FOM Hochschule für Oekonomie & Management
Hochschulzentrum Düsseldorf

Seminar Paper

in the study program
Wirtschaftsinformatik - Business Information Systems
Bachelor of Science (B.Sc.)

about the topic

Opportunities and threats when using Indoor Navigation in warehouses

written by
Frederik Reiff

First reviewer	Prof. Dr. Martin Przewloka
Matriculation number	544582
Date of submission	2021-07-31

Contents

Abbreviations

DC	Direct Current
IoT	Internet of Things
RFID	Radio Frequency Identification
RSS	Received Signal Strength
RTLS	Real Time Location System
SWOT Analysis	Strengths, Weaknesses, Threats & Opprtunities Analysis
UWB	Ultra Wide Band

1 Introduction

1.1 Problem Statement

In order for companies to bring their products to their customers, they need to create a logistic distribution chain. One of the biggest parts of such a distribution chain is a warehouse. Warehouses store materials as well as manufactured goods and everything that may be distributed. They give a structure to the logistic operations, but the benefits of warehouses come with monetary impacts as approximately 20 per cent of the total costs in a supply chain are related to logistic costs.[1] As automation is known for its financial impact for companies, it may be a good opportunity for logistic service providers to consider different potentials in the field of automation. Not always is automation the key for improving the efficiency of a warehouse, there are risks and threats that should be considered. Warehouse automation consists of multiple categories in which Indoor Navigation is one of them. In general the more you combine digital processes with physical process automation the closer you get to a self managing warehouse. According to the Oracle Netsuite, warehouse management systems and mobile scanning devices are one of the first things a warehouse can implement to reach a higher automation state. If the warehouse is supposed to reach a highly automated state, you have to consider Internet of Things solutions as well as wireless telemetry. Furthermore, one of the high-automation features are navigation systems.[2] As implementing such IT solutions is very expensive, it is an important strategic decision whether to jump on the automation train completely or only for a smaller selection of features. Implementing the technical requirements will not be enough for most warehouses as other IT-systems have to be configured or even changed to support and integrate the new automation process in the companies existing logistic chain and infrastructure.

1.2 Objectives

The chapter 1.1 describes the challenges companies face when they want to automate their business and especially their warehouses with the help of Indoor Navigation. In this seminar paper the focus is on companies' opportunities and threats when using Indoor Navigation in warehouses. As there are a lot of different technologies that can be implemented in different ways, this paper focuses on the opportunities and

[1] cf. Baker and Halim, 2007, p. 6.
[2] cf. NetSuite.com, 2020.

threats of Radio Frequency Identification and Real Time Location Systems based on Ultra Wide Band. With this information in mind, it should be evaluated how those technologies can be used in warehouses and furthermore, what benefit a combination of multiple technologies creates for a business and which weaknesses and threats can be reduced by a combination of those. The goal of this seminar paper is to give a scientifically based evaluation of the mentioned questions.

1.3 Approach

In chapter 1.1 the motivation for this seminar paper was described as well as the general issues companies are facing when considering an automation for their supply chain or in more detail their warehouses. One part of this automation process is the use of Indoor Navigation techniques in warehouses. As written in chapter 1.2, those Indoor Navigation techniques are the focus of this seminar paper. In order to fulfill the objectives, a technical foundation will be given as a preparation for the following analysis. The technical foundation focuses on two kinds of technologies in the sector of Indoor Positioning technologies. For both of these systems, Ultra Wide Band and Radio Frequency Identification, the technology will be briefly explained as well as the general characteristics. After the technical foundation was given in chapter 2, chapter 3 focuses on the analysis of Indoor Navigation in warehouses. For answering the objectives from chapter 1.2 a SWOT analysis will be conducted in chapter 3.1. A SWOT analysis contains two parts, on the one hand the strengths and weaknesses and on the other hand the opportunities and threats. The SWOT analysis will be focusing on a combination of both, RFID and RTLS, as this combination is often seen on the market. The strengths and weaknesses show the advantages and disadvantages of the technologies in general by scientifically researching literature to prove the arguments. The opportunities and threats however will focus on the advantages and disadvantages when using those technologies in the warehouse itself for the implementation of Indoor Navigation. After the analysis is completed, the results will be interpreted in chapter 3.2. Following is a final conclusion that will give an answer to the research questions and furthermore, it provides an outlook for the future use of Indoor Navigation in warehouses.

