements needed to achieve this flow, and the areas of computing associated with those levels.

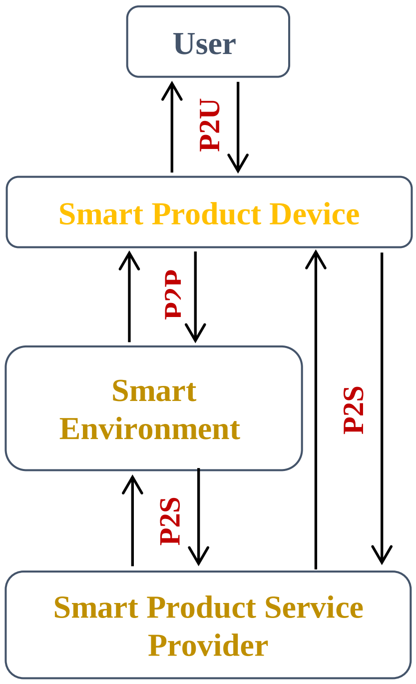

Figure (1) Levels of smart product design and associated interactions.

Table (1) levels of smart product design and associated factors

The design level	Functions	Types of interaction	Information flow	Physical requirements	Computing fields
Smart product device SPD	Provide an interactive user interface that realizes the main function of the product.	Product interaction with a user P2U.	From user to product	Control and operation unit - input modules such as sensors, operating switches and keyboards.	Physical computing
			From the product to the user	Controller and display unit - output units such as display	

				media and actuators.	
		Product interaction with the product P2P	Interchangeable with other products in a smart environment	Control unit and operation - communication media such as Bluetooth,	Physical computing
		Product interaction with a service provider P2S	Interchangeable with the service provider	Control unit and operation - communication media such as Ethernet or WIFI	Physical computing -The Internet of things
Smart product environment SE	Analyze information about user behavior and improve functional responses of products	Product interaction with the P2P product	exchange Information with smart products within the smart environment	Servers for handling data - communication media such as Ethernet or WIFI, cloud computing	Servers for handling data - communication media such as Ethernet or WIFI, cloud computing.
		Product interaction with a P2S service provider	Interchangeable with the service provider		
Smart product service SPS	Improve the functional aspects of the product by transferring the burden of operating, maintaining and updating the smart product from the user to the service providers	Product interaction with a P2S service provider	Information exchange between the smart product and the service provider	Servers for handling data	Communication media such as Ethernet or WIFI, cloud computing.
			Information exchange between the smart environment and the service provider		

From the analysis in the previous table, it shows that the greater participation of physical computing as a field of knowledge in the design and development of smart products lies at the first level of designing those products, which is the design of a smart product device, and below; the research discusses how to benefit from physical computing in support of smart product design.

Utilizing physical computing to support the design of smart products
The previous analysis of the levels of smart product design and the factors associated with it reflects the area of overlap between smart product design as an applied field and physical computing as a knowledge field, which contributes to forming a nucleus for utilizing physical computing to support the education and practice of smart product design, and this support has two aspects:
The first aspect is to support design education for smart products by taking advantage of physical computing. Physical computing in general includes many technological concepts related to electronics, software, communications, computing, interactivity and other technical concepts in an applied form, which allows the learner to acquire knowledge of these fields in a constructive method. Research Adopts a methodology to teach physical computing to design students in order to support the technical side of smart product designers.
The second aspect is supporting activities related to designing interactive interfaces for smart products. Physical computing provides the designer with the tools and knowledge necessary to build the interactive interface for the smart product device. By adopting design thinking as a general design methodology, which includes building models as one of the main design activities, it is possible to benefit from knowledge and skills of physical computing in building prototypes of interactive interfaces for smart product devices.

Results
• It is possible to divide the design levels of the smart product into three levels as follows: the design of the smart product device, which includes direct interaction with the user, the design of the smart product environment, which provides the interaction between the smart products in it, the design of the smart product service, that includes all services related to the smart product.
• The design levels of smart products are related to many other factors which include: functions, interaction types, information flows, physical requirements, and areas of computing.
• There are many areas of computing associated with designing smart products which include: physical computing, Internet of things, ubiquitous computing, cloud computing, machine learning, artificial intelligence and deep learning.
• Physical computing supports the first level of smart product design, as it mainly contributes to building the interactive interfaces of the smart product device.
• Proving the imposition of the research where it was possible to define a general framework for utilizing physical computing in support of smart product design, as the research found the possibility of utilizing physical computing in designing the interactive interface of the smart product device, which means supporting physical computing to teach and design practices related to smart products.
• It is possible to benefit from physical computing in support of design education for smart products. Physical computing includes many technical subjects that are taught in an applied

form, which allows constructive learning and the acquisition of knowledge in an experimental way.

- It is possible to take advantage of physical computing to build prototypes of interactive interfaces for smart product devices.

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