Autonomous Production Control: A Literature Review

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Abstract. Autonomous production control (APC) aims at improving production systems performance through fast and flexible reaction to changes in dynamic production environments. APC shifts the power of decision from a central planning unit, towards single intelligent and distributed logistic objects that can cope with the rising complexity of today's manufacturing systems. The purpose of this research is to analyse the current state of art on APC in discrete manufacturing industries, throughout a systematic literature review. The study's objectives were to: (1) identify specialists in APC; and (2) identify theoretical developments and practical implementations. The reviewed was obtained by searching the Scopus database - a total of 49 papers have been analysed. The findings revealed that there is not much work carried out on APC until now, and that most of the contributions are theoretical. It is hoped that this literature review will contribute to enhance research in this science field.

Keywords: Autonomous Production Control, Literature Review.

1 Introduction

The future of manufacturing industries depends largely on their capability to respond to the customers' expectations while maintaining a competitive advantage on their markets. Manufactures must produce a growing number of customized products [1], [2], with reduced life cycles, short delivery times and high adherence to the order' due dates.

Industry 4.0 allows to respond to these needs through autonomous Production Planning and Control (PPC). Traditional Production Planning and Control (PPC) systems are characterized by a central planning and controlling of the factory. However, the dynamics imposed by mass customization makes these systems less useful in the current days. This is due to the lack of flexibility to adapt to disturbances in the production environment, resulting from e.g. rush orders, machine breakdowns, etc. [3]. The development of Cyber-Physical System (CPS), obtained by advances at wireless communication, sensors and computing power, and the growth of Internet of Thing (IoT), in the last decade [4], [5], allows for new approaches to production control. One of these approaches is Autonomous Production Control (APC).

Autonomous production control (APC) aims at improving production systems performance through fast and flexible reaction to changes in dynamic production environments. APC can cope with the rising complexity of today's manufacturing systems due to the decentralized decision-making. APC enables each logistics object, e.g., resource, pallet or order, to make decisions on their own, concerning the way jobs (or orders) will be produced, sharing information between them, with no human interference [6]. This permits a holistic vision of real-time production towards making the best production control decisions.

This paper makes a systematic literature review on the theme of APC for discrete manufacturing industries. The focus is on following production control functions: (1) job release, which determines the jobs to be released to the shop floor and that decide when they should be released; (2) detailed scheduling, that allocates jobs to resources and sets the jobs priorities on the shop floor.

The remainder of the paper is organised as follows. The next section describes the research methodology used in this study, in section 3 the findings are presented and discussed and finally section 4 presents the conclusions and provides directions for future research work

2 Methodology

According to [7] a systematic literature review typically has the following nine purposes/ benefits: (1) reduces large amounts of information; (2) integrates pertinent pieces of information for decision-making, research and policy; (3) it is a scientific technique typically less costly than new research, especially if it is updated permanently; (4) facilitates the generalizability of findings; (5) permits a systematic valuation of relationships among variables; (6) helps to explain and discover inconsistent data or contradictory findings in a specific field; (7) empowers the statistical analyses in quantitative results; (8) increases the precision for the estimation of statistical risks; (9) improves the accuracy and allows verification due to the systematic methodology.

In this paper, a systematic literature review is accomplished using the main steps referred by [8], [9] namely: define research question, determine required characteristics, retrieve sample of potentially relevant literature, select pertinent literature, synthesize literature and report results.

2.1 Planning the review

To initiate this process the topic has been disputed in a brainstorming session with the authors to understand what is important to study. Then, the research questions were formulated. Due to the advent of Industry 4.0 and the increasing importance of Autonomous Production Control (APC) for manufacturing [6], it becomes relevant to (1) find out which are the specialist in the area of APC; and (2) known how is APC research evolving - throughout theoretical and empirical research work? This research questions are the basis of this work. The next step was to select the criteria of inclusion

or exclusion of papers. The approach used was to include all the documentation concerning autonomous control in production or manufacturing, involving production control functions such as sequencing, releasing, dispatching, between others. The content of the papers may be a framework, an application, a technique, a new method, etc. to perform typical tasks of production control in the context of autonomous decision-making in discrete manufacturing industries.

