PROCEDURE OF APPLYING THE GENETIC ALGORITHM FOR THE CREATION OF A PRODUCTION LAYOUT

MARTIN KRAJCOVIC, IVAN ANTONIUK, LADISLAV PAPANEK, RADOVAN FURMANN, VLADIMIRA BINASOVA, VSEVOLOD BASTIUCHENKO

University of Zilina, Faculty of Mechanical Engineering, Department of Industrial Engineering, Univerzitna 8215/1, 010 26 Zilina, Zilina, Slovakia

DOI: 10.17973/MMSJ.2022_12_2022133

vladimira.binasova@fstroj.uniza.sk

Due to the rapid increase and development of new information technologies, it is now possible to collect real data from the production process, thereby creating an image of a real plant in a virtual environment. The concept of a digital twin in the design of production systems consists of creating a digital twin of the entire production plant, which consists of a digital, real and virtual enterprise, which is a fundamental difference between the design of production systems in the concept of a digital enterprise and in the concept using a digital twin. The paper deals with the methodology of data collection, layout creation and the company's digital twin. The practical benefits of the proposed solution are mainly from the point of view of reducing the necessary time when designing the production layout, especially in the phase of variant design. Closely related to this is the possibility of checking a larger set of solutions, taking into account various limiting conditions. As this proposed solution reduces the time required in the phase of variant design, costs necessary for the creation of a new or changing production layout are reduced.

KEYWORDS

Digital Twin, manufacturing, GA, job shop.

1 INTRODUCTION

In today's globalized world, organizations are learning from the world's leading companies how to manage knowledge-based resources. The use of information and communication technologies, various tools and knowledge management strategies in organizations can lead to innovation. These innovations occur in services, products and processes and sustain competitive advantages in globalized economies around the world [Pablos, 2019].

In modern industrial practice, innovative solutions are constantly proposed for the design or improvement of production and assembly processes or entire production or logistics systems. In order to implement new technologies, companies must be able to combine the use of the latest and available technologies [Krajcovic, 2011], [Grznar, 2021]. When using them, it is essential that companies are aware of current development trends and the added value of new innovative solutions.

The pressure to constantly reduce costs is a concern of almost every manufacturing company. The price reflects the competitiveness and sustainability of the company. Many company costs are related to production efficiency. As part of the design of production layouts, designers often encounter complex, sometimes even contradictory requirements and a number of limiting conditions, which stimulates the effort to create new, progressive approaches to the creation of production layouts [Haluska, 2013]. The purpose of innovative approaches in the field of production design is to provide users with better quality elaborate designs, in a shorter time, while being able to implement individual limiting conditions and company priorities in the design [Sammen, 2020].

With the development of intelligent manufacturing, enterprises are using more and more new information technologies such as the Internet of Things (IoT), cloud computing, Big Data, and artificial intelligence to improve production efficiency and flexibility [Furmannova, 2021], [Durica, 2019]. New manufacturing models such as cloud manufacturing, green manufacturing, and service-oriented manufacturing are evolving to meet the new manufacturing requirements of socialization, personalization, services, and intelligence. [Vavrik, 2022]

Production scheduling plays an important role in custom manufacturing today. Under intelligent manufacturing, the new meanings of production planning are listed below [Fang, 2019]:

- Real-time production and flexibility are two goals of smart manufacturing. Due to a large number of operations, the complex relationship of cooperation, the strong continuity of production, the rapid change of conditions in modern industrial enterprises, and the failure of certain parts often affect the operation of the entire production system. Therefore, timely response to dynamic events in production planning becomes an important problem that needs to be solved urgently.
- Uncertain events usually occur in the production process, which could cause information asymmetry between the actual production process and the designed schedule and thus affect the achievement of the goal. Static shop planning results in a large deviation between the designed schedule and the actual production process, serious waste of production resources, and low production efficiency. Therefore, dynamic planning strategies should be considered in production.

Therefore, the process of designing and creating a system for production planning needs to be divided into several phases, namely:

- The initial stage of the project where the purpose of the proposed system is defined and the specific features that the system must contain in order to fulfil its purpose.
- Analysis of the current state (in the case of an already existing production system).
- Design of a data collection and monitoring system.
- Creating a virtual model of a new or existing production/logistics system.
- Design and implementation of the link between the real and virtual environment (digital twin).
- Verification of all processes and use of the designed system for evaluation, testing of various scenarios and production planning.

In this article, we focus on the methodology of data collection, layout creation and the company's digital twin. Our concept of such a system is shown in Figure 1.

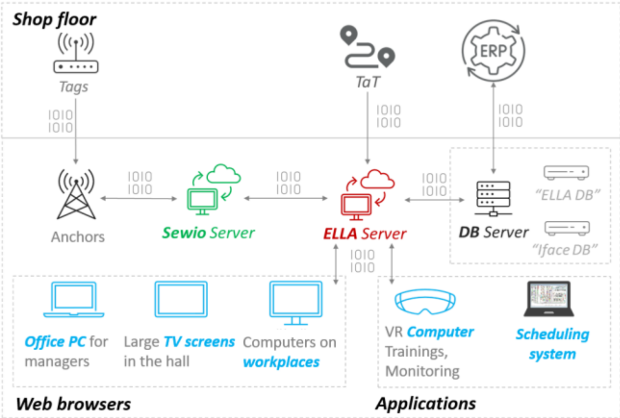

Figure 1. The infrastructure of the designed system

2 PROPOSAL FOR THE METHOD OF COLLECTION, STORAGE, PROCESSING AND TRANSFER OF DATA

The system of data collection, analysis, monitoring and use includes a variety of methods and technologies. In data collection, on the one hand, it is a monitoring system that contains a whole network of intelligent sensors, devices for real-time monitoring of the position and status of objects, and communication units that are also connected to PLC/HMI machines for reading operating parameters. On the other hand, it also involves data collection from enterprise information and control systems (MES, ERP, APV, SCADA).

