TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering
Vol. 67, Issue Special I, February, 2024

A SYSTEMATIC LITERATURE REVIEW ON AUTOMATIC COMPUTER AIDED PROCESS PLANNING

Sergiu ROSIANU, Gheorghe OANCEA

Abstract: *Manufacturing industries are facing challenging times influenced by the trends of automatization and digitalization. Industry 5.0, in Europe and other concepts implemented in other parts of the world, is defining specific guidelines for a more humancentric approach. The implementation of artificial intelligence models has been increased in different areas. In this article, using the systematic literature review methodology, the development of solutions for the Automatic Computer Aided Process Planning are analyzed. Different concepts, like Automatic Feature Recognition or the Multi Sectional Views, are being compared, to find and highlight the actual research potential. Using some evaluation criteria, the relevance of all discovered solutions is described, having in view the impact on human centricity.*

Key words: *Systematic Literature Review, Automatic Computer Aided Process Planning, Automatic Feature Recognition, Manufacturing process planning optimization, Computer Aided Design*

1. INTRODUCTION

From the trends that are present today in the worldwide economy, digitalization and the increased products customization are some of the most influencing for the manufacturing systems [1]. With the clear target to increase efficiency, the industries are investing in intelligent systems that support humans with their tasks. Different concepts have been created and followed by the most powerful economies in the world, using different names and platforms. The European Union has defined Industry 5.0 as a strategic initiative for Europe's transformative vision. Having a more human centric approach, Industry 5.0 recognizes the power that industry must assure for a more sustainable prosperity of society.

The computational power which computers can offer was and will remain a great aid for different engineering activities. With the development of the hardware also the efficiency of the automatic solution increased. After the introduction of the first general – purpose digital computer, some 80 years ago, different numerical problems could be solved faster. Different activities in manufacturing processes received the much-needed support of the computer and in this way started the era of CAx systems, like Computer Aided Design (CAD), Computer Aided Engineering (CAE), Computer Aided Process Planning (CAPP), Computer Aided Manufacturing (CAM) [2].

Following the evolutionary pathway of manufacturing development, one important milestone is the automatic transfer process of information between all the systems and processes, to achieve a high degree of automation. Human expertise, knowledge, and cognitive skills are key elements to be transferred to artificial model. That is still a challenge that worldwide manufacturing experts are dealing with. Designing and implementing automatic processes has led once again to a change of naming, like automatic computer aided process planning (ACAPP).

Further on, in this article, through the way of systematic literature review method, the solutions which support the automatic computer aided process planning are presented and the importance of the automatic feature recognition is evaluated.

First the research method is presented by bringing theoretical and practical knowledge about the systematic literature review. The results found are presented afterward, highlighting the relevant information about ACAPP, Automatic Feature Recognition (AFR), STandard for the Exchange of Product model data (STEP), Computer Aided Inspection (CAI).

After reviewing the results, some discussion points are formulated, to highlight the research potential and trends related to the answers to the research questions.

2. RESEARCH METHODS

2.1 Systematic Literature Review Method

The roots of the systematic literature reviews (SLR) can be found back in the 18th century. Although this is variable, depending on the articles which are accessed, the first use of the method is in a study by James Lind on the treatment of scurvy, in 1757 [3].

Considering the need to have more accurate unbiased reviews of the research conducted worldwide, the systematic procedure defined in SLR was found useful and adopted in different disciplines. Jessica Gurevitch et al. has estimated in 2018 that the total reviews available in the literature will be beyond 200,000 [4]. In 2022 the number of systematic reviews exceed 250.000 (Web of Science).

The systematic review method is gaining more interest in different engineering disciplines. As it was presented in the research preliminary results performed by Reed et al. [3] engineering education have embraced SLR methodology.

Another concept can be found in literature, in the form of Living Systematic Reviews (LSR), where the lag in incorporating the latest researched results is reduced in comparison with SR. The application of this method, as is reported by Zheng et al. [5], has received some attention in the last years, used in medical science and mostly to COVID-19 research.

The systematic of the method is described through different clearly defined stages and steps, that can be traceable trough out the research. This is used for conducting systematic literature review in operation management, from where the knowledge was transferred for this study (as presented in figure 1) [6]:

1. Planning and formulating the problem.
2. Defining the searching strategy.
3. Searching process.
4. Quality assessment.
5. Data analysis and synthesis.
6. Presenting results.

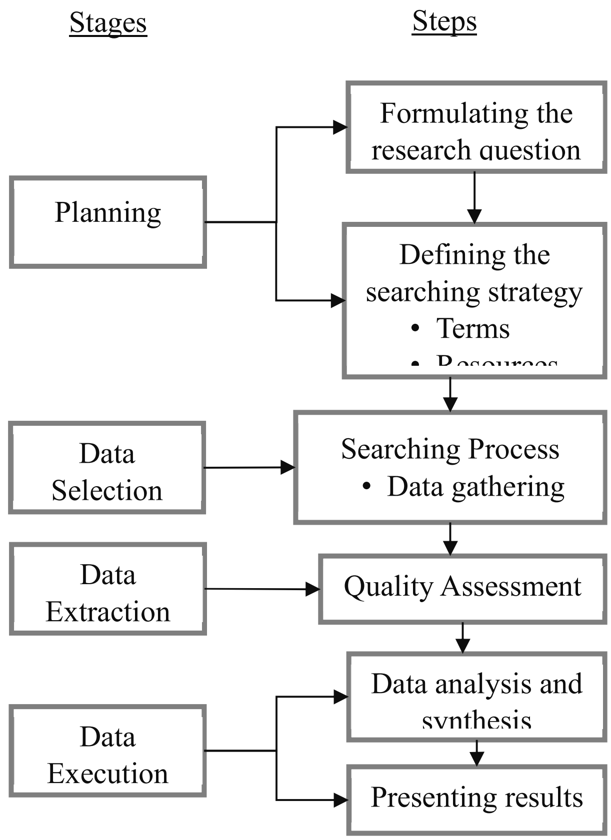

Fig. 1. Systematic review protocol based on stages and steps.