2 Technical Foundation

2.1 UWB based Real Time Locating System

A RTLS is used to identify any tagged object inside an area of coverage in a fraction of seconds. The equipment that is needed is usually an embedded electronic device with the ability to communicate to other devices in the near distance or inside the whole coverage area with the help of the system itself. In order to create such an area, it is needed to have at least three dedicated points, called anchors or beacons. This results out of geometrical logic whereas 3 points are needed in an two dimensional environment to reliably get the position of any object.[3] The object to be tracked is equipped with an embedded device, called a tag. This tag is the point you receive the position of when placing it inside an area containing at least three anchors.[4] The following figure shows a simple structure of a RTLS system. There are the named anchors and the tag is located in this area and its position can be determined by the arrows shown in red by different signal strengths from the tag to the anchors.[5]

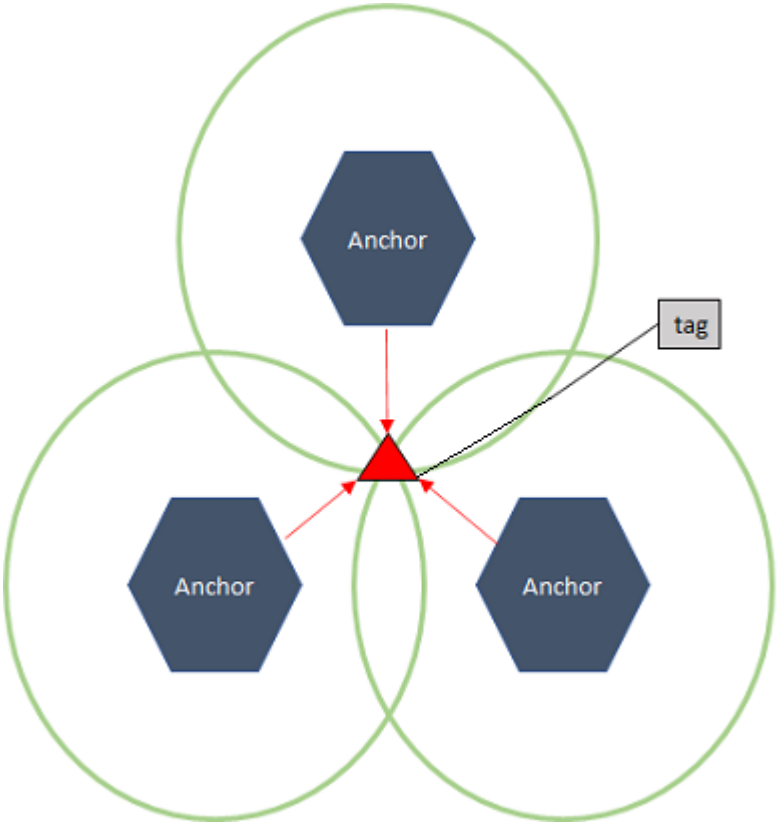

Figure 1: UWB positioning method[5]

[3] cf. Chantaweesomboon et al., 2016, p. 5.
[4] cf. Man et al., 2007, p. 3ff.
[5] cf. Huang et al., 2017, p. 136.

In order to get the distance between the tag and each anchor it is needed to have some kind of radio frequency, the calculating of the distance is then handled by the location engine, there are multiple options to read the distance. The most common method is to analyse the Received Signal Strength at the three anchors, but it is possible to use technologies like the angle of arrival or the time of arrival as well. The calculation uses location estimation algorithms like trilateration, triangulation and multilateration. The location engine needs server resources to calculate the position of each object with the help of algorithms. However, radio frequencies can interfere with each other similar to light and any other wave, therefore, using the RSS may not be the best option when having multiple objects to be tracked. In this case a time of flight technology can be used together with ultra wide background-color in order to accurately identify positions of objects. A common commercial implementation is the DW1000 IC by DecaWave based on the IEEE 802.15.4 standard.[6]

