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Integrated Product and Production Research on Introducing Internet of Things in Swedish Wood Industry Products

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Abstract

To enable transitioning the Swedish economy into a bioeconomy, Swedish wood industry need to increase added value and introduce new products to market by introducing new technology and improving the product and production development processes. Research in automotive industry have shown the need for integrating product and production development when introducing new technology in existing production systems, and have indicated a possibility of using specifically designed student case projects in order to generate qualitative data. In this paper, one student case project on product and production development in the Swedish wood industry, involving IoT wood products, is presented and evaluated.

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Keywords: Product system development; Case studies; Modularization; Smart products; Customer benefit; University as a Laboratory

1. Background

In 2015, the Swedish government set a goal to make Sweden the first fossil-free welfare state [1]. The idea is to only use renewable materials and energy sources, and also become carbon dioxide neutral before 2050 [2]. This could be done by for example increasing usage of renewable materials and reducing waste. One way of combining these is to develop new products from wood based materials, and thus use more renewable materials, along with an introduction of Internet of Things (IoT), which could be used to reduce waste [3]. The Vinnova funded BioInnovation research program [4], especially the IPOS research project and the work package called DeProtion, aims to investigate how development of wood products can be made easier and more suitable for new product applications, partly by implementing IoT [5]. In the light of this, this paper was written to investigate the effects of implementing IoT in the wood industry using a material-centered integrated product and production development process. The aim was to generate an example of a wood-based IoT product or system of products, as well as a first evaluation of what challenges occur in the development of such a product.

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2. Theoretical and technological framework

In order to understand the study and the terminology used, the theoretical framework of integrated product and production development and the technological framework of IoT will be further explained in this section.

2.1. Integrated product and production development

Integrated product and production development, or IPPD, is the development of product and production system as an integrated system in order to reduce development times [6]. The concept, as opposed to traditional product development processes where production preparation is at the end of the development process [7], involves production aspects early on in the development of a new product [8, 9]. IPPD can be seen as a continuation of principles such as concurrent engineering [10] or systems engineering [11], but use terminology more in line with traditional product development process models.

2.2. Internet of Things

Internet of Things (IoT) is a term used to describe networks of physical artefacts and products, equipped with embedded sensors and processors in order to gather, process and communicate data regarding their surroundings [12, 13]. The exact content of IoT is undefined as of today [14], but attempts at definitions usually include sensors and processors in combination with physical products. One of the main identified benefits from implementing IoT is improved customer service [15], but challenges such as privacy issues and knowledge have been identified as important challenges for further implementation of IoT in industry [15, 16]. As seen in figure 1, there is a need for a customer or user benefit in order to rationalize the data collection [17].

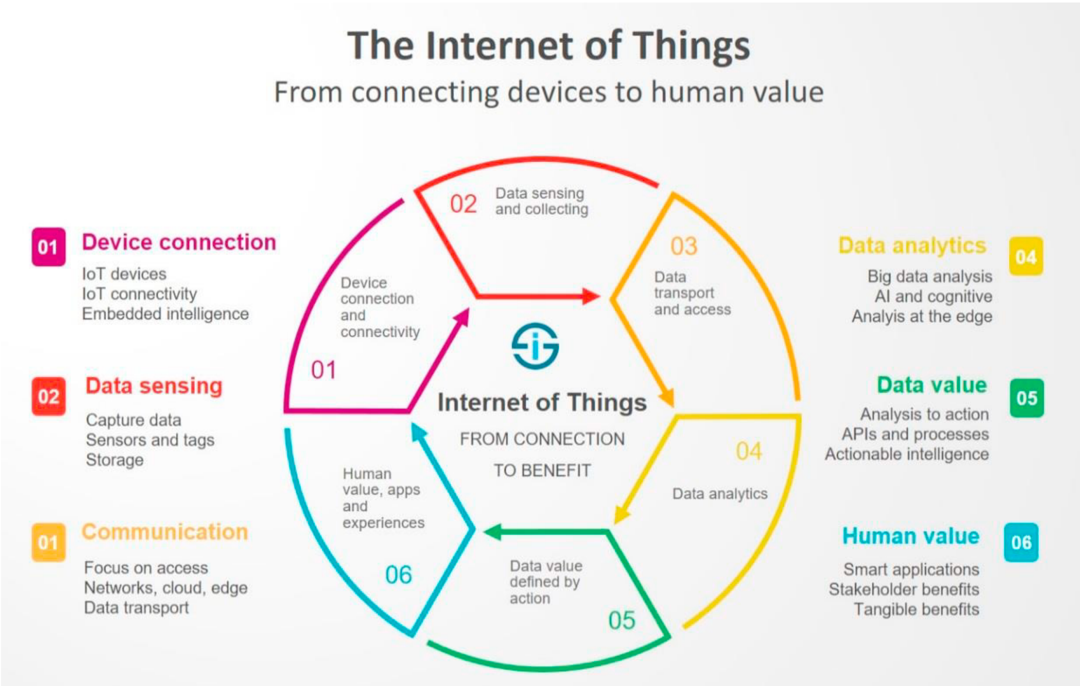

Figure 1. Schematic description of Internet of Things (from [17]).