2.2 Planning

The research questions were put together:

RQ1: Which are the researched methods supporting the automated computer aided planning process?

Reasoning: Automated computer aided process planning has been used for some time in manufacturing industries. Different methods, using artificial intelligence, are studied to optimize the planning of the manufacturing technology. Answering this question will reveal the actual tendency and challenges using automated processes.

RQ2: How important is the automatic manufacturing feature recognition for the optimization of the manufacturing planning process?

Reasoning: The feature definition and recognition of a product is an important step in the process planning. Upon the right clarification of the feature, decision of the manufacturing steps is being taken. If the process is being automated, then a certain optimization will occur. Answering this question will show the importance and the potential of this research field.

To find answers to the formulated research questions, a search strategy was defined, considering the search sources and the keywords. (See table 1)

Table 1

Search Keywords

Research Question	Search Keywords
1	Automated Computer Aided Process Planning
2	Automatic manufacturing feature recognition

The terms were used in the same query using the logical operator OR:

((TS=(Automated Computer Aided Process Planning)) OR TS=(Automatic manufacturing feature recognition)).

Mainly when talking about resources for this study, it can be considered the capacity of one person having access to different databases where essential publications are present. The sources where the search was performed are the most known in the field of engineering: Web of Science, Scopus, IEEE, Springer link.

2.3 Data Selection

To conduct a systematic review, a thorough evaluation of all relevant literature must be performed. The steps protocol, as presented by Yazid et al. [7], are described to assure the systematical search in the databases. To identify the articles that could be relevant to answer the research questions, the search process is conducted using the four selected databases. The extracted data is being transformed by removing duplicates, blanks and correcting missing important information (like author, abstract, publishing date). Some filtering criteria are set to choose only eligible studies, like recent papers, in the field of engineering.

A primary eligibility condition, used for the screened article, is the similarity between the searching term and the key words extracted from the abstract. Normally if the abstracts are well written, they express the essence of the article, in this way extracting the key words from abstract is to be considered a good approach to reveal if the study is answering the research question or not.

For this process step, the Natural Language Processing (NLTK) was used. NLTK is a leading platform for building Python programming language to work with human language data. It gives a practical introduction to programming for language processing [8].

The articles selected in this process step have similarity percentage bigger than 20% (maximal value is 39%). Inclusion is being determined by relevance after full-text qualitative synthesis and accessibility of the papers. Relevant articles after full text review will be 39, as presented in figure 2.

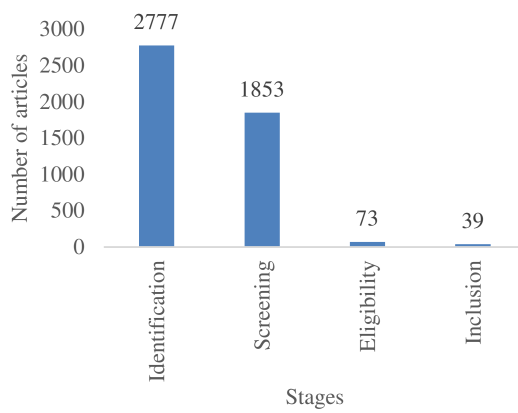

Fig. 2. Number of articles for every stage

2.4 Data Extraction

The quality assessment for the eligible and accessible articles was done by performing full-text review and rating them. The scores used for evaluation were 0, for the non-relevant studies that are not answering the defined questions and 1, for the relevant papers, that are bringing solutions in the field studied. The approach was adapted from the one used by Yazid et al. [7] without using the rating partially relevant, as it is not considered giving an objective perspective of this review. Using these assessment rules, 70% of selected, accessible articles are considered relevant to be extracted and used for synthesis.

2.5 Data Execution

For the qualitative assessment of the articles, with the objective to extract the relevant information that can be used to answer the formulated research questions, the evaluation criteria was set using the following categories: part type (for what kind of parts can the solution be applied), feature recognition method (which method was developed or used in order to recognize the geometrical feature), methods for ACAPP (methods developed or used for Automatic Computer Aided Process Planning), importance of automatic feature recognition (rated high to low, is the role of automatic feature recognition in the evaluated paper), research potential (what the authors considered as an opportunity to be further studied). This last step in systematic review protocol creates a taxonomy of methods and solution proposed to be used for process planning.

3. RESULTS

3.1 Search Results

Centralizing the data generated after the search procedure (see figure 3), using the defined keywords and the selected databases, resulted in a total of 1853 items. Of this 35% are from Web of Science, 35% from Scopus, 29% from IEEE and 1% from Springer link. The covered time frame in which these articles were published is between 1979 and August 2023 (presented in figure 4). Starting with 2014 there is a visible increasing tendency of the number of publications, revealing the research interest this topic has gained.

