Improving the Methods for Using the Data From IoT Devices in Smart Buildings
(Technical Topic)

The Changing Relationship Between Users and Their Buildings: Preventing This Transformation and Analyzing the Consequences from the Increasing Use of IoT Data in Smart Buildings
(STS Topic)

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

"Smart buildings" (also called intelligent buildings) are buildings which attempt to maximize their own potential in regards to cost or efficiency (Flax, 1991). As internet capable devices - otherwise known as IoT devices - continue to grow in use across all domains of life, the idea of industries creating intelligent capable buildings becomes more attainable and more effective. Today we see many buildings employ sensors, which are effectively IoT devices, in order to manage their buildings (Daissaoui, 2020). Leaders in the IoT industry claim that the year 2020 saw a 21% increase in the use of IoT devices -- this continues the perpetual increasing trend witnessed in previous years seen in Figure 1 (Goasduff, 2019). Although this may be alarming to some, this trajectory opens the door for unprecedented opportunities to improve the efficiency of older pre-existing technologies like buildings (Hayes, 1983). These IoT sensors are rich with information. They can record CO2 levels, temperature, electric usage, etc. all in the format of time series data. This information can then be analyzed to pull additional information like room occupancy, efficient energy allocation, etc. Each building has its own building management entity. This entity utilizes building management software to monitor the condition of buildings and identify key information for further building optimization. This software effectively consists of visual representations displaying the values of these sensors over time (Figure 2) (Yu, 2016).

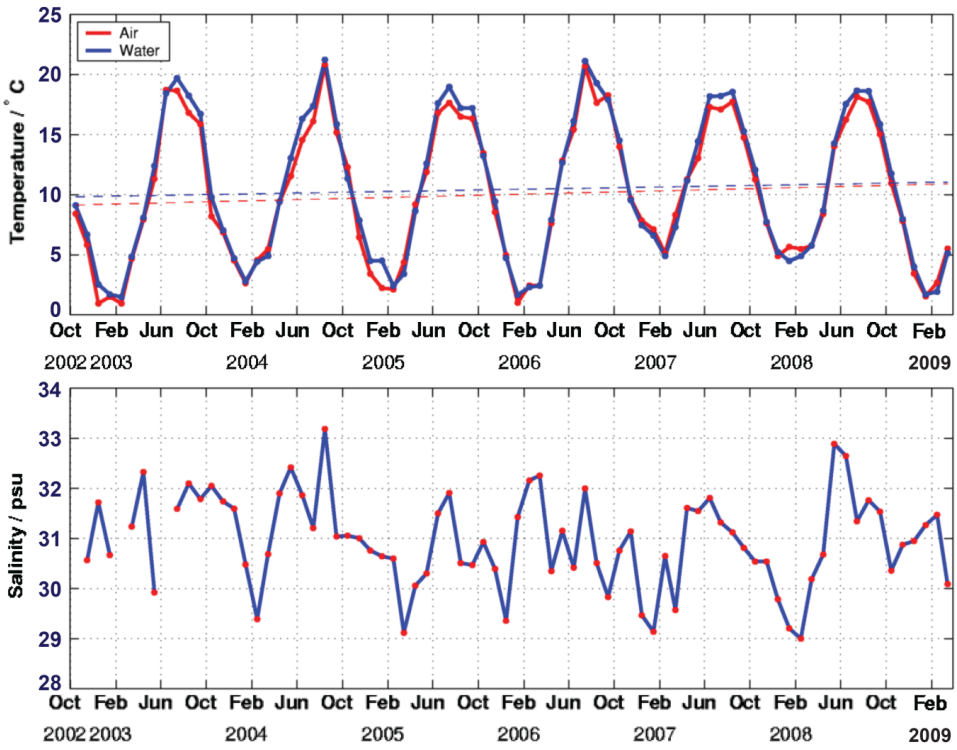
Figure 1

IoT Endpoint Market by Segment, 2018-2020, Worldwide (Installed Base, Billions of Units)