2.2 Conducting the review

The review was conducted in two searches. To keep results to a manageable number, the search was restricted to the title, abstract, and keywords of papers. The first search resulted in 2176 documents using "Autonomous Production Control". This search resulted in a set of documents out of the scope of our study (see next section). In a second search, this was further reduced to 97 documents by excluding apparently unrelated articles. These 97 papers are the result of a search conducted in March 2018 in one of the most popular and largest coverage database of scientific documents – Scopus, using the following script:

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TITLE-ABS-KEY (Autonomous Control) AND TITLE-ABS-KEY
(production OR shop floor OR manufacturing) AND ALL
(sequencing OR dispatching OR release OR capacity OR
allocation OR scheduling OR planning OR programming)
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After the abstract reading of these papers, only 49 were relevant to the scope of our study. The next section presents and discusses the findings obtained.

3 Findings and Discussion

In the past decades, there was a growing interest by the scientific community in Autonomous Production Control (APC). This can be noticed by observing Fig. 1 that resulted from the first search. Over the past two decades the number of papers published in APC more than duplicated every year, achieving 174 in 2017 from a total of 2167 published in the period between 1960 and 2017.

This first search resulted in documents about areas such as enabling technologies for APC (e.g., sensors, RFID) and in process industries, such as oil, fluid and gas production, which is out of the scope of this study. VOSviewer software [10] was used to give a general view of the main research fields in APC Fig 2.

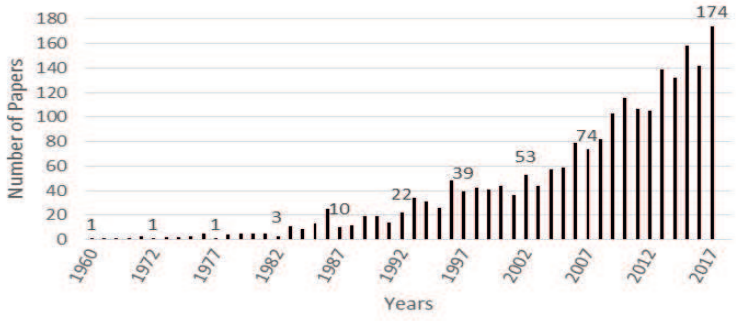

Fig. 1. Distribution of papers by year of publication.

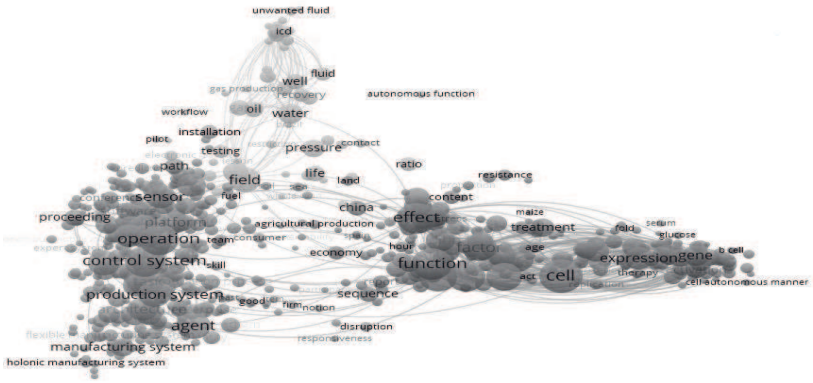

Fig. 2. Research fields in APC resulting from the first search.

Concerning the relevant papers, that resulted from reading all abstract, Fig 3. and Fig 4. makes a characterization concerning the journals that have published in APC and region (country) the authors of the papers are from, respectively.

