Serdica J. Computing **12** (2018), No 1–2, 65–82

**Serdica**
Journal of Computing

Bulgarian Academy of Sciences
Institute of Mathematics and Informatics

# USER EXPERIENCE DESIGN MODELS FOR INTERNET OF THINGS

Eugenia Kovatcheva

*UX is still a crossover of design, engineering, and customer service at its core.*

*No product is an island. A product is more than the product. It is a cohesive, integrated set of experiences*

*Donald Norman, "The design of Everyday" Former User Experience Architect, Apple*

Abstract. This paper is a review of user experience (UX) design models for IoT. The designing of a great connected product requires a holistic approach to user experience. Wide range of design layers are spanned, not all of them immediately visible. It requires cross-discipline collaboration between design, technology, and business. The designer's ability to meet those users' needs depends on the models describing the IoT ecosystems, technology enablers and business models.

*ACM Computing Classification System* (1998): D.2.10, H.5.2, I.5.2.
*Key words*: UX design, Internet of Things, UX design models.

**1. Introduction.** The dawn of user experience (UX) is in the fifties of the last century (the term was coined in 1990s by Don Norman and his group at Apple Computer). The UX profession has grown substantially. The main goal is to improve the lives of people by using the latest technology. It was the vision for Disney world. Walt Disney's guided principles were "know your audience, wear your guest's shoes, communicate with color, shape, form and texture...". He and his team were the first UX designers. Half a century later these principles are still alive, new technologies become more and more complex, which reflects in their applications [1].

As Donald Norman said: "I invented the term because I thought Human Interface and usability were too narrow: I wanted to cover all aspects of the person's experience with a system, including industrial design, graphics, the interface, the physical interaction, and the manual."

The design for connected products usually tends to focus on the most visible and tangible elements, but they are only part of the picture. Beautiful interface could be created, and users could still have a poor experience of the product as a whole. Designing for the IoT is inherently more complex than web service design. It has to do with the current state of the technology.

It reflects the immature understanding of compelling consumer IoT value propositions. Some of this stems from the fact that there are more aspects of design to consider. Tackling them independently creates an incoherent user experience [2]. This is a critical challenge for UX designers to go into the success of an IoT device synchronization.

**2. UX principles and models.** Today, UX Design usually refers to a person's experience with a digital product or service. It is the process of enhancing user satisfaction by improving the usability, ease of use, and pleasure provided in the interaction between the user and the product.

UX is a holistic term referring to a wide range of design disciplines involved in creating systems that are useful, usable, and pleasurable to use. The multidisciplinary field involves some major common practices such as industrial design, interaction design, information design, visual design, web design, service design, etc. Areas that UX design covers are illustrated by Debbie Seo (Fig. 1, 2016) based on Dan Saffer's book "The disciplines of user experience" (2009) [2].

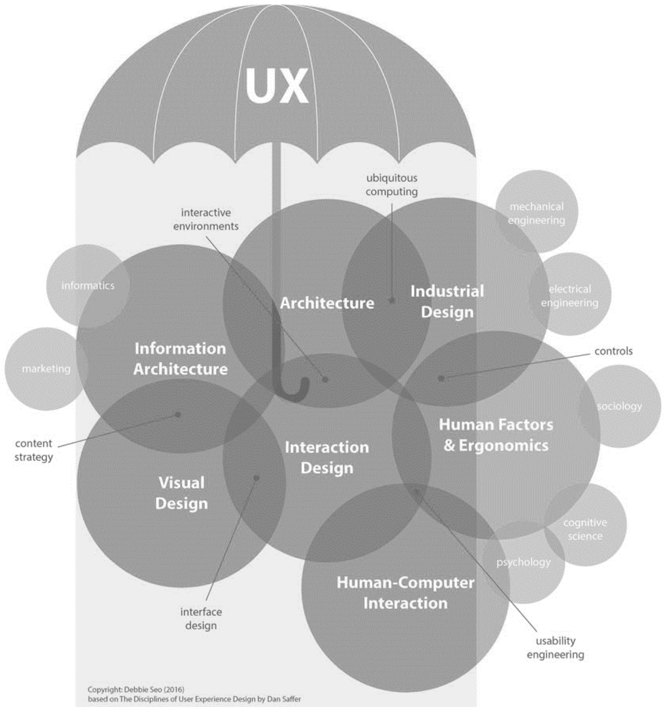


Fig. 1. UX design source [3]