The collected data needs to be extracted, filtered, and processed into the required form and analysis of the collected production data. Here it is a database system that uses Big Data tools and statistical analysis. The processed data will preferably be used to update the parameters in the digital model, but can also be processed into a graphical form, suitable for a general overview of the production situation.

The communication module is the so-called "link" between all elements of the proposed system. It is intended to ensure two-way communication between the real production system, the cloud and the simulation model. It is an immediate exchange of data for the purpose of an efficient scheduling process.

2.1 *Structure of monitored data*

According to nature, data can be divided into static, dynamic and random. So-called static data - are data that do not change over time and will be used mainly in the creation of a virtual model of physical production. Dynamic data change over time and can be influenced by various factors, random data are unpredictable events. Also, data can be collected from different departments of the enterprise, namely:

- Supply-customer chain,
- the marketing department,
- the purchasing and procurement department,
- warehouse management,
- production,
- maintenance,
- logistics.

Depending on the type of production, the volume of this data may vary. In order not to complicate the system with unnecessary information, it is necessary to select from the amount of data that will be really necessary for the problem of scheduling or adaptation of the production schedule. After defining all the necessary data, it is necessary to create a table structure in the environment of a database system (e.g. MySQL).

2.2 *Method of data collection and transmission*

There are several ways to monitor the condition of production equipment. In the Industry 4.0 concept, each plant is equipped with a number of sensors and transducers to monitor the current status, as well as a control unit that is also connected to the enterprise information system. If the device does not have a control unit, it is possible to connect the sensors directly to the database via the local network (Figure 2).

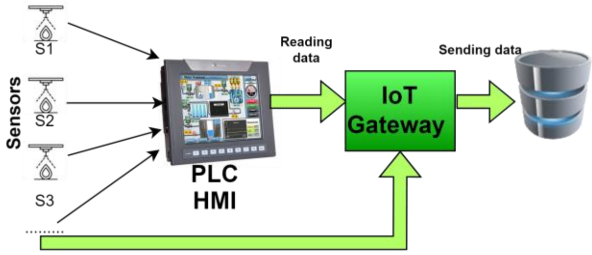

Figure 2. Method of online data collection from the production system

We are able to collect the following types of data from production facilities using Smart Factory tools:
- data needed for OEE calculation,
- data on the current status of the equipment,
- the number of well poorly-manufactured units,
- real operating times,
- information on stoppages and failures,
- other operating parameters.

The following technologies can be used to monitor moving objects in production (handling equipment, material, people):

- RTLS with an accuracy of up to 0.5m,
- Bluetooth positioning with an accuracy of 2-5m,
- Wi-Fi positioning with an accuracy of 3-5m,
- Bar and QR codes (must be scanned),
- RFID (identification is possible via RFID gateway),
- optical sensors,
- recognition by artificial intelligence.

Communication systems in an enterprise can be divided into several levels. At the lowest level, it is the communication between individual sensors, control units and actuators. The middle level can be classified as the local intranet and the highest level is the communication between the local network and cloud solutions, Big Data and BI.

When selecting a technology for data transmission, it is necessary to focus on its technical characteristics such as transmission volume, speed, reliability, etc., depending on the type of enterprise infrastructure, it is essential to choose a method of data transmission that will not interfere with other frequencies, in case of the presence of metal structures, the quality of the signal should not be affected by them, etc... Comparison of the most widespread data transmission technologies is presented in Figure 3:

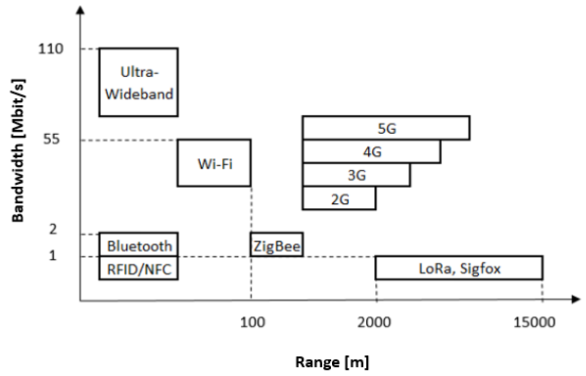

Figure 3. Data communication approaches [Skokan, 2020]

The general process of working with the data can be seen in the following Figure 4.