2.2 Radio Frequency Identification

Radio Frequency Identification as a stand alone technology is used to identify objects or persons in the near area. In order to use RFID multiple components are needed. Usually the two required components are the RFID tag and the reader.[7] The RFID tag can be separated into two different categories, one of them is a passive tag, the other one is the active tag. A passive tag contains an antenna and a microchip handling the communication to the tag and furthermore, it contains data in its memory. The active RFID tag has all the elements a passive tag has, but it adds a battery to the circuit. A passive RFID tag gets its energy from the reader via a electromagnetic field. A reader contains an antenna as well, furthermore, it has an interface responsible for encoding and decoding the data. The modulator is responsible to convert the data from a digital signal into a radio frequency which the antenna can then emit. The whole reader also has a controller which manages the different components of itself. In addition to that, the controller can handover the data received by a tag to servers, hosting the applications that require the data of the RFID tag.[8]

The communication between the reader and the RFID tag can happen without a direct line of sight.[9] The data transfer needs multiple prerequisites performed by the reader. If the tag is based on a passive design, one step is to transfer energy

[6] cf. Chantaweesomboon et al., 2016, p. 5.
[7] cf. Yamada et al., 2005, p. 1.
[8] cf. IDTechEx, 2004, p. 1.
[9] cf. Chen and Thomas, 2001, p. 1.

to the tag, this energy can be received once the RFID tag comes inside the reach of the reader's electromagnetic field created by the antenna which is built like a coil. Depending on the used RFID system, the frequency of the electromagnetic field can be in the kilo hertz or mega hertz spectrum. Once the tags and the readers coil are close enough to each other they built up a loop in which direct current can transfer.[10] The readers second job is to provide a carrier signal whose purpose is to transfer power and furthermore, transporting the data of the tag to the reader. This is often done with 13.56 mega hertz frequency when a high frequency RFID system is used. Some tags may have a clocking circuit, if so, the reader will be used to synchronize both of the clocks.[11] The third job the reader has to perform is to encode, decode, modulate and end-modulate the signals which is performed by the modulator and the coder built in in the reader.[12]

3 Analysis of Indoor Navigation in Warehouses

3.1 SWOT Analysis

Strengths

One strength of using RFID is that the tag itself needs no battery as long as it is passive. Attaching tags to each pallet is therefore quite cheap and takes little effort when mounting them onto the item to be tracked. The biggest advantage of such a passive tag is that there is no charging needed, because the energy is emitted via a magnetic field built up by the reader. This removes the need for infrastructure elements like charging stations for each tag. Moreover, there is no permanent power consumption as the electric field only needs to be activated while reading a tag.[13] If one wants to have an encrypted communication between RFID tag and reader, there is an option to use the first communication string, with a length of 128 bits, to encrypt and later decode the communication by the reader.[14] There are multiple ways of communication between a RFID tag and the reader, depending on which method is used, one can have different response times. In general, the error rate is higher if the response is expected to arrive faster, however, there are multiple ways of reducing the error rate with support of algorithms which results in response times

[10] cf. Chen and Thomas, 2001, p. 1.
[11] cf. Chen and Thomas, 2001, p. 2.
[12] cf. IDTechEx, 2004, p. 1.
[13] cf. Man et al., 2007, p. 4.
[14] cf. Man et al., 2007, p. 4.

of only one millisecond for every command.[15]
In addition to the strengths of RFID, RTLS has its own strengths too. RTLS is a great solution for tracking objects inside a large area with high accuracy. When tracking static objects, RTLS combined with UWB can cover areas of 160 meters with only three anchors while still having an accuracy of up to 15 centimeters.[16] Adding anchors to the area that is to be covered may give a higher accuracy depending on the placement. When the smallest distance of any object to the nearest beacon is smaller or equal to 30 meters, an error rate of only 2.3% is to be expected. As the error rate grows linearly with the distance, it is in general the best approach to place anchors in a way that they have the same distance to the next anchors like for example a triangle.[17] As long as the UWB frequency space is not already used by any other system, UWB is also a good way to use in warehouses having a lot of other radio signals inside the building like wifi as the electrical noise has no major impact on the performance. UWB based RTLS technologies in general profit from the low latency which can be achieved with different kinds of algorithms.[18] Due to low latency it can be useful as a positioning system for autonomous vehicles as it is possible to locate moving objects in a small amount of time.[19] Furthermore, RTLS has no need to have a line of sight to the object as the objects position can be estimated with the help of projection algorithms.[20]