3. Method: University as a Laboratory

In this paper, the method used is a case study [18] with the application of the University as a Laboratory concept. The University as a Laboratory concept is described by Henriksson [8] and Henriksson and Johansen [9], as a way of integrating research and education by using research based projects in senior engineering project courses. Projects are typically set up as integrated product and production development projects, and researchers are then observing the students' work pattern to investigate research questions related to development processes. The University as a Laboratory approach is analogue to the Industry as a Laboratory principles presented by Potts [19] and further developed by Björnsson [20, 21] among others.

Henriksson [8] indicates that there are many commonalities in findings from student case studies applying University as a Laboratory and industry-based projects, as shown in table 1 in a comparison between three projects: two applying University as a Laboratory (shortened UaaL in table 1) and one industry-based.

Table 1. Comparison between case study findings, adapted from [8].

Findings	Case 1 (UaaL)	Case 2 (UaaL)	Case 3 (Industry)
Assembly system effects on the introduction of new materials	X		X
Need for iterative development processes		X	X
Communication between product and production development		X	X
Need for simulation tools when evaluating multi-material design and new material introduction	X	X	X
Manufacturing process selection challenges	X	X	
Most demanding product requirements in production	X	X	X
Production and functional requirements separated in development	X	X	X
Organizational needs for introducing new materials		X	X
Product changes drive production system change	X	X	X
Joining multi-material bodies	X		
Backloading of assembly to later stages	X		X
Information, knowledge or requirements outside of scope affecting project		X	X
Process data and knowledge responsibility within development	X	X	X
Joining metals to metals		X	X
Joining sandwich materials to metals	X	X	
Adhesive joining		X	X

These commonalities makes it attractive to further develop and evaluate the University as a Laboratory concept. Earlier implementations of University as a Laboratory [9] have been applied to the automotive industry, but the nature of material-centered integrated product and production development project are similar across several different types of products.

In this paper, the case study was developed in collaboration with industry to evaluate a challenge the industrial partner have identified as a core challenge derived from customer demands; the introduction of IoT and "smart products". A project brief was delivered to the student team, and data collection has been made through course assignments, presentations and notes throughout weekly supervision meetings. The focus of the study has been on the development team's perception of challenges, and how the team have solved problems, not the exact technical specifications or functionalities of the end product.

4. The case studied

The challenge given to the students participating in the University as a Laboratory project was to develop a "smart" (Internet of Things-based) product or system for a wood industry company as the industrial partner, using the company's existing production system as a framework for production capabilities. The application and end product was selected to become a demonstrator, and a system for the industrial partner to develop without risk of breaking NDAs or exposing core intellectual property. Initially, the application was supposed to exist in a food truck environment, but this was changed towards a café environment later on in the project.

The development team consisted of seven students; six studying MSc in Design and product development and one studying MSc in Mechanical engineering. All students were in their ninth semester, making this their final semester before writing their master thesis.

The end result is a system for ordering and delivery of coffee/tea/chocolate in a café environment, mainly focusing on reducing confusion regarding the order and the "ownership" of each delivery, visualized in figure 2. The system is built upon four modules; a smartphone app, an ordering module, wall-mounted screens and a pick-up station (pictured in figure 3), all connected to the existing ordering system (as can be seen in figure 2) and utilizing NFC sensoring