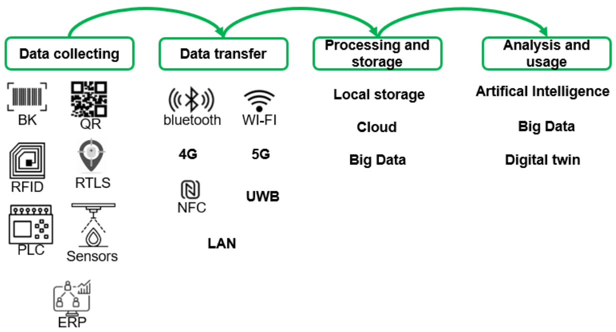

Figure 4. The general process of working with the data

3 CREATION OF PRODUCTION LAYOUT

Classical methods and tools such as the checkerboard are increasingly being combined with new methods that require computing. The methods used by designers in the placement of objects in production layout designs can be seen in the following breakdown [Krajcovic, 2019].

Heuristic methods are based on simple algorithms for solving and investigating the fulfilment of criteria (conditions) given by a particular algorithm. They are relatively simple, with a low number of computational operations and have high interactivity with the designer (the designer can intervene in the solution at each stage). However, they are not guaranteed to find a global optimum and are usually unable to determine how close the solution found is to the optimum. Heuristic methods are divided into:

- Exchange - they are based on the original setup, which they try to improve by exchanging individual objects (LAY method, RUGR method, CRAFT, MULTIPLE).
- Combined - use a combination of exchange and construction methods, usually the construction method generates an initial layout and this is subsequently improved by the exchange method (SAT LAY PLAN, Mabetra).
- Constructive - based on the sequential insertion of system elements into the layout, starting with the elements that have the highest intensity of material flow, or the strongest ties (SAT, ALDEP).
- Metaheuristic methods can produce higher quality outputs than traditional heuristics. Their advantage is that they can omit the local extrema found under certain conditions, which traditional heuristics cannot do. These include, for example, ant colonies, tabu search, or genetic algorithms.

Analytic methods such as linear programming, enumerative procedures, and dynamic programming are represented by optimization methods of operational analysis [Mleczko, 2014]. They are characterized by a mathematical model that describes the objective function and the boundary conditions for solving the problem. Their disadvantages are the high number of computational operations, the complex and often impossible mathematical description of the real conditions in the system, and the low interactivity of the designer with the proposed solution.

Graphical methods such as Sankey diagram, flow and relationship matrix or line diagram are suitable for solving simple problems, since a graphical representation of the layout is used in the search for the optimal solution.

3.1 Use of an interactive projection system

Modern planning and designing of production systems, solving complex parametric models with more than one monitored parameter requires inherent connection of used methods for planning and designing with computer technology. The computing hardware must have the appropriate software, too and ls for creating and analysing the proposed solutions installed. When testing the use of genetic algorithms to create a manufacturing layout in a three-dimensional environment, it is possible to use software running on a platform that interconnects several software solutions.
It is an interactive tool for effective team planning of manufacturing and logistics systems. It allows you to easily use 3D models to design a logistics or production concept and select the best option through analysis (Figure 5). Software solutions that can be classified into one group according to their focus: Twiserion Design Manager, VisTable, Visual Components.

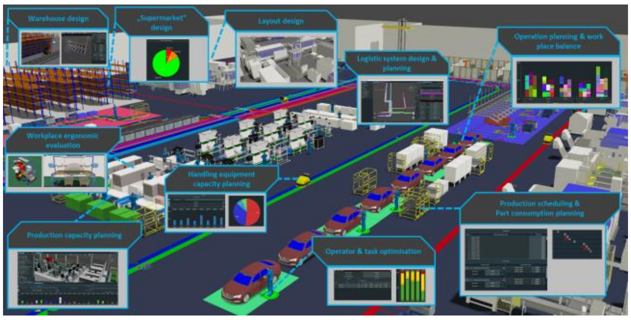

Figure 5. Interactive projection system modules (Software: Twiserion Design Manager)

It represents an innovative approach to the planning and design of production and logistics systems. During workshops, project team members can change the production layout with a simple hand movement on the screen and, thanks to the interactivity, immediately see the effects of the changes made, as the system redraws material flows and recalculates the monitored indicators in real time. It answers the question "What happens if ?".

The advantage of the software environment is the creation of complex models of production, logistics and warehousing systems. The spatial layout is created through parametric models, which in the production system are manifested, in addition to their three-dimensional spatial interpretation, by a set selection of behaviours and properties (physical properties, various production parameters, etc.), on the basis of which the system evaluates the monitored indicators.

The disadvantage is that it uses only basic graphical methods such as Sankey diagram, Spaghetti diagram, flow matrix and checkerboard table in planning the spatial layout. Most of the work is left to the experience and knowledge of the industrial planner. This disadvantage presents an area for us to explore the possibility of applying genetic algorithms for the design of manufacturing layout.

3.2 Genetic programming and genetic algorithms

Genetic are based on the idea of the Darwinian principle of evolution. The search for an optimal (criterion-based, sufficiently satisfying) solution takes the form of a competition within a population of gradually evolving solutions.

As the demands on the quality of the outputs to find a solution are getting higher and higher, and at the same time there is a requirement to arrive at these solutions in the shortest possible time, traditional algorithms for generating a layout are insufficient for the future and new alternatives must be sought. Based on this, the possibilities of applying genetic algorithms to the creation of a production layout in a three-dimensional environment, within the concept of the digital enterprise, are explored, aiming not only at the design of the individual departments but also at the layout of the machines themselves [Misola, 2013].