Weaknesses

Two of RFID's weaknesses are security and privacy. In the past this technology got criticism for the supposedly bad safety standards.[21] However, there are implementations which are secure enough that they can be used for paying in groceries stores.[22] The level of security can be raised by having security by design. As described in the technical foundation nowadays most RFID readers have an on-board coder which is responsible for encrypting and decrypting the communication between the RFID tag and the reader.[23] As the data can now be stored encrypted with hashing algorithms or other encryption technologies on the RFID tag itself, privacy issues like reading the tag from an unwanted external reader are no longer possible.[24] It should always be evaluated which data is stored on the tag as its data is still readable if the code is

[15] cf. Man et al., 2007, p. 5.
[16] cf. Esmaeilnejad, 2015, p. 36f.
[17] cf. Astafiev et al., 2019, p. 3f.
[18] cf. Mayer et al., 2019, p. 523.
[19] cf. Jin et al., 2019, p. 9f.
[20] cf. Schroeder et al., 2007, p. 92.
[21] cf. Heath, 2020.
[22] cf. Markman, 2020.
[23] cf. Henrici, 2008, p. 24ff.
[24] cf. Henrici, 2008, p. 47.

known. It is not possible to track by who a tag was read inside the tag itself as they have no log storage. In addition, the integration of RFID into a warehouse can be expensive as every item and/ or pallet needs a RFID tag which is way more expensive than a simple bar code. The benefits of a RFID based system are marginal if they are not necessary for an automated warehouse.[25] Moreover, the communication of a RFID tag to its reader can be affected by electrical noise, especially when trying to read more than one tag at the same time, the response signals can interfere, an anti-collision system can reduce this electrical noise by timing the tags, but other radio signals still can lead to issues. If a small area still contains too much tags it is impossible to read all of the tags.[26] RTLS as a technology fulfilled with UWB has weaknesses too, one of the biggest weaknesses is that this technology is not passive, therefore, the tag and the anchors need electricity. While the power supply for the anchor is not a big problem as it is a stationary device, the power supply for the tag can be quite difficult to manage as the tag is often mounted on a moving object and therefore, it needs a battery. The power management in particular makes it hard to estimate the remaining battery capacity as the energy consumption is often fluctuating.[27] It can happen that the area that is covered by the UWB signals may interfere with other technologies which might lead to issues for the RTLS technology and other technologies like collision avoidance systems.[28]

Opportunities

The RFID technology has a lot of strengths that could lead to a lot of opportunities for warehouses when implementing an Indoor Navigation system. RFID tags can store information about the object they are placed on, they can for example store meta information about a pallet like a pallet id. This pallet id can be looked up by the warehouse application to get more information about the pallets contents and its path in the supply chain. RFID tags are not directly relevant for autonomous vehicles to navigate, but they can serve as a logging support. A forklift can have an onboard RFID reader. Once a pallet is on the fork, the tag comes into the electromagnetic field of the reader and therefore, the warehouse application knows that this pallet is now on a dedicated forklift. In the next step the warehouse application looks up the pallet and sends the forklift the destination inside the warehouse. With this information the application triggers an order for the forklift to drive to the destination and drops of the pallet.[29] The drop off of the pallet can

[25] cf. Véronneau and Roy, 2009, p. 701.
[26] cf. Chen and Thomas, 2001, p. 85ff.
[27] cf. Costanzo et al., 2017, p. 235 ff.
[28] cf. Alarifi et al., 2016, p. 27f.
[29] cf. Sarma, 2004, p. 54ff.

be documented as the reader recognizes that the pallet's RFID tag is no longer inside its readable area. The strengths of an UWB based RTLS system create many opportunities for warehouses. The biggest opportunity arising from the use of UWB RTLS systems is that they can cover big areas with high accuracy as described in the strengths. As the average American warehouse is around 25000 feet in size according to US Energy Information Administration, it is very important for Indoor Navigation systems to provide the possibility to cover big areas. Furthermore, high accuracy is needed to use the space efficiently and prevent accidents.[30] In addition RTLS can be integrated for cheap prices as you only need a few beacons to cover the whole warehouse area.[31] Often the objects to be tracked by the RTLS are as big as forklifts therefore, the total costs for tags are very favourable.[32]