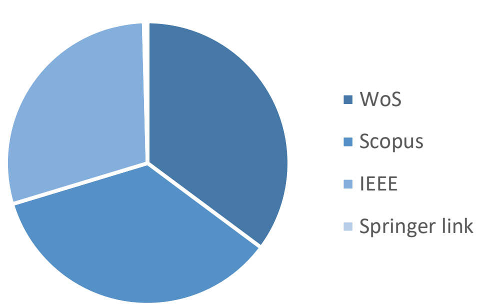

Fig. 3. Distribution of the found articles in databases.

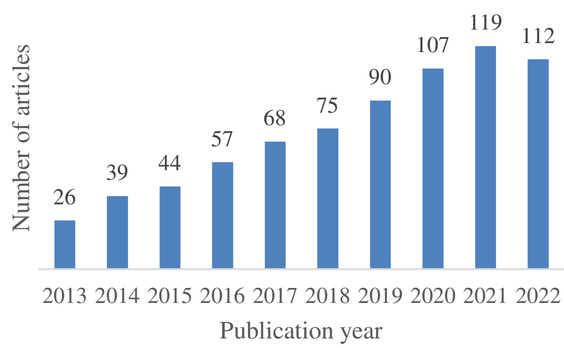

Fig. 4. Yearly development of published articles in the time frame 2014-2022

Regarding the type of reference where the articles were published, by adding classifiers to the publication name, the data shows that 32 % are linked to conferences, 21% appeared in journals and 43% in other types. (See table 2). Although this group also includes journals, that cannot be evaluated just by searching in the publication name. It can be observed that many of the journals are from the category of engineering-manufacturing. The journal from the first position has more than 50 items from the researched batch, and it will be in the first position in the analysis. (See figure 5)

Table 2

Reference type

Type of reference	**Number of articles**	**Percentage of items**
other	802	43%
conference	584	32%
journal	382	21%
symposium	70	3%
workshops	15	1%
Grand Total	**1853**	**100%**

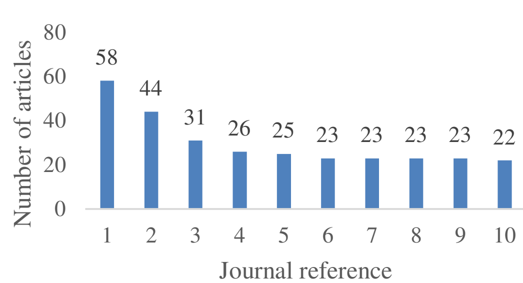

Fig. 3. Pareto of publications

3.2 Answering the research questions

RQ1: Which are the researched methods supporting the automated computer aided planning process?

The criteria for assessing the included articles are presented in table 3.

Table 3

Criteria of assessment

Criteria of assessment	Description
Focus on the ACAPP	If the article has a focus on ACAPP.
Methods described for ACAPP	Is there a specific method presented which supports the planning process
The focus technology	The researched concepts apply on a specific technology or mainly has a general approach.

As the role of CAPP system is to assure an interface between CAD and CAM data, the automation of the process is translated in most studies in the automation of data transfer. Commonly the transfer is from the source, CAD systems, to CAM or CAIP. In the relevant articles, which have a focus on ACAPP, the specific method for automation, is represented by the automatic feature recognition, mainly geometric but also manufacturing features.

Also, the opposite direction, to retrieve process knowledge by using Computerized Numerical Control (CNC) data, is being studied. [9].

Variant CAPP and group technology is a method still used in industry, having clear benefits by reducing cost, improving efficiency by creating a standardized production. Jong et al. [10] implements the group technology method for the molding processes, using classification and coding system to group the recognized features, with the objective to standardize mold manufacturing, thus reducing planning effort.

Zehtaban and Roller [11] propose another method of part classification in group technology, by using Opitz coding system. Being an open domain, this system was often used in industry in comparison with other methods.

A 23 percent of the articles that were included in the full text review (9 from 39), were coded as using neural network systems to assist the process planning. The networks are of different types: Convolutional Neural Networks (CNN), Artificial Neural Networks (ANN). Having different structures to support a better learning process: deep learning, transfer learning. These systems have become more popular for researchers, due to the lately development of computational capabilities. What is still challenging is the handling of the amount of data that is needed for the training step of such a neural network.

Zhang et al. [12] uses a 3D convolutional neural network having 8 layers and using a dataset of 24 feature from 144.000 models of prismatic parts. The framework was named "FeatureNET". Actually, the name "Feature net" was originally proposed by Selfridge (1959) (as the "pandemonium model") and is describing a theory of recognition and image constancy in human perception [13]. This concept was further developed by authors to respond to automatic feature recognition for CAD models.

"PointNet" [14], is an architecture developed for assembly, which uses a CNN, and the feature recognition is implemented using point clouds. Multi view CNN and extreme learning machines are used for machine tools, recognizing 3D shapes, and assuring an intelligent machine tool management system [15].

Using advanced learning strategies like transfer learning, data augmentation for neural network-based approach of the planning process, new concepts like multi sectional views (MSV) are being introduced [16].

As can be observed in figure 6, the automatic feature recognition (AFR) remains the most used method for transferring the data from CAD to other processes in this way supporting the automated computer aided process planning.

