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CONTENTS

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ASSESSMENT OF THE POSSIBILITY OF USING BAYESIAN NETS AND PETRI NETS IN THE PROCESS OF SELECTING ADDITIVE MANUFACTURING TECHNOLOGY IN A MANUFACTURING COMPANY

Abstract

The changes caused by Industry 4.0 determine the decisions taken by manufacturing companies. Their activities are aimed at adapting processes and products to dynamic market requirements. Additive manufacturing technologies (AM) are the answer to the needs of enterprises. The implementation of AM technology brings many benefits, although for most 3D printing techniques it is also relatively expensive. Therefore, the implementation process should be preceded by an appropriate analysis, in order, finally, to assess the solution. This article presents the concept of using the Bayesian network when planning the implementation of AM technology. The use of the presented model allows the level of the success of the implementation of selected AM technology, to be estimated under given environmental conditions.

1. INTRODUCTION

Additive manufacturing (AM) technologies are based on methods of manufacturing products from materials, e.g. metals, metal alloys, thermoplastics, ceramics or composites, mainly using their layering (Goole & Amighi, 2016). In contrast to subtractive methods, a number of benefits are seen in the use of AM technology, including maximum use of the material with a simultaneous reduction of post-production waste, the production of elements with a complex structure and shape that could not be achieved with traditional methods (Patalas-Maliszewska, Topczak & Kłos, 2020).

By characterising additive technologies, they can be divided into the following methods: layered extrusion of molten thermoplastic (*Fused Deposition Modelling, Fused Filament Fabrication*), curing of the applied material with UV (*PolyJet, ProJet*), lamination of material layers (*Laminated Object Manufacturing, Plastic Sheet Lamination*), curing photo-sensitive resin (*Stereo-lithography, Digital Light Processing*), sintering powders (*Selective Laser Melting, Direct Metal Laser Sintering)* and curing materials using a direct energy source (*Laser Engineering Net Shape, Electron Beam Additive Manufacturing*) (Patalas-Maliszewska, Topczak & Kłos, 2020).

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Additive technologies are used in modelling (Nagarajan, Hu, Song, Zhai & Wei, 2019), prototyping (Ahmed, 2019) and the repair and regeneration processes of machines and devices (Penaranda, Moralejo, Lamikiz & Figueras, 2017). According to the research conducted at the end of 2019, in western Poland, among 250 production companies, constituting 1% of production companies from the metal and automotive industries, it appears that approximately 44% of respondents declare the use of AM technology, of which approximately 46% are metal industry companies and approximately 42% are automotive industry companies. It was found that approximately 16% of metal industry companies are interested in implementing AM technology, while in the case of the automotive industry, about 36% of companies are interested in implementing AM technology (Patalas-Maliszewska, Topczak & Kłos, 2020).

It should be borne in mind that in order to achieve strategic goals, manufacturing companies are forced to make decisions in the area of their activity (Patalas-Maliszewska, 2012). The process of implementing AM technology in a production company is an investment that requires appropriate planning and forecasting. The analysis conducted on decision support models allows information and the appropriate planning of the project to be used effectively. In the literature (Biedermann & Taroni, 2006; Patalas-Maliszewska & Krebs, 2015; Constantinou, Fenton & Neil, 2016; Dahire, Tahir, Jiao & Liu, 2018; Fierro, Cano & García, 2020), one can find studies in which tools are presented that allow knowledge to be visualised in a qualitative and quantitative manner, using, *inter alia*, algorithms based on probability calculus. The emerging solutions and changes caused by the **Fourth Industrial Revolution**, *known as* ***Industry 4.0***, force manufacturing companies to analyse and evaluate potential implementations in the area of new manufacturing technologies. This article briefly describes AM additive manufacturing technology. Based on an analysis of the literature, the research gap in the area of the use of Bayes and Petri nets in the process of technology selection in manufacturing companies was identified and a comparative analysis of the network was carried out, taking into account the possibility of their implementation into the decision-making process in the field of the implementation of AM technology. The authors have presented the Bayes network model for the metal and automotive industries. On this basis, it is possible to determine the level of interest in AM technology and thus – to assess the possibility of its implementation in the enterprise.

2. CHARACTERISTICS OF PETRI NETS AND THE BAYESIAN NETWORK

2.1. Petri nets

Petri nets can be defined as a formalised model of processes enabling them to be accurately verified through analysis of basic network constructors (places, transitions, arcs and tokens). Petri network topology is a coherent, bipartite directed, graph with static features and dynamic, where places, transitions and arcs are used to model the static structure of processes and tokens, thus allowing their dynamics to be modelled (Kabir & Papadopoulos, 2019; Gao, Xu, Zhao, You & Guan, 2020; Giebas & Wojszczyk, 2018).

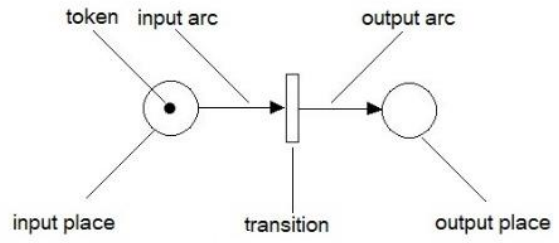

Fig. 1. Constructors of Petri nets

The structure of a classical Petri net is defined by an ordered four N = (P, T, I, O), where: P={p1 , p2 , p3 ,…, pn} is a finite set of places; T={t1, t2 , t3 ,…, tm} is a finite set of transitions (transitions); I: P × T → N is a function of the inputs, N is the number of edges between pit, O: T × P → N is a function of outputs, N is the number of edges between t and p. Petri net state, also called tagging, is a function representing a set of places into a set of natural numbers representing the number of tokens in a given place (Kabir & Papadopoulos, 2019; Gao, Xu, Zhao, You & Guan, 2020).

2.2. Bayesian network

The Bayesian Network (BN) algorithm is used in quantitative and/or qualitative modelling and forecasting. The functionality of the Bayes network enables the use of expert data where historical data is insufficient; this allows the collection and classification of knowledge through inference based on premises. The Bayesian network is based on two structures: directed and acyclic graph (1) and the probability table (2). The nodes included in the graph can be modified using logical functions, thus creating a network structure including a set of rules and facts (Wieleba, 2011; Aguilera, Fernandez, Fernandez, Rumi & Salmeron, 2011; Ramírez-Noriega, Juárez-Ramírez & Martínez-Ramírez, 2017; Karayuz & Bidyuk, 2015).

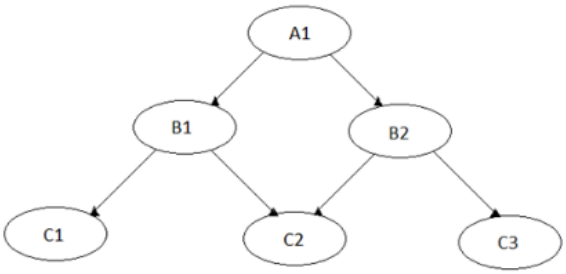

Fig. 2. Bayesian network structures over the set U = {A1, B1, B2, C1, C2, C3}, convergent connections

According to Bayes' theorem, if A and B are two random events and it is known that B has occurred, then the "a posteriori probability" of the occurrence of A, given that B has occurred, can be defined as:

$$P(A/B) = P(B/A)P(A)/P(B) \quad (1)$$

where P(A) and P(B) are the "a priori probability" of events A and B (Kabir & Papadopoulos, 2019).

2.3. Implications

Based on an analysis of the literature, a number of cases of the use of Petri nets and Bayes nets in modelling and evaluation of processes have been observed.

Examples of the application of the Bayes network have been described in the literature by Gran & Helminen (2001) – the authors used the BN model to assess the reliability of nuclear power plants. Models based on Bayesian networks have also been used to analyse the reliability of power systems and military machines (Yongli, Limin, Liguo & Yan, 2008; Daemi, Ebrahimi & Fotuhi-Firuzabad, 2012) as well as in modelling the mechanics of fracture (Nasiri, Khosravani & Weinberg, 2017). In the literature, there are also reports on the implementation of the Bayes network functionality in other areas, such as forensics (Biedermann & Taroni, 2006). Bayes' networks are used in risk assessment applications due to their flexible structure and the ability to include, *inter alia*, failure modes and states, components and systems, the uncertainty of system behaviour and data failure, during analysis. An additional advantage of BN is the ability to perform diagnostic analyses (Kabir & Papadopoulos, 2019). Bayes networks are used in the processes of estimating the optimal security threshold for complex industrial processes, where a dynamic risk assessment methodology, based on many process variables in real time, is proposed (Rebello, Yu & Ma, 2019). There have been attempts to prove the validity of the use of the probabilistic expert system as an industrial support tool, in preventing defects in the process and contributing to the increase in productivity (Rosário, Kipper, Frozza & Mariani, 2015). The work of Rosário, Kipper, Frozza & Mariani (2015) presents technical mapping and tacit knowledge acquisition in industry, with the participation of the Bayes network, modelling tacit knowledge in order to express it and present it in the form of rules to be used in production processes. In the work of Patalas-Maliszewska, Feldshtein, Devojno, Śliwa, Kardapolava & Lutsko (2020), the effectiveness of the data mining technique based on the Bayes algorithm was demonstrated for the analysis of trends in additive production processes and the practical application of knowledge, obtained using the Bayes algorithm. In the work of Shin, Kim & Lee (2015), an analysis of a production system with three volumes, *viz.*, ***planned production volume, quantity of delivered product*** and ***stock volume*** was performed, where it proved necessary to consider situations in which these three values would probably change due to various factors. For this purpose, a dynamic Bayesian network (DBN) was used, which is an extension of its basic form *and is also known as the belief network* for stochastic processes.

The Petri net, as a formalised graphical and mathematical tool enables modelling and analysis of the dynamic behaviour of systems, finding application in the case of visual representation of knowledge and inferential phenomena in expert systems (Yanrong, Hu, Yang, 2004; Louazani, & Sekhri, 2020). The possibility of using the network for the analysis and modelling of discrete events (Cassandras & Lafortune, 2008) is seen as a desirable phenomenon in the logical understanding of behaviour in the expert system (Liu, You, Li & Tian, 2017; Liu, Lin, Mao & Zhang, 2018). Their functionality is implemented, inter alia, in systems used to ensure safety, reliability and risk assessment. (Kabir & Papadopoulos, 2019). In the work of Lacheheub, Hameurlain & Maamri (2020), Petri nets have also found application in the analysis of business processes. The use of the functionality of the Petri nets assumed that consistency would be assured in the perspective of resources, by using the network to verify the correct execution of the business process with the resources initially allocated, based on some properties and choosing the path of similar low-consumption services. In the work of

Mansour, Wahab & Soliman (2013), Petri nets were used as a modelling tool for the construction of models for the diagnosis of faults in an element or section of a power plant, aimed at accurate fault diagnosis. The implementation of this type of solution aims to provide support and assistance in making decisions in critical situations and reducing the delay of recovery post-disaster. The development of the manufacturing sector has evolved supply chains into highly complex, dynamic and concurrent systems. Petri nets are characterised by formality and have been successfully tested in hierarchical modelling, analysis and in the control of distributed systems, which is desirable in the case of supply chain design (Fierro, Cano & García, 2020) and is a challenge for manufacturing companies in the area of the requirements of **Industry 4.0**.

In the case of the network model analysed, supporting the decision-making process in the implementation of AM technology, the authors decided to present the concept of using the Bayesian network as a tool that takes into account uncertain conditions based on the probability algorithm.

3. THE CONCEPT OF USING THE BAYESIAN NETWORK IN THE PROCES OF PLANNING THE IMPLEMENTATION OF AM TECHNOLOGY

At the end of 2019, research was carried out at 250 in metal and automotive industry production companies in western Poland, in order to recognise the needs and implementation status of additive manufacturing (AM). For this purpose, a dedicated questionnaire, consisting of closed and open questions was developed. 107 automotive industry companies and 125 metal industry companies were selected to build a tool supporting the process of selecting additive manufacturing technology. Two models of the Bayes network were designed in the study, for the metal and automotive industries, respectively. It was decided to use the research results containing answers regarding currently used AM technologies (1), the application of AM technology (2), used materials (3), interests in research on materials (4), factors determining the implementation of AM technology in the enterprise (5) and AM technologies that manufacturing companies are interested in (6). Based on selected questions present in the questionnaire, the nodes of the Bayesian network were designed. Where everyone had two alternatives suggesting the company's answer: YES – State 1 and NO – State 0, the results of the surveys regarding the question about the interest in the implementation of AM technology were aggregated and formed the basis for the result node in the Bayes network.

It is assumed that implementing the research results obtained *vis-à-vis* the designed Bayes networks and the network learning process carried out, will allow information to be obtained regarding the level of interest in implementing the selected AM technology in the manufacturing companies of a given industry.

The network modelling process included:

1. Designing a network for the metal and automotive industries, consisting of nodes corresponding to the following areas analysed:
   - AM technologies used by manufacturing enterprises (P9.1 nodes): FDM, EBM, laser technologies, processing technologies, welding, lamination and heat bonding technologies;
   - AM technology applications (P9.2 nodes): production, prototyping;

- materials used in production processes (P9.3 nodes): metals, other alloys, composites, polymers;
- materials on which the company wants to conduct research (P6 nodes): metals, other alloys, composites, ceramics, polymers;
- factors influencing the decision to implement AM technology (P10.2 nodes): Reduction of production costs (A), the effective use of material (B), freedom in product design (C), no assembly stage (D), personalisation of the product, according to specific, customer requirements (E), quick response to market needs (F), optimisation of product functions (G);
- AM technologies in which enterprises are interested (P10 node): metal industry – DMLS, SLS, welding; automotive industry – FDM, LOM, DLP, PolyJet, DMLS, SLS, SLA, EBM.

2. Analyzing the results of the questionnaire research and then selecting and preparing data corresponding to individual nodes.
3. Network learning (*each separately*) on the basis of the data prepared. The result was a graphical representation of the probability, determined in the network nodes, i.e. its initial state together with the strength of the relationship between the nodes.

The next step was to carry out network operation experiments and tests. The procedure included declaring the occurrence of selected states for individual network nodes and observing the probability obtained in the result node.

The GeNIe Modeler version 2.1 programme was used to build the Bayes network. The network for the metal and automotive industries was similar in design. Its result is the node P10_interest in AM. After science, for the metal industry network P(P10 = State1) = 31% (Fig. 3) and for the automotive industry P(P10 = State1) = 41%.

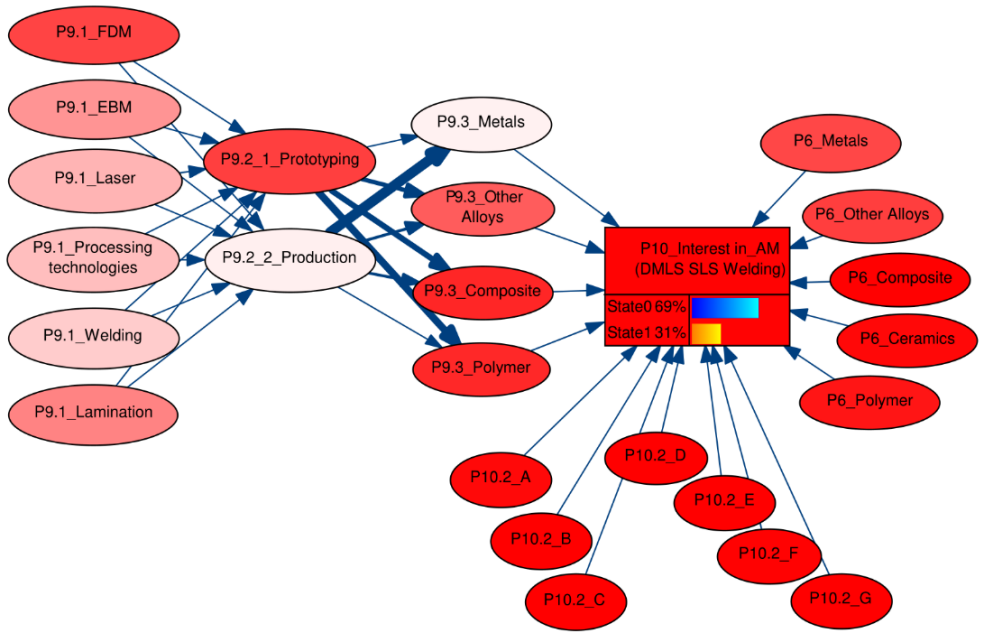

Fig. 3. Bayesian network for the metal industry

The models in Fig. 3 show the effect of the sensitivity analysis, i.e. the strength of the relationship between nodes. The bigger it is, the thicker the association. The intensity of the red nodes indicates the strength of the interaction with respect to the result node.

In order to verify the impact of the network vertices, in relation to P10 = state1, a "tornado analysis" was performed, based upon which, it is concluded that P10_2 A, *i.e. the factor determining the implementation of AM, that is to say,* ***cost reduction***, has the greatest impact on the increase in the probability of P(P10 = State 1). Nodes are in second place: P10_2 F – quick response to market needs and P10_2 G – optimisation of product functions. The P6_Ceramics node has the lowest impact, which corresponds to the company's interests in the field of material research on ceramics.

An analogous analysis was performed for automotive industry networks. The vertices: P10.2_A cost reduction and P10.2_C freedom in product design have the greatest positive impact on the level increase for State 1 in the result node P10_Zaintowanie_AM. The smallest change in probability was observed in the case of a set of nodes from analysis of interest in AM technologies, materials used and materials researched.

3.1. Research experiments

For the learned network, experiments were carried out based on the observation of its work under various conditions of uncertainty. Each time, the goal was to determine the probability of P10 = State1. In the case of the metal industry, tests were carried out that simulated the presence of State 1 at the following nodes: P9.1 Welding, P9.2 Production; P9.3 Metals; P10.2 A; P10.2 B; P10.2 C; P10.2 D; P10.2 E; P10.2 F; P10.2 G, P6 Metals, P6 Other alloys, P6 Ceramics, P6 Polymer, P6 Composite.

The experiment consisted of tests obtained by carrying out the following steps:

1. 1. Alternative State1 was declared for node group: P9.1 Welding; 9.2 Production; P9.3 Metals and P10.2 A, and then only for P10.2A vertex. In each case, the State 1 probability value determined, at result node P10, was recorded.
2. 2. It was examined whether the declared states in nodes (step 1) caused a difference in determining the probability of achieving State 1 for P10.
3. 3. The above steps were repeated for a group of nodes, taking into account, separately, the following vertices: P10.2 B; P10.2 C; P10.2 D; P10.2 E; P10.2 F; P10.2 G; P6 Metals; P6 Other alloys; P6 Ceramics; P6 Polymer; P6 Composite.

Selected results of the experiments dedicated to the metal industry are presented in Table 1.

Tab. 1. Experiments conducted on the Bayes network for the metal industry

Test No.	The alternatives observed in nodes	$P_{(P10 = State1)}$
0	Initial state after learning the network	0.31
1	(P9.1 Welding; 9.2 Production; P9.3 Metals; P10.2 A) = State 1	0.44
1a	P10.2 A = State 1	0.45
2	(P9.1 Welding; 9.2 Production; P9.3 Metals; P10.2 F) = State 1	0.44
2a	P10.2 F= State 1	0.48
3	(P9.1 Welding; 9.2 Production; P9.3 Metals; P10.2 E) = State 1	0.54
3a	(P10.2 E) = State 1	0.52
4	(P9.1 Welding; 9.2 Production; P9.3 Metals; P6 Metals) = State 1	0.38
4a	P6 Metals = State 1	0.37
5	(P9.1 Welding; 9.2 Production; P9.3 Metals; P6 Other Alloys) = State 1	0.49
5a	P6 Other Alloys = State 1	0.41
6	(P9.1 Welding; 9.2 Production; P9.3 Metals; P6 Ceramics) = State 1	0.50
6a	P6 Ceramics = State 1	0.47
7	(P9.1 Welding; 9.2 Production; P9.3 Metals; P6 Polymer) = State 1	0.50
7a	P6 Polymer = State 1	0.45

When analysing the obtained results, it can be noticed that the largest change in the result node P10, in relation to its initial state, was indicated for experiment 3, for the State1 declaration in: P9.1 Welding, 9.2 Production, P9.3 Metals and P10.2 E. The growth of probability, determined for State1, was also observed in test 3a, where the value of State 1 was set in the P10.2 E. This node corresponds to the factor that determines the implementation of AM technology, i.e. personalising a product to specific, customer requirements. A high level of P(P10 = State1) was also observed in the case of tests 6 and 7, where the determining variables were the materials on which the companies want to conduct research, namely ceramics and polymers. The lowest increase in the value of State1 was recorded for test 4, where the impact of the P6 Metals node, *as a material on which companies would like to conduct research,* was tested.

In the case of the automotive industry, experiments were carried out in order to observe alternatives at nodes: P9.1 EBM, 9.2 Production, P9.3 Other alloys, P10.2 A, P10.2 B, P10.2 C, P10.2 D, P10.2 E, P10.2 F, P10.2 G, P6 Metals, P6 Other alloys, P6 Ceramics, P6 Polymer, P6 Composite. The tests were carried out in three stages according to the procedure outlined for the metal industry network.

The results of the experiment have been collected and are presented in Table 2 which contains the tests for which changes in the result node P10 were observed.

Tab. 2. Experiments conducted on the Bayes network for the automotive industry

Test No.	The alternatives observed in nodes	$P_{(P10 = State1)}$
0	Initial state after learning the network	0.41
1	(P9.1 EBM; 9.2 Production; P9.3 Other Alloys; P10.2 A) = State 1	0.50
1a	(P10.2 A) = State 1	0.44
2	(P9.1 EBM; 9.2 Production; P9.3 Other Alloys; P6 Metals) = State 1	0.46
2a	P6 Metals = State 1	0.44
3	(P9.1 EBM; 9.2 Production; P9.3 Other Alloys; P6 Ceramics) = State 1	0.50
3a	P6 Ceramics = State 1	0.49
4	(P9.1 EBM; 9.2 Production; P9.3 Other Alloys; P6 Other Alloys) = State 1	0.48
4a	P6 Other Alloys = State 1	0.46
5	(P9.1 EBM; 9.2 Production; P9.3 Other Alloys; P6 Composite) = State 1	0.50
5a	P6 Composite = State 1	0.49
6	(P9.1 EBM; 9.2 Production; P9.3 Other Alloys; P6 Polymer) = State 1	0.50
6a	P6 Polymer = State 1	0.48

Based on the results obtained in the experiment, it can be seen that the greatest change from the value of State1 for the P10 node in the initial state was noted in the case of tests 3, 5 and 6, where State1 was declared for the nodes: P9.1 EBM, 9.2 Production, P9.3 Other Alloys and in the following nodes: P6 Ceramics, P6 Composite and P6 Polymer. The peaks, examined in the P6 group, correspond to the materials on which enterprises want to conduct research. The lowest change in P (P10 = State1) was observed in test no. 2 for the declared choice of P6 Metals.