Fig. 3. Distribution of publications by: Journal

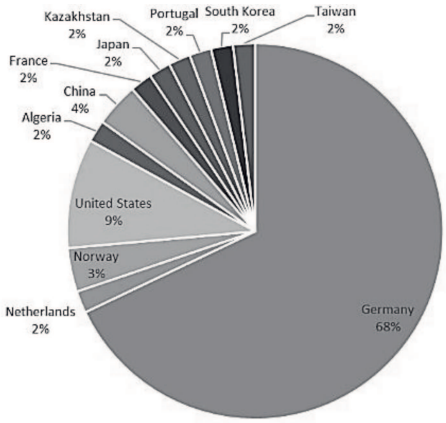

Fig. 4. Distribution of publications by: region

Next, we present and discuss the findings associated with each one of the research questions (RQ).

3.1 RQ1: Who are the specialists in Autonomous Production Control?

Fig. 5 shows the top 10 authors in number of publications in APC from a universe of 77. By a quick analysis to the Fig. 5 an eye-catching author appears: Bernd Scholz-Reiter. This author appears in 23 of the 49 selected papers, i.e., in 47% of the papers. Bernd Scholz-Reiter, start writing about APC in 1999, about 20 years ago, with [11] referring that traditional MRP systems don't have the flexibility to react effectively to disturbances in the production environment. Bernd Scholz-Reiter was head of the Fraunhofer Application Center for Logistics System Planning and Information Systems, which he founded, and headed the Bremen Institute for Production and Logistics (BIBA).

It is important to refer that a total 77 co-authors are responsible for these 49 papers. This number indicates a relatively small worldwide scientific community working in APC. Given the novelty of the field and the interest Industry 4.0 has aroused in the scientific community, it is expected that in near future these community can increase significantly.

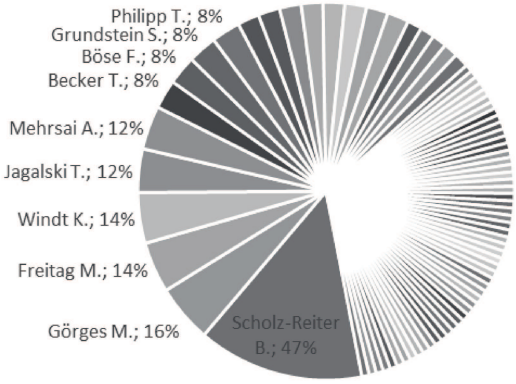

Fig. 5. Top 10 Authors in number of publications.

3.2 RQ2: How is APC research evolving - throughout theoretical or empirical research work?

In this case it's necessary to explain the differences between these research approaches. Theoretical research presents new frameworks, new methods, etc. in hypothetical contexts. The researcher does not use empirical data to build the theory but uses hypothetical examples. Neither does the researcher analyses concrete and specific works. Empirical research uses empirical evidence. Empirical research starts from specific concrete examples or observations to create a model and subsequently, a theory.

This research question helps to understand which path APC research work is following. Most of the publications, 44, covers theoretical issues. Through Table 1 we can realize a focus of the authors in one kind of paper for the development of new methods for APC. Table 1 categorizes papers according to: (1) theoretical vs. empirical; and (2) the proposal (new method, framework, methods comparison, other). Theoretical represent 90% of the papers, new method represents 49%, framework 21%, comparison between methods 18% and other areas researched 12%. This will help future research to identify theoretical developments, and practical issues that may lead to new theory build.

Table 1. Classification of the published papers.

Research Type	New Method	Framework	Methods Compraison	Others
Theoretical	43%	19%	16%	12%
Empirical	6%	2%	2%	

4 Conclusions

The main purpose of this paper was to carry out a literature review to better understand the current state of the research work in Autonomous Production Control (APC). In this context, two research questions emerged, namely: (1) who are the specialists in Autonomous Production Control? (2) how is this research evolving - throughout theoretical or empirical research work? The distribution of the number of publications in time, by editorial publication and by geographical region was also considered in the study. The main findings are summarized in the following. Research work in APC is still in the beginning, with most of the contributions being theoretical and concentrated in some geographical regions, such as Germany and USA (whereas in regions with developing countries few studies are found), with a huge contribute of one author - Bernd Scholz-Reiter. Future research work should extend the research questions into more detail, to better understand the contribution of APC to the company's competitiveness.

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