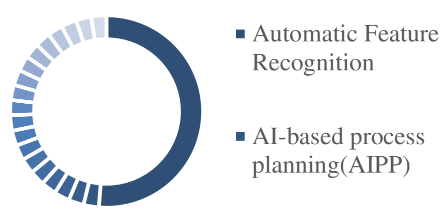

Fig. 4. Methods for ACAPP

RQ2: How important is the automatic manufacturing feature recognition for the optimization of the manufacturing planning process?

The criteria for assessing the included articles are presented in table 4.

Table 4

Criteria of assessment

Criteria of assessment	Description
Part type	Gives details of the type of the part
Feature recognition method	Present the method used for feature recognition
Importance of AFR	The evaluation of the importance of AFR for ACAPP

After coding and classifying the information extracted from the full articles review, the AFR is present in most of the studies for ACAPP. The logic rule-based method is the most used in the studies reviewed, followed by the knowledge-based (see figure 7).

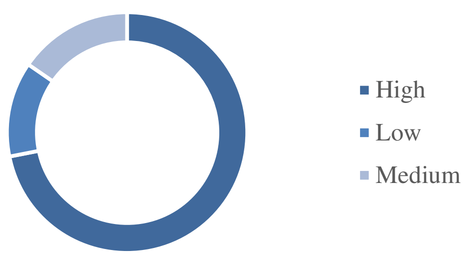

Fig. 5. Importance of automatic feature recognition

The development and application of neural networks has gained momentum, being mostly present in solutions labeled as learning-based approach (see figure 8 and 9).

The category of the parts on which different methods for feature recognition are applied has also been a coding field in the full text review. Figure 10 shows the occurrence of different families of parts. Most of the solutions are valid for all types of parts and some for specific ones, like prismatic, rotational. Tools and fixtures are also considered suitable subjects for AFR, being important components in process planning.

Luo et al [15] develops a contact-less, low-cost recognition technology using deep learning based intelligent recognition solution for machining tools.

Another solution in the area of computer aided fixture design was developed by Fuand Campbell using concurrent reasoning to generate optimal tool design [17].

The evolution of solutions for automatic feature recognition are correlated with the development of CAD systems and the computing power of the used hardware.

It can be observed in figure 9, from the distribution of the feature recognition methods based on publishing year of the research, that after 2016 the interest in applying intelligent solutions, like artificial neural networks, has increased.

The research potential can be discovered in the opportunities to decrease the computational times and reduce the number of needed data.

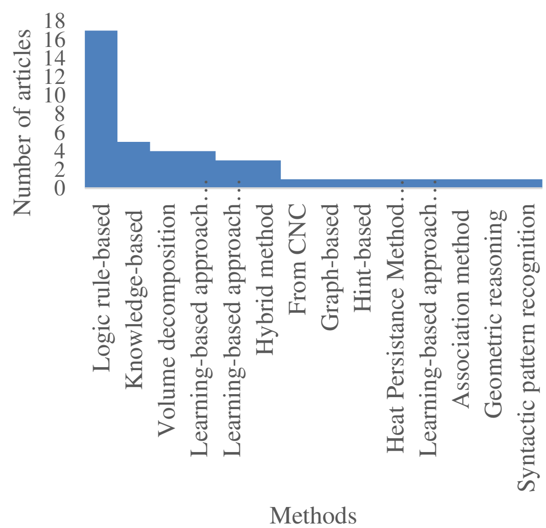

Fig. 6. Feature recognition methods

Going deeper insides of the full text review, another topic can be highlighted. To extract features from design models, the researchers, besides their own developed solution, have also used commercial CAD software (PTC Creo, Catia V5, Solidworks, AutoCAD).

After extracting the features, the next important step is to recognize and classify them into entities that can be manufactured. Based on numerical computation and knowledge, decisions related to manufacturing/planning process are taken. The algorithm for decisionusing different programming languages (like Visual Basic, AutoLisp, Python, C#, C++). making and feature recognition are implemented