The analysis of the impact of individual nodes and the observation of the change in the probability value can be used to determine the implementation opportunities of AM technology in the metal and automotive industries. In addition, **it allows**, *among other things*, **the most important factors and areas** that affect a positive or negative change in the probability of success, in implementing additive technology, **to be identified**. The information obtained from the experiments can also be used in the strategic analysis of the company, where the strengths and weaknesses of the planned technology are considered.

4. CONCLUSIONS

Manufacturing companies consider changes in the production technologies they use. This is related to the growing competitiveness of enterprises and the requirements set by the **Fourth Industrial Revolution** (**Industry 4.0**), i.e. the digitisation of processes and automation. Considerations of production companies and actions taken towards the adaptation of new technologies are determined primarily by the desire to reduce production costs, tailor products to specific customer requirements and respond quickly to the needs of the market. According to the research carried out in western Poland, about 44% of respondents use AM technologies in manufacturing companies, while over 25% are interested in implementing AM technology in their enterprises. The article proposes an approach supporting decision-making in the implementation of AM technology. The authors proposed two Bayesian network models, *viz.*, one model for the metal industry and one for

the automotive industry. The results of surveys selected and uploaded to the network and the appropriate learning of the network, allowed the level of interest in AM technologies to be determined for a specific industry, which can also be interpreted as the company's chances to implement AM technology. Research experiments were carried out on both networks to simulate the problems described by network nodes and their relationships. It has been observed that in the metal industry, in the case of welding metals for production purposes, the greatest impact on interest in implementing AM technology is the possibility of personalising a product to specific, customer requirements. Presumably, this is related to the possibilities offered by AM technologies, namely to produce elements with greater freedom of shape and complex geometry, which is not possible with conventional manufacturing methods. It is concluded that manufacturing companies see opportunities in gaining a competitive advantage, offering flexible production and adapting to the individual needs of customers. With regard to successes in implementing additive technology, the influence of the willingness to conduct material research on ceramics and polymers is important. This may indicate a desire to expand the range of manufactured products, search for hybrid solutions or cheaper alternatives. In the case of an experiment carried out on a network designed for the automotive industry, it was observed that material research carried out on composites, polymers and ceramics had the greatest impact. This may be related to the search for solutions, *vis-à-vis* new material. Additionally, it is important for the company to declare a vested interest in AM technology on account of a desire to reduce costs. The solution presented, based on the Bayesian network can help management to decide whether or not to implement AM technology. The article proves that the Bayesian network approach allows knowledge to be modelled under conditions of uncertainty regarding graphic presentation. The use of the algorithm makes it possible to test probabilities, with an indication of a decrease *vis-à-vis* an increase, in the chance of implementing AM technology under given environmental conditions.

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production control, SMEs, ETO, Mass Customization, Fuzzy Logic

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PRACTICAL APPLICATION OF FUZZY LOGIC IN PRODUCTION CONTROL SYSTEMS OF ENGINEER TO ORDER SMES

Abstract

In this paper the method of improving production control in engineer to order [ETO] small and medium sized enterprises is presented. Briefly, the strategy of Mass Customization [MC] and a concept of the hybrid MC-ETO production system are demonstrated. Thereafter, a method of choosing components for small batch manufacturing in advance, under conditions of single unit ETO production system, with application of fuzzy logic is described. This approach can be used in ETO companies during their transition into the hybrid MC-ETO production systems. The research was done in a collaboration with experts from the real ETO pro-duction system, in Polish SME, which manufactures mechanical parts.

1. INTRODUCTION

1.1. Theoretical background

Small and medium sized enterprises [SMEs] have ability to establish a very flexible production systems, at which a high variety of production can be successfully manage. This could be done even under conditions of the single unit, technologically challenging, prototypes manufacturing (Ruta & Zborowski, 2011). In fact, some of SMEs major in the strategy of engineering and producing unique products in response to specific order of the customer. In the literature, this strategy is called the engineer to order [ETO], and is characterized by the customer involvement in the product creation on the very beginning of value chain (Bonev, 2015). ETO production profile seems to be tailored for conditions of 21st century economy, when demand for customized products is reaching the highest level ever (Aleksic, Jankovic & Rajkovic, 2017).

One of an ETO-SMEs evolution directions could be a development in the areas of designing and manufacturing along with concept of Mass Customization [MC] (Cieśla & Gunia, 2019). The essence of MC is to provide customized products which are at the same time affordable, thus highly competitive in the market (Pine, 1993). The general foundation of MC research was the transition from a mass producer to a mass customizer, which should lead to lowering production costs and securing the long-term competitive advantage, by means of structural and process adjustments (Xu, Landon, Segonds & Zhang, 2017).

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But after the phase of systematizing MC knowledge, some of the researchers become attracted by its alternative utilization – the possibility of transition from ETO production to MC. As a result, a concept of the hybrid MC-ETO production system was introduced (Haug, Ladeby & Edwards, 2009; Mleczko, Byrdy, Cieśla & Kłaptocz, 2020). The aim of MC application in the ETO-SMEs is to lower the manufacturing costs and simultaneously maintain a sufficient level of customization. One of the most important foundation of MC-ETO, which is primary in the opinion of the author of this article, is products modularity. In this manner it is understood as a method of designing, based on combining of universal construction modules, for higher production repeatability (Mleczko, Byrdy, Cieśla & Kłaptocz, 2020). It should lead to limit the number of components, which must vary to provide the product personalization, thus effects in more stable manufacturing (Viana, Tommelein & Formoso, 2017; Cieśla & Mleczko, 2019). This approach can be used in ETO enterprises as an indicator for changes in production philosophy, switching the perspective from single unit to at least small batch flow. In the connection with management adjustments, this should lead to lowering manufacturing costs per unit. For smooth transition relevant tools will be needed in the company, to support adaptation of production control processes. However, commercial solutions often do not apply under conditions of demand uncertainty (Sobaszek & Gola, 2015), which often occurs in customized goods market. That leads to the conclusion, that dedicated approach may be needed, during transition from ETO into the hybrid MC-ETO production systems (Duchi, Tamburini, Parisi, Maghazei & Schönsleben, 2017).

1.2. Initial research and motivation

The author of this paper, for last 10 years have been investigating ETO-SMEs from metal-mechanic sector, focusing on their attempts to maximize manufacturing repeatability. In the most successful companies in this manner, the contribution of designing engineers during these activities was significant. Their managers were focused on knowledge reuse aspects as well as products reconstruction along with concept of modularity. However, when redesigning phase was well-advanced, and manufacturing could be commissioned, new challenges on the operational level were noticeable. The difficulties arose first of all from uncertainty which components and in what amounts should be produced in advance, to obtain increase in quantity of a single manufacturing batch, and simultaneously avoid long storage period. Moreover, production planning methods must be adjusted to the new circumstances, as well as workshop logistics infrastructure for in process storage and transportation. In one of the investigated enterprises, issue of choosing construction modules for production in advance left without clear answers. This almost blocked the whole evolution process. Experts from this enterprise claimed that under uncertain market conditions that they are dealing with, it is impossible to prepare unambiguous method of modules selection. They indicated that blurred forecasts and historical turnovers are the only available data for this decision-making process. The risk of error under this kind of uncertainty, which could result in freezing of the significant assets in a long-term components storage, is then too high. Thus, it was decided, to investigate the possibility of application Fuzzy logic [FL] in this problem solution, since it is suitable to describe vagueness and imprecise information (Rutkowski, 2012).

1.3. The aim of the research

The aim of this research is to investigate application of FL for the purposes of components selection to initiate in advance components manufacturing, before actual demand for them appears in a production system. It will be done on the basis of turnover statistics obtained from company's ERP system and specific knowledge of the experts. The aim is to increase manufacturing quantities in ETO-SMEs, from a single unit to at least small batch production. An essential condition for this consideration is to avoid storage of in advance components, but a short waiting time before final assembly will be acceptable due to specifics of ETO production. The research is to be carried out in Polish ETO-SME from the metal-mechanical sector, which supply high precision mechanical parts to many countries from EU as well as USA, Russia, Egypt, and others. This enterprise strives to consistently evolve with MC principles and identified a need for supporting adjusted to this transition decision-making processes. The author of this article will attempt to fill the existing research gap and broaden understanding of the practical technics of supporting hybrid MC-ETO production systems in their evolution.

2. BASICS OF FUZZY LOGIC THEORY

Research described in this article, was began with a general training, providing basic scope of FL knowledge to the company experts, that were designated for the project. In this chapter, exactly the same scope was presented, to acquaint the reader with the simplicity of the approach, which was forced with constrained number of workhours dedicated by company to the project. Moreover, well-known aspect of knowledge limitation in SMEs should be always considered, when designing methods for a real production system. The training was supplemented with practical calculation examples, which were neglected in this chapter.

The FL is employed to handle the concept of partial truth, when dealing with ambiguous phenomenon or expression. The formal description of these objects with classical set theory or bivalent logic is impossible. Typical vague impressions are "young man", "big city", "high temperature" (Rutkowski, 2012).

A fuzzy set A on universe (domain) X is a list of ordered pairs (Rutkowski, 2012):

$$A = \{x, \mu_A(x)\}; x \in X \tag{1}$$

where μ_A: $X \rightarrow [0,1]$ is called the membership degree (membership function), whereby 3 general situations can be distinguished:

$\mu_A(x) = 1$ means that x belongs completely to the fuzzy set,

$\mu_A(x) = 0$ means that x does not belong to the fuzzy set,

$0 < \mu_A(x) < 1$ means that x is a partial member of the fuzzy set.

The FL theory allows to map so called fuzzy relations between two or more fuzzy sets. The common method when designing fuzzy relation is intersection, when the membership of element x to set $A \cap B$ is determined as a minimum from $\mu_A(x)$ and $\mu_B(x)$ (Rutkowski, 2012).

3. THE RESEARCH

3.1. The scope of the research

The research was conducted in the enterprise which manufactures steel mechanical parts and equipment. The company employs around 50 people of which about 50% are production workers, 20% are product and process engineers and 30% are administrative, sales and logistics personnel. Approximately 15% of the company's revenue is gained from one product range, which is produced using assemble to order strategy [ATO]. Its components are manufactured in batches containing from 5 to 40 pieces. Remain 85% of revenue is gained from customized products, which are produced using ETO strategy. For last 2 years management board systematically endeavor to design unification among similar customized products by means of defining and redesigning construction modules. The aim is to establish specified products families with slightly narrower range of customization to obtain better repeatability in invoicing, designing and manufacturing. For the research described in this paper, company's management board assigned 4 experts: 1 from sales department, 1 from supply & logistics department and 2 from production department.

3.2. Plan and conduct of the research

It was assumed that the investigation should be conducted along with 5 steps plan presented on figure 1.

The first step was conducted as described in chapter 2. In the second step of investigation, experts were asked to propose fuzzy concepts, which in their opinion can be useful in qualifying components from newly designed product families for lunching in advance manufacturing. After brainstorming different ideas, discussion was initiated in order to build consensus, however problem was multidimensional and it took more than a one panel to accomplish the task. Finally, experts decided that prevailing number of ideas can be stated in two fuzzy concepts: "sufficient consumption of the component" and "sufficient universality of the component". By "universality" they understood the use of the component in multiple versions of final products which were actually manufactured.

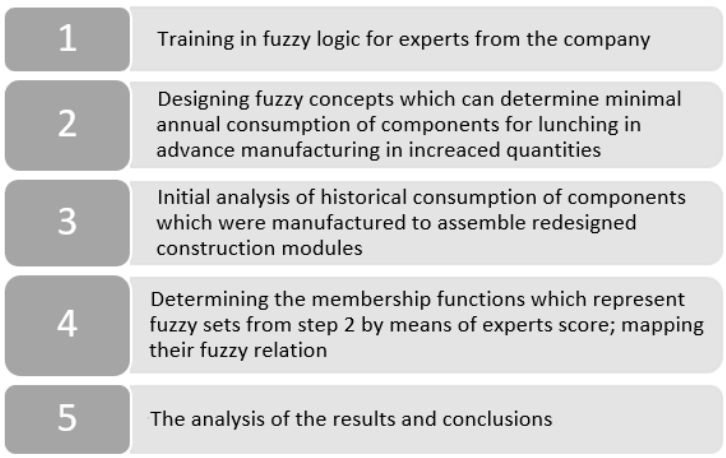

Fig. 1. Research plan

In the third step of the investigation, experts were asked to suggest sufficient period of time for initial analysis of historical consumption of components. They agreed that production of redesigned construction modules had started approximately 3 years before. Thus, it was suggested, that fuzzy concepts defined in the second step of investigation should be redefined as follows: "sufficient consumption of the component in last 36 months" and "sufficient universality of the component in last 36 months". Experts agreed with proposal. Documentation of newly designed products (along with MC concept), as well as their components and construction modules were from the beginning distinguished with specific drawings markings. Therefore, it was possible to use unambiguous filter pattern in consumption records of company's ERP system to identify historical turnovers. Then the time frame was narrowed to last 36 months and obtained list was exported to the spreadsheet. Using flexibility of data presentation in spreadsheet, experts where investigating consumption statistics for different components and construction modules which they expected to be representative in context of in advance manufacturing. In the end of the third step of the investigation, particular sheets with consumption statistics were printed for after meeting reflections.

In the fourth step of the investigation, experts were asked to confidentially evaluate the scores from 0 to 1 to defined in the second step of the investigation fuzzy concepts. "Sufficient consumption" and "sufficient universality" where stated in numbers from 0 to 10 for the evaluation. The results where aggregated and averaged. Thereafter 2 membership functions were determined and their fuzzy relation was mapped as presented in the subchapter 3.3.

3.3. Research findings

The values of the membership degree for designed fuzzy concepts were determined as the arithmetic mean by adding up the scores given by each of 4 experts. Determined membership functions were presented on figure 2 and figure 3. For x values greater than those presented on the figures, calculated membership degree was always square to 1.

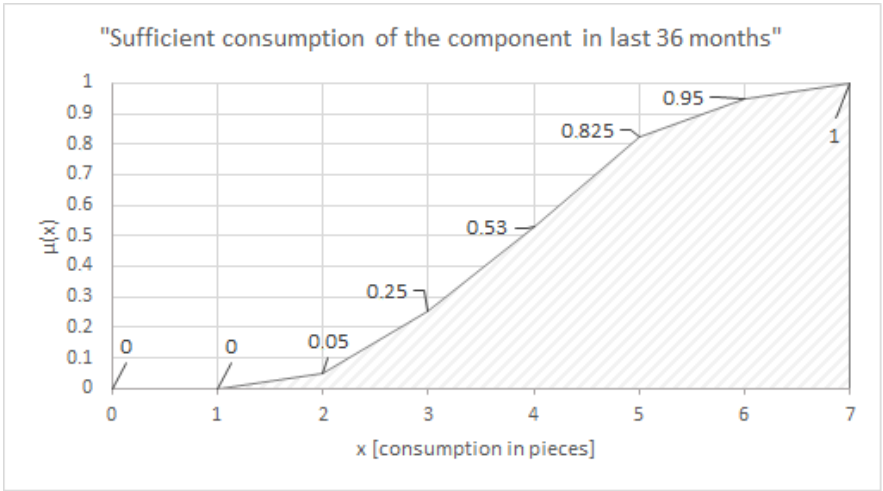

Fig. 2. Membership function of fuzzy concept "sufficient consumption of the component in last 36 months"

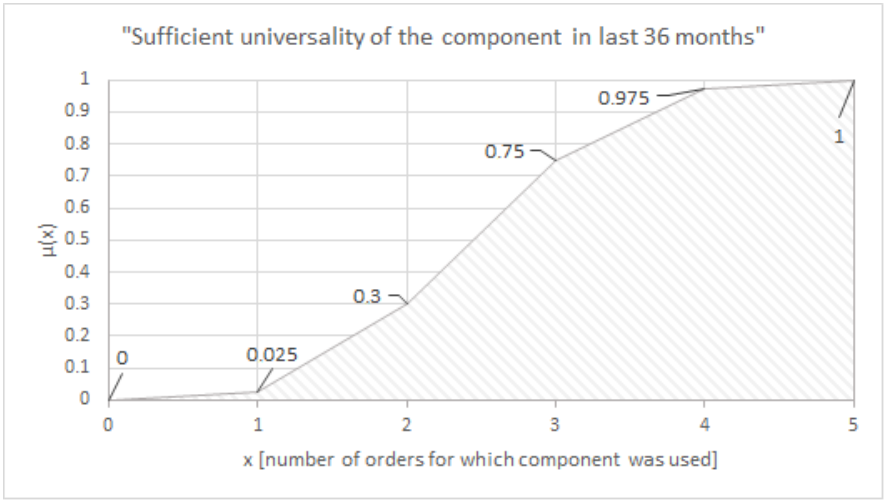

Fig. 3. Membership function of fuzzy concept "sufficient universality of the component in last 36 months"

The fuzzy relation of the investigated fuzzy concepts was mapped using the intersection method. Results were presented in table 1 and figure 4.

Tab. 1. Investigated fuzzy relation

Sufficient consumption of the component in last 36 months	**Sufficient universality of the component in last 36 months**							
	μ(x)		**0**	**0.025**	**0.3**	**0.75**	**0.975**	**1**
		pieces	**0**	**1**	**2**	**3**	**4**	**5**
	0	0	0	0	0	0	0	0
	0	1	0	0	0	0	0	0
	0.05	2	0	0.025	0.05	0.05	0.05	0.05
	0.25	3	0	0.025	0.25	0.25	0.25	0.25
	0.53	4	0	0.025	0.3	0.53	0.53	0.53
	0.825	5	0	0.025	0.3	0.75	0.825	0.825
	0.95	6	0	0.025	0.3	0.75	0.95	0.95
	1	7	0	0.025	0.3	0.75	0.975	1

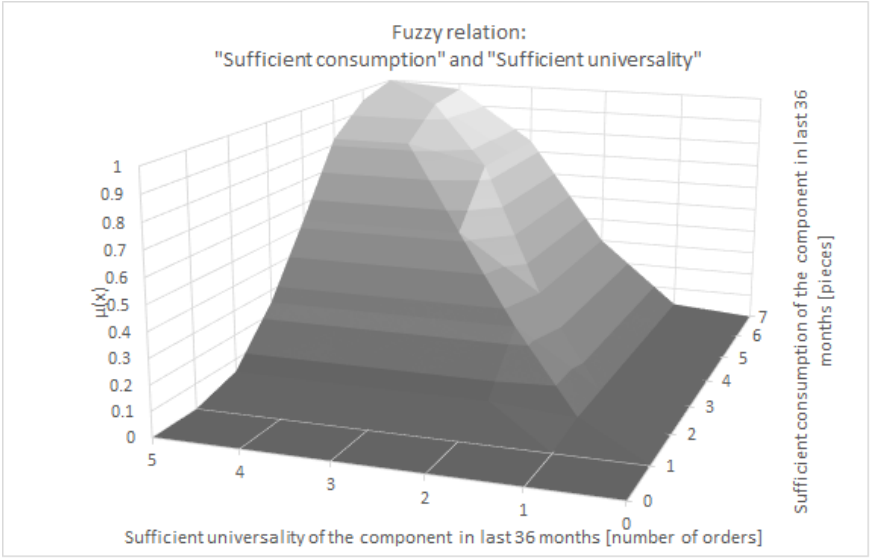

Fig. 4. Investigated fuzzy relation

3.4. Research conclusions

Research findings described in the subchapter 3.3 were presented and discussed with the experts on the last project meeting. As practitioners, they instantly proposed to calculate the membership degree for particular components, which were distinguished during initial analysis of historical consumption (step 3). On that basis, suitability of investigated fuzzy logic application for supporting production control system in the company was discussed and below findings were concluded:

- the membership degree in the mapped fuzzy relation is accurate enough to reflect the biased opinions of the experts for qualifying components or construction modules to in advance manufacturing,
- normally, under conditions of average workload in the investigating production system, in advance manufacturing could be initiated when $\mu(x) \geq 0.5$ in the fuzzy relation,
- by using the membership degree as the decision criterion for initiating in advance manufacturing, the production flow can be controlled under different levels of workload – for example $\mu(x) \geq 0.3$ can be sufficient when production system is underloaded and $\mu(x) \geq 0.9$ when it is overloaded,
- presented findings raised doubts on the part of the experts as to the score's values given in the fourth step of the investigation, but they decided not to make adjustments until the end of the first year of testing.

4. CONCLUSIONS

Experts designated to the described in this paper project showed their great involvement in work and determination to achieve relevant effects. As a result, this research has met its objective successfully and its findings will be verified by practitioners, under conditions of real ETO-SMEs production system. It should be stressed that, the designed decision criterion is a draft which needs further examination. Components and construction modules which will be selected for in advance manufacturing by means of presented method should be subject to prior manufacturing costs analysis. It should involve comparison between unit costs under conditions of existing single unit production profile and implemented in advance production in small batches. Another problem for further investigation is the moment in time of launching in advance manufacturing. For example, it can be initiated in response to actual MRP demand or temporary underloaded bottlenecks of manufacturing system. It can therefore be concluded that further research in the scope of MC-ETO and ETO-SMEs production strategies are needed to fill the current information gap. Issues presented in this paper are the part of the broader study conducted by the authors, with the purpose of designing comprehensive decision-making procedure for in advance manufacturing, under conditions of ETO-SMEs production systems.

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image processing, spectrum analysis,
pulsating marker, localization, mobile robotics

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ANALYSIS OF THE POSSIBILITY OF USING MARKERS EMITTING PULSATING LIGHT IN THE TASK OF LOCALIZATION

Abstract

This work shows the possibility of using spectral analysis in order to detect characteristic points in recorded images. The specific point is a marker in the form of a diode that flashes at a certain frequency. Main assumptions of the processing algorithm are the recording of a sequence of images and treatment change of level of brightness for each pixel as a time signal. The amplitude spectrum is determined for each time signal. The result of data processing is an amplitude image whose pixels brightness corresponding to the intensity of source of pulsating light emitting specific frequency. This new data representation is used to detect position of markers. The algorithm was researched in order to select optimal marker colors and pulsation frequency. The results are described in a summary.

1. INTRODUCTION

Location systems perform a critical role in mobile robotics and in many fields of technology that support people in challenging tasks.

The localization focuses on the problem of determining the position of object in a given frame of reference. The localization solutions are widely used both in the ordinary car navigation and the advanced military location system. Location systems refer to a wide spectrum of techniques. The development of computers has contributed to the evolution of location systems that based on image processing and analysis. It is worth paying attention to the basic functional features of such systems and their properties, such as the scope of application (open area or indoors) or refresh frequency of measurements. Described features affect the decision to choose the best solution. In the area of authors interests was systems that allowed to obtain information about position in the range up to about 200 m. GNSS-based solutions were omitted due to their limited accuracy in buildings. The attention was paid on UWB radio systems and positioning systems based on camera and markers. Radio systems enable measurements on large distances but they also have many disadvantages which disposed the authors to supplement them with vision systems.