A number of powerful and rapidly evolving software and hardware solutions or technologies are currently available for the designer. As these technologies evolve, more advanced and detailed three-dimensional visualization is also coming to the fore. The technology enables advanced visualization with relatively low hardware requirements while ensuring ease of use for end users. The demonstration of advanced technology for three-dimensional visualization is shown in Figure 6.

Figure 6. Demonstration of advanced technology for three-dimensional visualization

3.3 Genetic Algorithm Application Procedure for Production Layout Generation

However, before specifying the requirements for the solution, it is first necessary to determine where the application will be used. In particular, it is necessary to determine what kind of production systems the solution will be designed for, as the differences between production systems can be very large - whether it is the volume of production, the technology used, the way the material is handled, or other aspects. For the application of the solution, we have therefore set a classical, small-medium series engineering production, with the assumption of piece material handling. In order to determine the most suitable parameters as well as the overall form of representation of the solution, it is first necessary to determine the requirements that the solution should meet. After specifying the application usage, we determined the requirements for the solution as follows:

- Connectivity, as one of the key requirements we have identified the ability to connect the solution with the planning software to create 3D layouts.
- The possibility of specification of the layout, with the variety of production systems and possible requirements that are placed on them, it is important to implement within the developed algorithm the possibility of setting parameters for a more detailed specification of the solution sought for the purpose of better quality results.
- The use of genetic algorithms, the core of the solution will therefore use selection, recombination and and mutation and other operators of the genetic algorithm to find a solution.
- Listing and visualizing the outputs, within the runtime of the program it is necessary to give the user concise but clear information about the status of the solution. When finished, the solution achieved also needs to be visualized.
- Clarity and simplicity of the user interface, the input data as well as the specification of the required solution should be clearly sorted by sections and easy to use for the user [Kumar, 2012].

As part of the research solution, a software module was designed based on the proposed algorithm to provide the calculations (using the genetic algorithm), Figure 7. For the layout generation problem, a software environment was selected in which a solution can be developed and validated using genetic algorithms and digital enterprise tools. Taking into account the module designs, previous steps and algorithm outputs in Section 3.2, a manufacturing layout design algorithm using genetic algorithms was developed (Figure 8).

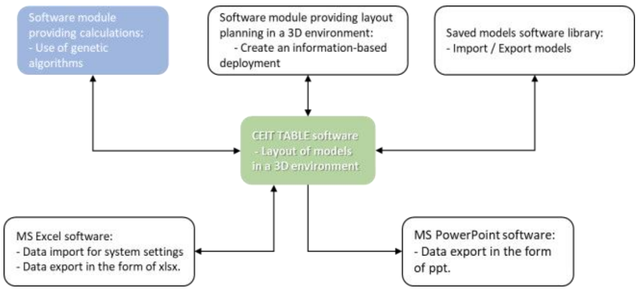

Figure 7. Interconnection of individual modules and software tools

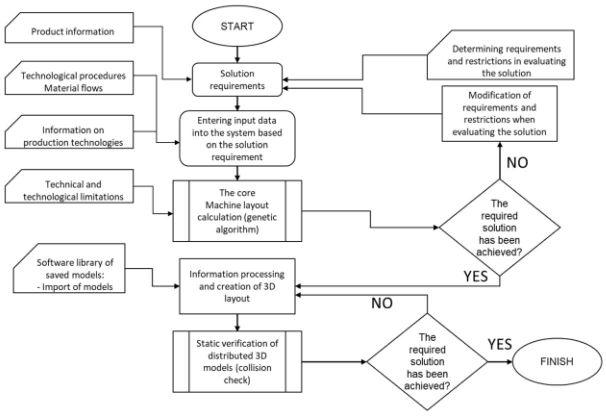

Figure 8. Production layout design algorithm using genetic algorithm

In the following sections, the individual steps of the algorithm itself will be specified and described in more detail:

Generating the initial population - the first step is to create an initial population that represents the set of solutions that will be further developed. In our solution, a single individual is made up of genes equal in number to the loaded value of the number of machines to be deployed. The order of the individual genes corresponds to the order in which the machines will be placed in the design.

Evaluation of individuals by fitness function - the generated population needs to be evaluated by a fitness function. This consists of two weighted components, the intensity-weighted and distance-weighted (f_{ID}), the intensity-weighted and distance-weighted (f_V), and the relationship-weighted (f_V).

Decision Blocks - In this step, the conditions specified in the four decision blocks for the termination of the algorithm need to be compared with the current state of the solution.

The first condition is to achieve the maximum number of generations (iterations) - G_{max}. The second condition is reaching or exceeding the maximum allowed fitness value - f_p. The third condition is to achieve the maximum solution time - t_{max}. The last condition is to exceed the specified number of iterations (Imax) without improving the achieved solution.

This condition must be incorporated into the design to avoid long computation times if the desired value of the fitness function f_p is not determined (or is unachievable) and no improvement in the value of the fitness function is already present in the solution, thus leading to the assumption that an outlier in the solution set has been found [Misola, 2013].