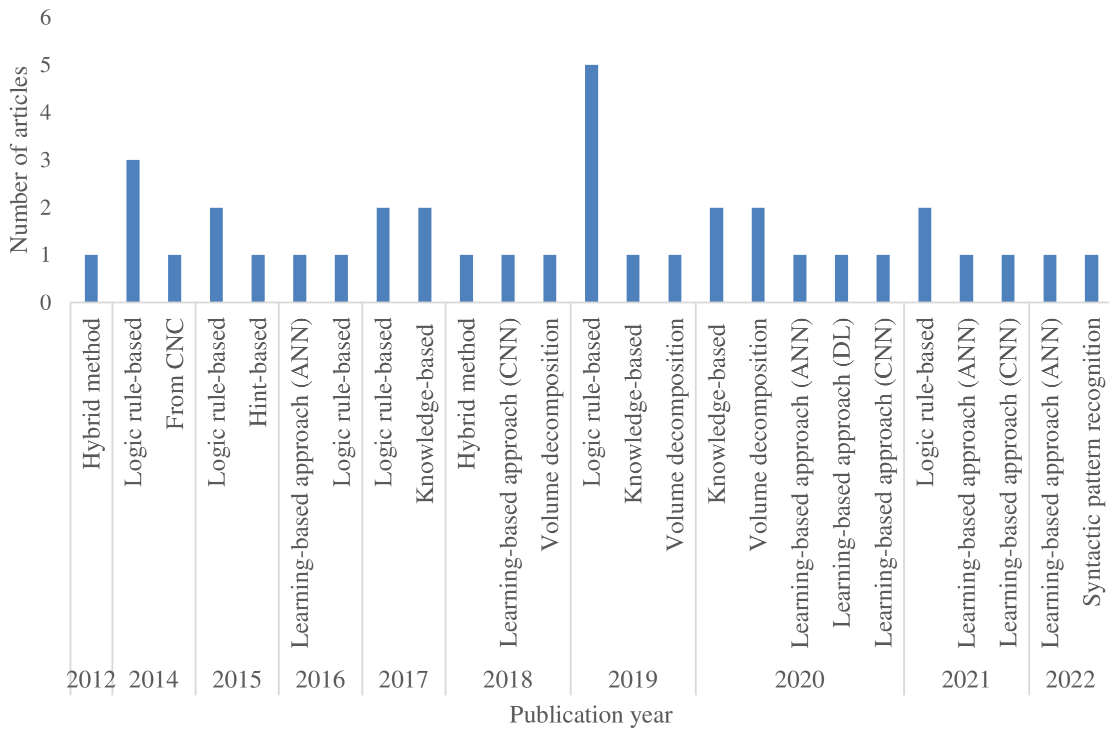

Fig. 7. Feature recognition method – development timeline

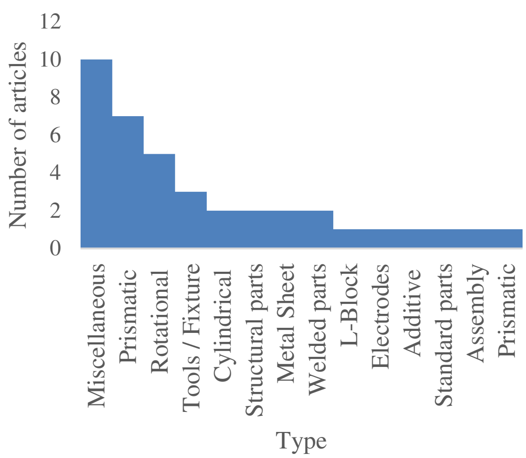

Fig. 8. Part type

Kukreja et al., proposed a smart manufacturing system for the automated remodeling and manufacturing of standard parts, using Autodesk Inventor to model parts and export data into standardized format (STEP AP203). With the use of Visual Basic scripts, the CAD data are linked to CAM system. A rule-based approach for reasoning is proposed and an automatic remodeling, new efficient pattern matching technique for feature recognition [18].

Another relevant example of using different platforms for feature recognition is the research conducted by Kiani and Saeed, describing a solution for automatic spot-welding feature recognition. The CAD data is extracted from the standardized file format (STEP AP203) and recognized using a script programmed in Python [19].

The articles considered, relevant for the full text review, provide valuable solutions for different manufacturing technologies, the most present are the metal removing ones (see figure 11).

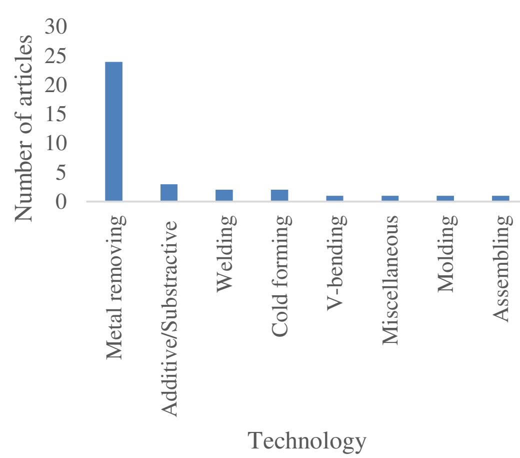

Fig. 9. The technologies in focus

Jong et al. classified features for molds using a hybrid approach, graph-based and rule-based using a custom Web-based application build in Pro/Web.Link (PTC) [10].

3.3 Automated computer aided process planning (ACAPP)

The development of computer aided process planning is strongly correlated with the appearance and existence of CAD systems and the introduction of CNC.

Jianbin Xue presented the manufacturing industry evolutionary path to improve and computerize the process planning, which can be grouped in following 6 stages [20]:

1. Manual classification; standardized process plans.
2. Computer maintained process plans.
3. Variant CAPP.
4. Generative CAPP.
5. Dynamic, generative CAPP.
6. Hybrid CAPP and expert systems.

Nowadays, the CAPP types found in the applications, are the following [20]: variant, generative, expert system, neural network, and hybrid.

1. *Variant CAPP* - mainly the system is based on group technology classification and works by matching codes of a pre-established process plan. The advantage of using the variant CAPP is the actions that are fulfilled to reach standardization and to create family of parts with the same design and manufacturing features. In the manufacturing, different coding systems were applied and used like: MICLASS, KK-3, Opitz. The feature-based methods were also introduced in the variant CAPP, creating a common understanding between designers and process engineers about the characteristics of a specific part.

2. *Generative CAPP* - the key element in such a system is the definition and implementation of decision rules for process planning. All these rules are implemented through computer language in order that the process can be assisted. Depending on the complexity of the part which should be manufactured, the decision-making algorithm is also more or less complex. Data availability is an important factor in creating an accurate system.