The UX as an umbrella gathers Interaction Design, Industrial Design, Visual Design and other to focus upon how people interact with technology, to enhance their understanding of what can be done, and to ensure an enjoyable experience based on the principles of psychology, art, and design. The UX design is a human-centred design. It is a philosophy [3] which starts with empathy towards users, their needs that the design is intended to meet. As the ancient Greek philosopher Plato notes in his dialogue *Republic*, *A need or problem encourages creative efforts to meet the need or solve the problem*. He called *Necessity the mother of invention*. This is still the case today. Good design starts with an understanding of psychology and technology. First of all it requires good communication on both sides—people–machines. People–machines communication starts with an identification of the needs. The understanding comes about primarily through observation. Often potential users are unaware of what their true needs are and how to improve their life. Identification of the users' needs seems to be one of the most difficult parts of the design. At the end of the design process with implementation of the services is the very important communication from machine to person, indicating what actions are possible, what is happening, and what is about to happen. What is significant for the good UX design does not follow the design thinking process linearly. There are possibilities to turn back (Fig. 2.) and tune each step.

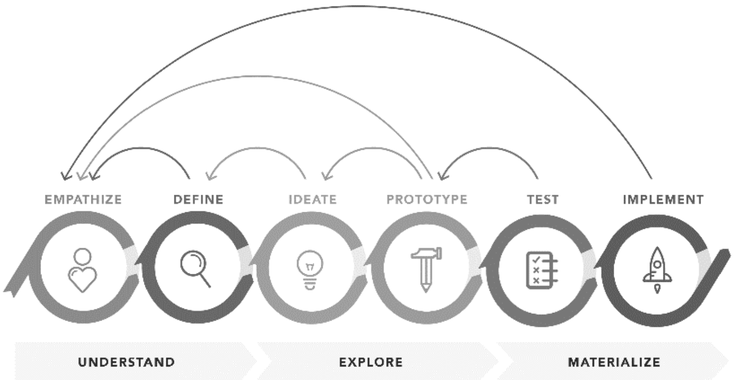


Fig. 2. Design thinking Source NNGroup.com

**2.1. Principles of interaction.** Nowadays the users' needs are more oriented to the responsive things. The designers have to focus their attention on the arising issues and to take proper actions towards having a smooth collaboration of the interacting person and devices. Don Norman lists several significant principles of interaction [4]:

- **Affordance or Visibility**—clear for the user—know how, know what to expect from the services/product and how to access them/it. It refers to the relationship between a physical object and any interacting agent (human, animal, machine and robot). The presence of an affordance is jointly determined by the qualities of the object and the abilities of the interacting agent.
- **Signifiers or Feedback**—indication of the user's action—communication device to the recipient—refers to any mark or sound, any perceivable indicator that communicates appropriate behavior to a person. The signifiers are planned. For success the feedback must be

immediate and planned. The signifiers have to be **consistent**—the same reaction corresponds to the same action every time.

- **Mapping**—the relationship between control and effect. This is a technical term (from mathematics—relationship between the elements of two sets of things). Mapping in terms of design is the relationship between the format of the representation and the actual things—a concept in design and layout of controls and representation. If the mapping is natural, analogous to the real perception and spatial environment, this leads to the **perceptual principle**.
- **Naturalness principle**—experiential cognition is aided when the properties of the representation match the properties of the thing being represented.
- **Constraints**—limits to an interface or an interaction—they are physical.