Segment	**2018**	**2019**	**2020**
Utilities	0.98	1.17	1.37
Government	0.40	0.53	0.70
Building Automation	0.23	0.31	0.44
Physical Security	0.83	0.95	1.09
Manufacturing & Natural Resources	0.33	0.40	0.49
Automotive	0.27	0.36	0.47
Healthcare Providers	0.21	0.28	0.36
Retail & Wholesale Trade	0.29	0.36	0.44
Information	0.37	0.37	0.37
Transportation	0.06	0.07	0.08
Total	**3.96**	**4.81**	**5.81**

Source: Gartner (August 2019)

Figure 2



It is not hard to imagine that, with the explosion of the use of IoT sensors and the time series data associated with it there is a need for evolution within building management software. Within the industry of building management software there is a lack of urgency in response to this change in the data itself. Building management software that relies on older and simpler methods will become a bottleneck in the journey towards *maximizing efficiency* within a building (Yu, 2016). Efficiency in this context can take the form of efficient energy allocation or even efficient methods for searching for information. Creating an immense loss of opportunity and making building managers blind to the diverse and rich information that can be extracted from this data.

In this prospectus, my team and I propose a system that efficiently takes advantage of the explosion in sensor data to provide a better experience for building managers without sacrificing the previous relationship users have with their buildings. Additionally, this prospectus will provide an STS analysis of the relationship between users and smart buildings. Specifically, in order to prevent any detrimental changes to the relationship between users and smart buildings and in order to identify the consequences of changing this relationship.

Technical Topic: Improving the Methods for Using the Data From IoT Devices in Smart Buildings

There is an opportunity to improve the methods for using IoT sensor data by using information retrieval methods to produce buildings that move closer towards smart buildings. Here I will justify this claim by providing historical examples of similar trends and connecting it with the current state of IoT device usage in buildings. Then I will emphasize the importance of

improving the methods for using IoT sensor data and how my team and I plan to improve the current state of IoT data usage.

Similar trends in IoT sensor data have appeared in other industries. In this historical example they also employed information retrieval methods to deal with unordered and non-categorical data.One can draw parallels between the explosion of sensor data with the explosion in websites during the beginning of the Internet. Both scenarios called for a rethinking of the management systems regulating it. In the case of the Internet prior to this explosion there were websites dedicated to mapping out the websites on the Internet. It accomplished this by using database methods (Sharma, 2012). This meant categorizing websites into predefined groups which were determined by some oracle (expert). This was easy enough when the Internet was small and simple. However, as the Internet grew exponentially in size bringing along complex sites, this database method for cataloging websites became obsolete. This is when websites like Google started to pioneer the search engine (2017, Sadeghi). The search engine is an information retrieval system. This means that the Search Engine attempts to extract valuable information from complex, unstructured data. Information Retrieval systems work by predicting what the user's need is (what they are searching for in the case of Google) instead of taking what the user says as literal (database method) (Sharma, 2012). This revolutionary system provided by Google allowed users to tap into the rich information provided by the Internet without being hindered by its complexity and size.

The increase in sensor data used in Intelligent Buildings is very similar to the event seen in the Internet. The explosion of websites called for a rethinking of current technology in order to take advantage of the vast amounts of information. The sensor data provided by IoT devices is unordered and is hard to fit into categorical groups. The data will only get much more complex

as the technology behind the devices matures. Current software will continue to struggle and even worsen as years go by without any innovation in this field (Yu, 2016).

Innovation can be brought through information retrieval methods. Information retrieval methods are perfect for managing large and unstructured data like the data we see associated with IoT devices in intelligent buildings (Sharma, 2012). These methods will help extract valuable information from the sensor data itself further optimizing the experience of building managers and allowing them to maximize the efficiency of their buildings. However, the information retrieval methods used for websites by Google are not directly transferable. Therefore, plenty of thought and consideration should be placed on recognizing the needs of building managers and what aspects of information retrieval would be most useful for their use cases. Currently modern software for building management is stuck in the "database" period of the Internet. In order to resolve this problem, building managers need to be given a piece of software that will provide tools for managing the massive amounts of rich data created by sensors within intelligent buildings.

