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**Internet of Things for Smarter Homes:
A Taxonomy-based Analysis of IoT Applications**

*Internet der Dinge für intelligentere Häuser:
Eine Taxonomie-basierte Analyse von IoT-Anwendungen*

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1. Introduction

“The ultimate promise of the smart home technology is to make us the master of a home that we command by multiple ways!”

– Hogar Controls Inc (Global Home Automation Company) 2019¹

The Internet of Things is a concept that with its introduction has extended the basic definition of the internet by enabling interaction of many different smart devices between each other and with humans within a global network.² Its influence can be observed in many areas of life. Our homes are one of those areas. Hogar Controls Inc believes that by utilizing the IoT, we can finally become true masters of our home. The statement implies different services that a smart home is offering to its owners. Controlling functions, monitoring functions and automation are just some of the service offerings of a smart home³ which are only made possible by a huge number of different smart home IoT devices that represent the underlying technology.

Bevor coming home you can rise up the heating so that it will be warm when you arrive. Even being out of the house you get a message when the postman rings at your doorbell and you can advise him through the speaker to drop off the package in the backyard⁴. You can also feed your dogs by tapping on your smartphone while being at a concert. All these examples are use cases of a smart home and behind all of them there are smart devices which enable the smart home to provide the specific services. Those smart devices differ with respect to their services and their individual technical configurations.

The diversity of those products is not sufficiently addressed in the literature, and research still lacks of a proper classification of IoT devices in the smart home sector. Most classifications that are to be found in the field of smart homes classify objects by their scope of application⁵ and although this criterium is one aspect when describing the service of a smart home device there are still more elements that need to be considered. In order to further close this research gap, this paper is going to investigate smart home devices more closely regarding their capabilities and characteristics by answering the following research question:

RQ: What are conceptually grounded and empirically validated technical configuration and service elements of IoT devices in the context of smart homes?

This thesis aims to shed light on different dimensions of smart home devices including technical configuration and service elements. By doing so a better understanding for such products can

¹ Hogar Controls Inc., *Instagram* (2019), <https://www.instagram.com/p/BxNPsq1gkod/?hl=de>.

² cf. Ibrahim Mashal and Ahmed Shuhaiber, "What makes Jordanian Residents buy Smart Home Devices?", *Kybernetes* 48 no. 8, (2019), p. 1681.

³ cf. Liang Zhang et al., "Research of the Key Technologies of the Smart Home based on IOT", *Mechatronics Engineering and Modern Information Technologies in Industrial Engineering* 713-715 (2015), p. 2304.

⁴ cf. Michael Schiefer, "Smart Home Definition and Security Threats", *IEEE 2015 Ninth International Conference on IT Security Incident Management & IT Forensics* (2015), p. 114.

⁵ cf. Joseph Bugeja, Paul Davidsson and Andreas Jacobsson, "Functional Classification and quantitative Analysis of Smart Connected Home Devices", *IEEE 2018 Global Internet of Things Summit (GloTS)* (2018), pp. 1–6.

be gained which allows researchers to use this paper as a foundation for further analysis of smart homes and its products. Practitioners could analyze existing and new potential products which is especially relevant for competing companies.

The research question is going to be answered by developing a taxonomy of smart home devices utilizing the taxonomy development method by Nickerson et al.⁶ Smart home devices were identified from real market places and dimensions as well as characteristics of such devices were empirically and conceptionally worked out while using the just mentioned approach. The results were then crosschecked with the existing literature again through text mining and a cluster analysis was used to point out different archetypes of smart home devices. In order to help researchers to assign new and other objects to a certain archetype a decision tree was provided which also can be used by potential future customers of smart home products to find a device which satisfies their needs.

The first part of this thesis addresses the history of the internet of things, the status quo and how the development drives smart homes and its devices. This is followed by an explanation on how classification systems are adding value and why they are helping us to understand a certain group of objects. The research design section describes which methodological approaches have been used within this thesis. This concerns the taxonomy development, the cluster analysis and interpretation as well as the text mining. In section 4 the taxonomy development is being presented, including the explanation of the framing, all individual iteration steps and finally the resulting taxonomy itself. As a next step, the taxonomy is being analyzed by performing a cluster analysis which results in archetypes that are being described and from which a decision tree can be derived. Within section 6 text mining of smart home literature is being performed to evaluate the previously developed taxonomy. This is followed by a discussion of the findings of this thesis. Towards the end of this paper the limitations are demonstrated in section 8 and a conclusion as well as recommendations and ideas for future research are being provided in section 9.

⁶ cf. Robert C. Nickerson, Upkar Varshney and Jan Muntermann, "A Method for Taxonomy Development and its Application in Information Systems", *European Journal of Information Systems* 22, no. 3 (2013).

9. Conclusion and Outlook

Smart homes and their devices are enabled by the Internet of Things and provide many different services to the user which leads to comfort through automation, safety through awareness and many other advantages. Since smart home devices can be versatile within this paper a taxonomy was developed in order to classify smart home products. 100 smart home devices were examined and classified and a taxonomy was developed by undergoing four iteration steps. The final taxonomy revealed twelve dimensions and 41 characteristics which in combination explain the technical configuration elements of a smart home device as well as its service elements. The data from the taxonomy was then used to analyze the devices regarding possible clusters which then allowed to identify a total of nine archetypes. They consist of Robotic Devices, Remote Controls, Lifestyle Products, Sensors & other simple Devices, Health Appliances, Energy & Resource Management Devices, Hubs & Controllers and Lighting, Plugs & Switches.

A decision tree was provided for researchers to assign new objects to one of the archetypes as well as to help in the decision-making-process for customers to choose a smart home device which matches with their needs.

To validate and increase the relevance of the taxonomy with all its dimensions and characteristics a literature analysis using text mining has been performed. This way the much more empirical taxonomy could be crosschecked against the importance of certain characteristics that scientific papers are suggesting.

Other than the discussed possible future directions that could be derived from the limitations in chapter 8, this paper can be seen as a starting point for many other scientific questions.

Since the taxonomy in this paper is mainly focusing on the present status quo, for future research it would be interesting to examine the development of the characteristics of smart home devices. There might be a shift or trends towards certain characteristics that could be observed. There might even be new characteristics that emerge in the future. The taxonomy, therefore, can be further developed in the future, introducing new products with new characteristics.

While reviewing all smart home products it became clear that some of them do not just differ in terms of their characteristics but also differ in their ratings on certain platforms and in the number of sales. This implies that valuable information could be extracted by analyzing the archetypes that emerged from our taxonomy regarding the feedback they got on platforms like Amazon and Ebay. This feedback could be measured by the review stars or the number of sales of each product. The results of that analysis could be used to find out which of the archetypes or characteristics seem to be most promising for companies to consider for their own products and product portfolio.