**2.2. Models.** As Jakob Nielsen says [5]: "What users believe they know about a User Interface strongly impacts how they use it. Mismatched mental models are common, especially with designs that try something new."

The definition of the **mental model** is the user's beliefs about the system at hand. It is an important concept in the human computer interaction design. Significant here is that the model is based on beliefs, not on facts, and usually a gap appears between designers' and users' mental models. Everyone has their own mental model, it is specific for each user's brain. Different cultures often form different mental models.

The individual mental model might be changed based on stimuli from elsewhere. People form mental models through observation [6], immersive experience, and culture. Having formed a mental model, the user often rejects an experience that does not match that model.

**Conceptual models**—a simplified explanation of how things work [7]. John Mylopoulos defines Conceptual modelling as the activity of formally describing some aspects of the physical and social world around us for the purposes of understanding and communication [8]. They are valuable in providing understanding, in predicting how things will behave. Conceptual models take what users know and how the system actually works and build a bridge between the two, so the user can understand. The conceptual models are the designer's vision of the service and products. Mylopoulos categorises the conceptual models into dynamic, static, international and social. The visualisation of the models might be constituted with user flows, mind map, class diagrams and so on. Nearly every diagram that represents concepts and their relationships is a conceptual model.

For designing a good, understandable, enjoyable product, i. e., creating a good conceptual model, good communication and understanding the end user's mental model are necessary.

**2.3. Paradox.** The technology potential is to make life easier and more enjoyable but at the same time, added complexities increase with technology. The design problem posed by technological advances is enormous.

**2.4. Challenge.** The design is a synergy of multiple heterogeneous items and disciplines. Cooperative effort of a number of different disciplines is required. Each discipline has a different perspective. The final solution has to be affordable, to be able to be manufactured and serviced. The good product life cycle management is crucial. Finally, people have to actually purchase it. It doesn't matter how good a product is if, at the end, nobody uses it. The designers have to ensure the user's security of the final product. Obviously the UX design is multilayered (Fig. 2).

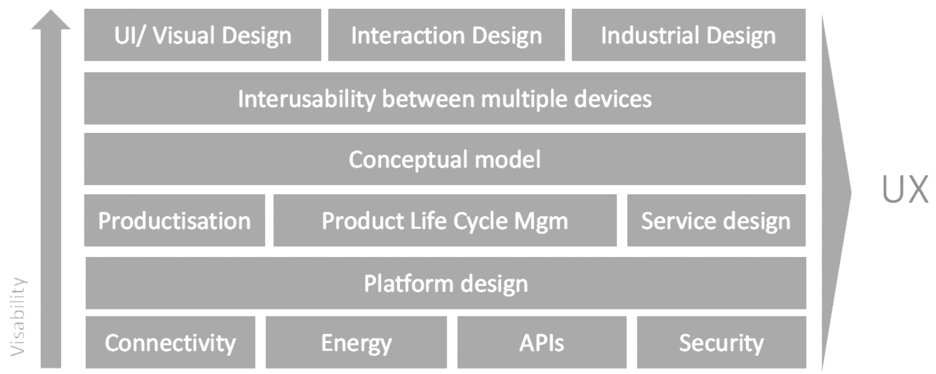


Fig. 2. Multilayered UX design source [2]

There are many reasons for the insufficiencies of UX design: the limitation of technologies, of the designer's ability, impossibility to hold down cost. The main thing is knowing the users. Gaps in consumer awareness are due to lack of communication with them. There is a mismatch between the logical engineer's thinking and the users' expectation.

The complexity of the UX design increases for the Internet of Things (IoT) applications.