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Vision systems realize the location process based on markers which generally are distinctive object with known position. The vision system can recognize them and uses their coordinates to determine the position of another object or camera. Markers should stand out from their environment in order to the vision systems correctly recognizes them. It should be noted that vision solutions are very popular because of the relative low price and a small number of components which usually come down to camera, computer and markers. Vision systems are often supported by the machine learning algorithms which detect features like shape or color of the marker. Vision systems will able to recognize markers in the recorded images, if they achieve the appropriate learning cycle with known examples.

The use of machine learning elements is one of many ways to detect the marker in an image. However, the use of classic vision solutions seems unrealistic because of the expected measuring range and the limited ability to recognize markers at large distance. The solution of this problem might be identify of pattern powered by the frequency of the light emitted by the marker.

The aim of this article is to present an image processing algorithm that looks for pulsating light sources based on spectral analysis. The article presents the features of this methods, its properties, advantages and indicates potential application in location systems. The chapter 2 contains a literature analysis focusing on information about application markers and camera in various location systems. The chapter 3 describes the processing method, its main assumptions and shows the consecutive steps of algorithm operations. The chapter 4 presents the description of the test stand, whereas the last two chapters include the presentation of research results and conclusions.

2. LITERATURE ANALYSIS

The light source as a marker is often used in localization issues. Hassan, Naeem, Pasha, Jadoon and Yuen (2015), Maheepala, Kouzani and Joordens (2020), Wang C., Wang L., Chi, Liu, Shi and Deng (2015) all present the state of knowledge and techniques on the use of light markers in the process of determining the position. The reviews mainly focus on location methods that should be used for indoor localization. The use of light sources such as LEDs brings many benefits. Light signals are less susceptible to interference from radio waves. Moreover, they should ensure bigger accuracy of the location system operation compared to systems based on Wi-Fi or Bluetooth signals. The receiver of light signals can be a photo-receiver or a camera. The photo receiver responds to changes in illuminance whereas the camera records images. Maheepala, Kouzani and Joordens (2020) discuss the location methods with light markers and they give the common name of all methods as LIP (Light-based Indoor Positioning Systems). LIP systems use a light signal as the main way of transmitting information about markers location that is necessary to determinate the position of other object. Figure 1 shows the division of LIP systems into different categories.

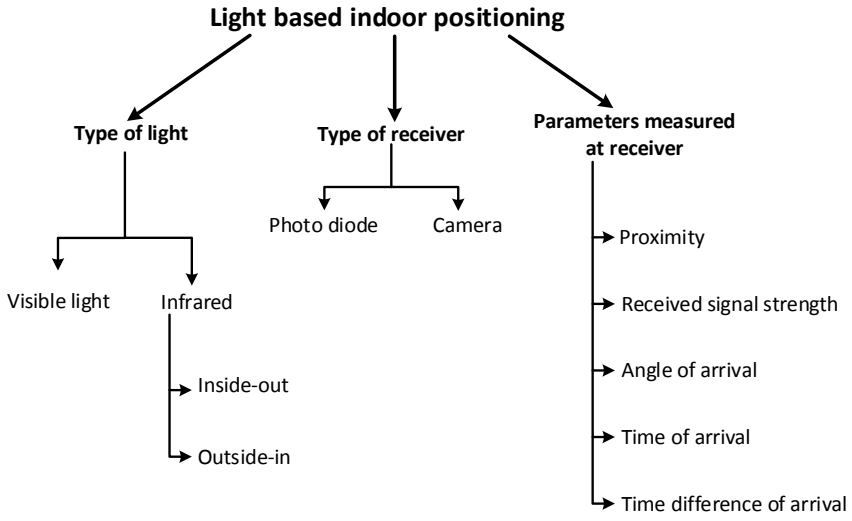

Fig. 1. Classification of LIP systems (Maheepala, Kouzani and Joordens, 2020)

The presenting algorithm of location of pulsating markers can be treated as a LIP system because it uses the signal of visible light that is received by the camera. The marker should be in the camera field of view in order to be recorded in images. The presenting algorithm needs just one pixel with capturing marker to determinate its position.

Some articles describe specific examples of location systems based on markers. Moon, Choi, Park and Kim (2015) use pulsating markers with a location system and a smartphone camera. Each marker has own unique pulsation frequency. The exposure time of each of the pixel columns changes during recording images. It looks like the matrix had a "moving shutter". Consequently, a band effect arises in the CMOS sensor while some columns register the LED on and others the LED off. If the recording image is conversed to grayscale, image areas with the figures of pulsated markers can be found by applying the OTSU binary filter (Moon, Choi, Park and Kim, 2015).

Raharijaona et al. (2015) use infrared diodes that send signals of different frequency. The receiving device is constructed in the form of a cube with three optical sensors (each in a different plane). It receives signals that are demodulated in order to identify the correct frequencies of LED pulsations. Then, the position of the object with infrared markers can be estimated by analyse of the power of the demodulated signal components. The solution from Raharijaona et al. (2015) shows a marker-based location method that does not use camera and image analyse.

The camera was not used in the solutions presented by Hossen, Park and Kim (2015), Jung, Hann and Park (2011), Moon, Choi, Park and Kim (2015) and Zhang, Chowdhury and Kavehrad (2014). The role of the signal receiver was played by an optical sensor. This sensor usually has a compact size, therefore it can be installed in small objects. The optical sensor records one-dimensional signals whose analyse can be faster than image processing and analysis (it depends on the hardware used to perform the calculations). This solution also allows to determine the position based on several parameters, like: received signal strength level (RSS), angle of arrival (AOA), or time of arrival (TOA). More information about the listed parameters can be found in Zhang, Chowdhury and Kavehrad (2014).

On the other hand some articles include examples of using a camera as a receiver. The camera makes it easier to obtain information about marker color compared to ordinary optical sensors. Kuo, Pannuto and Dutta (2014), Yeon Kim, Cho, Park and Kim (2012) all indicate that marker color can hide information about the coordinates of the marker in a given reference system. This solution has practical application in mobile robotics. The vehicle can correct its position based on the known information about the location of the markers that should be visible in the field of view of the robot camera. Guan, Wen, Zhang and Liu (2018), Hong et al. (2020) and Wu et al. (2020) all present solutions using machine learning algorithms that support the position estimation process. Thanks to this, the authors achieve a lower error in determining the position compared to the estimation results without machine learning elements.

The authors of article propose the interesting location algorithm contained to discussed solutions. Some of them are used in the task of indoor location whereas the presented algorithm can be used in an open space and outdoor location task. It can be replenishment of systems based on UWB technology. The algorithm refers to the general technique of analysing the change in pixel brightness levels over time. It is similar to the algorithm discussed by Kuo, Pannuto and Dutta (2014). The analysis of the operation of the presented method brings many interesting conclusions that will be discussed in the following chapters.

3. BASIC INFORMATION ABOUT THE ALGORITHM

The main purpose of the presented image processing method is to locate pulsating light sources on the recorded images. Light sources pulsate with a known frequency. If the brightness level of change of a single pixel is treated as a time-varying signal, such a signal can be subjected to spectral analysis in order to find the component in relation with the pulsation frequency markers. The recording images sequence can transform to amplitude image performing the above information on each pixel from a matrix. The amplitude image uses intensity of the signal with the searching frequency and shows the area with figures of pulsating markers. The amplitude image is also normalized in order to improvement the quality of image and cut out the noise.

3.1. Main assumptions

The basic assumption of the method is the use of light markers that emit pulsating light at a specific frequency.

Images should be recorded continuously in the basic variant. Then the selected number of frames should be subjected to spectral analysis. The frequency of recording images should be known and constant, because the marker pulsation frequency depends on it (the recording conditions must be maintained in accordance with the Nyquist statement).

Images should be recorded and saved in RGB format. Thanks to this, each layer can be analyzed separately. If the marker emits pulsating light in a specific color, only one layer of RGB format can be analysed. This assumption allows to curtail an operation time compared to analyse of all layer of images.

3.2. Scheme of operation

In order to locate pulsating markers, The presented algorithm needs the following input parameters:

- recording time and recording frequency of image by camera,
- resolution of recorded images,
- color and pulsation frequency of the light sources,
- processed layer of RGB format.

Figure 2 shows block diagram with successive processes that make up the presented method.

The camera records a sequence of images after entering the input parameters. Images is saved in RGB format. Then the algorithm selects one of the layers (red, blue or green) in order to read the brightness level change for each pixel.

The processing algorithm reads the brightness level for a pixel with the index [a, b] (where recorded image has size AxB and a = 1, ..., A, b = 1, ..., B) for each recorded image. The result of this operation is a signal of the brightness level changing of the pixel [a, b] over time. This signal is subjected to the Fast Fourier Transform in order to obtain amplitude spectrum. A harmonic for LED pulsation frequency should be located on the spectrum according to the diagram in Fig. 2.

Then the amplitude value of expected harmonic is read and stored on the new image at the position in accordance with coordinates of researching pixel (it will be position [a, b] for considered example).

The described procedure is repeated for each pixel from the set A*B pixels. The resulting image is the set of all amplitudes for the signal component related to the marker pulsation frequency. Then, the image is normalized. It consists in finding the amplitude with the maximum value in the resulting image and dividing all pixel by found value. Consequently, all pixels will be in the range <0, 1>. The location of pulsating marker is potentially represented by pixels whose value is closer to one. In the end, the image is binarized in order to better present the marker position.

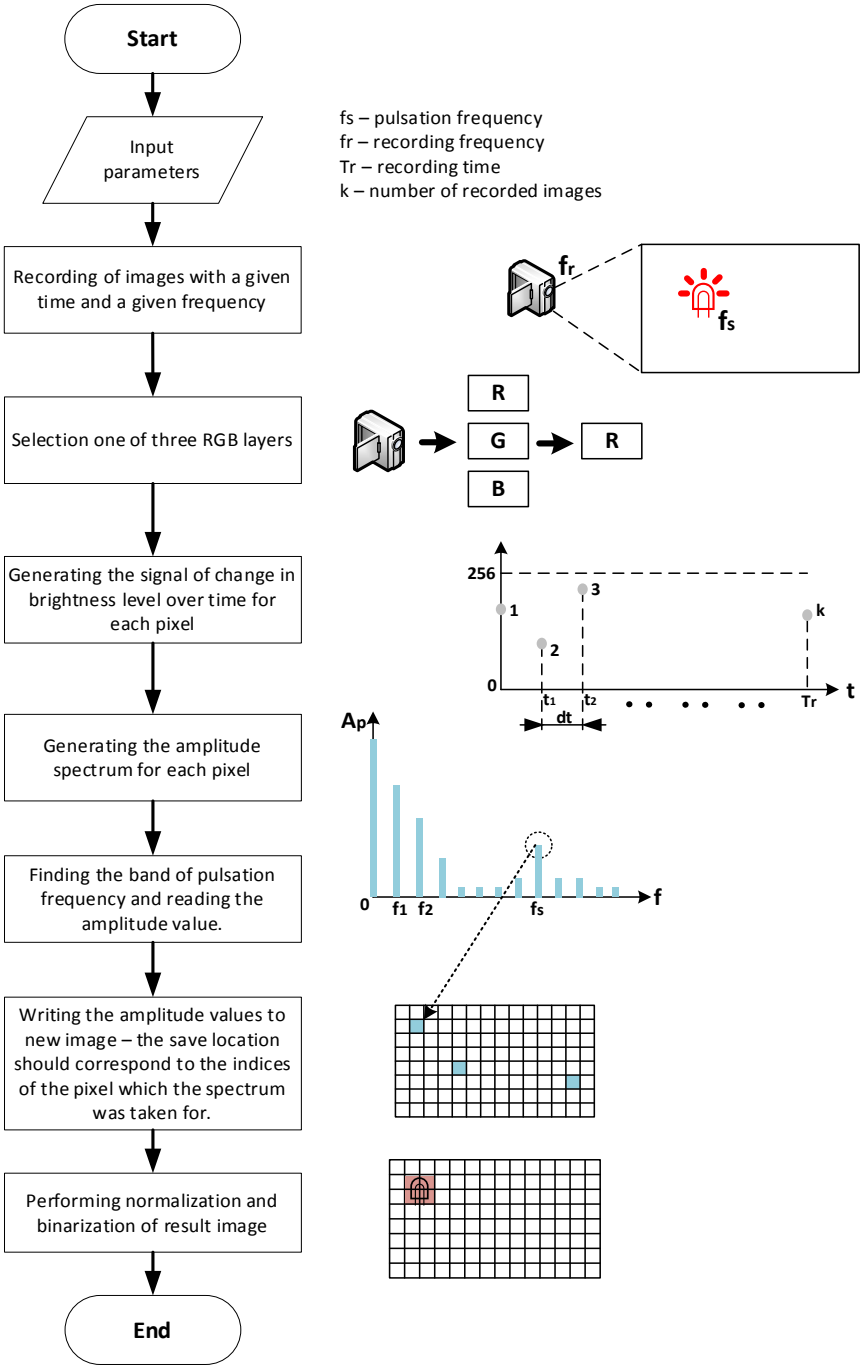

Fig. 2. Block diagram showing the steps of examined method of image processing

4. PURPOSE OF THE RESEARCH AND STAND TEST

The MATLAB program was used to present the results of the image processing method because the MATLAB has extensive possibilities in the field of image processing and analysis. The operation scheme in Fig. 2 has been implemented as a computer program. The captured images were processed and the algorithm generated a binary image with a figure representing the found marker as a result.

The aim of the research was to verify the operation of the method and selection the optimal parameters in terms of the quality of the obtained images. The tested parameters were the color and frequency of the marker pulsation.

4.1. Equipment used for tests and input parameters

The following components were used for the tests:

- markers: four LEDs, each of them has a different color,
- the recording device: a PlayStation Eye camera,
- the STM32 F411 board, which generated a PWM signal with a given frequency, which powered the LEDs,
- computer equipped with MATLAB.

The connected measuring equipment is shown in Figure 3.

The input parameters for the tested method were as follows:

- image sequence recording time: 2s,
- resolution of recorded images: 640 x 480 pixels
- recording frequency: 75 Hz,
- diode color: red, green, blue, yellow,
- LED pulsation frequency: 5, 10, 15, 20, 25, 30 and 35 Hz.

Each of the RGB layers of the recorded images was processed. The frequencies were selected so as to they were less than half the recording frequency of the camera. The marker was stationary and it was located on the contact plate. The STM board powered the diode with a signal of a given frequency. The LED flashed with pulsating light as a result.

Fig. 3. The test stand to research method of pulsating markers location

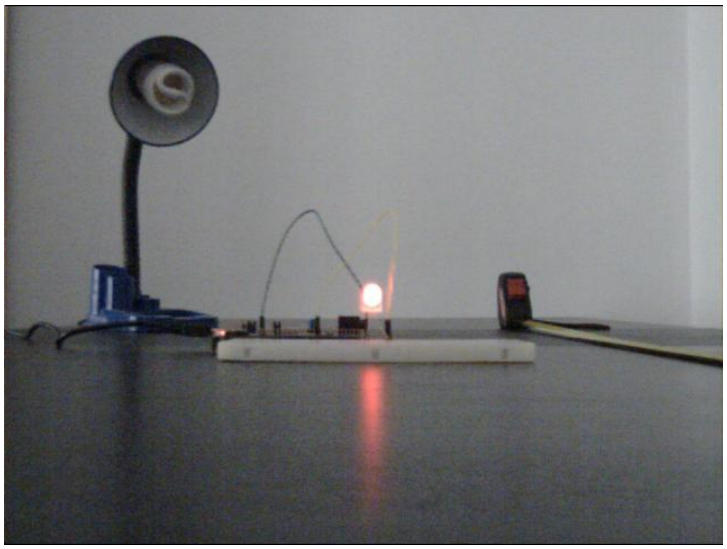

Fig. 4. The image from the perspective of the PlayStation Eye camera lens

5. RESEARCH RESULTS

This chapter presents the most important observations and conclusions from the stage of research on the processing algorithm. The following sections present examples of amplitude spectrum of changes in pixel brightness levels and the amplitude images obtained as a result of the algorithm. The results of the research on the selection of the appropriate color and frequency of the marker pulsations were also presented.

5.1. Frequency analysis of images

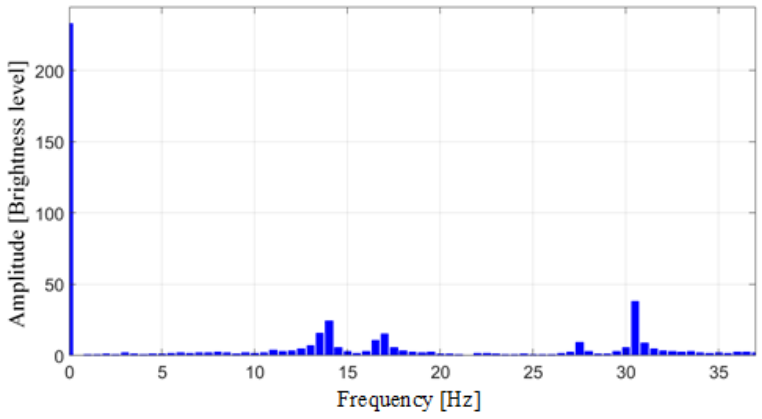

Fig. 5. Amplitude spectrum of the signal of brightness level change for an pixel which the marker was registered on – marker parameters: red color of light, R layer (red) of image, pulsation frequency 30 Hz

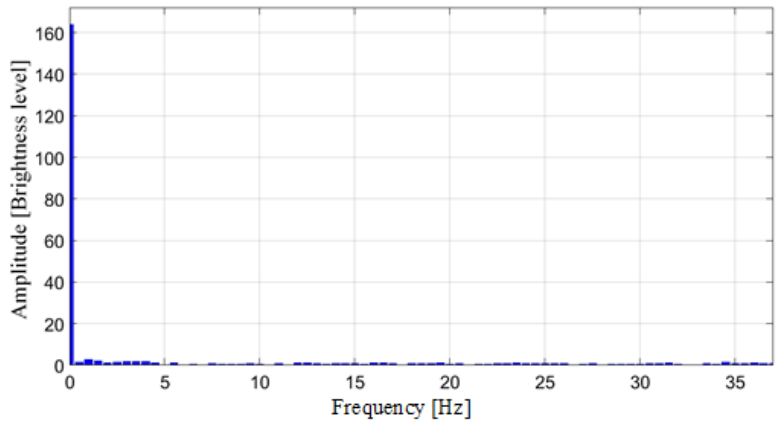

Fig. 6. Amplitude spectrum of the signal of brightness level change for an pixel which the marker was not registered on – marker parameters: red color of light, R layer (red) of image , pulsation frequency 30 Hz

Figures 5 and 6 show the signal spectrum of the brightness level change for the pixel where the marker was captured and for the background. There is a harmonic for the frequency close to the marker pulsation frequency in the spectrum in Fig. 5. No additional bands were observed for the normal pixel from the background without the band for the mean value. Additional fringes around 15 Hz are related to the aliasing phenomenon. The amplitude image is presented in Figure 7 in order to better understand the formation of the resulting image. It is the amplitude values composite for the frequency of 30 Hz for all pixels of the matrix.

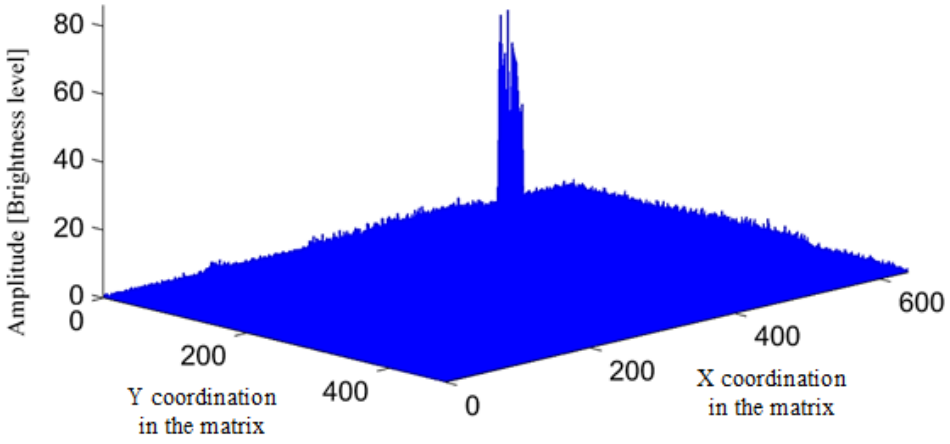

Fig. 7. The amplitudes of the pulsation frequency of 30 Hz for each pixel in form of a three-dimensional graph

The high amplitude values are the area where the marker was recorded. The results were normalized and the exemplary results are presented in the next section.

5.2. Result images

The following figures from number 8 to number 11 show the images that are result of applying the processing using spectral analysis. The images are shown in normalized and binary form. The result was obtained for each tested color and frequency. The figures below show only some of the considered cases.

Fig. 8. Normalized result image for a blue LED pulsating with a frequency of 15 Hz

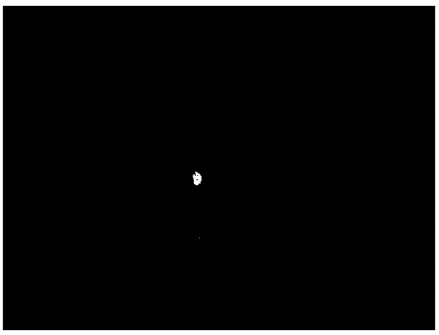

Fig. 9. Binary result image for the blue LED pulsating with a frequency of 15 Hz, binarization threshold 0.6

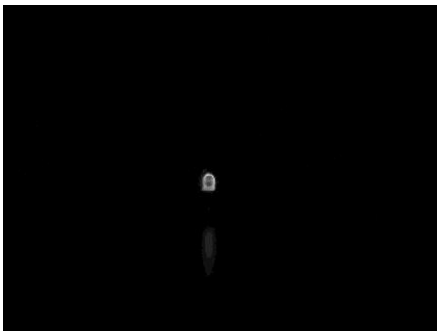

Fig. 10. Normalized result image for a red LED pulsating with a frequency of 30 Hz

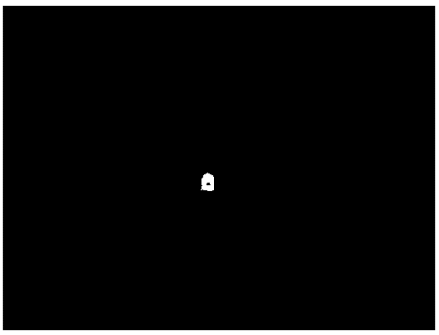

Fig. 11. Binary result image for a red LED pulsating with a frequencyof 30 Hz, binarization threshold 0.3

The amplitude images were realized for each marker color. However, the visibility of the LED in the image depends on its parameters. The binarization threshold was different for each marker color.

5.3. Selection of the marker pulsation frequency

The authors proposed a comparative measure of the obtained images in order to select the appropriate pulsation frequency. This measure is called the normalized average value of the background brightness level. The proposed measure is the average value of the brightness levels of the background pixels after the normalization process. The smaller the value, the final binary image should contain less noise. The following figures show graphs with the calculated index of the normalized average value of the background brightness level for different cases of the diode color and pulsation frequency.