Selection - if none of the termination criteria has been met, the algorithm proceeds with selection, i.e., selecting individuals to be crossed among themselves and subsequently mutated. For the generated solution, it is appropriate to choose selection by roulette rule, with a probability distribution of selection proportional to the achieved fitness of the individual. This method was chosen based on the better searchability of the complex set of solutions when combining parents and evaluating them later, as well as the speed of computation.

Crossover - Once individuals are selected, recombination occurs between them. The design initially handled single-point and uniform crossover, which are frequently used in genetic algorithms. Thus, to streamline the crossover process, partially matched crossover (Figure 9) was incorporated for similar types of coding individuals. The procedure of partially matched crossover is as follows:

- generate two random points defining the genes that the parents exchange,
- pair the values of the genes that were exchanged,
- match the values of the parents to the genes in which there is no conflict,
- apply the paired values to the genes with conflict.

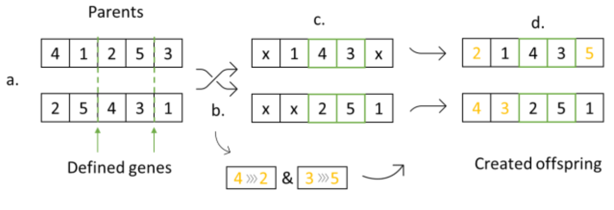

Figure 9. Partially paired crosses

Mutation - After crossbreeding comes mutation. However, for this type of coding solution, traditional mutation, i.e., changing the value of a random gene, is not an option, as this would automatically require corrective action to remove duplicates or unaligned machines. Therefore, mutation by inversion, or replacement, is chosen (Figure 10). Since inversion is a relatively large intervention in the solution, we have divided the probability for replacement or inversion in the ratio 80:20.

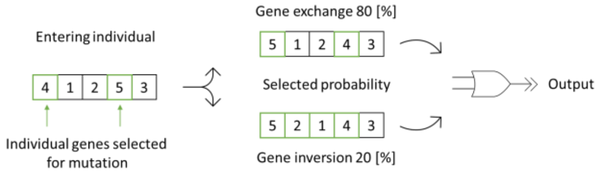

Figure 10. The principle of mutation of the proposed solution

Within the mutation, it is necessary to determine the probability value, which depends on the solved problem. Therefore, we again performed an experiment in which the parameters are the same as in the crossover probability experiments with the difference that the mutation probability is varied in the range of 0.01-0.25. The crossover probability is set at 0.85.

The results show that with low mutation probabilities, the run converges later, as it depends mainly on the randomly generated initial population and its crossing in individual iterations. Only a small number of individuals are modified by mutation operators. As the probability of mutation increases, the run converges on average sooner and with a better solution, although we can notice in both tables the high dispersion of the generation of the found solution, caused by the randomness of the mutation. We recommend using a mutation probability in the range of 0.05-0.15. Since we don't want the algorithm to go into a random crawl, we don't recommend higher probabilities within the initial settings.

Creation of a new population – following the action of genetic operators, parents are replaced by offspring. In the case of using elitism, when we saved the best so far achieved solution as part of the suitability assessment, this individual replaces one of the descendants of the individual with the worst suitability. After this step, the algorithm returns to the step of evaluating new individuals using the fitness function. The algorithm is repeated in cycles until one of the terminating conditions is met.

Decision block – achieving the desired result. After the completion of the operation of the genetic algorithm, outputs are generated in the user interface: the block production layout, the achieved fitness value and the information in which iteration it was achieved, and a graph showing the evolution of the average and elite fitness values of the population.

3.4 Result of the software module providing the calculations

In order to verify the functionality of the proposed algorithm for creating a production layout, we performed an experiment (arranging 24 machines according to certain criteria, for three types of products), in which we compare the function of the algorithm with the commercially available Factory Plant/opt solution, which is part of the Factory Design and Optimization software tool. To get a better comparison, we repeat the experiment for times 1, 5, 10 and 20 minutes.

After entering all parameters and input data, the calculation took place within the specified time limits. Subsequently, the achieved solutions (production layout layouts) were assigned data on the frequency of movements, and the points between which a certain activity occurs on the specified products. In Table 1 we see a comparison of the resulting parameters (total logistic performance per year) of layout arrangements for both types of algorithms. The results of the compared algorithms in graphic form and the comparison of the average values of the evaluated criteria in percentages are shown in Figure 11 and Figure 12.

Table 1. Results of compared algorithms for designing the optimal production layout

		Proposed genetic algorithm			Factory Design and Optimization algoritmus		
Phase	Calculation time[min]	Distance [m]	Costs [€]	Time [min]	Distance [m]	Costs [€]	Time [min]
Round n. 1	1	657064,03	29249,97	80164,20	770414,29	29608,20	80668,73
Round n. 2	5	587135,08	28776,70	77835,06	728713,90	29519,01	80823,45
Round n. 3	10	507693,25	28549,76	77667,18	631026,65	29077,01	79323,15
Round n. 4	20	494892,15	28469,24	77297,11	609235,67	28996,54	79133,27