**2.5. IoT challenges.** The "Internet of Things" (IoT) refers to increasing the objects connectivity, cloud computing, increasing computer power and sensing abilities. The end user's understanding is related to wearables—activity trackers; connected cars and home technologies; medical or wellness devices, public or urban systems. IoT functionality can be distributed across multiple devices with different capabilities and ways of communication: internal among them or external with humans (screens, flashing, sounds) and environment (sensors). The UX design might create responsive services. Designing for the IoT raises all the challenges of cross-platform design and wider variety of device form-factors. Many devices are without screens, as are the intermittently connected ones. Even simple tasks can quickly become complex in an IoT ecosystem where people, hardware and services are connected [9]. UX designers no longer work on 2D digital products only. According to the user experience designer of Beyond Design Julia Alberts [10], there are four IoT challenges in UX design:

- **Cross-Functionality of Design**—Independently of variety of IoT "ingredients", users need to feel that everything is connected simultaneously with no disruptions.
- **Service of the User Experience**—Every piece of the IoT puzzle is essential to give users the best experience out there.
- **IoT is Primarily Unparalleled**—Maintaining the level of connections —Different parts of a system can be out of sync with one another. These disturbances might not be noticed. The continuous back-up prevents any hiccups in the experience.
- **The Arrangement of Code**—The combination of devices and code that makes a system work is called the system model. The designers need to understand the form and function of a conceptual model of how companies develop their systems for users to use on a daily basis from

searching for products, to adding them to a cart, to logging into an account and paying.

According to Porcenaluk, IoT designers have to make five Important UX Design Decisions: Enhance the Experience, Works Locally, Upgradeable, Extendable, and Secure [11]. These refer to other opinions [12, 13, 14]:

- Prepare for Evolving User Interactions—extension of existing systems interacting with IoT will involve moving fingers and head movements with virtual reality. Already there are several examples for gadgets which observe our activities.
- Design Interactions of the Future but leverage what is known already—rethinking, adaptation and prediction of the users' needs with a balance between the familiar and the new expectation.
- Design Contextual Experiences—context means timely and purposeful—focus on the micro-interaction driven experiences, timely, and purposeful—more meaningful and valuable.
- Design Anticipatory Experiences—in combinations of AI, machine learning, computer vision, sensor fusion, augmented reality, virtual reality—developing the intelligent IoT systems to do things automatically in a predictable manner.
- Most Importantly, Make It Useful and connect people! The experience needs to open interaction. Connectivity brings fundamental changes.

Before IoT connectivity the questions regarding product/services were: who, how, when, and why, as well as lifespan and any risks. IoT connectivity reshapes the challenges and complexity of product/service design—the interconnectedness. It defines the technology and imposes new requirements. The impact of IoT technology on products is categorised by Deloitte experts [15] into four main transformations:

- synergy between physical and digital worlds—with IoT enablement of a physical product, embedded sensors are able to capture and transmit data about that product over a network;
- constantly connected—an IoT-enabled object will necessarily stay connected to a network to facilitate the communication of data;

- moving from single object to part of a larger system—the difficult separation of a product's physical makeup from its digital components in a IoT connectivity introduces wider interactions that complicate design
- constantly evolving uses—and life cycles—pre-connected world.

**3. UX Models for IoT.** There is no single design philosophy. The decision to use any particular philosophy for IoT design depends on the context, and sometimes designers call for more than one approach. According to Sniderman et al. [15] the most relevant are:

- Systems thinking—to bring order to complexity, which allows engineers and designers to understand the boundaries between different parts of a product, even when those parts can be separated by thousands of miles and owned by different organizations. Systems thinking focuses on looking at the object as part of a larger ecosystem rather than discrete and independent.
- Design thinking—if systems thinking is fundamentally about understanding the complex ecosystem in which a product operates—a step further to place a human at its center. Designers can assess the users' needs, likes and dislikes of their products and everything around it.
- Lean startup—"fail fast, succeed sooner," lean startup focuses on rapid iteration or agile approaches to better meet customers' needs. One of the principles of lean startup is to produce an optimized design quickly, with minimal waste.

These design philosophies are like parallel roads to the same city: In IoT product design, the organizational change is required to meet the complex, changing demands of connected products.