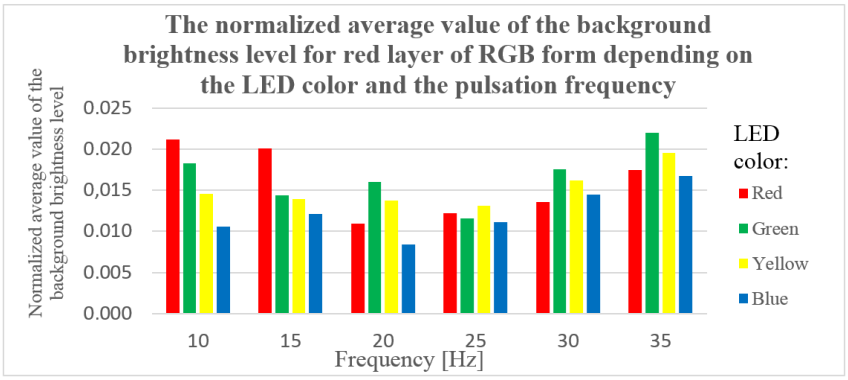

Fig. 12. Graph showing the normalized average value of the background brightness level for red layer of RGB form and for different cases of the LED color and pulsation frequency

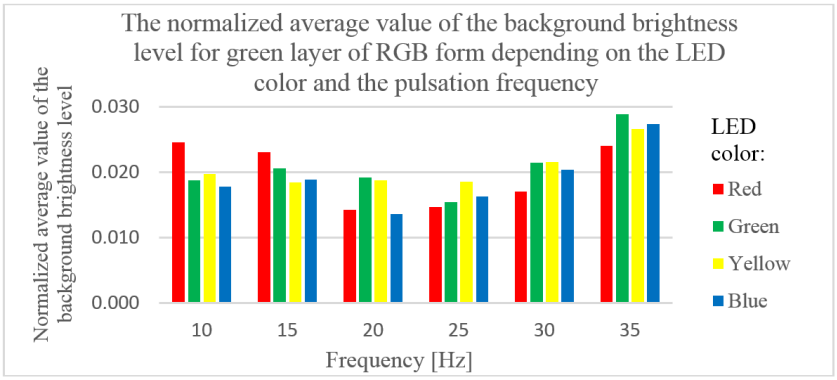

Fig. 13. Graph showing the normalized average value of the background brightness level for green layer of RGB form and for different cases of the LED color and pulsation frequency

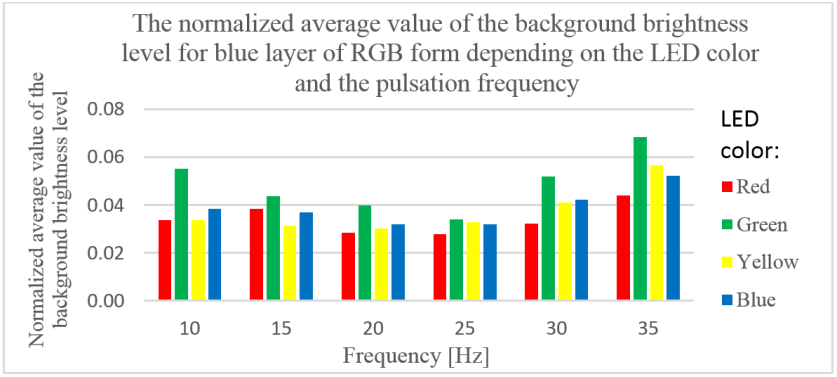

Fig. 14. Graph showing the normalized average value of the background brightness level for green layer of RGB form and for different cases of the LED color and pulsation frequency

The above charts show higher index values for the blue layer compared to the other layers. The blue layer has twice the normalized mean value of the background brightness level. Higher values could potentially indicate a greater susceptibility to noise in the resulting images. Therefore the R and G layers will be chosen to the processing image.

Moreover the graphs was analyzed in order to search frequencies which the indicator value was the lowest for. Both for the red and green layers, the searching values were 20 and 25 Hz. Measurements showed that these are the leading markers pulsation frequencies whose the average value of the background level is as low as possible.

5.4. Color selection of markers

The best colors for marker light were chosen red and green based on the following observations:

- the images obtained for the yellow marker had lower quality than the images for the other markers – the yellow color did not correspond to any of the RGB recording layer colors,
- the images obtained for the blue marker showed the LED with too bright contours – the blue LED emitted too high light intensities and the matrix was too saturated,
- the best quality of the detected markers is for the green LED on the normalized amplitude images – the markers shape in this case has been best preserved,
- the images obtained for the red marker had the lowest indicators of the normalized average value of the background brightness level.

6. SUMMARY

The presented processing algorithm treats images as a series of two-dimensional data recorded in time. It allows to obtain binary images representing the registered marker, which was demonstrated during the presentation of the research. The presented method can potentially be used to build a location system that looks for objects equipped with pulsate markers. What is more, the algorithm can locate markers both indoors and outdoors, over long distances. It should only be remembered that the spectral analysis of high-resolution images might require a lot of computing power in order to achieve an acceptable level of the algorithm working time. It is worth emphasizing that the amplitude image presents initially and effectively filtered data that may constitute a starting point for further analyzes and a more sophisticated marker search. Nevertheless, this approach solves the problem of modern methods of tag detection by searching for a shape or color.

6.1. Conclusions

The assumptions of the presented processing algorithm are correct. The authors managed to obtain binary images with the detected pulsating marker as a white figure in the black background. The resulting images were obtained in each case, however, they differed in the quality of the figures. The most scattered figure and the most background noise were observed in the case of the blue diode. The images generated for the yellow LED had the lowest quality compared to the other marker colors. The most compact diode image was obtained for the green color, whereas the lowest value of the background brightness was obtained for the red diode.

The using of spectral analysis allowed to obtain clear binary images without using of advance image processing methods. The analysis of changes in pixel brightness level over time requires looking at several images simultaneously. This is a different approach to processing than performing operations on a single image. The best results were observed for the pulsation frequencies of 20 and 25 Hz. However, it should be emphasized that these are the values selected for the camera used in the research. It is possible that the best pulsation frequencies will be different for an other class of equipment. The method based on pulsed markers has potentially many advantages. Not only the amplitude of the signal can be analyzed, but also its phase. Potentially, the orientation data of the tags can be encoded in the phase and color information.

6.2. Further research directions

The presented processing algorithm is a method with great potential, which makes us look at images as a set of signals of brightness level changing over time. In further research, an attempt will be made to use more sophisticated algorithms for time-frequency analyzes in order to detect temporary amplitude values. The Fourier analysis has averaging properties, which can be a problem in the case of changing marker positions. The possibility of modifying the marker color or the phase shift of the generated light signal by various markers is another interesting area of development of the proposed method.

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Reverse Engineering, Additive Manufacturing, Point Cloud, Mesh, Reflectance

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RESOLUTION IN THE 3D MODELING OF OBJECTS FOR ADDITIVE MANUFACTURING AND REVERSE ENGINEERING – SHUTTER EFFECT

Abstract

This article presents a proportional relationship between Shutter and the value of the resolution scanning system that allows decision making for modeling 3D parts used in reverse engineering and additive manufacturing. As a first step, the object of interest is treated to dim excessive brightness, then the object is scanned (by point cloud or mesh) with the use of a Handyscan 700 scanner. The point cloud is processed with the Geomagic software Desing X to generate a CAD image and a ".stl" file for 3D printing.

1. INTRODUCTION

During the development of a new product, it is necessary to carry out a systematic analysis of the ideal manufacturing technique that will best adapt to the needs and budget of the customer (Akhmet & Fen, 2016; Ruan et al., 2016; Babel, Sawicki & Gasiorowski, 2021; Rojo, Bonilla & Masaquiza, 2018; Lan et al., 2018). The current demand for quality and low cost products has lead us into a new industrial revolution for manufacturing (Herrmann, 2002; Pedroza, 2018), where computer-aided design, CAD, software plays an important role in the design process. In the last three decades, the world has witnessed a digital transformation of every aspect of life and society. There exists a multitude of examples regarding this change: CAD, CAM, CAE systems, TDT, magnetic resonance, TAC, 3D ultrasound, etc (Bilal et al., 2020; Gonzalo, Sandra & Rodrigo, 2020). 3D scanning is among these techniques, which consists of capturing geometric information of a physical object by means of large capacity data acquisition tools such as laser scanners, optical digitizers, probes, contact arms, coordinate-measuring machines and computerized axial tomography scanners

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(Babel, Sawicki & Gasiorowski, 2021; Li, 2001). A 3D scanner can be defined as a device that analyses a real-world object or environment to collect data on its shape and possibly its appearance. The collected data can then be used to construct digital 3D models (Saorín et al., 2017; Montusiewicz, Czyz & Kayumov, 2015; Montusiewicz, Czyz & Kesik, 2015; Fines & Agah, 2008; Ojeda, Belete & Batista, 2014).

In this paper we establish a proportional relationship in the process of data acquisition, such that the data processing reduces the processing time during reverse engineering.

2. DEVELOPMENT

In this section, the process of digitization and CAD modeling of an object is presented.

2.1. 3D Digitization

The first step in reverse engineering consists in capturing the object's geometry. This is done by means of a Handyscan scanner shown in Fig. 1. More specifications of this scanner are given in Table 1.

Fig. 1. Handyscan 700 scanner

The following procedure was considered for the scanner's manipulation: 1. Hamdyscan 700 position. When scanning the object of interest, it is important to keep a distance of 12 in from the object. The scanner has poka-yoke LED that indicates the correct distance. The scan is done until a homogenous point cloud is obtained as seen in Fig 2.

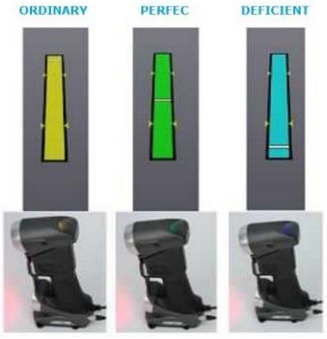


Fig. 2. Distance poka-yoke

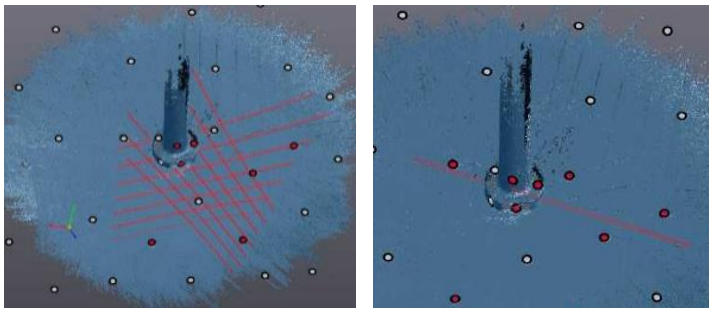
Tab. 1. Handyscan 700 technical specifications

Specifications	Handyscan 700
Dimensions	122 x 77 x 294 mm
Scanning speed	480 000 measures/s
Scanning area	275 x 250 mm
Light source	7 transversal lasers (+1 additional line)
Laser type	II (safe for unintentional eye exposure)
Resolution	0.050 mm
Precision	Up to 0.030 mm
Volumetric accuracy	0.020 mm + 0.060 mm/m
Volumetric accuracy (with 3D Maxshot)	0.020 mm + 0.025 mm/m
Safety distance	300 mm
Depth of field	250 mm
Object size (Recommended)	0.1–4 m
Connection standard	1 USB port 3.0
Operation Temperature	15–40 °C
Operation Humidity (without condensation)	10.90% Figure 2.

Points of reference. The digitization process with a scanner includes preparation of the working table using stickers or reference points that provide a reference frame to capture the object's surface. The object's preparation depends on it size. Sticker are not required on small objects. For large objects, reference points must be located strategically in such a way that three of these points must always be aligned for surface recognition, as seen in Fig. 3.

Fig. 3. Object preparation

It is important to mention that due to surface characteristics, the scanner used in this work provides two different kinds of laser beams, as seen in Fig 4. The first type has a parallelogram pattern typically used for planar surfaces. For regions on the object's surface which have different depths and angular shapes it is convenient to use a linear laser beam.



a) **b)**

Fig. 4. a) Parallelogram laser pattern, b) linear laser

Point cloud (mesh). Information is captured and sent to the VXelements software. The result is one or several point clouds that represent the entire object. The point clouds may contain points that do not correspond to the object's surface geometry. The actual object that was digitized is shown in Fig. 5.

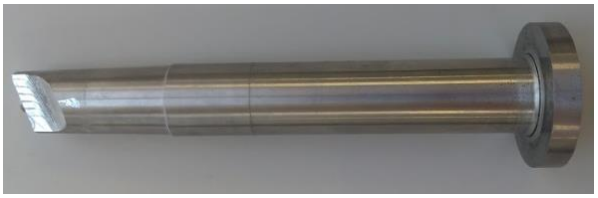


Fig. 5. Side bolt

The object's brightness is an important factor that must be considered during the scanning process, since it can cause problems while generating the point cloud as seen in Fig. 6 where it is observed that the object's shape is incomplete due to its brightness.

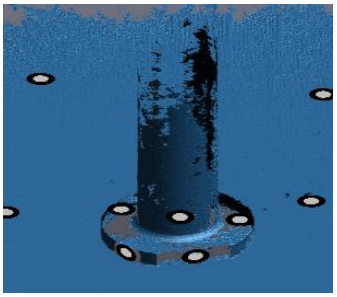
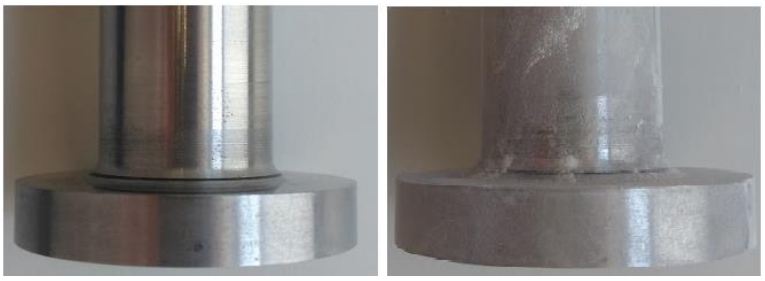


Fig. 6. Scanned object digitized in Xelements

For this purpose, it is recommended to apply white chalk on the object's surface to reduce its brightness (Fig. 7), thus minimizing distortion of the point cloud and reducing the total processing time.



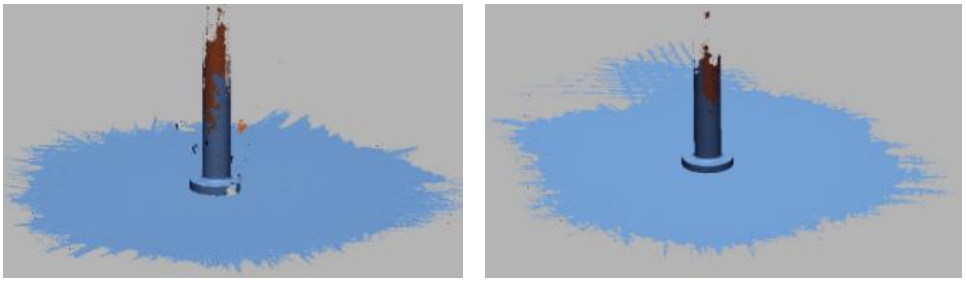
a) **b)**

Fig. 7. Scanned object: a) high brightness, b) reduced brightness

One of the most important parameters while scanning an object is the shutter speed. The shutter regulates the frequency and intensity at which the laser is projected towards the object. The shutter must be adjusted according to the object's color.

2.2. Point cloud processing

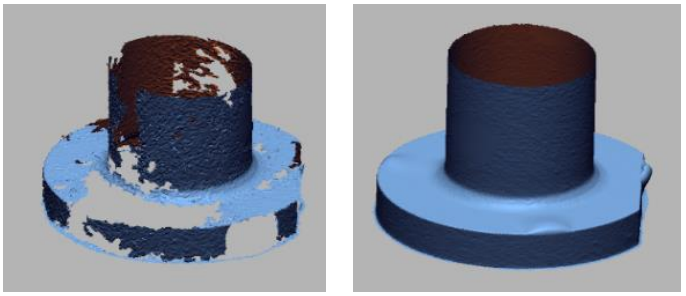
In Fig. 8 we observe that the point cloud has vortex regions in areas around holes, surfaces that are not completely defined and on the working table. Thus, we process the point cloud in order to eliminate all those points that do not belong to the desired object.



a) **b)**

Fig. 8. Point cloud: a) high brightness, b) reduced brightness

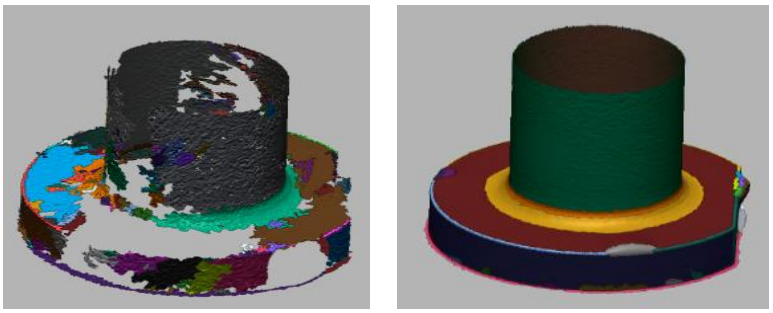
The point cloud is further processed by smoothing all even surfaces and breaking the piece in segments for easier visualization. As observed in Fig. 9, the point cloud is better defined when the object's surface was treated to reduce its brightness, hence reducing the processing time and increasing accuracy in the design of the CAD model.



a) **b)**

Fig. 9. Processed point cloud: a) high brightness, b) reduced brightness

It is necessary to mention that the point cloud is not yet a solid, it only serves as a reference for the CAD drawing. We also observe that after segmentation, the object is also better defined when its surface was treated to reduce brightness, as seen in Fig. 10.

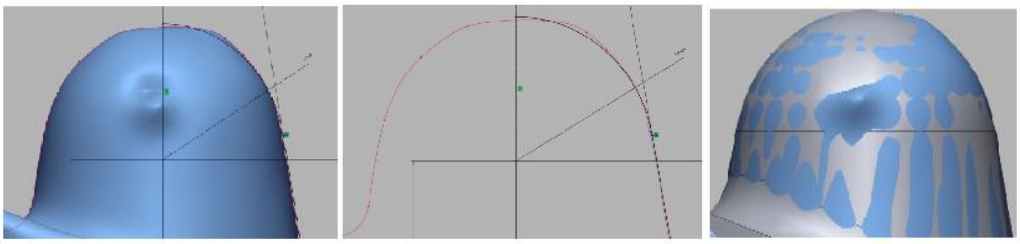


a) **b)**

Fig. 10. Segmented point cloud: a) high brightness, b) reduced brightness

2.3. CAD drawing

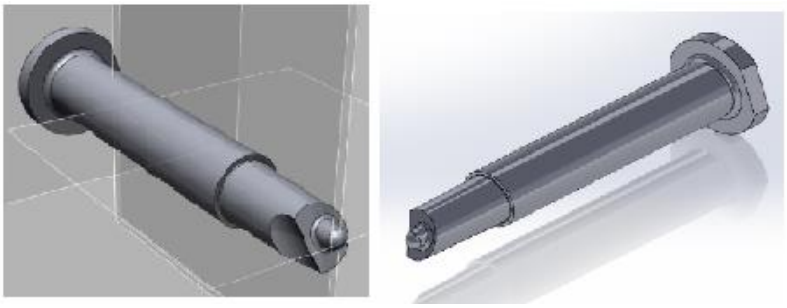
Once the processing and cleaning of the point cloud is done, we proceed to create the CAD drawing using the Geomagic Desing X software. To make the drawing, we take as reference those lines generated by the point cloud (Fig. 11) in order to keep the lines in the drawing close to the digitized ones, thus obtaining a good approximation to the original dimensions.



a) **b)** **c)**

Fig. 11. Sketch generation a) point cloud, b) reference lines, c) CAD model

The drawing allows for the object's dimensions to be modified. The objects geometry may be improved and corrected if necessary. In Fig. 12 we observe the CAD model of the object presented previously in Fig. 5. The model can be converted to several formats for its use by software such as Solidworks and other applications.

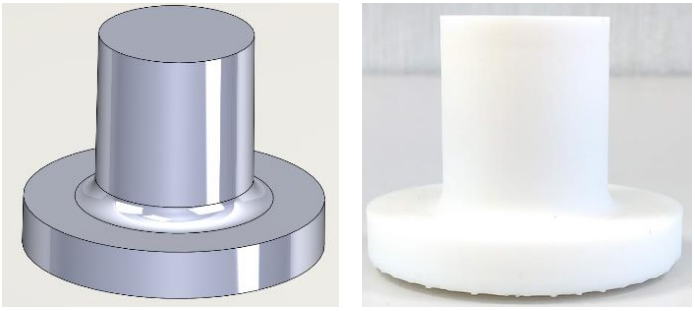


a) **b)**

Fig. 12. CAD model in a) Geomagic Desing X, b) Solidworks

2.4. 3D printing

One of the advantages of digitizing a piece is the capacity to manufacture it by 3D printing as many times as necessary. For the purpose of this study we printed only a segment of the object as seen in Fig. 13.



a) **b)**

Fig. 13. a) CAD model, b) 3D printed object

3. RESULTS AND DISCUSSION

As mentioned above, excessive brightness of the object may complicate the digitization of its surface. For this purpose, we do 24 test scans where we modify the scanning resolution and the shutter speed on the object with and without brightness. The qualitative and quantitative results are presented below. We also compare the final dimensions of the physical object with the CAD model and the 3D printed piece.

3.1. Brightness effect on the scanning process

Fig. 14 presents the object's dimensions that will be analyzed in this work.

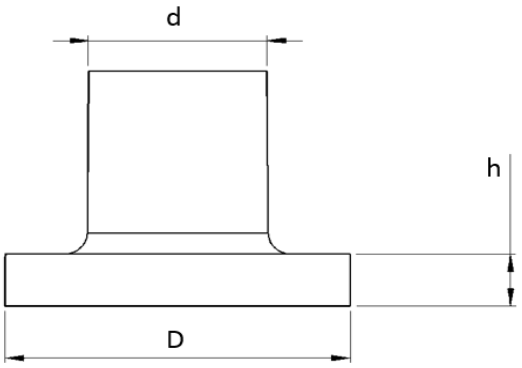


Fig. 14. Measures

Tables 2 and 3 show the results obtained during scanning at different surface conditions (with and without brightness), resolution (0.2, 0.5 and 1 mm) and shutter (0.6, 2.6, 4.6, 6.6). From Table 2 we observe that the dimension variability for the part with full brightness is of 0.183–1.917%, 0–0.5% and 0.708–5.272% for dimensions D, d and h respectively. On the other hand, for the part without brightness, we obtained ranges in the order of 0.03–0.05%, 0.223–1.817%, 1.13–7.39% for dimensions D, d and h respectively. Hence, we observe that the part without chalk has larger data dispersion than the part with chalk. This trend also occurs for all values of shutter speed. Considering the D dimension, a shutter speed of 0.6, 4.6, and 6.6 yields a dispersion of 0.045–1.017%, 1.334–2.367% and 0.033–1.634% respectively for the part with brightness and 0.183–0.934%, 0.33–1% & 0.033–0.367% respectively for the part without brightness.