3. *Expert system-based* - the automation and intelligence degree of the system is increasing by building algorithms that are correlating process knowledge with the input parameters, to solve problems and give solutions. The limitation using expert systems is the constraint of the knowledge field.

4. *Neural networks-based approach for CAPP* - by using neural networks. The system is able to learn and adapt to new manufacturing domain and knowledge. There are some deficiencies that have been studied in the last years and visible progress was made to reduce them. Due to the complex structure of a neural network, which in most of the cases have a large number of nodes, the training process is quite time consuming and needs a considerable amount of data.

5. *Hybrid systems* - when using a combination of ideas and concept from variant and generative system then are defining a hybridization method to define the process. Jianbin Xue describes [20] the CAPP intelligent function model as a collection of data bases, auxiliary intelligent functions, information feedback and kernel function. The model is built to have the self-learning ability, to be effective and efficient.

The future CAPP systems will be considered *Intelligent* or *Smart*, having the ability to adapt to different parts and technologies and being effective and efficient in taking decisions. There are different technologies and methods which support the implementation of CAPP systems. Those are present in the articles reviewed and applied for specific parts and technologies: feature-based, knowledge-based, neural networks, genetic algorithms, agent-based, fuzzy set theory, Petri nets, interned-based, STEP-compliant, and functional blocks.

3.4 Automatic feature recognition

The feature-based systems have created a common engineering language which supports a better connectivity of design and manufacturing functions, thus making the process planning more accessible [20].

Mainly the features used in the process are dividing into families like [21]:

1. Functional.
2. Design.
3. Technological.

4. Machining.

The common methods for feature recognitions are [22]:

1. Syntactic pattern recognition.
2. Predicate calculus – predicate logic.
3. Graph based design recognition methods.
4. Volumetric convex hull decomposition methods.
5. Hint based.

When taking in account the degree of human intervention in the planning process with respect to feature identification, it can be divided the systems into three main groups:

1. Manual recognition.
2. Semi-automatic recognition.
3. Automatic recognition.

The automatic feature recognition methods can be classified in [2]:

1. Syntactic pattern recognition.
2. Graph-based.
3. Hint-based.
4. Logic rule based.
5. Artificial neural network.

The feature recognition methods have advantages and disadvantages, which are mentioned in different reviewed research. When having simple, non-interacting features, then the rule-based approach is the faster and easiest, but quite challenging when the features are complex and interact with each other. In the case the design has predefined or standard entities then the graph-based approach is the best solution. The advantage of this method is the ease of adding new feature. It is not performing well for the intersecting geometries. The hint-based approach is working well in the case of recognizing known features that intersect themselves but lacks the performance for complex entities. In this case a modified, hybrid method is more suitable.

A neural network can significantly improve the processing time for feature recognition and support the decision-making process. The performance of such artificial networks is strongly correlated with the data - training quality and quantity.

3.5 STEP

STEP is the acronym of STandard for the Exchange of Product model data and was introduced in 1985 by ISO (International Organization of Standardization). Still then the standard is still used to have a common language between the CAD and CAM systems.

The Product Life-cycle Management (PLM), the process managing the complete product life cycle from conception to disposal, has different instruments and standards regarding products. STEP is the most common and used in industry.

The standard contains many Application Protocols (AP), which include functions an engineer needs to perform a specific activity (like CAM or CAPP).

The most popular Application Protocol for CAD is AP-203: Configuration Controlled Design (STEP Tools, n.d.).

3.6 Tool path

The path followed by a tool is an essential part in the process planning and a lever for productivity improvement of manufacturing technologies. In the articles reviewed, the tool path is treated from different view angles.

Zhang et al. [9] present a method for feature recognition from CNC programs, to generate the process plan. The tool path, for milling operation, is described in the CNC program, through geometrical entities of the product.

The other approach is to generate the tool path after recognizing features describing the model. This is studied and presented by Ma et al. [23]. For intelligent manufacturing using electric discharging electrodes, a hybrid feature recognition method is used. The tool path is automatic generated, and the process plan is created using genetic algorithm, considering defined rules.

3.7 Computer aided inspection

Similar with CAD/CAPP/CAM, Computer Aided Inspection (CAI) is a methodology used in manufacturing to evaluate the properties of the produced products, like dimensions, form deviations, and surface descriptions [24].

The CAI could be integrated with CAPP/CAM thus the feedback from the assessment of parts could be used to create or optimize the process planning.

The research presented by Li et al. [25] describes such a method of using the feedback from inspection process to map the features of parts used in aircraft industry. A knowledge- and rule-based reasoning is proposed to recognize feature types.

Similar conclusions are presented by Ma et al. [23], meaning that the data generated from computer-aided inspection process can be used to improve process planning and parameter selection, have a value added for the robustness of the whole system.

4. DISCUSSION

After reviewing the selected and the most representative articles to give answers to the research questions and after presenting the results of the systematic study of the literature, some points should be brought into discussion.

It was observed that feature recognition is still the foundation and common language of the computer aided process planning. Automation of feature recognition strongly correlates with the automation of process planning.

Besides the traditional methods used for recognition and classification, the most complex and computationally intensive methods using artificial intelligence have gain quite a representative research interest. A challenge that is currently debated and used as evaluation criteria of neural network is the data availability. The ability of a network to respond to different feature types, easy to complex, is the aim of solution proposed in the review articles.