**3.1. Facets of IoT UX.** A specialist in UX design for the Internet of Things (IoT) is a designer of connected objects who must require a holistic approach. Focus on tangible parts, as industrial design of part of the object or User Interfaces (UIs) design, is not enough. Rowland offers a *Framework for IoT Design* [9]. Many layers of the design of a connected object must be taken into account as shown in Fig. 3—a good view of the whole picture.

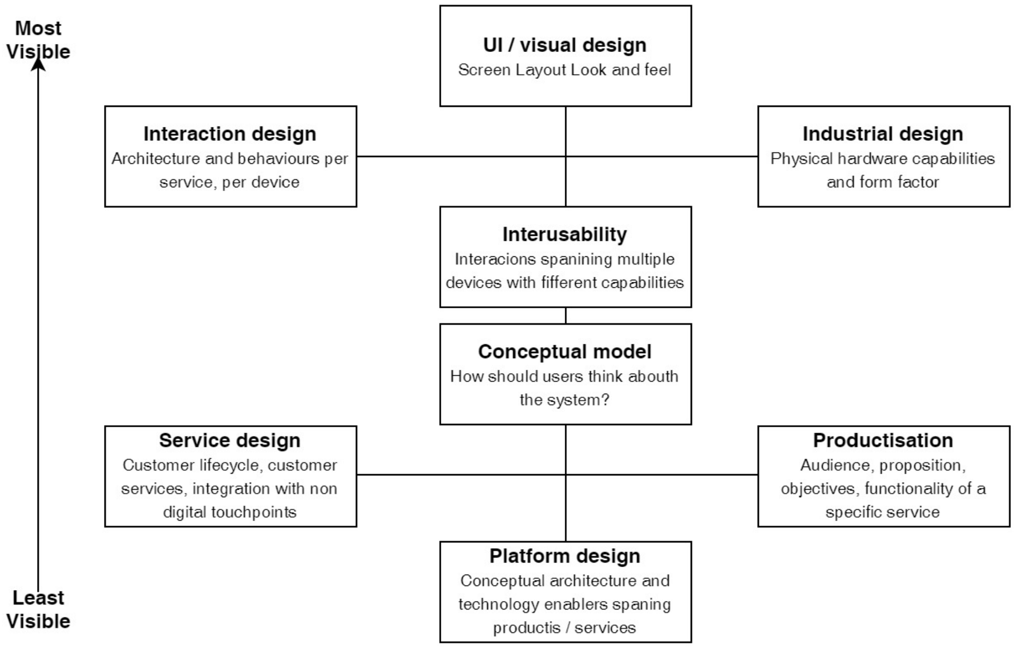


Fig. 3. Framework for IoT Design Source. Claire Rowland [9]

**3.2. A Spiral UX Design Model.** Hang Guo's model [16] describes the essence of UX design—two simultaneous processes of mutual adaptation: a systematic design process and a spontaneous user-research process. The spiral model supports gradual discovery of the problem space as part of its core concept. Fig. 4 shows one possible way of adapting the spiral model to a UX design process.

- The team analyzes user needs and brainstorms product concepts.
- A leading designer:
  - consolidates ideas rather than the team attempting for consensus;
  - communicates concepts to the team and usage scenarios and gets their feedback;
  - explores alternative designs with the team;
  - produces the final design through a convergent process.