Fig. 16 shows the D dimension variability for a shutter speeds of 2.6 (for shutter speeds of 0.6, 4.6 & 6.6 see Fig. 15, Fig. 17 and Fig. 18) in order to visualize trends and difference between the parts with and without brightness. From Fig. 16 we observe that the part with brightness shows higher variability percentage at a higher resolution due to laser scattering from the surface of the part. This high reflectance of the material causes some features on the object's surface not to be recognized, thus we obtain a larger error between the dimensions of the point cloud and the physical object.

Tab. 2. Shutter value 0.6 and 2.6

Shutter 0.6						
Resolution (mm)	**Dimension**	**Physical part**	**Dimensions (mm) CAD**		**Diference between phiysical and CAD models (%)**	
			Whit glow	**No glow**	**Whit glow**	**No glow**
0.2	D	59.980	60.007	60.540	0.045	0.934
	d	31.370	31.390	31.290	0.065	0.255
	h	10.000	10.436	9.974	4.360	0.258
0.5	D	59.980	59.873	60.180	0.178	0.333
	d	31.370	31.240	31.370	0.414	0.000
	h	10.000	9.049	9.791	9.511	2.086
1	D	59.980	60.590	59.870	1.017	0.183
	d	31.370	31.200	31.300	0.542	0.223
	h	10.000	10.500	9.799	5.000	2.015
Shutter 2.6						
0.2	D	59.980	58.830	60.000	1.917	0.033
	d	31.370	31.370	31.200	0.000	0.542
	h	10.000	9.473	9.887	5.272	1.135
0.5	D	59.980	59.870	60.000	0.183	0.033
	d	31.370	31.210	31.300	0.510	0.223
	h	10.000	10.071	9.748	0.708	2.520
1	D	59.980	59.750	59.950	0.383	0.050
	d	31.370	31.460	30.800	0.287	1.817
	h	10.000	10.454	9.261	4.535	7.393

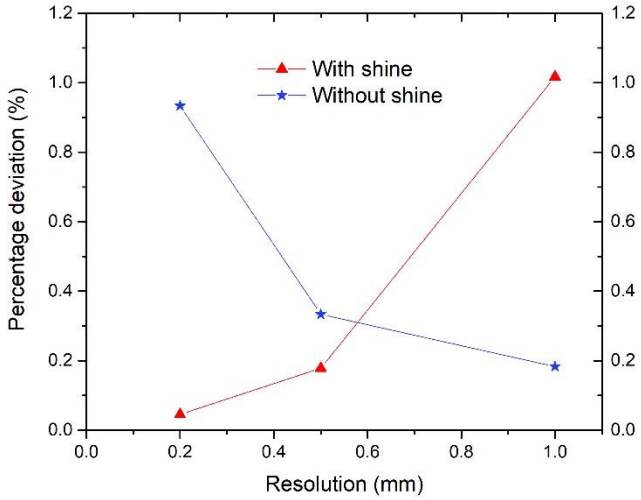


Fig. 15. Shutter value graph 0.6

Tab. 3. Shutter value 4.6 and 6.6

Shutter 4.6						
Resolution (mm)	**Dimension**	**Physical part**	**Dimensions (mm) CAD**		**Diference between phiysical and CAD models (%)**	
			Whit glow	**No glow**	**Whit glow**	**No glow**
0.2	D	59.980	59.180	60.040	1.334	0.100
	d	31.370	31.300	31.200	0.223	0.542
	h	10.000	9.830	9.875	1.700	1.246
0.5	D	59.980	59.840	60.000	0.233	0.033
	d	31.370	31.400	30.400	0.096	3.092
	h	10.000	9.970	9.636	0.300	3.641
1	D	59.980	58.560	60.000	2.367	0.033
	d	31.370	31.000	30.600	1.179	2.455
	h	10.000	9.570	9.283	4.300	7.172
Shutter 6.6						
0.2	D	59.980	59.920	60.000	0.100	0.033
	d	31.370	31.400	31.200	0.096	0.542
	h	10.000	9.750	10.000	2.500	0.000
0.5	D	59.980	60.000	60.000	0.033	0.033
	d	31.370	31.200	31.200	0.542	0.542
	h	10.000	9.410	9.660	5.900	3.400
1	D	59.980	59.000	60.200	1.634	0.367
	d	31.370	31.200	31.200	0.542	0.542
	h	10.000	10.000	9.600	0.000	4.000

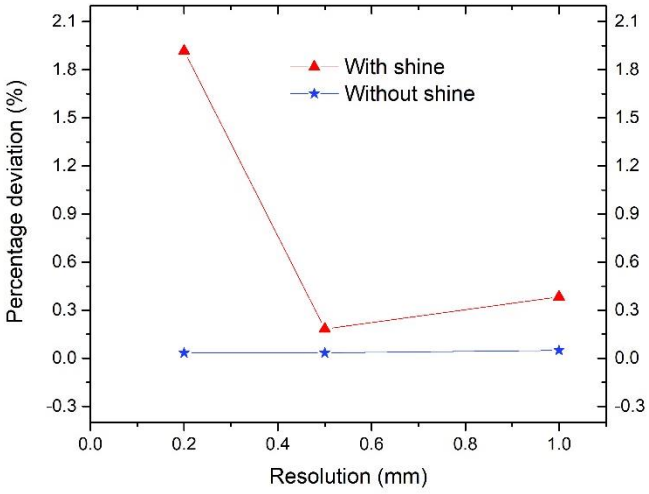


Fig. 16. Shutter value graph 2.6

In the case of the part with chalk, the D dimension variability is lower with higher resolution since the laser is stable on the surface of the object due to its lower reflectance relative to other optical properties. This behavior occurs for all the values of shutter speed studied in this article.

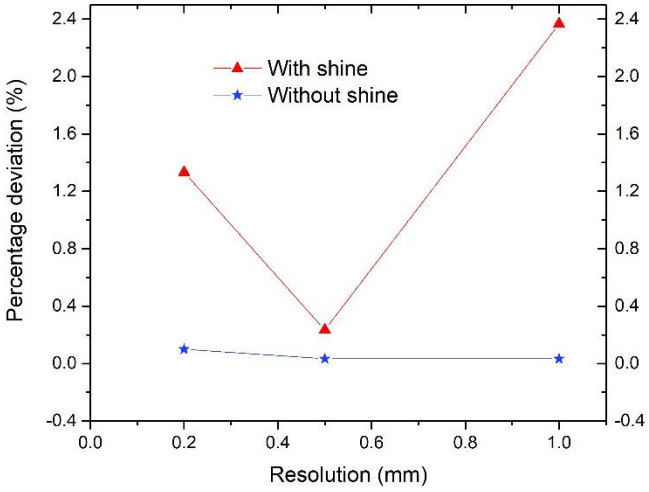


Fig. 17. Shutter value graph 4.6

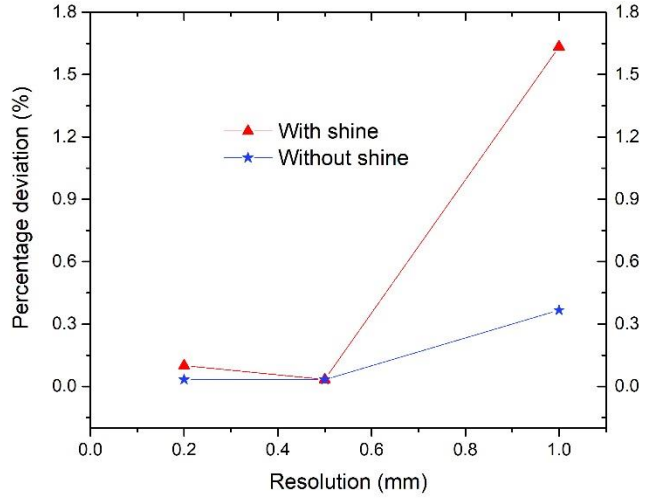


Fig. 18. Shutter value graph 6.6

Lastly, from previous results (See Fig. 15–18) the importance of the resolution by shutter effects was demonstrated. Regardless the shine condition, and for the specific case of this article, the lowest difference (0.6%) between the physical part and the point cloud dimensions was calculated when at resolution of 0.5 is selected.

4. CONCLUSIONS

In this work we scanned a bright object whose surface was dimed to minimize its optical reflectance thus obtaining a geometric approximation of the object within 99.9% of its morphologic characteristics such as smoothness and dimensions. For white color we used a shutter speed of 2.6 and 2.5 mm of resolution. With these parameters, the difference relative to the original object was of 0.033%. For the parts with a high reflectance index, we propose a combination of 2.6 – 4.6 in shutter speed with a resolution of 0.5 mm. Finally, respect to original dimensions, a cumulative error less than 1% was obtained during the scanning and digitizing process of the part.

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WiMax transceiver, design, analysis, MATLAB-Simulink

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NOVEL SIMPLE DESIGN AND ANALYSIS OF WI-MAX TRANSCEIVER USING MATLAB-SIMULINK

Abstract

This paper provides analysis of WiMAX systems from its background to their architectures highlighting merits and demerits, topologies, structures and looks deep into transceiver systems architecture, then specializes on the radio frequency (RF) front-end part of the WiMAX transceiver system in which a model is designed. Thereafter, the model is implemented in MATLAB Simulink and the results are investigated and analyzed.

1. INTRODUCTON

Worldwide Interoperability for Microwave Access (WiMax) is a wireless communication framework that permits PCs and workstations to interface with fast information networks, (for example, the Internet) utilizing radio waves as the transmission medium with data transmission rates that can surpass 120 Mbps for each radio channel. The WiMax framework is characterized in a gathering of IEEE 802.16 industry standards and its different revisions are utilized for specific types of fixed and mobile broadband wireless access (Erceg & Hari, 2017; Lee, 2015).

WiMax is framework that is basically utilized as a wireless metropolitan area network (WMAN). WMANs can give broadband information communication access all through a metropolitan or city geographic region. WMANs are utilized all through the world and their applications involve client broadband wireless Internet services, leased lines and digital TV (IPTV) services. WiMax broadband wireless can rival optical broadband connections, digital subscriber line (DSL), and cable modem (Gray, 2006; Tarapiah, Atalla & Daadoo, 2017; Tebepah, 2018).

The 802.16 structure was planned for fixed area Nomadic service. Nomadic service is the giving of communication services to more than one location. While nomadic service might be given such a large number of locations, nomadic service ordinarily needs the movable communication device to be fixed in location through the use of communication service.

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For mobile service, the 802.16e was born. The 802.16e detail adds mobility management, extensible authentication protocol (EAP), handoff (call transfer), and power saving. WiMax has a few diverse physical radio transmission choices which permit WiMax framework to be sent in areas with various regulatory and frequency accessibility requirements. Several works on the topic of this paper can be found in literature (Erceg & Hari, 2017; Tembhekar, Thote & Zade, 2019).

1.1. Problem definition

Wireless communication is one of the most quickly developing enterprises in the present society. Mobile phones, wireless email and other ongoing innovative creations have prompted the interest for wireless access any place one goes. The consequence of this interest produced Wi-Fi (wireless fidelity) "hotspots" in which institutions; similar to Mustansiriyah University, set ups a wireless network to be gotten to by students and staff while in the campus area. The speed and range restriction have prompted an interest for more up to date innovation to additional grow the wireless market, to be named WiMAX.

2. METHODOLOGY

2.1. Design model

The novel design of the low-intermediate frequency (IF) RF front-end WiMAX transceiver involves integration of various components to work as a unit. The overall implemented model for the transmitter and the receiver is shown in Fig. 1.

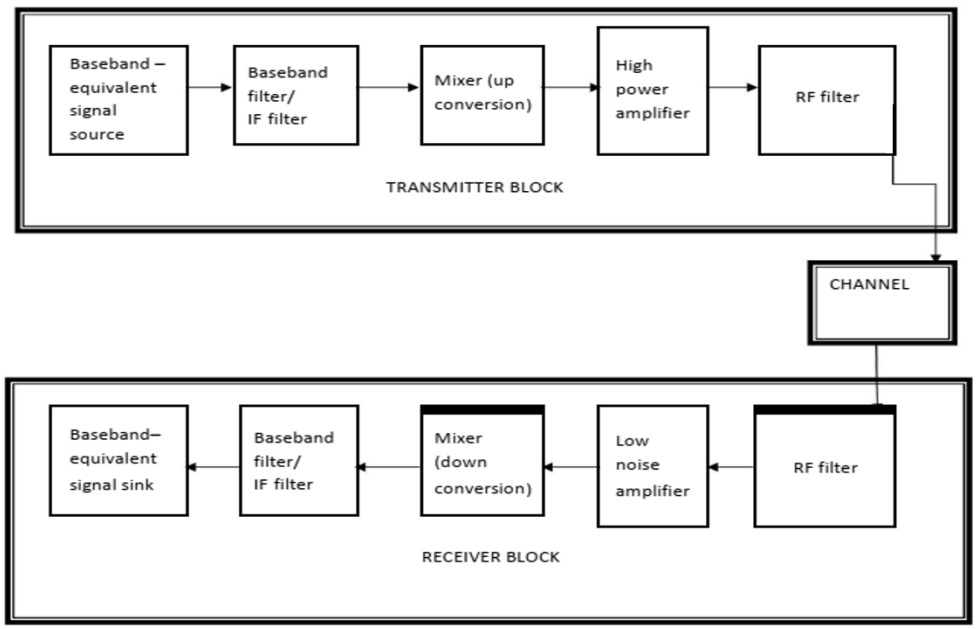

Fig. 1. Novel design of the low-IF-front Wi-Max transceiver

2.2. Design description

2.2.1. Baseband equivalent signal source

The signal source in the model includes the following components:
- A random integer generator block, used as source of random data,
- A modulator and a pulse shaping filter that performs Quadrature Phase Shift Keying (QPSK) modulation and root raised cosine pulse shaping,
- An up converter block that multiplies the modulated signal by a carrier frequency.

The sample frequency is set at 8 MHz.

2.2.2. Baseband equivalent signal sink

The signal sink in the model includes the following components:
- A down converter block that converts the signal from real passband to complex baseband,
- A root raised cosine pulse shaping filter that decimates back to one sample per symbol, and a QPSK demodulator block,
- Bit-Error-Rate (BER) calculation block.

The sample frequency is set at 8 MHz with a baseband bandwidth of 1 MHz.

2.2.3. IF filter

There are two band pass IF filter blocks are utilized. The strategy solution is Butterworth of order 3. In the pass-band and monotonic in general, the magnitude response of a Butterworth filter is extremely flat. 1 MHz and 10 MHz are the lower pass-band edge frequency and upper pass-band edge frequency respectively.

2.2.4. Mixer

A mixer can be described as a device with three ports that uses a nonlinear or time-varying element to convert frequency. Normally in a wireless communication systems all signal processing is done in baseband because it is easy to process low frequency signals. To be able to transmit through the wireless channel however the signal has to be brought to a higher frequency, which is done by modulation and up conversion in the transmitter, this effect has to be undone in the receiver which corresponds to demodulation and down conversion in the receiver (Muaayed F., 2020). Up and down conversions are done with mixers as follows:

Up converter

$$f_{IF} + f_{LO} = f_{RF}$$

The local oscillator frequency (f_{LO}) is set at 2.5 GHz, and f_{IF} at 10 MHz.

$$f_{RF} = (2500 - 10)\ \text{MHz} = 2.51\ \text{GHz}$$

Down converter

$f_{RF} - f_{LO} = f_{IF}$

The f_{LO} is set at 1.8 GHz.

$f_{IF} = (2510 - 1800)\ \text{MHz} = 710\ \text{GHz}$

This satisfies the Low-IF architecture theory in which the RF signal is translated to intermediate frequency closer to the baseband frequency.

2.2.5 RF filter

Two band pass RF filter blocks are utilized. The design strategy is Butterworth of order 3. The magnitude response of a Butterworth filter is extremely flat in the pass band and monotonic overall. 2.4 GHz and 2.6 GHz are the lower pass band edge frequency and upper pass band edge frequency respectively.

2.2.6. High power amplifier (HPA) and Low noise amplifier (LNA)

High-power amplifiers are principally utilized in transmitters and are planned to raise the signal's power level before sending it to the antenna. This power boost is important for the receiver to achieve the optimal signal-to-noise ratio, and it will not be detectable without the received signals.

Low Noise Amplifier (LNA) is the first amplifier in the RF receiver frontend; typically it is the first or second component after the antenna. It is intended to increase the power of the signal received, which is normally very small (could be as weak as –200 dBm. LNAs are designed to add as little noise as possible, such that the signal to noise ratio (SNR) stays above the minimum required SNR of the receiver. The SNR is defined as the ratio between the wanted signal and the noise and is usually specified in dBs. Every receiver has a minimum SNR at its input, if the SNR drops below this value, the error in the received signal will be high (Al-Rawi, 2020; Al-Rawi, Abboud & Al-Awad, 2020).

The HPA gain is set at 200 and The LNA gain is set at 120.

2.2.7. Channel

An Additive White Gaussian Noise (AWGN) Channel block set to signal-to-noise (Eb/No) mode. It specifies two bits per symbol because the modulation format is QPSK. The signal power is 1/(2·8) watts. This is because the original signal power at the modulator is one watt. The signal samples by factor eight by utilizing the root-raised cosine filter up, and then the power decreases by this factor. The real portion of the signal will be taken by the output of frequency up conversion block, thereby decreasing the power again, this time by a factor of two.

3. RESULTS AND DISCUSSION

MATLAB Simulink simulates the model in Fig. 2, and the parameters of its components are seen in Tab. 1.

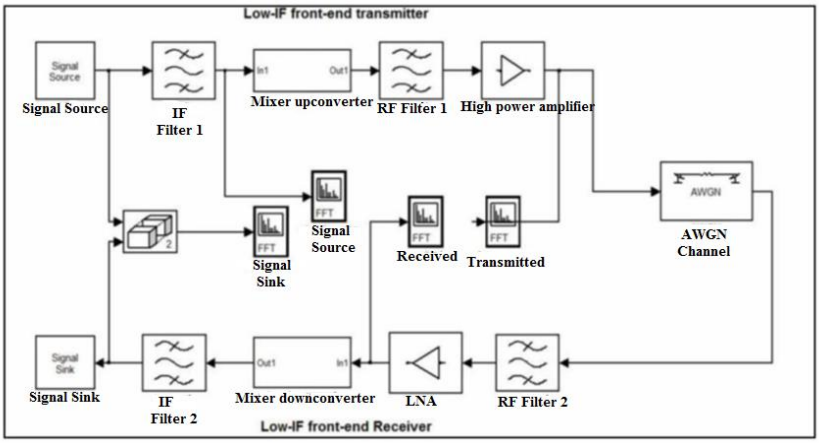

Fig. 2. Simulated model Low-IF-RF front end Wi-Max transceiver

Tab. 1. Parameters configurations

Parameters	RF Filter	IF Filter	HPA	LNA	Mixer	Power Amplifier	Channel
IIP2 (dBm)	–	–	–	0	0	0	1
IIP3 (dBm)	–	–	–	1	1	0	1
NF (dB)	1	5	2	1	0	0	8
Gain (dB)	-1	0	200	120	2	100	0
Order	3	3	–	–	–	–	–

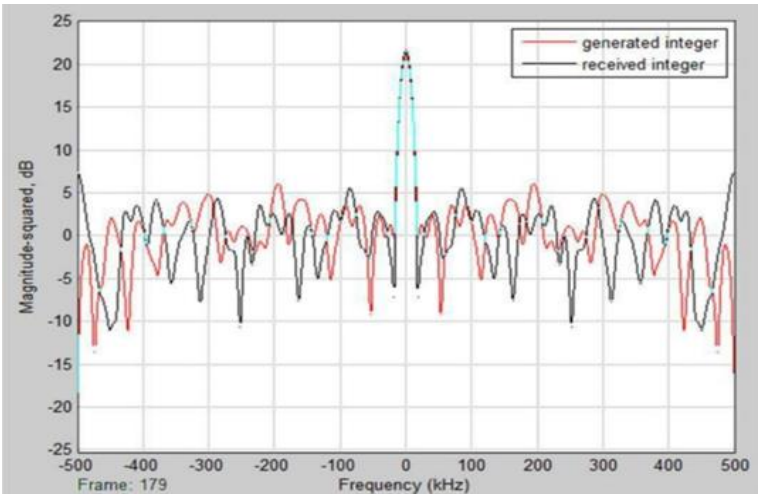

Fig. 3. Spectrum of Signals generated and received

A random integer signal of about twenty KHz is generated and received as appeared in Fig. 3. A modulator and a pulse shaping filter that achieves QPSK modulation and root raised cosine pulse shaping are passed through the generated signal, as shown in Fig. 4.

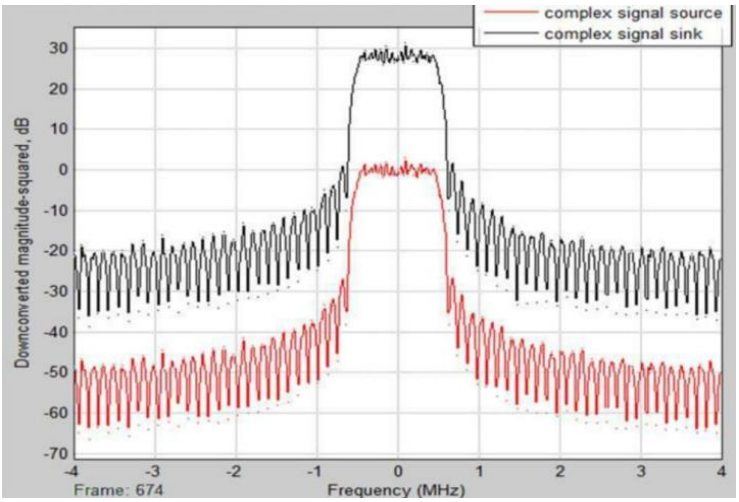

Fig. 4. Modulated QPSK signals transmitted and received

It is generated a base–band equivalent frequency signal (two to three) MHz with a one MHz bandwidth. As shown in Fig. 5, after being passed through the Low-IF RF front-end topology framework, this signal is transmitted and received.