Threats

Even though the implementation of Indoor Navigation techniques offers many opportunities, it creates a few threats too. Integration of automated processes into an warehouse is a decision that starts long-term projects with a huge grade of planning and designing.[33] If the integration is not well planned, it can lead to a deterioration of the previous state as the potential for errors is greater and the processes do not run smoothly.[34] The combination of RFID and RTLS is very unique for every single warehouse which results in an individual implementation and less chances of standardization. Those disadvantages could cost a lot of money as an initial investment.[35] Another problem that arises with partial automation is that the connection between the automated processes and the manual processes often requires an adaption on the employees side. This adaption of new processes can lead to resistance as changes in the area of responsibility may not be accepted. The impact for such resistance would be huge for the performance of all employees working for the company.[36] In addition to the mentioned risks, one of the biggest threats companies face is the migration of legacy systems to the new warehouse management applications supporting Indoor Navigation as the stored data needs to be converted and the existing processes needs to be adopted and redefined.[37]

[30] cf. "U.S. Energy Information Administration - EIA - Independent Statistics and Analysis", 2020.
[31] cf. Sun and Ma, 2017, p. 87.
[32] cf. Sun and Ma, 2017, p. 89.
[33] cf. Baker and Halim, 2007, p. 130-136.
[34] cf. Säfsten et al., 2007, p. 25-36.
[35] cf. Baker and Halim, 2007, p. 135f.
[36] cf. Baines, 2004, p. 448-462.
[37] cf. Lototsky et al., 2019, p. 78-82.

3.2 Interpretation of the Results

Based on the earlier analysis, several conclusions can be drawn from the SWOT analysis. First of all, the combination of the Radio Frequency Identification and the Ultra Wide Band based Real Time Location System technology brings many advantages when it comes to the provision of navigation of autonomous vehicles inside a warehouse as it eliminates multiple weaknesses of the stand alone systems. While RFID is very useful for controlling the stock and keeping track of items inside the warehouse, which way they took and where their destination is. The navigation between the current position and the target location can be accomplished by the RTLS system as it can cover the whole warehouse and is precise enough to coordinate the navigation of multiple vehicles via path algorithms with barely any delay. Accordingly there are whole processes that have to be implemented to make use of RFID and RTLS.
RFID should step in as soon as any good enters the warehouse as it is responsible for maintaining the stock data. When it comes to the movement of goods or pallets by forklift trucks RTLS comes into play as it is responsible to provide the data the applications need for creating a path which the trucks need to drive. A RFID scanner mounted onto a forklift makes it possible to track items inside a warehouse and furthermore, it provides more reliable data on whether a forklift has successfully picked up and dropped off an item. However, the implementation and adaption of existing warehouse processes is very critical as the businesses often need to keep their operation going while implementing changes. Consequently a good change management needs to be performed in order to prevent work stoppage. If the risk assessment is not carried out carefully, major incidents cannot be avoided. This could already jeopardise a partial automation project. In addition to the risks associated with implementation, there can also be problems with automated operations in regular business. As the technology is still in the maturity phase, it is currently difficult to achieve sufficiently low error rates and furthermore, the precision is often not high enough for forklifts to pick up pallets which would need to be covered by other technologies such as video camera analysis. The costs for the hardware of the technologies are low however, the initial costs for the integration are quite high, especially when new applications need to be integrated in the processes. A lot of potential technical issues can be covered when for example designing a warehouse infrastructure, it should be considered which application or system uses what kind of frequency in order to keep the functionality of the different systems without reducing the number of radio signals inside the building. One technical issue might be especially problematic in a warehouse when using RFID as it is not possible to

read RFID tags when there are condensed in one small area. As a pallet can store a lot of items depending on the size, it might not be possible to give every item a tag. Moreover, some items are too small to give them a tag, but it is essential for an RFID system that every good has tag. A solution for that problem would be to track only pallets and not every item on the pallet with RFID tags.