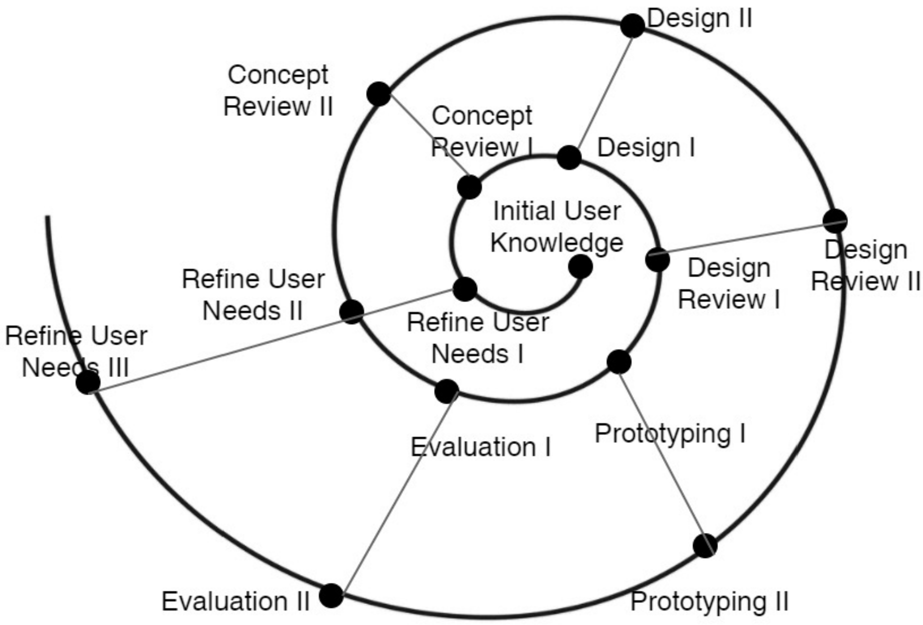


Fig. 4. Spiral UX Design Model [16]

- The team reviews the design.
- The lead designer or team creates prototypes—from lo-fi to hi-fi.
- The team
  - selects the right evaluation methods for the fidelity;
  - incorporates the evaluation results into refined user needs.

This spiral development model adapted to UX design helps to break organizational silos between user research, UX design, and technical design and implementation teams.

**3.3. CUBI UX Model.** The CUBI UX Model is a framework which supports the understanding of the user experience key components. It improves client communication and identifies gaps when creating effective experiences.

This model helps deconstruct the major components, which consist of: Content, User Goals, Business Goals, Interaction.

The intersections in the diagram define the process by which users navigate through content through the provided interactions, which include attraction, reactions, actions and transactions (Fig. 5). In order to have an effective experience, a product needs to be comprehensive, useful, usable and branded—another set of intersections marked with stars—so-called Experience Factors.

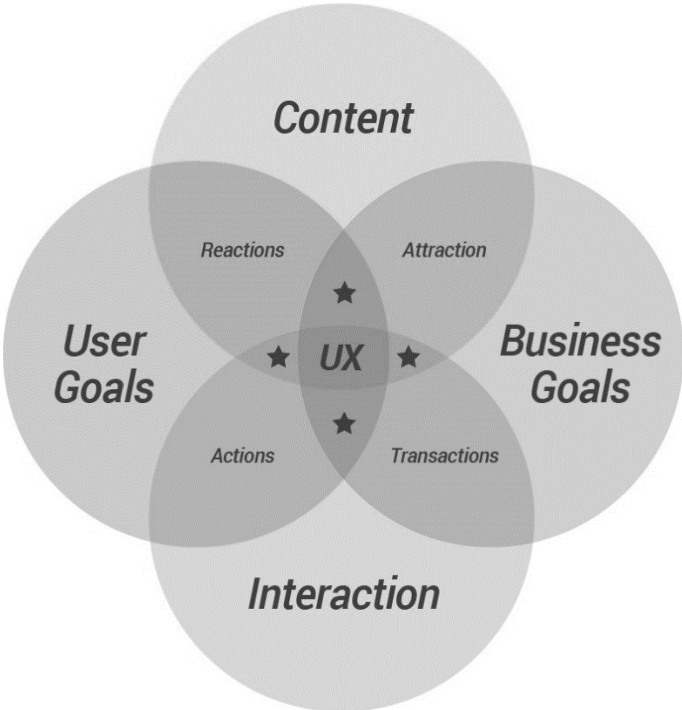


Fig. 5. CUBI model UX model [17]

The CUBI serves multiple purposes: Creativity, Communication, Simplification, Collaboration, Gaps.

The model provides a framework for presenting content more creatively. Creative experiences have the potential to greatly engage users and provide more unique brand experiences. Greater communication keeps the strategy on track and supports common terminology and language between designers and clients. This model simplifies the complex design process and can help identify gaps within the design process.