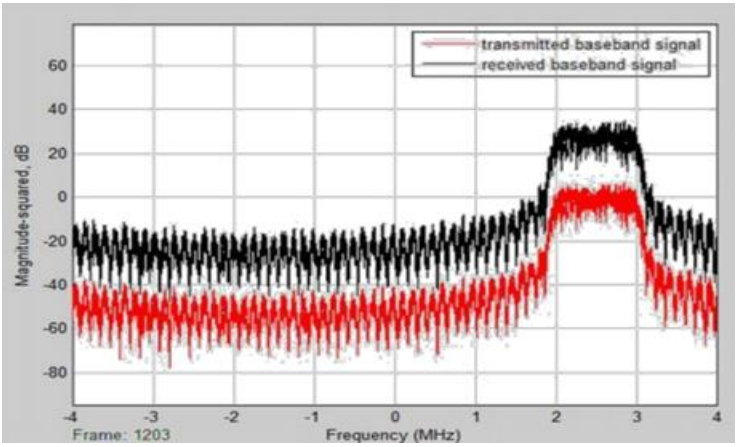

Fig. 5. Transmitted and received spectrum of base-band signals

The transmitted signal constellation is shown in Fig. 6, while the constellation of the signal received is shown in Fig. 7. The nonlinearity in the amplifiers and mixers caused the signal constellation to be spread. A nearly perfect 90° phase shift between the I and Q (In-Phase/Quadrature) paths is responsible for the limited bandwidth of the baseband signal. The BER is 0.5 because of the framework's relatively low noise figure (NF). Excessive noise in the device may have caused the signal to be overcome by noise, rendering the signal unrecoverable.

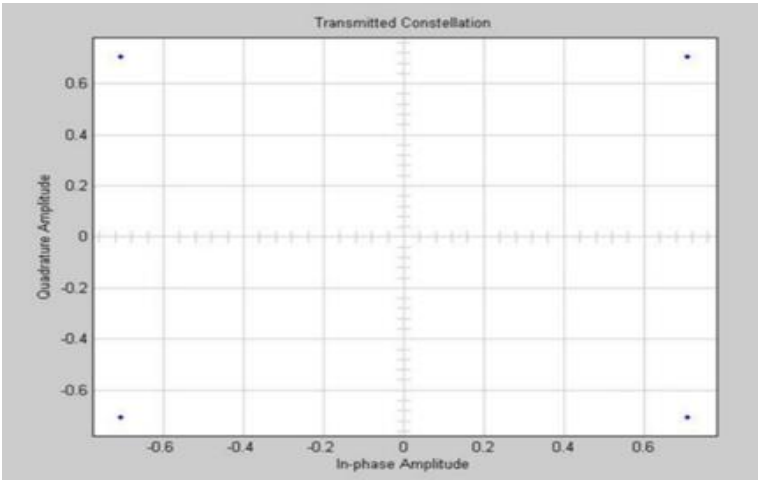

Fig. 6. The constellation Transmitted

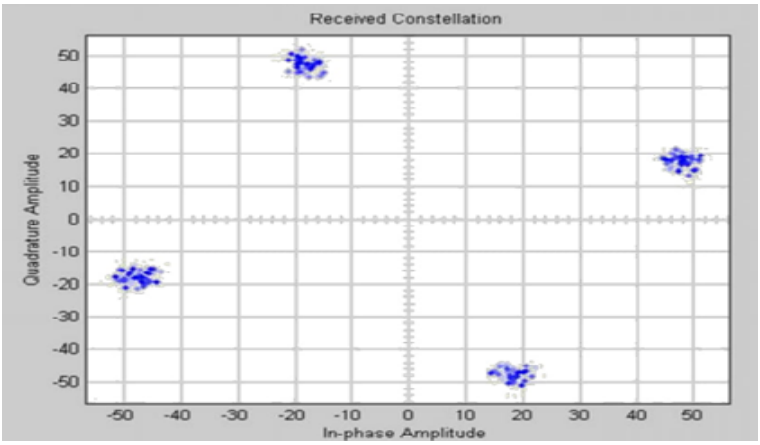

Fig. 7. The Constellation Received

4. CONCLUSION

The WiMAX technology can easily be inferred to be an innovative technology that is poised to revolutionize the world. A novel simple analysis and design methodology for a Low-IF RF front-end WiMAX transceiver was demonstrated in this paper. Using MATLAB Simulink, the model was implemented and successfully examined.

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Virtual Reality, laser scanning

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VIRTUAL REALITY IN PRODUCTION LAYOUT DESIGNING

Abstract

Information technologies allow for improving production systems functioning especially thanks to a possibility of solving complex production problems in a very short time. The production system designing is increasingly based on virtual reality, and more specifically on the concept of a digital factory. It enables to create virtual models of real objects and use them for visualization of products and manufacturing processes. The presented examples of new information technologies, which are used in production practice, are the main object of this paper.

1. INTRODUCTION

Today, competitive global markets require high quality, quick production and low cost. Such markets requirements create the need for collaboration of all professions, from engineers and managers to shop floor workers. The future success requires sharing knowledge and experience (Gregor et al., 2007; Plinta & Więcek, 2012) with the use of new information technologies. The highly competitive environment requires in production practice new software systems for designing, testing, process planning, manufacturing and assembly (Tatarchenko, Lyfar & Tatarchenko, 2020).

Another decisive factor for further development is quality of its engineers, who are responsible for innovations. The evolution of production systems mainly follows the development of innovative technology and its direct environment, like machines, devices, methods and tools aiding the work related to preparing technical documentation, including description of product models, processes and production resources (Gregor, Herčko & Grznár, 2015). This can be achieved by introducing shorter production cycles, new products and manufacturing processes development, minimization of the supplies level, more efficient logistics, and the usage of effective and innovative ideas of production realization, like Lean Production, JIT (Just in Time), Total Quality Management, and particularly, Digital Factory Technologies (Davis et al., 2012; Gola, 2014).

The main types of software, used in production enterprises, are linked in PLM solutions, which control different parts of the manufacturing cycle. CAD systems define what will be produced, Manufacturing Process Management defines how it will be manufactured, ERP informs when and where it is created, whereas MES provides shop floor control

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and simultaneously manufacturing feedback (Danilczuk & Gola, 2020). The stored information generally aids communication and improves making decisions, but also removes human errors from the design and the manufacturing process. Nowadays, Industry 4.0 has become a very popular concept, which in its assumptions integrates various software applications (Bučková, Krajčovič & Edl, 2017; Kolberg & Zühlke, 2015).

2. VIRTUAL REALITY

The Digital Factory concept bases, which enables to create virtual models of real objects and use them for visualization of products and manufacturing processes (Westkaemper et al., 2001).

It is possible to use Virtual Reality technologies to design 3D spatial models and 3D modelling and examination of properties of real objects. Virtual Reality can be used for different kinds of analysis connected with product development, designing production processes, workplaces, production systems, etc. The use of Virtual Reality for design and optimisation of production processes and systems is often called Digital Factory application (Dulina & Bartanusova, 2014; Furmann & Krajčovič, 2011; Krajčovič et al., 2013).

Digital Factory can be described as a virtual picture of a real production. It represents the environment integrated by computer and information technologies, in which reality is replaced by virtual computer models. Such virtual solutions enable to verify all collisions and critical situations before real implementation of the proposed solutions. Digital Factory can support planning, organization and optimisation of complex production, and simultaneously creates right conditions for team work, providing quick feedback among designers, technologists, production systems designers and planners (Furmann, Furmannová & Więcek, 2017).

From the perspective of spatial arrangement optimization, the most important decision criteria include minimization of transport activities, material flow, suitable connection between external logistics chains, minimizing the need for space, minimizing inventories and production cycles, fulfilling the requirements regarding health and safety at work, flexibility and possibility of future changes.

For the above mentioned reasons, production layout design requires implementation of a few following basic steps:

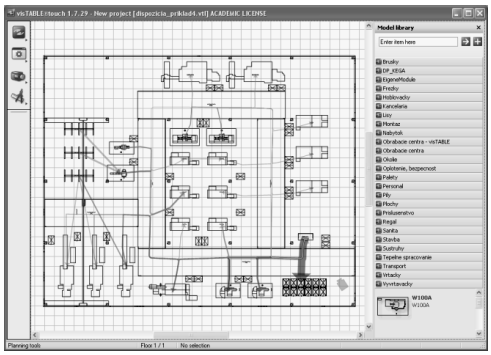
1. Collection, processing and analysis of input data.
2. Designing an ideal layout.
3. Constraints specification and creation of a real system and its evaluation.
4. Visualization of the proposed solution.

Real layout design in the virtual environment requires the following steps:

1. Preparation of 2D/3D objects – can be performed as follows:
   - usage of libraries of 2D/3D objects from the used software,
   - acquiring new 3D models using reverse engineering methods,
   - creating new models using CAD applications with application of 3D scanning method.
2. Modelling of the production system - this phase comprises:
   - saving objects from the library on the projection surface,
   - defining relations between objects,
   - designing transport lanes and networks.

3. Layout optimization – with the usage of analytical tools.
4. Visualization of the production system – 2D or 3D layout of the production system, which may be presented as classic visualization by computer monitor, using a projection table, or using virtual technology and augmented reality.

The result is a realistic layout of workplaces, which respects all the existing constraints in production presented in 2D or 3D view (Fig. 1).



a) 2D layout

b) 3D model

Fig. 1. The real layout of workplaces

3. PROJECT STAGES

The purpose of this paper is to present parts of procedure implemented to develop models of objects. Models can be used in design and reorganizing processes in production halls, staff trainings and validating workstations ergonomics using VR technology.

There are several ways of extracting 3D models of equipment in production halls. The first one is to adopt Factory Design Suite asset library used in designing factories. Factory Design Suite delivers a registry of machinery, units and facilities layout and is compliant with Inventor and AutoCAD. Production halls equipment, architectural building tools, transport devices, mannequins, storage machines, industrial robots and safety equipment can be found within.

The second method is to source the models directly from the manufacturer. It is becoming a common practice for vendors to share 3D models of their products as it allows the customers to save time that otherwise would have to be spent on creating the model.

The third approach allowing to obtain precise geometry data of a production hall and its facilities consists in 3D scanning of a given object and, subsequently, creating its 3D model. There are couple of steps involved in this action, presented in figure 2.

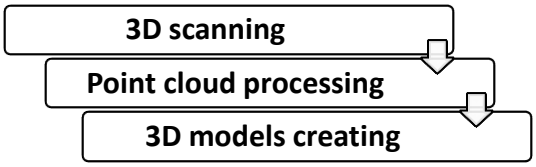


Fig. 2. Project stages

3.1. 3D scanning

3D scanning is a technology that develops rapidly and allows to collect geometric and measurements data of a scanned object quickly and precisely. Essential characteristics of mentioned technology are described below:

- Speed – expressed in the amount of points registered in xyz coordinate system within a second.
- Accuracy – indicated by measurement error observed within a determined length. In the case of FARO LS 880 phase based laser scanner, mentioned in the later part of this paper, the measurement error amounted to ±3 mm within 25 m distance.
- Resolution – the higher resolution the greater amount of points constituting the point cloud representing the projection of scanned area. It is a compromise between the accuracy of a scan and the time of measurement which is directly proportional to resolution.
- Scanning area – totals to 360° horizontally and 320° vertically, therefore the surface under the stand on which the scanner is placed will not be included.
- Color scanning. In case of FARO LS 880 scanner, connecting a camera is required to achieve such result as it takes a series of pictures constituting a groundwork to color the point cloud extracted in the process of scanning.

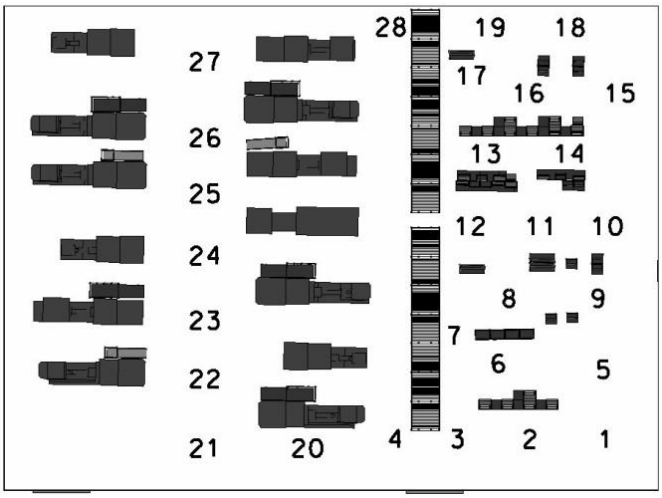


Fig. 3. Map of scanner's positions

Becoming familiar with the object and creating a map of scanner's position should be done prior to commencing the scanning process. Such practice allows to avoid so-called "dead areas" – fields that were not reached by the scanner and, as a result, geometric data were not registered. Figure 3 presents the map of scanner's position developed for the scanned object. Additionally, layout of referential items (shields and bullets) fundamental in the process of connecting scans in a point cloud should be designed.

3.2. Point cloud processing

Another stage of the process is to connect individual scans in one point cloud. FARO SCENE software supports this procedure in quick and precise manner due to automatic shield and reference bullet recognition. Figure 4 displays three point clouds from single standpoints, whereas figure 5 shows a complete point cloud build from 28 individual scans.

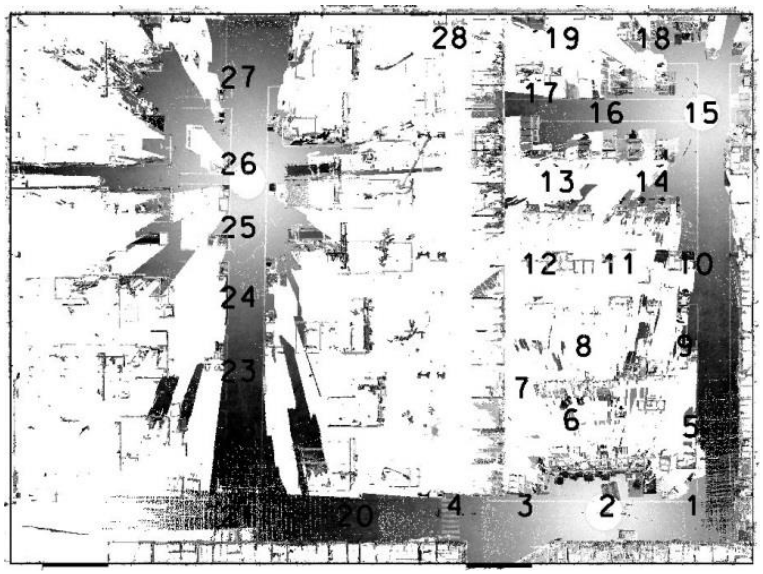


Fig. 4. The point clouds from single standpoints

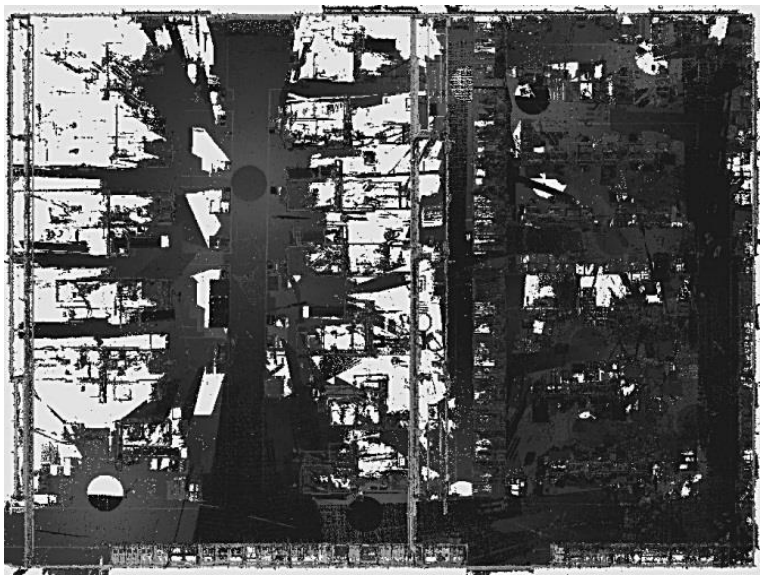


Fig. 5. Complete point cloud

Processed data are subsequently exported to a format supported by the environment in which the 3D model is going to be created. In case of discussed project it was a POD format. There exists also a possibility to share a point cloud via SCENE Webshare which enables to screen it through Internet browser.

There is also a possibility to create a virtual walk around the facility by means of panoramic pictures (TruView). Frequently, it supports the modeling process because makes is easier to recognize objects that would be hard to identify on the basis of point cloud itself. Moreover, TruView allows to perform measurements of scanned objects or to decipher coordinates of selected points.

3.3. 3D models creating

The creation of 3D models of a production hall and its equipment is the final preparation stage. Bentley Descartes application was used to construct the 3D models as it is adapted to cooperate with point clouds. Modeling consisted in creating outlines of appropriate cross-sections which, subsequently, were extracted into area within accurate length – arising from the point cloud. Figure 6 presents transition from an illustrative part of a point cloud to the 3D model of a work station.

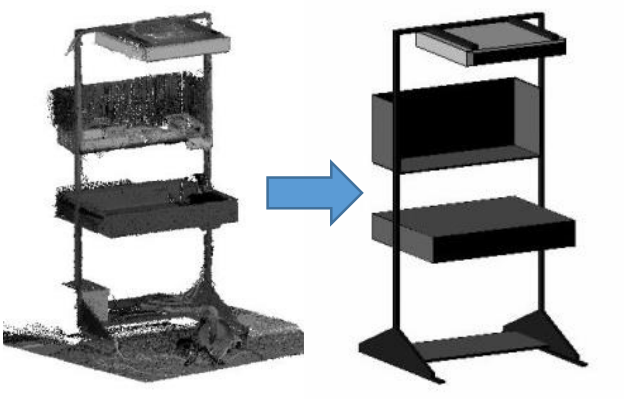


Fig. 6. Transition from point cloud to 3D model

Models of a hall and its equipment prepared in such manner were subsequently exported to FBX format which makes it possible to use them in virtual reality environment after converting to active object in Unity 3D.

4. POSSIBILITIES OF USING A MODEL AND VIRTUAL REALITY

A hall and its equipment created by using a method described above may be adopted in production layout designing, in designing new production spaces and reorganization of existing ones. Software available on market allow for conducting a series of analysis and simulations such as: material flow analysis, planning of work station arrangement, determining distribution of the routes of transportation means and regulating the efficiency of production lines. In case of less advanced analysis a model created in any program that

allows for its display and editing (AutoCAD, Inventor, Bentley Descartes) is considered to be helpful. Figure 7 shows an illustrative change of workplaces arrangement performed in Bentley Descartes program. In case of need for creating a visualization, virtual reality is a great solution that allows for carrying out a virtual walk around created production hall, implementing changes in workstation positioning and searching for new solutions. Figure 8 presents what the hall looks like in virtual reality.

Staff training which should be as close to real working conditions as possible and, at the same time, should minimize the cost and reduce danger of carrying them out. Considering those factors, VR environment seems to be the ideal solution, therefore it has been gaining considerable popularity in recent years. Initially, virtual reality was used mainly in military training yet it promptly started to be implemented in fields of ergonomics, safety and in cases where trainings conducted in real conditions could pose a threat for health and safety of humans. Examples of such circumstances are observed in virtual operations, works in nuclear power plants (in order to reduce ionizing radiation) and mines where working environment is extremely threatening. Taking into consideration that 40% of accidents involve young workers, trainings allowing for high competence level prior to commencing work seem to be a considerably promising solution (Grabowski, 2012).

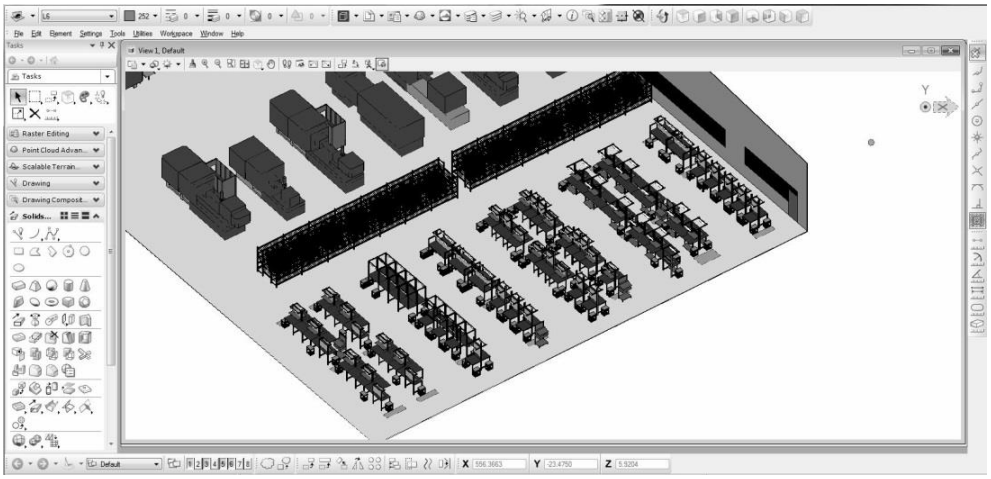


Fig. 7. Change of work station arrangement performed in Bentley Descartes

Creating a digital twin which constitutes a digital copy of a real production system and is created in order to optimize it. The concept of a digital twin is based on 3 pillars: real, digital and virtual world. The first one is created by a real factory, where the project is implemented in digital environment and there, thanks to sensors collecting and analyzing data from real-time production processes, allows for a variety of operations, namely: shortening and improving production process, locating inefficient processes, reducing the time of launching new products. The digital part is represented via digital models and may be evaluated by means of computer simulation. It involves planning and virtual staff trainings. The last component binds together the real-time production system with a virtual model of production system which is called digital twin (Skokan, 2019).

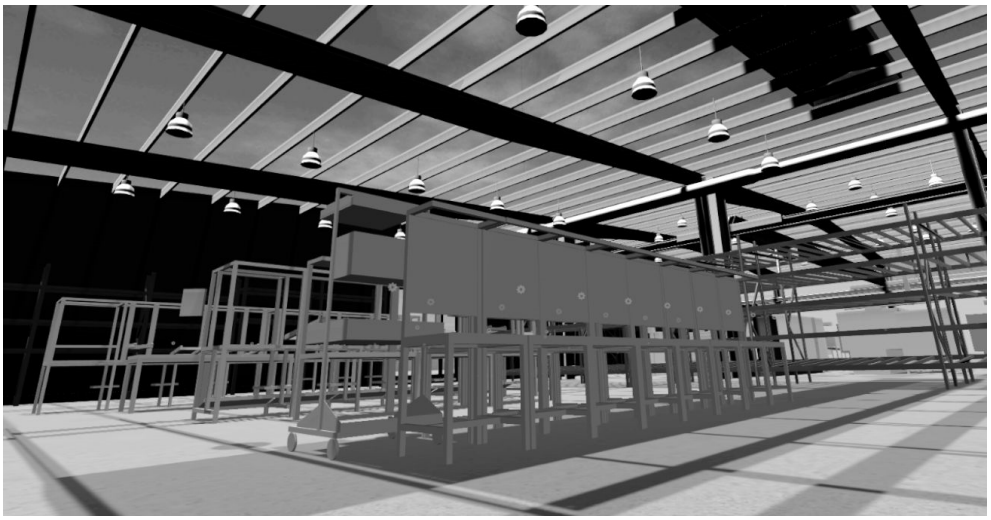


Fig. 8. Model based on point cloud

Quick validation of newly designed solutions in terms of ergonomics, it is next usage of this technology. It consists in connecting virtual and augmented reality by means of CERAA application which has a unit adopting augmented reality to conduct analysis of worker's ergonomic positions. A user within virtual hall may perform his or hers work and the chosen positions can be compared with a mannequin and acceptable range of motion screened via CERAA application. The advantage of such solution is eliminating the need for establishing a real workspace in order to test it in terms of ergonomics. Additionally, models created with the usage of parametric measurements can be altered quickly and revised with respect to suitable anthropometric measurements of workers. A wider scope of discussion regarding proposed conception, together with presenting functionalities and restrictions of a system, will be a matter of a separate publication.