4 Conclusion

Automation has become one of the key drivers of the modern economy therefore, it is a reasonable question when warehouses will be automated. As the transportation of goods inside a warehouses is one of the core business operations of a warehouse, Indoor Navigation can be a feasible solution for automating this operation. RFID and RTLS based on UWB are two of the most relevant technologies influencing the core operation as they show less theoretical weaknesses than other technologies like Bluetooth. Even if these technologies work well in theory, their practical use involves many risks that are mainly business decisions rather than technical issues. The automation of a core operation has a high risk and therefore, it might not be worth it to change the business dramatically with the risks of loosing control and having outages in the daily operation. The biggest challenge for companies is the migration of processes, it would be more feasible to design a warehouse from scratch with the best technology, but it is not a suitable solution as it would be too expensive, therefore, businesses have to try to automate small parts of their operations. When it comes to Indoor Navigation this is probably not possible as the operation that is automated is one of the core operations. If a distribution company decides to automate their indoor warehouse transportation they need to prepare the migration with great detail which means that it is necessary to perform risk assessments and a lot of design iterations. Furthermore, automation is often a controversial process for employees and it might have an impact for the performance of the whole business. The future will show whether the automation of manual steps is worthwhile or whether it is not better to rely on alternative in-house transport, such as conveyor belts, in the sense of just-in-time production. Even if Indoor Navigation in warehouses may not be the primary operation to automate, the technologies RFID and RTLS based on UWB will improve as the research on those technologies has risen a lot in the past year with the focus of automation for businesses.

Bibliography and sources

Alarifi, A., Al-Salman, A., Alsaleh, M., Alnafessah, A., Al-Hadhrami, S., Al-Ammar, M. A., & Al-Khalifa, H. S. (2016). Ultra wideband indoor positioning technologies: Analysis and recent advances. *Sensors*, *16*(5), 707.

Astafiev, A., Zhiznyakov, A., & Privezentsev, D. (2019). Development of indoor positioning algorithm based on bluetooth low energy beacons for building rtls-systems. *2019 International Russian Automation Conference (RusAutoCon)*, 1–5.

Baines, T. (2004). An integrated process for forming manufacturing technology acquisition decisions. *International Journal of Operations & Production Management*.

Baker, P., & Halim, Z. (2007). An exploration of warehouse automation implementations: Cost, service and flexibility issues. *Supply Chain Management: An International Journal*.

Chantaweesomboon, W., Suwatthikul, C., Manatrinon, S., Athikulwongse, K., Kaemarungsi, K., Ranron, R., & Suksompong, P. (2016). On performance study of uwb real time locating system. *2016 7th International Conference of Information and Communication Technology for Embedded Systems (IC-ICTES)*, 19–24.

Chen, S. C., & Thomas, V. (2001). Optimization of inductive rfid technology. *Proceedings of the 2001 IEEE International Symposium on Electronics and the Environment. 2001 IEEE ISEE (Cat. No. 01CH37190)*, 82–87.

Costanzo, A., Dardari, D., Aleksandravicius, J., Decarli, N., Del Prete, M., Fabbri, D., Fantuzzi, M., Guerra, A., Masotti, D., Pizzotti, M., et al. (2017). Energy autonomous uwb localization. *IEEE Journal of Radio Frequency Identification*, *1*(3), 228–244.

Esmaeilnejad, S. (2015). *Accuracy assessment of uwb rtls for tracking resources on construction sites* (Master's thesis). Graduate Studies.

Heath, R. (2020). Rfid credit cards: Should you worry about protection? https://www.bankrate.com/finance/credit-cards/rfid-credit-cards-should-you-worry-about-protection/

Henrici, D. (2008). *Rfid security and privacy: Concepts, protocols, and architectures* (Vol. 17). Springer Science & Business Media.