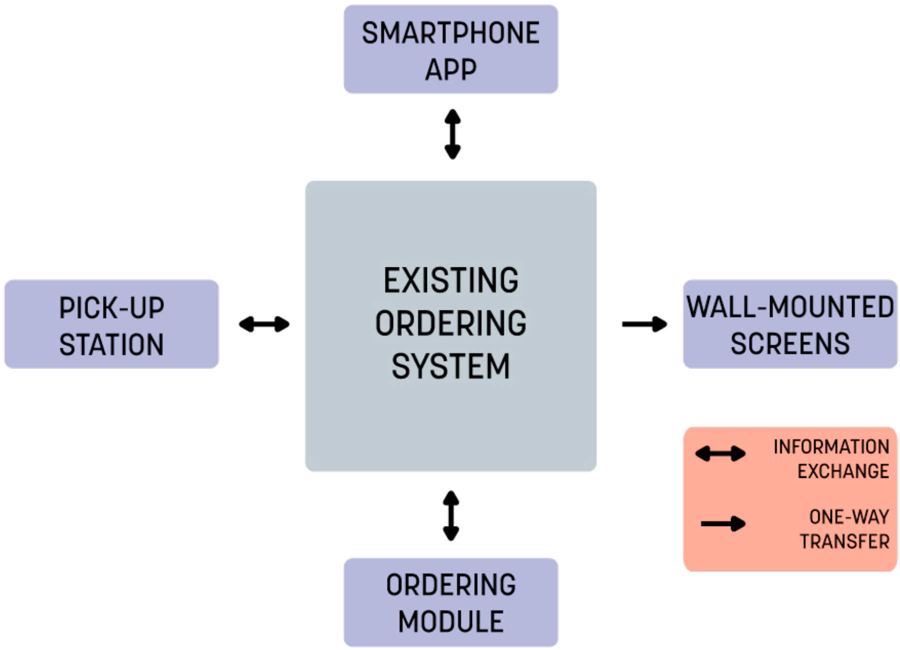

Figure 2. Schematic presentation of the new system design

technology. The main data analysis is still done in the existing ordering system, but there is connectivity with customer-owned devices (in the smartphone app) and propriety units (the pick-up station and ordering module). The data transport described in figure 1, is visualized as arrows in figure 2.

Proof of concept-units were built and presented as the end-of-course exhibition, showing a functioning stand-alone system of smartphone app (as software prototype), ordering module and pick-up station.

5. Findings and analysis

Early findings from the project show that there are classical product development-related challenges with integrating IoT into wooden products. The first finding is that integration of IoT demands some minimum of customer/user requirements to be justified, since it is an additional cost versus creating "traditional" wooden products. In this case, the end product application was changed due to the first application not being suitable: the interviewed users expressed no need for reduced time waiting in line, since their decision metrics for choosing a certain food truck was not based on time or quality, but simply cost-centered. This meant that all quality-increasing efforts that add cost were decided to be unsuitable for this application. Instead, a café environment was chosen as the application since the customer needs were more pronounced in this application. This challenge of understanding the customer's needs and behavior is described in established product development literature [7].

The second finding is that the new IoT product system creates challenges in making design decisions on system complexity. A system with a certain level of functionality can be built up on a complex integration of simple components, or a smaller (less complex) system of more complex components, or any variation inbetween. The level of increased complexity in the production system also needs to be assessed in the design process, something that increases demands on the design decisions similar to what Prasad has described as systems engineering principles [10].

The third finding is that some IoT applications and products can easily be introduced into the wood industry production system. With development of micro computers such as Arduinos, communication units can be prepared as modules and assembled to the finished product within the existing production system with little to no change of existing infrastructure. Other solutions can be implemented with established solutions and with traditional techniques for woodworking, or requires smaller development of established techniques and solutions. In this case, sensors and diodes were hidden behind veneer (as in the pick-up station pictured in figure 3) applied in traditional manner as an example of how established solutions can solve the integration of IoT in wood products.

The fourth finding is that the development of an integrated system like the one in the observed case demands an adaptive approach to requirements elicitation and quantification. A continuously updated requirement specification became a way for the development team to manage the complexity of the system. The end product system responds to emotive and functional requirements for the café customer, functional requirements for the barista and production-based requirements. This ties into the second finding regarding the configuration of the system and paints a complex picture of requirements that needs fulfillment.

Figure 3. Pick-up station prototype (photo courtesy of student team).

The fifth finding is that testing this type of system of product becomes significantly more complex than testing multiple independent products, or at least is viewed as more complex by design engineers observed in the case study. The testing of the system was a source of concern for the development team, and was ultimately decided against. This implies a need for better test design tools, to reduce the cost and investment necessary for testing on a system level.

4. Conclusions and further studies

In this paper, the authors have indicated that the integration of IoT into wood industry products could be done within the scope of traditional production development processes, given three prerequisites:

- Inclusion of production aspects early on in the development process (adapting an integrated product and production development approach)
- Application selection in order to increase customer/user benefit of IoT in wooden products
- Selection of technology for physical entities and processing distribution

The design of the product system is an important challenge to solve, since this affects the level of complexity for a multiple of downstream challenges in the development of an IoT system.

Modularization also needs to be taken into consideration, in order to aid assembly and reduce the need for redesign of the production system. The level of modularization is also dependent on the product system design. Henriksson [8] has suggested an increased focus on material selection and interfaces when investigating modularization efforts, something that could be applied to these product types as well. If that is the case, sensors and integrated technology should be viewed as one material, with special properties (the limiting material properties of all included materials are combined into one “meta-material”). This should be further investigated in future studies, to evaluate whether this interpretation of materials are useful or if another approach is needed.

More production technologies should also be developed towards managing the integration of technology and sensors, in order to expand the design space for design engineers working with IoT products in wood-based materials.

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