5. CONCLUSIONS

A quest for intensification of the process of obtaining information regarding the reality is reflected in the development of laser scanning technology as it allows for precise, non-invasive and quick registration of digital data about the examined object. Diverse types of scanners coupled up with devices supporting the scanning process provide means for highly precise scanning of objects with various surfaces and sizes.

An intense development of laser scanning led to implementing this technology in various sectors of industry. A point cloud, which is the result of 3D scanning, provides a diverse set of information about the object and gives the opportunity to obtain any view, capture and cross-section established on formerly registered data is a huge asset of the 3D scanning. 3D models based on point cloud can be used in management, stocktaking, planning and analysis. They may also serve as the basis for being used in virtual reality environment which gains considerable amount of implementations. Some of them being: production layout designing, staff trainings, creating digital twins, validating workstations ergonomics without the need to have them in physical form.

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search engine optimization, Google, page ranking, Information Retrieve

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SEARCH ENGINE OPTIMIZATION: A REVIEW

Abstract

The Search Engine has a critical role in presenting the correct pages to the user because of the availability of a huge number of websites, Search Engines such as Google use the Page Ranking Algorithm to rate web pages according to the nature of their content and their existence on the world wide web. SEO can be characterized as methodology used to elevate site keeping in mind the end goal to have a high rank i.e., top outcome. In this paper the authors present the most search engine optimization like (Google, Bing, MSN, Yahoo, etc.), and compare by the performance of the search engine optimization. The authors also present the benefits, limitation, challenges, and the search engine optimization application in business.

1. INTRODUCTION

Search engine optimization (SEO) is the mechanism by which a website or web page is improved to maximize the frequency and quantity of organic traffic from search engines (Kareem, 2009). Effective SEO means a web page is more likely to appear higher on the results page of a search engine (SERP). Google is the most popular search engine, but other search engines (Bing, Yahoo, DuckDuckGo, etc.) also have their own special web page crawling algorithms which return the top results of the search (Schwartz, 1998). SEO is the process of helping to raise the rank of your website on Google and other search engines, thereby having your website in front of more users, growing company and making you a pioneer in the industry (Kareem & Okur, 2020a). Before you dive deep, it is incredibly critical that you have a good strategic strategy. Ranking for keywords is fine, but it is also critical, maybe even more so, to ensure that you meet your customers at each point of the purchasing process (Xu, Chen & Whinston, 2012). It's incredibly important to realize that SEO is not something you should take a half-assed approach to; before you dig in, you need to have a good strategic strategy. Ranking for keywords is fine, but it is also important to ensure that you meet your customers at each point of the purchasing process (Kareem & Okur, 2018). SEO tracking software such as Google Search Console make it easy to get quick insights on the results of page-specific or site-wide search engines (Kareem & Okur, 2020b). For a specific date set,

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users can find statistics about which queries produce the largest volume of traffic, as well as the location a page rates for particular keywords. Although a page's search ranking might be the best predictor of SEO efficiency, when calculating SEO, there are several other success metrics that are valuable. Another website monitoring platform, Google Analytics, gives background for other indicators that could directly or indirectly influence the SERP rating of a blog. Such metrics include: page length, pages per visit, mobile traffic, bounce rate, visits returned (Schwartz, 1998).

2. LITERATURE REVIEW

There is still the very old discussion about who is best and why while addressing search engines. The internet is available through a multitude of engines, some arguably weaker than others, from Google and Bing, to Yahoo and DuckDuckGo. There are two main facets of the nature and responsibility of the search engine: its aesthetic appeal (how the results are formatted and displayed) and its consequences. By concentrating on the characteristics of the performance, as architecture is largely a secondary usability function (although still important) and contrasts the two main Google and Bing search engines

Larry Page, Sergey Brin, launched Google in 1998 when Bing was developed as a successor to Microsoft's MSN Search, Windows Live Search and later Live Search in 2009. Google actually owns a 73.02 percent share of all users of the desktop search engine, while Bing only holds a 9.26 percent share (Schwartz, 1998).

Michael Basilyan, a senior program manager at Bing, reported in 2014 that "content quality" is one of the key priority areas of the page ranking phase of the search engine. In its rating estimation, Bing takes three attributes into consideration: the contextual importance of a website, the meaning, and the consistency of the content. Topical significance questions if a website page is linked to the query, i.e. "Does it address the query?" content analyzes contextual and historical users and asks specifics, such as whether the query might be about a common recent issue, what the user's physical location is, the search history of the user, etc. finally, and most notably, the standard of content explores three crucial questions: "Can we trust this content?" "Is the content helpful and sufficiently comprehensive?" and "Is the material easy to find and well presented?". While these are not the only variables taken into consideration by Bing in its page ranking system, they are what Bing finds to be the most important. In the other hand, for Google, it's impossible to rely on only a few key rating considerations. Google SEO consultants could name the most significant factors in the ranking algorithm with over 200+ ranking factors, such as keyword use, site structure, site speed, time spent on site, number of inbound links, and inbound connection quality. Google and Bing use many of the same page rating variables, quite clearly, but what separates the two rivals is the variations in how they use them. While the disparity between Bing and Google is not dramatic, certain characteristics are worth mentioning. While Google's search algorithm excels in matching synonyms and related terms with queries and data, Bing needs more precise matching of keywords to acquire precise search results. In addition, Bing continues to assign preference in page ranking to pages that are important to recent events. For eg, the first link on Google is the official Indian tourism site while searching for it in Google and Bing, while Bing shows news articles first; preceded the ranking of the official tourism website. However, if a website includes Flash content, Bing trumps Google in a significant feature, it is much more likely to score higher on Bing than Google.

Due to difficulties linking to a single article, Google's algorithm appears to often rate pages with flash lower than their counterparts. Finally, unlike Google, Bing appears to take the domain age of a website further into account and has a bias towards. Bing and Google varied only marginally in the effects they showed while researching the algorithms and page outcomes of the two search engines. An analysis conducted by SurveyMonkey showed in a study by Search Engine Land that most users would choose search results branded as 'Google,' even though the results were directly created by Bing. Participants preferred Google searches 57 percent of the time and Bing 43 percent of the time, a figure slightly lower than the current market share for the two search engines, while no company name was imposed on the results. it comes down to a mixture of individual tastes and brand prejudice. Despite Bing's recent modifications in its search algorithms to the point that the page results of Bing and Google are impossible to discern, Google has become a household name that is well-respected and consistent in its results and the importance of its page rankings for the majority of searches (Smith, 2010).

3. SEARCH ENGINE OPTIMIZATION

Search Engine Optimization is a short version of the word SEO. The optimization process was usually designed to illustrate the search results carried out by offenders of search engines such as Google, Yahoo Overture, etc. The web pages of these websites are ranked in the top ranks. From the above, it can be inferred that, in short, SEO is a method of improving the search engine that will be able to produce the necessary search results available to users. Search Engine Optimization is known to be an efficient way to optimize the eminence and degree of user traffic by the intrinsic search possibilities for the given website or domain. This is regarded as a type of natural search. This can be divided into algorithmic and organic again. The higher the ranking given to it by the SEO, the greater the search for that particular website or domain. A frequent refresh of the contents and, in particular, axioms that will increase the traffic will help maintain the high-ranking rates. In collaboration with various practitioners and groups who try to collect understandable knowledge and the method to determine the importance of a given keyword optimal for the search inquiry, search engine optimization is a big industry. Crawling, indexing, sorting, measuring importance, and retrieving are some of SEO's essential tasks. From the point of view of the aforementioned discussion, it can be understood that the optimization of the search engine is a type of operation that will increase the eminence and degree of user traffic for a particular business intent of the organization's website. The search engine optimization function is based on the algorithm of the search engine. The search engine can have natural capability checking methods that can be of two types, namely algorithmic and organic scanning processes. Generally, a ranking is given to the website that, when it is checked for full time and is ranked among the first 10 queries, would formalize a high rate. As it is noted that the first set of listings in the search engine is invariantly clicked by many of the customers, it is very important for company websites to face a hectic rivalry. The optimization of the search engine is known to be a mechanism designed to boost the visibility of the website in question. This was strengthened by taking a single axiom or a word similar to it. The optimization of the search engine deals with the data and design-related problems required to address the dilemma of a site's ranking or rating. The job of optimizing the search engine is not restricted

to a single attempt, since it hinders checking through trace and slip technique, constantly reviewing, periodically improving the output standard such that the site's rank is maintained. For this reason, organizations typically delegate this role to businesses or individuals who are specialists in this area. It is estimated that the search engine would include an estimated 500 billion posts. Therefore, a company's individual website may want to face a lot of competition to obtain a top ranking. With a productive degree of promotions and consumer drawing capacity, the need for optimization has grown, which is made possible by improving the company's websites. It can be inferred from the above that the optimization of the search engine is a means of increasing the popularity of the company's websites. The optimization of the search engine would use a particular axiom or key restrictions for the specific websites so that the company's website will be listed as the attacker types the specific word. Trafficking, however, would largely depend on the usefulness of the phrases protected by the website. And it is very important to upgrade the material on the web for this reason. Generally, the corporations lend out for upgrading to other partnerships (Thelwall, 2015). The Comparison of Statistical and Automatic Methods.

Tab. 1. Comparison of Statistical and Automatic Methods

Statistical Method	Automatic Method
Statistical methods require relevance judgments from experts and searchers to prioritize the web pages in the search engine's database.	Automatic methods use the users' interaction with browsers to assess the quality of web documents.
Statistical methods require additional cost for expensive experts' judgments.	Automatic methods for search engine evaluation require low cost.
No real time data is gathered.	Only real time data are collected.
Long time period is required to evaluate the web pages.	No additional time period is required.
Limited to decisions of small group of people.	The web pages are evaluated and assigned numeric scores on the basis of decisions from all the searchers.
Searchers role becomes partial in the relevance score computation.	Searchers play a vital role to decide the usefulness of web-documents.
Experts know their contribution in evaluation of web-documents.	Searchers often do not know about the hidden judgments collection.

4. METHODS

Seven separate search engines were evaluated using ten search queries; both the accuracy and response time of the search results obtained were then compared between the search engines (Edosomwan & Edosomwan, 2021).

4.1. Selection of Search Engines

Yahoo, Google, Gigablast, AlltheWeb, Zworks, AltaVista, and Bing/MSN were the search engines chosen for comparison in this report. During the discovery process of the Web search engines to be analyzed, attention was paid to the inclusion of a number of search engines so that the results obtained could serve as a basis for assessing the search algorithm used by the different search engines. Some of the search engines chosen are not the most common or the most recognizable ones. Therefore, the findings of the analysis would educate users about their various capabilities and thereby theoretically improve the usage of search engines that perform better. In addition to Web records, certain search engines often index content stored on other Internet applications, such as chat groups and Gopher (a network that directs users to businesses that provide those goods and/or services), but this analysis considered only Web databases. Also, centralized web search engines such as CUSI (Configurable Unified Search Index) were not considered because they just compile and do not provide something new with current web information (Edosomwan & Edosomwan, 2021).

4.2. Test queries

On all search engines, ten search queries were planned for use. These queries were meant to assess different features that each search engine claims to provide, as well as to reflect varying degrees of difficulty of searching. For the sake of familiarity, the searches were often meant to fall into the information technology domain, so that the investigators could judge the search results as appropriate. In four classes, the ten queries were listed as follows:

a. Short queries:
- What is data mining? (Query 1)
- Web Navigators (Query 2)
- Neural networks (Query 3)
- Evolution of processors (Query 4)
- Keyword searching (Query 5)

b. Boolean logic (AND/OR) queries:
- Searching AND sorting (Query 6)
- Clustering OR clustering algorithm (Query 7)

c. Natural language queries:
- Search the Internet using natural language (Query 8)
- How do I get the best search result on the Web? (Query 9)

d. Test environment

As the web browser for the analysis, Microsoft Internet Explorer was chosen because it is compatible with all the search engines selected and is locally the most commonly used browser. Two machines with different settings but with the same specifications were used: An Acer computer with an Intel Celeron M 440 CPU, 80 GB of hard drive (1.86 GHz) and 52 MB of DDR2 ram, and a Hewlett Packard computer (2.10 MHz) with an AMD Semipro SI-42 processor, 140 GB of hard drive and 1 GB of RAM. Those obtained from the Hewlett Packard machine are the findings shown. Results from the repeated exercise are not discussed because the results of the analysis have been similar and do not improve. Ideally, any question should be executed at the same time on all search engines, meaning that neither should have the benefit of being able to index the new page above the other one if a relevant page is added. That was not technically realistic for this analysis and so each question was checked on all the search engines on the same day within thirty minutes of each other. In order to be returned, all search engines that return an error of '404' (i.e., route not found) or '603' (i.e., server not responding) are noted. Return trips were made at varying periods of the day to prepare for the likelihood of daily maintenance downtime for the facility (Edosomwan & Edosomwan, 2021).

e. Response time

Answer time was determined by a stopwatch and was calculated as the interval between entering a search query and obtaining the first search results. To determine the response time, we picked one question from each category. The selected queries were: Query 1 (Group A), Query 6 (Group B), Query 8 (Group C) and Query 10 (Group C), respectively (Group D). It then determined the average response times for each search engine and for each question chosen (Edosomwan & Edosomwan, 2021).

f. Precision

Accuracy was described for this analysis as the relevance of a search result to a search query and was calculated independently for the first ten search results by both investigators. In order to decide if it satisfied the intended outcome, we reviewed the quality of each obtained outcome, but did not attempt to read the full-text Web document by following the links given due to time considerations and variable connection reliability. A precision score was determined on the basis of the number of outcomes considered significant during the first ten collected (i.e., a score of 1 indicates that all ten search results were relevant and a score of 0.5 indicates that only five of the first ten results were relevant). We not only measured the average accuracy score for each question to determine the overall output of each search engine we tested, but also determined the average accuracy score for each search engine, based on all ten queries (Edosomwan & Edosomwan, 2021).

g. Working of search engine optimization

To grasp the idea in depth, the operation of the search engine is very important. The search engines typically optimize a specific web page whose very small and special main term or constraint is coined once after the optimization type is submitted, then ranked as the first few search results based on the sum of the search frequency. This will also increase the traffic as the customer performs a request for a specific word. The search engines carry out frequent updates to the material in order to help the pages at a comparable stage. In two distinct ways, namely human power-driven, the search engines can be categorized and the

other is a crawler-supported engine. Therefore, the study is carried out in a step-by-step phase in the row as identification of relevant key words, estimation of market strength, enhancement of the website, and creation of web page connections, acquiescence, inquiry, adjustment and reporting. Engine powered by Crawler: This sort of search engine is intended to send a spider to follow multiple sites and apply the spider's results to the search engine's indexes. In a return of the spider, the updating of the websites is done once as it gives the new details through looking. Therefore, when the quest in this engine begins, the entire index is scanned for matches with the searched word. Google is an example of the Crawler type of search engine. The index is a kind of bulky catalog that stores a copy of each web page uncovered by the spider and checks the index. Human-driven search engines: a small representation of the article such as the name of the author or the name of the individual organization that will fit the engine directory will be needed for this sort of search engine. Through upgrading the new pages, this sort of search engine would not vary the ranking of a given domain, but instead incorporate the new stuff so that each website can be searchable. Look Smart is an example of this type of search engine. Hybrid Search Engine: Separate search engines are now using all the aforementioned approaches to improve web page content in the index referred to as 'hybrid search engines.' MSN and Yahoo are a case in point for this sort of search engine. It can be inferred from the above topic that, before beginning to customize a web, the operation of search engine optimization is very important. This would begin with a clear procedure flow, such as the identification of relevant key words, the determination of the level of competition, the enhancement of the page and the development of web page connections, approval, inquiry and alteration and documentation. Search engines can be assisted by crawlers, human power powered and hybrid search engines, among other types. Each will confine the search process to a different method. A spider is sent to follow different places in the crawler system, and the resulting spider finds are added to the search engine indexes after a single term is provided in the search engine choices. In order for the quest to begin, the human guided method would require a short summary or the name of the author of the writings. The search engine hybrid form will show all the original search process systems so that the full search capability is given in this form (Mustafa, Yousif & Abdulqadir, 2019). Depending on the degree of relevance, the classification or rating of the websites may be given to the webpages of the crawler type of a search engine. The importance of matching the term with the key terms identified is accomplished by using an algorithm that differs with each search engine type, but the functioning of the algorithms is identical to: Tracing main constraints: The search engines scan the headlines, title tags or the opening of two snippets to trace the highest matching word with the text (Mohamed & Khoshaba, 2012). Main restriction frequency: The search engine tests the frequency of a given constraint in such a way that the term frequency predicts the accuracy of the web. Spam prevention: spam creation, such as click-through assessment and connection scrutiny etc., is not constrained by the optimization of the search engine (Hawezi, Azeez & Qadir, 2019). From the view of the author above, it is clear that the search engine optimization crawler method would estimate a specific site's ranking depending on the number of times the index word is searched on the specific site. The ranking would depend on the value of the website's coined word. The search functionality of the platform that has different features such as key constraint tracing, key constraint frequency checking and spam prevention will be determined by an algorithm (Amin, 2017) .

h. SEO Benefits

Search Engine Optimization has acquired a lot of boom and the value has increased further with the increased Internet offenders (King, 2008). For a business, the optimization of search engines has several advantages: Both regionally and internationally, the axioms or primary restrictions outlined would encourage dominance in the viewer. For enterprises that run abroad, this would be very useful. When run with important and most appropriate axioms and key terms, the search engine would maximize the degree of traffic for the website of the specific company. The SEO aims to transform searchers' traffic to prospective customers and is therefore considered the best way to improve the business. After the optimization process, the visibility element of the company's website will begin. The customers are also aware of the exclusive services and goods of the business firm in question. The optimization of the search engine is found to be more functional and advantageous relative to any other form of traditional marketing. Compared to all other marketing types, the optimization of the search engine is successful in increasing immense earnings on investment returns. This would increase the company's revenue and earning (Kareem, 2009). The rating offered by the SEO would help to maintain the website of the firms for a very long time for comparison and is a very cheaper solution compared to other approaches (Abdalwahid, Yousif & Kareem, 2019). From the above discussion it can be understood that, the search engine optimization will provide lethal advantages to the businesses such as controlling the traffic volume, increased sales and revenues, high profits, more benefited way of advertising of the services and products of a company, cost effective, high range of visibility, global and local visibility, lesser capital for investment, etc. (Kareem, Yousif & Abdalwahid, 2020).

From the aforementioned discussion, it can be understood that the optimization of the search engine would provide firms with lethal benefits, such as traffic flow management, improved sales and earnings, high profits, more beneficial advertisement of a company's services and goods, cost-effective, high exposure range, global and local visibility, reduced venture capital, etc.

Traditional method: the traditional method was known to be the inscription of a single article and presenting the same to numerous other directories to collect in their index before the introduction of the search engine optimization process (Telnic Limited. 2009). The conventional methodology has several shortcomings in the customary setup that mostly rely on data presentation approaches that can generate greater traffic, but are least concerned with the type of information in that article. Therefore, SEO uses sophisticated algorithms that can approximate the degree of accuracy from an onlooker's viewpoint. It is apparent from the above that the conventional methods have two modes discussed above, such as crawler and human-driven quest choices. The web pages were sent to all of the directories previous to this search engine option, and would include a replica of the same article in each search engine (Schwartz, 1998; Kareem & Okur, 2020a).

i. Limitations of SEO

Search Engine Optimization has different challenges and limits (UKEssays, 2018). Few of these are discussed in the following manner: Limitation on idioms and key restrictions: the biggest limitation is met in the form of inadequacy of the same axioms and key constraints combined for the same domain with a single platform under search engine optimization (Amin, Shahab, Al Azzawi & Sivaram, 2018). This would be a big downside and will decrease the human traffic on that specific location. This is due to uncertainty over choosing a fitting axiom.

This is due to uncertainty about the collection of sufficient axioms. Competition limitation: competition increases when two separate websites are protected by the same axiom or primary restrictions. In this case, in order to achieve a certain rank, websites are met with opposition. Subpage limitation: the subpages of the websites must still retain the axioms and core restrictions that are in a position to be changed each time and remain updated in order to improve the ranking and increase the traffic (Berman & Katona, 2013). Lingually: Most conventional search engine optimizers run on a single language medium that can restrict the search to a specific geography. Limitation of crawl ability: After passing through millions and millions of web pages, the crawling nature will be constrained and thus the speed of the search will be impaired (Zhang & Cabage, 2016). Duplication limitation: in the search engine, the duplication of a single web page happens when a specific page is submitted several times with similar content (Yang & Ghose, 2010).

After the optimization of the websites takes place, the limitations listed above which exist. Different novel strategies, few of which are addressed here, will efficiently minimize this type of restrictions. From the above debate, it can be inferred that the optimization of the search engine has numerous drawbacks that will minimize the company's performance. Few of the restrictions are conflicting phrases and main constraints, restriction due to high degree of competition, subpage limitation, lingual issues, crawl capacity limitation, issue with the replication of web pages in the search engine index. Innovation Methods in SEO: In the present day, the optimization of the search engine is known to be the standard process. An advanced methodology applied by the system of pay per click or PPC (David Wallace, September 2003). This would be an ambitious and creative solution as the search engine optimization system has multiple challenges to be found or ranked. Since the SEO is confident of the difficulties of coining specific idioms or keywords that are really important to the current trade, the consumer trafficking problem will end up. These websites are not specified if the search terms are not relevant. From the above, it can be inferred that with the development of technology in recent years, new technologies are evolving to solve the shortcomings of conventional search engine optimization. The author clarified the complexity of coining the phrases or axioms that are exact fits for the company's website services or merchandise, since this will minimize the traffic of the redirected consumers if correctly listed. Innovation was then prevented from solving this problem (Keti & Askar, 2015).

j. SEO and Business

The advantages of new developments over the conventional optimization of search engines are as follows:

- The breakthrough optimistically minimized the replication process of the original material of the web pages.
- Increased pace of the crawler's search skill.
- The essence of scalability has improved.
- Enhanced effectiveness and traffic for the company.
- High scores are probable.