The CUBI model is based on layers on each of its elements:

- Content: there are five layers to consider for incorporating content. Content Types are aggregated to create Content Models. The content types and models can have an applied Content Treatment. A Content Method can provide a narrative or framework for the content. All of these elements are organized through Content Architecture:
    - Content Types—content includes a variety of media including photography, video, audio, data, documents, and other things.
    - Models—combine the different content types into a more recognizable model or format.
    - Treatments—content can also have applied aesthetics and treatments—unique tone or personality-based.
    - Methods—content can be presented in more creative ways—more interesting and engaging.
    - Architecture—the structure and organization of information.
- User Goals—there are five layers to consider when incorporating user goals. Each User Type has a set of Needs they are trying to fulfill. Users are motivated to take action. Repeated Behaviors can produce significant user Outcomes.
    - User Types—understanding of the different user types is important to be use the end product.
    - Needs—understand and define the relevant needs and aspirations that will help users.
    - Motivations—how users are motivated to fulfill their needs.
    - Behaviors—it is important to research the user's current behaviors and how new motivations can potentially drive behavior change.
    - Outcomes—the combination of Needs, Motivations and Behaviors can then translate into meaningful and measurable outcomes for users.

- Business Goals—There are four layers to consider when incorporating business goals. The Operations support the business Offerings. When customers have positive brand experiences and transactions they provide business Outcomes, which help fulfill the business Mission:
  - Operations—People, Resources, Connected Experiences.
  - Offerings—The business may offer an ecosystem of products and/or services.
  - Outcomes—The offerings ultimately support meaningful metrics and Key Performance Indicators that help support business success.
  - Mission—The mission statement should guide decisions and clearly define goals.
- Interaction—There are four layers to consider when incorporating interaction. A set of Patterns are provided in a System. The system can be available on multiple Devices to encourage certain types of Human Interaction.
  - Patterns—Design patterns are reusable components and interactions.
  - Systems—contain navigation, flows, feedback, and notifications to help the user progress and achieve their goals.
  - Devices—key to understanding the capabilities and constraints of the targeted devices.
  - Humans—formal or informal, personal or interpersonal, social, or some other type.

**3.4. IoT Multi-Touchpoint UX.** The issue of multi-touch point experience design cuts across the fields of service design, interaction design, product design and omnichannel design [18].

The augmentation in IoT field increases the complexity of new products and services. The technology becomes popularized and is used differently by various types of users. IoT-based products and services must offer a variety of touchpoints so as to be able to address the socio-material conditions of use.

Taking IoT-based products and services in domestic settings as a starting point for some central opportunities and challenges for multi-touchpoint experience design through the case of IoT design—the approaches for designing multitouchpoint experiences:

- Technology Probes—a user research method that makes use of an open-ended technological artifact in order to collect user data while also involving users in the design process.
- Contextual Inquiry—a well-established participatory design approach that "helps people crystallize and articulate their work experience". It offers a specified way to empathize and understand user experience including instances of implicit interaction.
- Proposed tool—a coherent multi-touchpoint IoT UX is important for designers to involve users in the design process in a meaningful way.

**4. Conclusion.** Designers will need to design IoT-driven experiences that are contextual, helpful, and meaningful—optimized for people, not technologies. The ability of things to interact with other things has been growing exponentially. What is crucial is the final interaction between things and people. Designing a UX for IoT that engages users is one of the biggest challenges. The IoT products succeed only when they solve real problems and make users' lives easier.

Design is the critical component that bridges IoT technology's potential with meeting real human needs. There is no single design approach. IoT design requires a sharp focus on user needs that conveys the benefit quickly. Designing IoT UXs is design of behavior change.