Huang, S., Guo, Y., Zha, S., Wang, F., & Fang, W. (2017). A real-time location system based on rfid and uwb for digital manufacturing workshop [Manufacturing Systems 4.0 – Proceedings of the 50th CIRP Conference on Man-

ufacturing Systems]. *Procedia CIRP*, *63*, 132–137. https://doi.org/https://doi.org/10.1016/j.procir.2017.03.085

IDTechEx. (2004). Basic components of an rfid system. https://www.idtechex.com/fr/research-article/basic-components-of-an-rfid-system/42

Jin, T., Sadeghpour, F., & Jergeas, G. (2019). Feasibility investigation and accuracy assessment for a new generation uwb tracking system. *Proceedings, Annual Conference-Canadian Society for Civil Engineering*, 1–10.

Lototsky, V., Sabitov, R., Smirnova, G., Sirazetdinov, B., Elizarova, N., & Sabitov, S. (2019). Model of the automated warehouse management and forecasting system in the conditions of transition to industry 4.0. *IFAC-PapersOnLine*, *52*(13), 78–82.

Man, A. S., Zhang, E. S., Lau, V. K., Tsui, C. Y., & Luong, H. C. (2007). Low power vlsi design for a rfid passive tag baseband system enhanced with an aes cryptography engine. *2007 1st Annual RFID Eurasia*, 1–6.

Markman, J. (2020). Rfid: Tiny wonders behind friction-free grocery shopping. https://www.forbes.com/sites/jonmarkman/2020/04/28/rfid-tiny-wonders-behind-friction-free-grocery-shopping/

Mayer, P., Magno, M., Schnetzler, C., & Benini, L. (2019). Embeduwb: Low power embedded high-precision and low latency uwb localization. *2019 IEEE 5th World Forum on Internet of Things (WF-IoT)*, 519–523.

NetSuite.com. (2020). Warehouse automation: The how, when & why. https://www.netsuite.com/portal/resource/articles/inventory-management/warehouse-automation.shtml

Säfsten, K., Winroth, M., & Stahre, J. (2007). The content and process of automation strategies. *International Journal of Production Economics*, *110*(1-2), 25–38.

Sarma, S. (2004). Integrating rfid: Data management and inventory control are about to get a whole lot more interesting. *Queue*, *2*(7), 50–57.

Schroeder, J., Galler, S., Kyamakya, K., & Kaiser, T. (2007). Three-dimensional indoor localization in non line of sight uwb channels. *2007 IEEE International Conference on Ultra-Wideband*, 89–93.

Sun, E., & Ma, R. (2017). The uwb based forklift trucks indoor positioning and safety management system. *2017 IEEE 2nd Advanced Information Technology, Electronic and Automation Control Conference (IAEAC)*, 86–90.

U.s. energy information administration - eia - independent statistics and analysis. (2020). https://www.eia.gov/consumption/commercial/reports/

Véronneau, S., & Roy, J. (2009). Rfid benefits, costs, and possibilities: The economical analysis of rfid deployment in a cruise corporation global service supply chain. *International Journal of Production Economics*, *122*(2), 692–702.

Yamada, I., Shiotsu, S., Itasaki, A., Inano, S., Yasaki, K., & Takenaka, M. (2005). Secure active rfid tag system. *Ubicomp2005 Workshops*, *5*.

Ehrenwörtliche Erklärung

Hiermit versichere ich, dass die vorliegende Arbeit von mir selbstständig und ohne unerlaubte Hilfe angefertigt worden ist, insbesondere dass ich alle Stellen, die wörtlich oder annähernd wörtlich aus Veröffentlichungen entnommen sind, durch Zitate als solche gekennzeichnet habe. Ich versichere auch, dass die von mir eingereichte schriftliche Version mit der digitalen Version übereinstimmt. Weiterhin erkläre ich, dass die Arbeit in gleicher oder ähnlicher Form noch keiner Prüfungsbehörde / Prüfungsstelle vorgelegen hat. Ich erkläre mich damit einverstanden, dass die Arbeit der Öffentlichkeit zugänglich gemacht wird. Ich erkläre mich damit einverstanden, dass die Digitalversion dieser Arbeit zwecks Plagiatsprüfung auf die Server externer Anbieter hochgeladen werden darf. Die Plagiatsprüfung stellt keine Zurverfügungstellung für die Öffentlichkeit dar.

Mülheim, 30.7.2021 F. Reiff

(Ort, Datum) (Eigenhändige Unterschrift)