It can be inferred from the above that the advantages of modern technologies on the conventional search engine for business purposes are to boost traffic, decrease repetition, increase search speed, scalability, enhance effectiveness, etc. (Smith, 2010).

5. CONCLUSION

The benefit of search engine optimization is essentially the fact that it increases your website's popularity. Visibility is everything in modern business if you intend to go ahead. People ought to be able to locate you, because given the number of rivals, i.e., others who choose to be positioned for the same keywords, this is not a simple feat. It should be able to appreciate how this reflects your industry as you understand the value of exposure. You can see how other areas of industry are impacted, such as sales, reputations, etc., starting with the number of visitors to the website, which is the first one to change once you maximize exposure. If you ignore the benefits SEO provides, you will miss dramatically in terms of the three variables: advertisement, publicity and sales. What you need to keep in mind is that improving search engines is a long-term task that will need months to demonstrate any signs of progress. No immediate strategies and resources are available that will help you achieve immediate results, regardless of what anyone says otherwise. The reports are more accurate and long-lasting, considering the time taken to spend in working on SEO. Some of the most commonly used software that can assist with multiple activities that are part of SEO, ranging from keyword study to website review, are the tools we suggest in this book. There are lots of other apps, both free and charged, and the latest ones that are being created at this time, so feel free to explore and discover the resources that you find easy to use and that can really help with the tasks as part of SEO that you are about to perform. Finally, as the internet has become such an expansive and competitive virtual environment, a comprehensive, tactical and precise endeavor is to get the best out of the potential a search engine offers. Also that is why it has to be studied and refined, which leads one to the conclusion that optimization of search engines is not only a guideline for modern business, but if you want to run a profitable online business, it has become a must. More than 3 billion users use the internet, and this figure rises every year, as you can see on the map below, which makes it a large proportion of people worldwide, and one of the easiest ways to do so if you wish to meet them is to customize your website to improve the likelihood of people reaching you.

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classification, leaf edges, leaf veins morphological, wavelet convolutional neural network

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PLANT CLASSIFICATION BASED ON LEAF EDGES AND LEAF MORPHOLOGICAL VEINS USING WAVELET CONVOLUTIONAL NEURAL NETWORK

Abstract

The leaf is one of the plant organs, contains chlorophyll, and functions as a catcher of energy from sunlight which is used for photosynthesis. Perfect leaves are composed of three parts, namely midrib, stalk, and leaf blade. The way to identify the type of plant is to look at the shape of the leaf edges. The shape, color, and texture of a plant's leaf margins may influence its leaf veins, which in this vein morphology carry information useful for plant classification when shape, color, and texture are not noticeable. Humans, on the other hand, may fail to recognize this feature because they prefer to see plants solely based on leaf form rather than leaf margins and veins. This research uses the Wavelet method to denoise existing images in the dataset and the Convolutional Neural Network classifies through images. The results obtained using the Wavelet Convolutional Neural Network method are equal to 97.13%.

1. INTRODUCTION

Leaves are an important component in plants. The way to identify the type of plant is to look at the shape of the leaf edges. These leaf edges can affect the shape of veins in plants. In this vein of plants, there is a clear correlation between vein characteristics and some leaf traits, such as damage and drought tolerance (Scoffoni et al., 2011). Botany, agriculture, and horticulture all rely heavily on computer identification and classification of plants. Not only for non-experts, but also for botanists and ecologists, to enhance identification and classification. Plant classification can be used to learn more about a plant's genus or family (Heredia, 2017). Veins can be used to classify plants because they carry information relevant to plant classification when shape, color, or texture cannot be observed. However, because humans only see leaves based on their shape, this feature frequently goes unnoticed.

Machine learning advancements, especially in computer vision, have made classification less difficult. Convolutional Neural Network is an architecture constructed by a typical visual sense system of living things, consisting of several layers of convolution where each layer performs functions that are mediated by cells in the visual cortex (Gu et al., 2018; Zhang, Wang & Liu, 2018). Convolutional Neural Networks are intended to process data in the form of multiple arrays. Numerous information modalities are as various exhibits: 1D convolution

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for signs and groupings, including language; 2D convolution for picture or sound spectrograms; and 3D convolution for video or volumetric images (Lecun, Bengio & Hinton, 2015). Convolutional Neural Networks have evolved over time, from 5 layers to 50 layers. Based on its development, there are 10 common Convolutional Neural Network architectures, namely LeNet-5 (Choi et al., 2005), AlexNet (Krizhevsky, Sutskever & Hinton, 2012), VGG-16 (Simonyan & Zisserman, 2015), Inception-v1 (Szegedy et al., 2015), Inception-v3 (Szegedy et al., 2016), ResNet-50 (He, Zhang, Ren & Sun, 2016), Xception (Chollet, 2017), Inception-v4 (Szegedy, Ioffe, Vanhoucke & Alemi, 2017), Inception-RestNets (Szegedy et al., 2017), and ResNeXt-50 (Xie, Girshick & Doll, 2017). Because of its high accuracy, this Convolutional Neural Network architecture is a machine learning approach that is often used for image recognition or classification.

Images that are used as a dataset for image recognition or classification will be mixed with a certain amount of noise. Noise will deteriorate the image quality (Hongqiao & Shengqian, 2009). Wavelet transform is often used for image denoising because it has low entropy, high multi-resolution, flexibility, etc. (Song, Ma, Cao & Han, 2016).

Wavelet Convolutional Neural Networks have begun to be widely used, especially in the medical field. In the medical field Wavelet Convolutional Neural Network is used to reconstruct MRI images (Ramanarayanan, Murugesan, Ram & Sivaprakasam, 2020), heart rate classification (Bouny, Khalil & Adib, 2020), and image restoration to repair degraded or degraded images (Liu, Zhang, Zhang, Lin & Zuo, 2018).

In this study, a classification based on the shape of the leaf edges and veins was performed using the Wavelet Convolutional Neural Network technique, where the wavelet serves to denoise the image.

2. RELATED WORK

2.1. Convolutional Neural Network

Previous research used a Convolutional Neural Network as image processing for plant identification (Lee, Chan, Wilkin & Remagnino, 2015; Grinblat, Uzal, Larese & Granitto, 2016), classification (Yalcin & Razavi, 2016; Dyrmann, Karstoft & Midtiby, 2016; Liu, Yang, Cheng & Song, 2019; Alimboyong & Hernandez, 2019), and classification based on leaf features (Lee, Chan, Mayo & Remagnino, 2017).

2.2. Wavelet

There are many types of Wavelet Transform, one of which is Discrete Wavelet Transform. Discrete Wavelet Transform has the advantage of temporal resolution, which can capture frequency and location information.

Discrete Wavelet Transformer is widely used for image denoising (Mohideen, Perumal, & Sathik, 2008; Kimlyk & Umnyashkin, 2018), because it produces a non-redundant image representation that gives better spatial and spectral location than image formation.

2.3. Wavelet Convolutional Neural Network

The Wavelet Convolutional Network architecture in Figure 1 illustrates the image processing flow. The Convolutional Neural Network wavelet processes the image fed through a convolution layer with a 3×3 kernel and 1×1 padding. Figures after Conv. Indicates the number of

output channels. A 3×3 convolutional kernel with stride 2 and 1×1 padding is used to reduce the size of feature maps. The inserted images are decomposed through multi-resolution analysis, then the images are combined. Projection shortcut is performed with 1×1 convolution. The output of the convolutional layer is the vectorization of the combined global mean which is then followed by the fully connected layer (Fujieda, Takayama & Hachisuka, 2018).

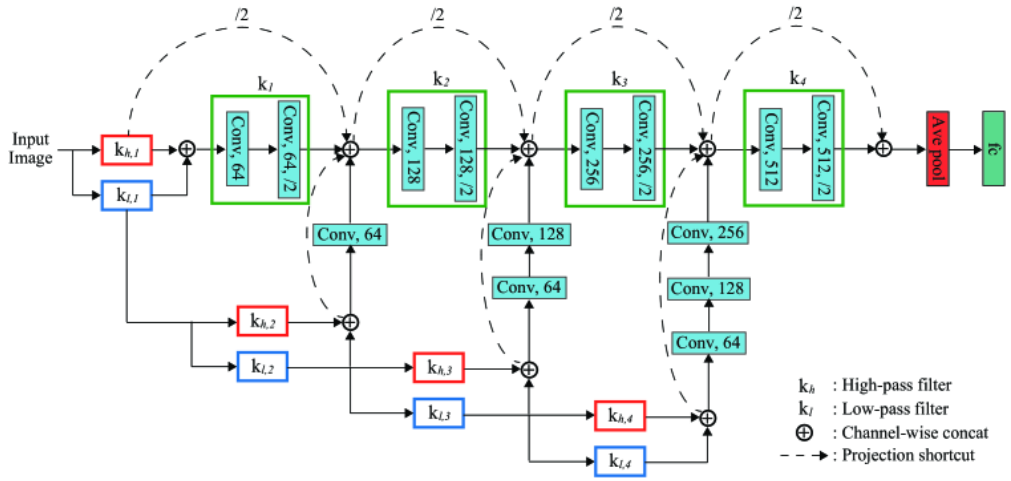

Fig. 1. Convolutional Neural Network Wavelet Architecture (Fujieda et al., 2018)

3. METHODOLOGY

There are several steps taken in this research. Table 1 will show details of the steps taken during the study.

Tab. 1. Research Implementation Phase

No.	Research Stage	Description
1.	Literature review.	The literature review is done by looking for references from journals, books, or the internet regarding previous research related to the research to be carried out, judging by the methods and objects used.
2.	Data collection.	The data was collected by taking pictures of plant leaves from the internet that matched the type of leaf edge shape and combining them with data from the Swedish dataset.
3.	Preprocessing and processing data.	The data that has been collected are then grouped according to the shape of the leaf edges and leaf veins. After that it is divided into training data and test data.
4.	WCNN modeling.	The making of this model is based on the Wavelet Convolutional Neural Network concept.
5.	Analysis and evaluation of results.	At this stage, the results of the plant classification are then analyzed, which affects the results of the classification of these plants. After that, an evaluation is carried out to whether there is anything that needs to be improved or developed so that the results obtained are as desired.
6.	Conclusions.	Based on the analysis and evaluation of the results, a conclusion is made on what affects the results of the classification of these plants.

3.1. Wavelet Convolutional Neural Network

Convolutional Neural Network is a spatial approach to image processing, such as image classification and identification. The spectral approach is also a good image processing, which is found in Wavelets. The spatial and spectral approaches have different characteristics. However, if these two approaches are combined, it will complement the weaknesses of the spatial approach, where this approach has limitations in multi-resolution analysis.

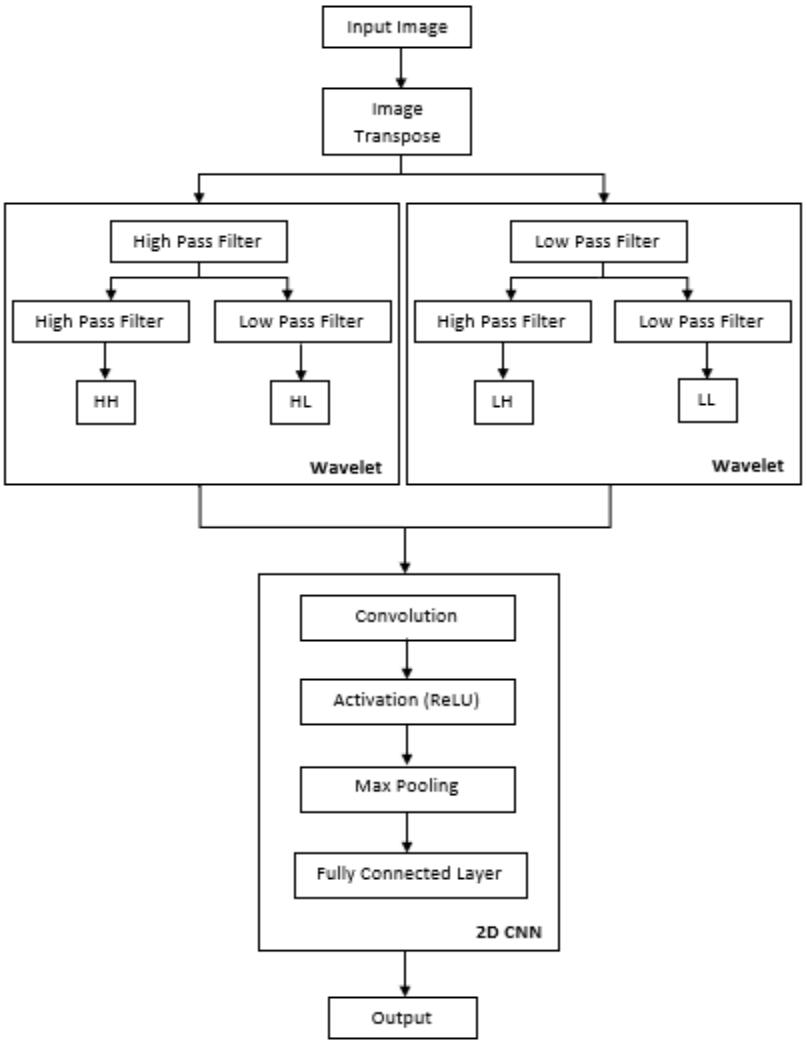

Fig. 1. Wavelet Convolutional Neural Network Flowchart

Figure 2 shows the flow of the classification process using a Wavelet Convolutional Neural Network. First, the image is inserted and then it is transposed from a matrix array to a vector. The inserted image is 224×224 in size. After that enter the filter analysis process, where the High Pass Filter and Low Pass Filter are carried out. Analysis filters are used to

obtain approximation and detail. The results of the analysis filter will produce four bands labeled HH, HL, LH, and LL. Then, during preparation, join the Convolutional Neural Network phase, which goes through the convolution layer and uses batch normalization in the network until the activation layer. In both experiments, Adam's optimizer was used, as well as the Rectified Linear Unit (ReLU) as an activation function, and fully connected layer.

3.2. Rectified Linear Units

Activation function using Rectified Linear Units (ReLU), where each negative element is set to 0.0 with no exponential, no multiplication or division operations. The ReLU functions are:

$$f(x) = max(0, x) \tag{1}$$

3.3. Adam Optimizer

Optimization uses Adam's optimization algorithm, where the algorithm is useful for updating weights in neural networks. This algorithm can be used effectively to solve deep learning problems that use large amounts of data (Kingma & Ba, 2015).

4. RESULT AND DISCUSSION

Figure 3 shows the dataset used in this study. The dataset used was 1,943, of which 1,524 were training data and 419 were test data. The dataset contains types of leaf types, namely Aculeate, Biserrate, Crenate, Crenulate, Crispate, Dentate, Denticulate, Incesed, Lecerate, Lobed, Palmatifidus, Palmatilobed, Palmatipartitus, Pinnatifidus, Pinnatilobed, Pinnatisect, Serrate, Serrulate, Sinuate.

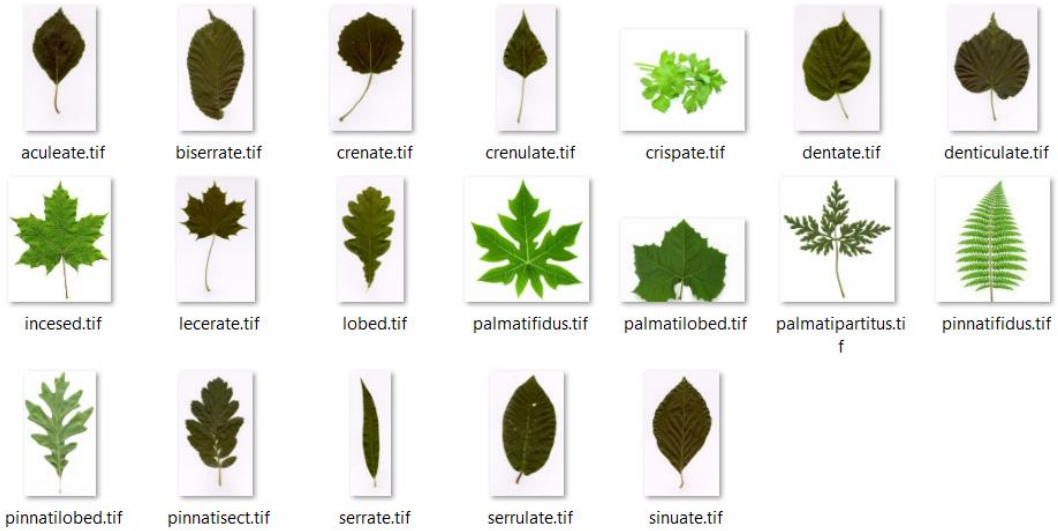

Fig. 2. Dataset

Figure 4 show the dataset after being transformed by the wavelet, a series of sub-band images with different resolutions can be obtained. The far left is a low frequency image, the next three images are a horizontal high frequency, a vertical high frequency, and a diagonal high frequency.

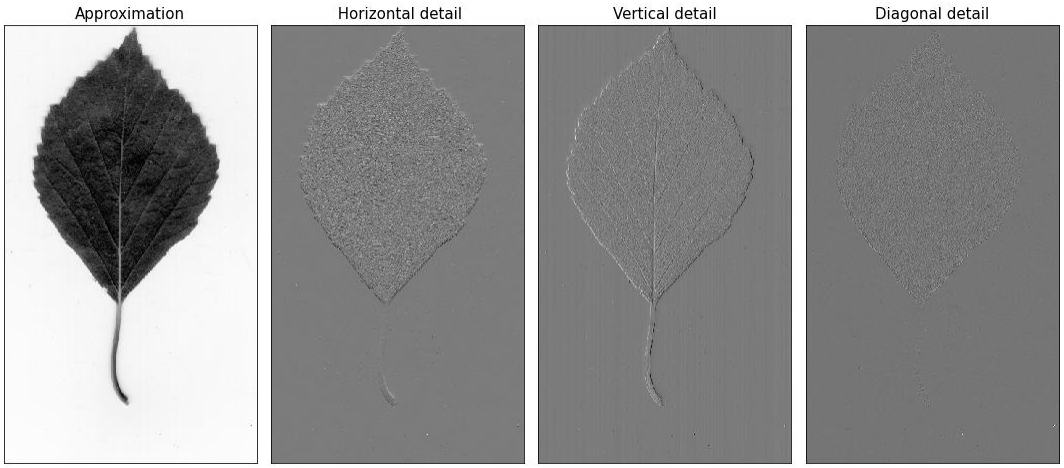

Fig. 4. Wavelet Transformation Results

The blue line reflects the level of accuracy during training, while the yellow line represents the level of accuracy during testing. The classification results give a value of 97.13% using epochs 100 and batch size 32.

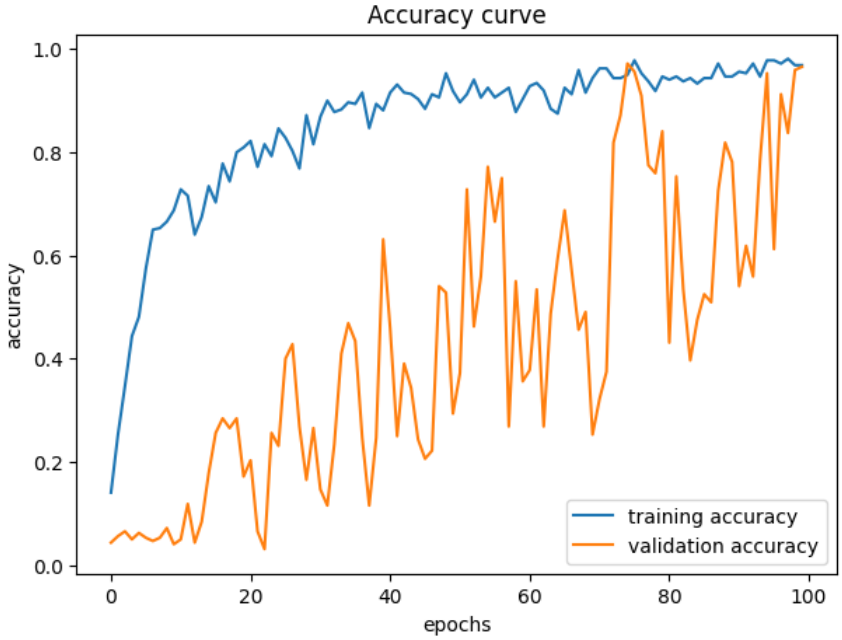

Fig. 5. Accuracy Graph

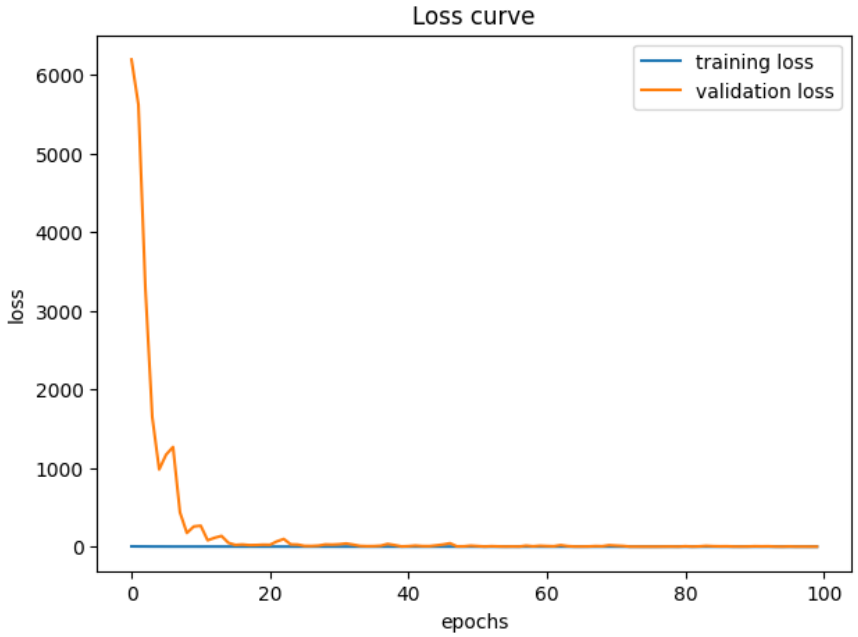

Fig. 6. Loss Graph

Based on the results of image classification using the Wavelet Convolutional Neural Network, the results show that the Convolutional Neural Network Wavelet has the best accuracy of 97.13% at epochs 100 and batch size 32. The classification results are higher than previous studies that classified 22 species of weeds and plants using the Convolutional Neural Network with an accuracy of 88% (Dyrmann et al., 2016), classification of plant leaves using the Convolutional Neural Network. with an accuracy of 87.92% (Liu et al., 2019), classification of plant leaves uses hybrid deep learning with an accuracy of 93%.

5. CONCLUSION

Combining Wavelets as a method for denoising image and Convolutional Neural Network using Adam's optimizer as a leaf classification method based on leaf edge and leaf morphological veins can provide good classification results, proven by the level of accuracy 97.13% and loss of 0.7%.

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