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Parallel Design of a Product and Internet of Things (IoT) Architecture to Minimize the Cost of Utilizing Big Data (BD) for Sustainable Value Creation

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Abstract

Information has become today's addictive currency; hence, companies are investing billions in the creation of Internet of Things (IoT) frameworks that gamble on finding trends that reveal sustainability and/or efficiency improvements. This approach to "Big Data" can lead to blind, astronomical costs. Therefore, this paper presents a counter approach aimed at minimizing the cost of utilizing "Big Data" for sustainable value creation. The proposed approach leverages domain/expert knowledge of the system in combination with a machine learning algorithm in order to limit the needed infrastructure and cost. A case study of the approach implemented in a consumer electronics company is also included.

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Keywords: Internet of Things; Big Data; Product Design; Machine Learning; Sustainability

1. Introduction

In today's Big Data (BD) craze, companies are going "all in" on big data. They are investing billions in Internet of Things (IoT) infrastructures and the necessary personnel to support them. These companies are looking for diamonds (i.e., efficiencies and cost savings) in the rough (billions of unstructured data points) in order to justify the added investment and ongoing costs. More specifically, the manufacturing sector has seen considerable research in this area because the industry generates a large amount of unstructured and structured data that ideally can be processed and then used to achieve significant improvement in product design, manufacturing efficiency, cost reductions, scalability, resiliency, and environmental sustainability [1,2].

However, many of the companies that have been banking on big data still do not have much to show for their efforts [3]. In fact, those same companies have not even cashed in on the information systems that that they put into place 10-15 years ago [3]. The current approach of creating these extensive IoT frameworks involves outfitting legacy products, processes, and systems with numerous sensor nodes and IT systems in order to collect a significantly large dataset, only to have a fraction of it filtered into a usable state. Although excellent in theory, this approach can lead to an astronomical initial investment that could hinder any practical implementation into a production environment. On the other hand, if this approach is implemented blindly, there is a great risk associated with managing the new overhead. This trap is caused by the idea that information is free. While information is free, the ability to access it and use it in a way that can be beneficial is far from free. Everything from collecting the data points, to processing, and then storing them has an associated cost. For example, if only one million data points out of the original one billion is actually usable in a way that they can see a return on investment, then there was a waste of 99.9% of the data collected.

With that in mind, there is a need for a counter approach to implementing big data that can minimize the cost in order to realize sustainable value creation. Therefore, this paper

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presents an approach that is comprised of leveraging domain/expert knowledge of a system, product, and/or process in combination with an advanced machine learning algorithm. The premise of the approach lies in consolidating the functionality of the system into minimal hardware and physical infrastructure. By designing the system hardware in parallel with the IoT architecture, the amount of data collected can be trimmed to the amount that will actually be used.

2. Previous Work

For years, the vision of the IoT and its impact on product design and manufacturing has been being molded for future implementation. It can be said that the IoT is a means for aligning the physical and information life-cycles [4]. This vision suggests that this intimate connection and the information itself presents a major source of value [4, 5]. Dubey et al. [6] suggest that Big Data (BD) is one of the emerging research areas that are considered “game changers” in the manufacturing sector. The claim is that the use of big data can see a 15-20% increase in return on investment and surplus cash for customers [6].

Looking at IoT and BD through the lens of sustainability, the sought-after gain from such an implementation is information that mainly aims at reducing energy and resource consumption. However, there must be a balance of the amount of energy and resources used to build the required infrastructure and support system in order to prove a net improvement [7]. In addition, it is suggested that improvements to sustainability can also come in the form of combining multi-source information, and then making a calculated decision from that information using cloud computing and web services [8]. Although many companies are going after cost reductions, those reductions will inevitably give way to the law of diminishing returns. Because of this, other companies have seen better results utilizing big data in sales, marketing, and research and development in order to increase profits indirectly [9].

There have been several case studies involving the use of IoT and BD in order to drive sustainable value creation. In Pan et al. [10], a framework is built surrounding the HVAC and building industry and the use of IoT systems to improve energy usage. The approach envisions creating significant economic benefits, as well as social and environmental benefits. Tao et al. [11] presents an integration between an IoT system and a traditional PLM system. This work provides an idea for collecting environmental and life-cycle data throughout the entire life-cycle. The work also proposes the idea of a big Bill of Material (BOM) that uses the integration interface with the IoT systems in order to exchange and transform information. The next case considers the idea of using cloud based technologies in order to support product services [12]. In other words, a decision support system is built on top of the BD foundation. In other cases, these services are built to be proactive by building in predictive models and analytics into the decision support system [6].

Another case is seen in the food production sector where the application of BD to the supply chain can have implications for many industries. The work claims that analytics can translate customer requirements into an increase in sales, by being able to mine the rationale from metadata. In addition to the positives, the utilization of BD results in negatives as well. For example, tailored consumer level detail can result in the loss of purchasing options among other things [13].

Cost, energy, and resources have been discussed extensively, yet water is considered sparingly. The work by Koo et al. [14] advocates using the IoT technology for sustainable water development. The proposed solution consists of using sensors that capture water data through a virtual platform and control system. This work established three benefits: leak detection/prediction, optimization of production, and optimization of consumption.

3. Proposed Approach

The proposed approach for implementing an IoT system for sustainable value creation consists of leveraging domain/expert knowledge of a product, process, and/or system by the means of parallel design of the system hardware and the IoT architecture. In addition to the co-design element, the other essential component to the proposed approach is combining the domain/expert knowledge with a machine learning algorithm. This machine learning algorithm allows for more information to be extracted from the IoT sensor network than what would traditionally be measured.

For example, in a traditional IoT system you may have Node 1 measuring time, Node 2 measuring value “A”, Node 3 measuring value “B”, Node 4 measuring value “C”. However, with this approach, because the system is being designed in parallel, one is aware through an understanding of the physical system that Node 2 can be slightly altered to be a dynamic measurement and a function of time. With that alteration combined with the use of a machine learning algorithm, Node 2 solely becomes able to represent time and values A, B, and C. This paradigm suggests that the number of sensors does not have to be equal to the number of measured values.

The overall approach can be seen in Figure 1, where the product, process, and system are being designed in parallel

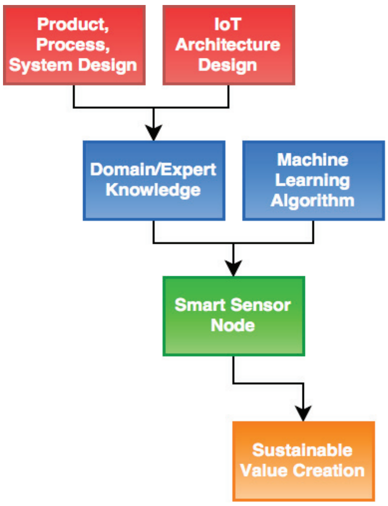

Fig. 1 Overview of the Proposed Approach