**Acknowledgement.** This research was supported by the National Science Fund at the Ministry of Education and Science of Bulgaria through the project *Conceptual Modeling and Simulation of Internet of Things Ecosystems (KoMEIN).*

## REFERENCES

[1] STEVENS E. The Fascinating History of UX Design: A Definitive Timeline. 2018. https://careerfoundry.com/en/blog/ux-design/the-fascinating-history-of-ux-design-a-definitive-timeline, 20 October 2018.

[2] ROWLAND C. User Experience Design for the Internet of Things: Why It's More than UI and Industrial Design. O'Reilly Media, 2015.

[3] ROSS E. UX in the context of Industrial Design. Nectar, 2016. https://nectarpd.com/ux-in-the-context-of-industrial-design, 20 October 2018.

[4] NORMAN D. A. Things That Make Us Smart: Defending Human Attributes in the Age of the Machine. Addison-Wesley. Boston, 1993.

[5] NIELSEN J. Mental Models. Nielsen Norman Group, 2010. https://www.nngroup.com/articles/mental-models, 20 October 2018.

[6] BALLAV A. Mental Models and User Experience. UX matters, 2016. https://www.uxmatters.com/mt/archives/2016/05/mental-models-and-user-experience.php, 20 October 2018.

[7] NORMAN D. A. The Psychopathology of Everyday Things. In: The Design of Everyday Things: Revised and Expanded Edition. Basic Books, 2013, 1–36.

[8] MYLOPOULOS J. Conceptual Modelling and Telos. In: P. Loucopoulos, R. Zicari (eds). Conceptual Modelling, Databases, and CASE: An Integrated View of Information System Development. New York: John Wiley & Sons, 1992.

[9] Rowland C., E. Goodman, M. Charlier, A. Light, A. Lui. Designing Connected Product: UX for the Consumer Internet of Things, 2015.

[10] Alberts J. User Experience for IoT. Beyond Design, Inc., 2016. `http://www.beyonddesignchicago.com/user-experience-for-iot`, 20 October 2018.

[11] Porcenaluk J. UX Design for IoT—5 Important UX Design Decisions. IoT for All, 2017. `https://www.iotforall.com/ux-design-iot`, 20 October 2018.

[12] Designing the Internet of Things—5 Key Principles. IoT for all, Guest Writer, 2017. `https://www.iotforall.com/designing-the-internet-of-things`, 20 October 2018.

[13] Ortiz S. How to Design Delightful Experiences for the Internet of Things. Toptal. `https://www.toptal.com/designers/ux/how-to-design-delightful-experiences-for-the-internet-of-things`, 20 October 2018.

[14] Feffer M. The Internet of Things Will Change UX Design. Dice, 2015. `https://insights.dice.com/2015/10/08/the-internet-of-things-will-change-ux-design`, 20 October 2018.

[15] Sniderman B., G. Gorman, J. Holdowsky, J. Mariani, B. Dalton. The design of things Building in IoT connectivity. Deloitte & IBM, 2016. `https://www2.deloitte.com/insights/us/en/focus/internet-of-things/connected-products-designing-for-internet-of-things.html`, 20 October 2018.

[16] Guo H. When Change Is Constant: A Spiral UX Design Model. UXmatters, 2015. `https://www.uxmatters.com/mt/archives/2015/04/when-change-is-constant-a-spiral-ux-design-model.php`, 20 October 2018.

[17] Stern C. About the CUBI UX Model. CUBI User Experience Model, 2016. http://www.cubiux.com/about.php, 20 October 2018.

[18] Gkouskos D., P. Linde. Designing for IoT Multi-Touchpoint UX. In: Experience Design for Multiple Customer Touchpoints. NordiCHI'16 Workshop, Gothenburg, Sweden, 2016. https://blogs.aalto.fi/multixd/files/2016/09/MultiXD16_paper_6.pdf, 20 October 2018.

*Eugenia Kovatcheva*
*University of Library Studies and Information Technologies*
*119, Tsarigradsko shose Blvd*
*1784 Sofia, Bulgaria*
*e-mail:* e.kovatcheva@unibit.bg

*Received May 15, 2018*
*Final Accepted July 15, 2018*