STS Topic: The Changing Relationship Between Users and Their Buildings: Preventing This Transformation and Analyzing the Consequences from the Increasing Use of IoT Data in Smart Buildings

With the inclusion of IoT devices in buildings, the user experience might change and thus the user's relationship with buildings can change. Users in this context involve a diverse range of actors. For example, users can directly mean the building manager. In this case his experience may be more efficient and his job can be made easier. However if we define the user to be the general public (or someone who is simply using the building), they may have a different

experience. Since this user does not directly benefit from the use of IoT devices in smart buildings, they may come to different conclusions of its use. If the user is initially intimidated by the use of intelligent devices within the building then they may choose to opt out of interacting with that building. We can already see similar trends in fearing other technology like the 5G tower case (Seal, 2020) and autonomous vehicles (Vosooghi, 2019). In both these cases the use of sophisticated technology makes people question that previously trusted technology's security. The inclusion of IoT devices can cause an area of doubt within users and thus will cause them to act differently towards these buildings. If the building is being used as a marketplace for products then those business owners will experience financial losses from a loss in customers. This STS topic aims to analyze the consequences of the new relationship between users and smart buildings with the goal of providing an approach to preventing detrimental transformations in the relationship.

In order to research this STS topic we can analyze historical examples. The effect of technology on a user's trust is a well-studied topic in STS. Even though much of the studies conducted cover other technologies, we can still use many of the current findings for the case of intelligent buildings. In the study conducted on the impact of Weather Forecasting they found that accuracy should not be traded for better consistency (Burgeno, 2020). Therefore, it is acceptable for the system to be inconsistent as long as it is accurate most of the time or if it improves over time. This is important for the case of intelligent buildings because we are making it based on information retrieval methods which by definition will be inaccurate (at least in the beginning of its use) (Sharma, 2012). This is so because it uses corrections from the user to learn how to better understand the data and the user's needs. Based on this study we can also determine that the user's trust is partly determined by how accurate the technology is. As long as

a system can guarantee that it will at least be accurate in its solutions, then user's will grow to trust the system and be more inclined to use it.

Why is user trust important when making design decisions in new technologies? To some this may seem obvious but hopefully I can point out some edge cases that the knowledgeable reader may miss. Firstly, it has been well studied that a user's trust is directly proportional to a user's willingness to use a new technology (Vosooghi, 2019). In the case of "Robo-Taxis", an autonomous fleet of commercial taxis, the company funding these taxis found that users need the safety of new technologies to be guaranteed before use. This places heavy emphasis on the design decisions made during the inception of the project. Safety of the user - whether that be their body, life, or privacy - needs to be placed in the highest priority when creating revolutionary technologies. Therefore, it is important develop an approach that will address user trust else the loss of trust can overshadow the technical solution

This discussion has defined a possible transformation in the relationship between users and IoT devices. And emphasized the importance of proposing an approach to addressing this change. I have provided a glimpse at techniques for conducting this STS research in hopes of remedying this STS problem.

Overall Conclusion

The work described here should provide a piece of software for building management. This software will provide information retrieval methods to manage buildings by utilizing IoT sensors that have been increasing in use within intelligent buildings. This could lead to the discovery of new efficiencies within buildings, these efficiencies could take the form of efficient energy allocation or efficient searching for information a building manager needs. Additionally in order to ensure that these new efficiencies are properly utilized, a thorough study of the

relationship between users and intelligent buildings is proposed. This will properly define the STS environment around intelligent buildings. If both of these deliverables are successfully provided then intelligent buildings will be successfully led to the next iteration of building management software.

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