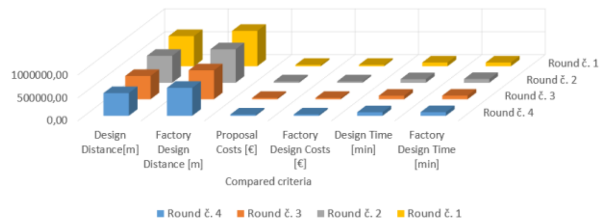

Figure 11. The results of the compared algorithms

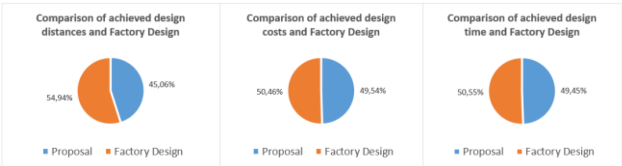

Figure 12. Comparison of the average values of the evaluated criteria

These results show that the algorithm proposed in the experiment in all time variants offers better results (distance by 9.88% on average) than the Factory Desing solution, which, for unknown reasons, in some cases did not comply with the dimensions of the workplaces. The proposed algorithm also arrived at solutions where there was no crossing or returning of material flows to the same extent as in the compared Factory Desing solution, we can state that workplaces were placed more efficiently.

In addition to the created script for the interactive projection system, the results are also saved and displayed in the form of an xlsx file. Restrictions are displayed by the respective codes and machines by numbers 1-n. The order corresponds to the order of entry of the machines in the tables of intensity, relations and dimensions. The achieved fitness value and the generation in which it was achieved are displayed (Figure 13).

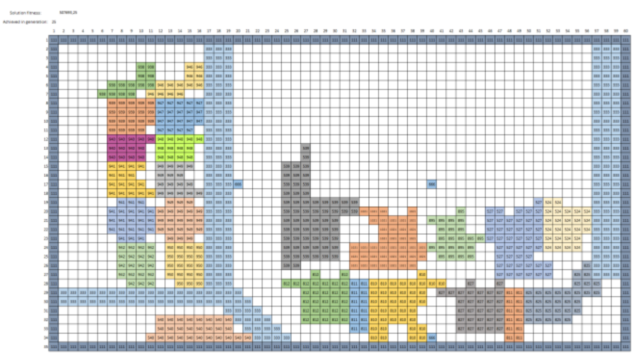

Figure 13. Display the output of the module

The next step of the research in this area will be to finalize the architecture of the interactive planning software so that it can process the data from the designed module providing the calculations and create the proper optimal layout of the machines from them. It will assign machine objects directly from its library of saved models. The results of importing data from the designed module are shown in Figure 14.

Figure 14. The result of importing data from the designed module (Software: Twiserion design manager)

The practical benefits of the proposed solution are mainly from the point of view of reducing the necessary time when designing the production layout, especially in the phase of variant design. Closely related to this is the possibility of checking a larger set of solutions, taking into account various limiting conditions. As this proposed solution reduces the time required in the phase of variant design, costs necessary for the creation of a new or changing production layout are reduced.

4 CREATING A DIGITAL TWIN THROUGH THE CONNECTION OF REAL AND VIRTUAL SYSTEMS

For wireless data transmission within the plant, it was decided to use the UWB network due to its high transmission speed and resistance to interference by other frequencies or building elements. UWB tags are connected to all tracked elements - via sensors, machine control units, handling units and handling devices, personnel tags track the location of operators.

Technically, the structure of the project is built in such a way as to combine several functional points into one unit for monitoring industrial objects.

Dynamic data from the production system is collected using three types of UWB tags:

- personal UWB tag. It is characterized by small dimensions and weight, it is suitable for monitoring operators and smaller elements. Contains a non-rechargeable 600mAh battery,
- tag for logistic means. It has a rechargeable battery, a USB interface for charging and configuration, and the possibility of wireless configuration. It is designed for tracking logistics equipment and larger elements,
- UWB sensor for machinery. It does not contain a battery and is wired to the machine. It serves to read and send all necessary data collected from the device.

The tags emit a UWB signal that is picked up by anchors (fixed objects placed in the manufacturing workshop). The anchor processes the UWB signal and transmits it to the RTLS server for processing via IP LAN networks. Filtering, processing and storage of collected data takes place on the server.

Other data such as technological procedures, parts lists, orders, etc. are stored in the company information system, e.g. ERP.

Next, the collected data is sent to the database server, which combines all existing databases. Data from various sources are converted and written to a central database repository. Data from the central database serve as input data for superior control and information processes. The main tool in this phase is the SQL (Structured Query Language) database, which is intended for data manipulation and definition (selection, insertion, modification and deletion). Communication is secured through standardized TCP/IP protocols.

5 POTENTIAL FOR EXTENTION: THE USE OF THE DIGITAL TWIN IN THE AREA OF PRODUCTION SCHEDULING

There is a trend to use new progressive technologies and methods of industrial engineering for production planning and scheduling [Buckova, 2020], [Filipova 2021]. The digital twin concept makes it possible to significantly shorten the planning process, offers tools for collecting and sorting data in real-time, and enables the verification and evaluation of designed solutions through dynamic simulation.

The DD-based custom manufacturing planning architecture consists of two parts: physical space and virtual space, as shown in the figure. These two parts communicate with each other through communication channels. In the virtual space, planning data can be obtained from a monitored source in the physical space, for example, from equipment, workers, MES, ERP, etc. Planning strategies can be obtained and simulated using planning models and algorithms with acquired source data. The final verified schedule is sent back to the physical space for execution. The concept of a digital twin scheduling system is shown in Figure 15.