The commercial CAD software systems have also increased their capabilities to extract and recognize features. The newest technologies will most probably be applied and used in the future.

In the summary of the research potential mentioned by authors in the reviewed articles, some common points can be highlighted. As presented in the previous chapters, there are different methods for feature recognition. Most of them are using knowledge stored in databases, others have the capability to adapt using new data and information. Most of the systems developed perform well recognizing separated non intersecting features. The increasing complexity of the surfaces contained in the part geometry and features intersection, is a direction where the research potential is found. Another idea that could be highlighted is the relevance of features of complex shape, with respect to the manufacturing capabilities of the industrial processes. The extracted information from CAD is not only proposed to be used in the manufacturing operation (CAM) but also in inspection process planning (CAI). Automatic generation of quality inspection requirements and reports is also an area where research interest can be found.

What can also be discussed is the necessity for capturing manufacturing knowledge and data from the shop floor and transferring it to reasoning algorithms from CAPP.

5. CONCLUSION

The answer to the questions: *Which are the researched methods supporting the automated computer aided planning process? How important is the automatic manufacturing feature recognition for the optimization of the manufacturing planning process?* was searched in the literature, using the systematic review approach. Different evaluation methods and coding criteria were used to establish the relevance of the researched topics described in articles. After presentation of the results in the sections before, some conclusions are formulated.

The industry is investing time and resources in the automation of the planning process. The technology, production process and product knowledge are key elements to be used in manufacturing planning.

This knowledge is safe guarded from companies and transformed into mathematical models, then used to simulate different situations that could happen in manufacturing.

Considering the opinion of the authors of the reviewed articles, automation of the process planning is still a research direction with significant research potential. Having also in view different trends, like the circular economy, increasing the demand of fully customizable products and digitalization, the methods supporting the CAPP are adapting to the current manufacturing requirements. One important milestone is the automatic process to transfer information between all the systems to achieve a high degree of automation. Recognition of features from the manufactured parts, classification of the data and transformation of all information in process plans, are important elements in automatic manufacturing.

Closing the loop of the data circulation in the complete product life management, bringing the relevant data back to redesign the product, is relevant for manufacturing better, cheaper, and more sustainable products.

6. REFERENCES

[1] Breyer-Mayländer, T., *Industrie 4.0 bei Hidden Champions*. Springer Fachmedien Wiesbaden, 2022. doi: 10.1007/978-3-658-36201-0.

[2] Al-wswasi, M., Ivanov, A., and Makatsoris, H., A survey on smart automated computer-aided process planning (ACAPP) techniques, International Journal of Advanced Manufacturing Technology, vol. 97, no. 1–4, pp. 809–832, Jul. 2018, doi: 10.1007/s00170-018-1966-1.

[3] Reed, J., Phillips, M., Epps, A. Van, and Zwicky, D., An Early Look at a Scoping Review of Systematic Review An Early Look at a Scoping Review of Systematic Review Methodologies in Engineering Methodologies in Engineering An Early Look at a Scoping Review of Systematic Review Methodologies in Engineering, 2020. [Online]. Available: https://cochrane.org

[4] Clarke, M., Partially systematic thoughts on the history of systematic reviews, Systematic Reviews, vol. 7, no. 1. BioMed Central Ltd, Oct. 27, 2018. doi: 10.1186/s13643-018-0833-3.

[5] Zheng, Q. … Tian, J., Past, present and future of living systematic review: A bibliometrics analysis, BMJ Global Health, vol. 7, no. 10. BMJ Publishing Group, Oct. 11, 2022. doi: 10.1136/bmjgh-2022-009378.

[6] Thomé, A. M. T., Scavarda, L. F., and Scavarda, A. J., Conducting systematic literature review in operations management, Production Planning and Control, vol. 27, no. 5. Taylor and Francis Ltd., pp. 408–420, Apr. 03, 2016. doi: 10.1080/09537287.2015.1129464.

[7] Yazid, S., Yusri, Y., Kamran, L., Aini Zuhra Abdul, K., and Maznah lliyas, A., Systematic review of STEP-NC-based inspection, The International Journal of Advanced Manufacturing Technology, 2020, doi: https://doi.org/10.1007/s00170-020-05468-7.

[8] Bird Steven, Klein Ewan, and Loper Edward, Natural Language Processing with Python --- Analyzing Text with the Natural Language Toolkit. O'Reilly Media, Inc., 2009. Accessed: Mar. 20, 2023. [Online]. Available: https://www.oreilly.com/library/view/natural-language-processing/9780596803346/

[9] Zhang, X., Nassehi, A., and Newman, S. T., Feature recognition from CNC part programs for milling operations, International Journal of Advanced Manufacturing Technology, vol. 70, no. 1–4, pp. 397–412, Jan. 2014, doi: 10.1007/s00170-013-5275-4.

[10] Jong, W. R., Lai, P. J., Chen, Y. W., and Ting, Y. H., Automatic process planning of mold components with integration of feature recognition and group technology, International Journal of Advanced Manufacturing Technology, vol. 78, no. 5–8, pp. 807–824, May 2015, doi: 10.1007/s00170-014-6627-4.

[11] Zehtaban, L. and Roller, D., Automated Rule-based System for Opitz Feature Recognition and Code Generation from STEP, Computer-Aided Design and Applications, vol. 13, no. 3, pp. 309–319, May 2016, doi: 10.1080/16864360.2015.1114388.