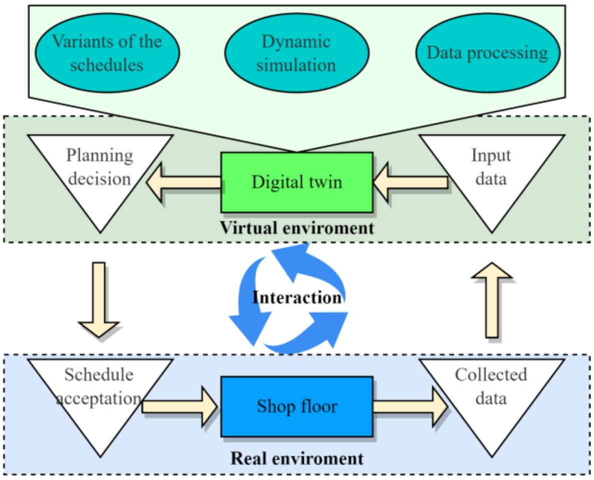

Figure 15. Concept of digital twin scheduling system

Such a concept should ensure constant monitoring of the real state of production, and in case of unforeseen events, the digital twin should immediately react to deviations and create a new plan for production and logistics, which will be sent back to production through communication channels.

6 CONCLUSIONS

The current design and planning of production systems has gone through a lot of modifications from classic design, where 3D objects were used in a real environment, which were later implemented in 2D, or 3D digital environment. We call this concept the digital enterprise. In addition to the transformation of these objects into a digital environment, it was possible to perform various types of analysis that help users create the best desired detailed solution in a digital environment, which is later applied in a real environment.

The main goal of the contribution was to show a new approach to the design and optimization of production processes. With the development of intelligent technologies, it is possible to expand the already known concept of the Digital Enterprise and move it to the next level through the data connection of the Digital and real enterprise with the provision of constant interaction, thus creating a new concept - the Digital Twin. Therefore, in the first part of the article, the concept of the given idea is shown.

The second chapter deals with the very design of the data collection system and brief analysis of available means and technologies for working with data.

The paper also described the proposal for the integration of the evolutionary algorithm with an interactive software environment for the 3D design of production layouts. The proposed case study points out how useful advanced technologies can be in the design of the production layout, in the phase of creating conceptual designs, taking into account various limiting conditions. The functionality of the proposed solution was verified using experiments, and the results of solving an equally complex task were compared with commercial software. Based on the results, it can be concluded that the proposed tool for creating the production layout meets all requirements and offers an optimal solution to the set problem, taking into account the limiting conditions. A design tool with interconnected modules and communicating elements can mediate information and feedback in the process of creating changes for further decision-making by industrial organizations. The long-term sustainability of manufacturing companies can be looked at through tools that could help companies sustain their existence and prosperity. Thanks to innovative technologies (such as simulation technologies, and interactive design systems supported by the function of genetic algorithms), companies can design and verify the accuracy of new production solutions in a simple and effective way before the process starts in the space itself.

Based on the created layout in the digital environment and the set data collection system, it is possible to create a link between production and its digital form. The output is a digital twin that can be used for various purposes such as project activities, optimization, and monitoring, whether at a higher level using simulation software to create a planning application for scheduling in real-time. The concept of the digital twin-based scheduling system and simulations is briefly described in Section 5.

ACKNOWLEDGMENTS

This research was funded by Slovak research and development agency, grant number APVV-19-0305.

REFERENCES

Book:

[de Pablos 2019] de Pablos, P. O.; Lytras, M. D.; Visvizi, A.; Zhang, X. Opportunities for Information Technologies and Knowledge Management to Answer Emerging Challenges for Manufacturing and Services Industries in the Digital Economy: DE PABLOS ET AL. Hum. Factors Man. 2019, 29 (1), 3–4. https://doi.org/10.1002/hfm.20786.

[Krajcovic 2011] Krajcovic, M. Modern approaches of manufacturing and logistics systems design. In Digitálny Podnik [Electronic Source]; CEIT SK: Žilina, Slovakia, 2011; p. 12. ISBN 978-80-970440-1-5.

[Haluska 2013] Haluska, M.; Gregor, M. Concept of the system for design and optimization of configurations in new generation of manufacturing systems. Int. J. Manag. Soc. Sci. Res. Rev. 2016, 1, 181–184. (2013)

[Sammen 2020] Sammen, SS; Ghorbani, MA; Malik, A .; Tikhamarine, Y .; AmirRahmani, M .; Al-Ansari, N .; Chau, K.-W. Vylepšená umelá neurónová sieť s optimalizáciou Harris Hawks pre predpovedanie hĺbky prečistenia po prúde od skoku na skok. Appl. Sci. 2020, 10, 5160. https://doi.org/10.3390/app10155160

[Fang 2019] Fang, Y., Peng, C., Lou, P., Zhou, Z., HI, J., Yan, J. (2019): Digital-Twin-Based Job Schop Scheduling Toward Smart Manufacturing. IEEE Transactions on Industrial Informatics, vol. 15, no. 12, pp. 6425-6435, Dec. 2019, doi: 10.1109/TII.2019.2938572.

[Skokan 2020] Skokan, R. 2020. Designing production systems using the digital twin concept. University of Zilina. Disertation thesis.

[Krajcovic 2019] Krajcovic, M., Hancinsky, V., Duluna, L., Grznar, P., Gaso, M., Vaculik, J. 2019. Parameter Setting for a Genetic Algorithm Layout Planner as a Toll of Sustainable Manufacturing. In SUSTAINABILITY, Volume 11, Issue 7, Article Number 2083, 2019, ISSN 2071-1050

[Filipova 2021] Filipova, I. – Dulina, L. – Bigosova, E. – Plinta, D. 2021. Modern Possibilities of Patient Transport Aids. In: 14th International scientific conference on sustainable, modern and safe transport (Transcom 2021). Virtual conference 26 May – 28 May 2021, Slovakia. Transportation Research Procedia, 55, 510-517.

[Buckova 2020] Buckova, M. – Gaso, M. – Pekarcikova, M. Reverse logistic In: InvEnt 2020: Industrial engineering – Invention for enterprise: proceedings. Bielsko-Biała: Wydawnictwo Akademii Techniczno-Humnistycznej, 2020. – ISBN 978-83-66249-48-6. pp. 36-39.

[Furmannova 2021] Furmannova, B. – Gabajova, G. – Matys, M. 2021. Training centers in industry. In: Technolog. ISSN 1337-8996, 13 (4), 2021, pp. 15-19.

[Mleczko 2014] Mleczko, J.; Dulina, L. 2014. Manufacturing documentation for the high-variety products. In MANAGEMENT AND PRODUCTION ENGINEERING REVIEW. Volume 5, Issue 3, Page 53-61, DOI 10.2478/mper-2014-0027, ISSN 2080-8208

[Grznar 2021] Grznar, P.; Gregor, M.; Gaso, M.; Gabajova, G.; Schickerle, M.; Burganova, N. 2021. Dynamic simulation tool for planning and optimisation of supply process. In INTERNATIONAL JOURNAL OF SIMULATION MODELLING, Volume 20, Issue 3, Page 441-452, DOI 10.2507/IJSIMM20-3-552, ISSN 1726-4529

[Vavrik 2022] Vavrik, V.; Fusko, M.; Buckova, M.; Gaso, M.; Furmannova, B.; Staffenova, K. 2022. Designing of Machine Backups in Reconfigurable Manufacturing Systems. In APPLIED SCIENCES-BASEL, Volume 12, Issue 5, Article Number 2338, DOI 10.3390/app12052338, eISSN 2076-3417

[Durica 2019] Durica, L.; Gregor, M.; Vavrik, V.; Marschall, M.; Grznar, P.; Mozol, S. 2019. A Route Planner Using a Delegate Multi-Agent System for a Modular Manufacturing Line: Proof of Concept. In APPLIED SCIENCES-BASEL, Volume 9, Issue 21, Article Number 4515, DOI 10.3390/app9214515, eISSN 2076-3417

[Kumar 2012] Kumar, Abdhesh a Pachauri, Praveen. 2012. Optimalization drilling sequence by genetic algorhitms. International journal of scientific and research publications. 2012, Zv. 2, 9.

[Misola 2013] Misola, Maricar G. a Navarro, Bryan B. 2013. Optimal facility layout problem solution using genetic algorithm. Internationalc Journal of Mechanical, Industrial Science and Engineering. Vol. 7, 2013, No. 8, s. 622-627.

CONTACTS:

Prof. Ing. Martin Krajcovic, PhD.
University of Zilina, Faculty of Mechanical Engineering
Department of Industrial Engineering
Univerzitna 1, 010 26 Zilina, Slovak Republic
tel.: 00421 513 27 18, e-mail: martin.krajcovic@fstroj.uniza.sk

Ing. Ivan Antoniuk, PhD.
University of Zilina, Faculty of Mechanical Engineering
Department of Industrial Engineering
Univerzitna 1, 010 26 Zilina, Slovak Republic
tel.: 00421 513 27 27, e-mail: ivan.antoniuk@asseco-ceit.com

Ing. Ladislav Papanek
University of Zilina, Faculty of Mechanical Engineering
Department of Industrial Engineering
Univerzitna 1, 010 26 Zilina, Slovak Republic
tel.: 00421 513 27 13, e-mail:ladislav.papanek@fstroj.uniza.sk

Ing. Radovan Furmann, PhD.
University of Zilina, Faculty of Mechanical Engineering
Department of Industrial Engineering
Univerzitna 1, 010 26 Zilina, Slovak Republic
tel.: 00421 513 27 33, e-mail: radovan.furmann@fstroj.uniza.sk

Ing. Vladimira Binasova, PhD., DiS.
University of Zilina, Faculty of Mechanical Engineering
Department of Industrial Engineering

Univerzitna 1, 010 26 Zilina, Slovak Republic
tel.: 00421 513 27 27, e-mail: vladimira.binasova@fstroj.uniza.sk

Ing. Vsevolod Bastiuchenko
University of Zilina, Faculty of Mechanical Engineering
Department of Industrial Engineering
Univerzitna 1, 010 26 Zilina, Slovak Republic
tel.: 00421 513 27 19, e-mail: vsevolod.bastiuchenko@fstroj.uniza.sk