[12] Zhang, Z., Jaiswal, P., and Rai, R., FeatureNet: Machining feature recognition based on 3D Convolution Neural Network, CAD Computer Aided Design, vol. 101, pp. 12–22, Aug. 2018, doi: 10.1016/j.cad.2018.03.006.

[13] Andy Matuschak, Feature net, https://notes.andymatuschak.org/Feature_net.

[14] Worner, J. M., Brovkina, D., and Riedel, O., Feature recognition for graph-based assembly product representation using machine learning, in International Conference on Control, Automation and Systems, IEEE Computer Society, 2021, pp. 629–635. doi: 10.23919/ICCAS52745.2021.9649784.

[15] Luo, L., Yang, Z. X., Tang, L., and Zhang, K., An ELM-Embedded Deep Learning Based Intelligent Recognition System for Computer Numeric Control Machine Tools, IEEE Access, vol. 8, pp. 24616–24629, 2020, doi: 10.1109/ACCESS.2020.2965284.

[16] Shi, P., Qi, Q., Qin, Y., Scott, P. J., and Jiang, X., A novel learning-based feature recognition method using multiple sectional view representation, Journal of Intelligent Manufacturing, vol. 31, no. 5, pp. 1291–1309, Jun. 2020, doi: 10.1007/s10845-020-01533-w.

[17] Fu, W. and Campbell, M. I., Concurrent fixture design for automated manufacturing process planning, International Journal of Advanced Manufacturing Technology, vol. 76, no. 1–4, pp. 375–389, Jan. 2015, doi: 10.1007/s00170-014-6247-z.

[18] Kukreja, A., Manu, R., and Lawrence, K. D., Towards the development of a smart manufacturing system for the automated remodeling and manufacturing of standard parts, International Journal on Interactive Design and Manufacturing, vol. 15, no. 2–3, pp. 353–363, Sep. 2021, doi: 10.1007/s12008-021-00758-0.

[19] Nazir, M. S., Gul, S. T., Nadeem, S., Pakistan Institute of Engineering & Applied Sciences. Department of Electrical Engineering, Institute of Electrical and Electronics Engineers. Islamabad Section, and Institute of Electrical and Electronics Engineers, Automatic Spot Welding Feature Recognition From STEP Data. 2019.

[20] Jianbin Xue, *Integration of CAD/CAPP/CAM*. Walter de Gruyter GmbH, Berlin/Boston, 2018.

[21] Chlebus, E. and Krot, K., *CAD 3D models decomposition in manufacturing processes*, *Archives of Civil and Mechanical Engineering*, vol. 16, no. 1, pp. 20–29, Jan. 2016, doi: 10.1016/j.acme.2015.09.008.

[22] Grabowik, C., Kalinowski, K., Paprocka, I., and Kempa, W., *A survey on methods of design features identification*, in *IOP Conference Series: Materials Science and Engineering*, Institute of Physics Publishing, Nov. 2015. doi: 10.1088/1757-899X/95/1/012120.

[23] Ma, H., Zhou, X., Liu, W., Li, J., Niu, Q., and Kong, C., *A feature-based approach towards integration and automation of CAD/CAPP/CAM for EDM electrodes*, *International Journal of Advanced Manufacturing Technology*, vol. 98, no. 9–12, pp. 2943–2965, Oct. 2018, doi: 10.1007/s00170-018-2447-2.

[24] Ron Branch, *How to Close the Loop on the Digital Manufacturing Workflow*, *https://www.verisurf.com/blog/article/computer-aided-inspection/*, 2011.

[25] Li, Y., Wang, W., Li, H., and Ding, Y., *Feedback method from inspection to process plan based on feature mapping for aircraft structural parts*, *Robotics and Computer-Integrated Manufacturing*, vol. 28, no. 3, pp. 294–302, Jun. 2012, doi: 10.1016/j.rcim.2011.09.006.

ANALIZA SISTEMATICĂ A LITERATURII PRIVIND PLANIFICAREA AUTOMATĂ A PROCESELOR CU AJUTORUL CALCULATORULUI

Rezumat: Industriile manufacturiere se confruntă cu vremuri dificile, influențate de tendințele de automatizare și digitalizare. Industria 5.0, în Europa și alte concepte similare implementate în alte părți ale lumii, definește linii directoare specifice pentru o abordare mai centrată pe om. Modelele de inteligență artificială cât și implementarea lor în diferite domenii a crescut. În acest articol, folosind metoda de analiză sistematică a literaturii, este prezentată dezvoltarea soluțiilor pentru planificarea automată a proceselor asistate de calculator. Diferite concepte, cum ar fi recunoașterea automată a caracteristicilor sau vederile multi secționale, sunt comparate, pentru a găsi și evidenția potențialul real de cercetare. Folosind câteva criterii de evaluare, este descrisă relevanța tuturor soluțiilor descoperite, având în vedere impactul asupra centralității umane.

Sergiu ROSIANU, PhD student, Department of Manufacturing Engineering, Transilvania University of Brasov, sergiu.rosianu@unitbv.ro, B-dul Eroilor nr. 29, Cod postal 500036, Brașov, România, corresponding author

Gheorghe OANCEA, professor, Department of Manufacturing Engineering, Transilvania University of Brasov, gh.oancea@unitbv.ro, B-dul Eroilor nr. 29, Cod postal 500036, Brașov, România