Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 99 (2021) 555–560

www.elsevier.com/locate/procedia

14th CIRP Conference on Intelligent Computation in Manufacturing Engineering, CIRP ICME '20

Cloud manufacturing: Theoretical localization within production theory

Robert Henzel [a,*], Carsten Ellwein[b], Georg Herzwurm[c], Oliver Riedel[b]

[a]*University of Stuttgart, Graduate School of Excellence advanced Manufacturing Engineering (GSaME), Nobelstr. 12, 70569 Stuttgart, Germany Germany*

[b]*Institute for Control Engineering of Machine Tools and Manufacturing Units, University of Stuttgart, Seidenstr. 36 D-70174 Stuttgart, Germany*

[c]*University of Stuttgart, Chair of Information Systems II, Keplerstr. 17, 70174 Stuttgart*

* Corresponding author. Tel.: 49-711-685-84186; fax: +49-711-685-82388. *E-mail address:* Robert.Henzel@gsame.uni-stuttgart.de

Abstract

The industrial production landscape is significantly affected by digitization. In the course of this development, various production paradigms have been proposed, such as ubiquitous manufacturing, distributed manufacturing or, most recently, cloud manufacturing.
A selective discussion and interpretation of these similar concepts remains in the literature as a research gap. Following the call for research, the aim of this paper is to distinguish the concept of cloud manufacturing from neighboring production paradigms and to locate it within the theory. This goal will be achieved by means of a literature analysis as well as argumentation based on it and finally presented graphically.

Peer-review under responsibility of the scientific committee of the 14th CIRP Conference on Intelligent Computation in Manufacturing Engineering, 15-17 July 2020.

Keywords: Ubiquitous manufacturing; Distributed manufacturing; Cloud manufacturing

1. Introduction

The manufacturing domain is changing rapidly. The actual meaning of manufacturing could be formulated as follows: 'making articles by physical labour or machinery, especially on a large scale' [1].

Hence, there is a logical transformation from some kind of input towards a specific output, i.e. product. The rational as well as the actual meaning within this process didn´t have changed at all over time; manufacturing still is some kind of transformation. The crucial change lies within the needs of actual outputs together with new possibilities and opportunities regarding the transformation process itself. In the following some crucial developments regarding the manufacturing domain are synthesized.

There has been a shift towards 'user-centric' and 'participant-centric' philosophy [2] e.g. blurring the boundaries between consumers and producers. Moreover, there is a need to account for complexity, disturbances as well as uncertainties. This is due to the worldwide globalization and therefore, worldwide connectivity and availability of manufacturing enterprises. Traditional supply-chains do not make hold at cross-national borders anymore, they are largely interconnected [3].

Going back to Wright´s citation of the meaning of manufacturing – nothing, content-wise, has changed at all. Nevertheless, traditional manufacturing systems are not suited to account for the mentioned environmental changes within the manufacturing domain, as traditional manufacturing systems are often highly centralized. Generally, a central manufacturing system schedules and controls the production facility. The hierarchical control of a traditional manufacturing system is suitable for batch production in a steady state, but not for small batches in a dynamically changing environment. The need for a distributed e.g. heterarchical control structure becomes evident.

The advent of information technology and the internet in the last two decades provided meaningful tools to cope with the changed manufacturing environment. In this regard, several production paradigms have been proposed. A non-exhaustive list would entail Agile Manufacturing [4], Lean Manufacturing [5], Distributed Manufacturing [6], Ubiquitous Manufacturing

Peer-review under responsibility of the scientific committee of the 14th CIRP Conference on Intelligent Computation in Manufacturing Engineering, 15-17 July 2020.
10.1016/j.procir.2021.03.076

[7] or Cloud Manufacturing [8]. These developed production paradigms are aiming to account for the mentioned changes within the manufacturing environment. Whilst Cloud Manufacturing is a meaningful development and combination of previous production paradigms [9], there is general heavy theoretical ambiguity regarding concurrent production paradigms.

The goal of this paper is to eliminate a well-chosen ambiguity between three concurrent production paradigms: Distributed Manufacturing (DM), Ubiquitous Manufacturing (UM) and last but not least Cloud Manufacturing (CM).

The literature body of knowledge consists of even more assumable concurrent production paradigms – e.g. Digital Manufacturing or Intelligent Manufacturing. Whilst acknowledging their existences, these further comparisons are not in the scope of this article.

Actually, contradictory findings for our chosen comparison of DM, UM and CM are fueling an utter research need of clarification and thereby, dominating the relevance of possible other theoretical comparisons of concurrent production paradigms.

Firstly, it is interesting to note that the literature on DM and UM is highly fragmented due to the fact that both have demonstrable applicability in a wide variety of sectors as well as in varying contexts. Most of the literature in both paradigms are focusing on implementation topics e.g. development of an architecture or an algorithm. Pure theoretical contributions in both paradigms remain somehow underrepresented.

Secondly, one could argue the opposite content for CM. Here, the literature consists mainly of theoretical contributions, while actual implementations remain somehow underrepresented. It is nevertheless important to note, that the literature base in CM is shifting nowadays towards more implementation topics.

The following equalizations or ambiguous statements are highlighting the particular research need for a meaningful comparison and distinction of the concurrent paradigms DM, UM and CM.

In [10], the authors are implying several times the equality of CM and UM. Apart from several pure content-wise implications of equality, the authors did even implement a pure CM-definition into a table of UM-definitions. Additionally, the authors of [7] are implying that CM is a subset of UM e.g. CM is applying UCT-technologies in the manufacturing management and process planning domain. Following this ambiguity further, the authors of [11] didn´t distinguish between UM and CM, too. To provide another piece of evidence for this ambiguity, the authors of [12] did analytically compare UM and CM and found a non-equality, as there are important underlying differences.

Interestingly, one can find the same ambiguity statements within the DM literature. In [13], the authors cite DM research articles within the CM section, implying an assumable equality of both.

When inspecting the current National Institute of Standards and Technology (NIST) landscape for manufacturing in [14], the authors actually did distinguish between DM and CM. Here, the authors did list Holonic Manufacturing (which is a reasonable representation of DM according to [15]) by neighboring and not equaling to CM.

Interestingly, there is similar observation of ambiguity between another production paradigm: CM and Smart Manufacturing (SM). Whereas the authors in [14] and [13] actually do distinguish between CM and SM, the authors in [12] come to the conclusion that CM is a SM paradigm, implying equality of both. This similar observation in a neighboring field is further spurring the motivation of this particular research. It seems to be a common and relevant problem within the manufacturing literature.

Henceforth, there is a major research need to finally clarify the distinction and relationship between DM, UM and CM.

In order to differentiate between the paradigms of Ubiquitous Manufacturing, Distributed Manufacturing and Cloud Manufacturing, these terms are defined in the following chapter. Thereby, the meta database Google Scholar is used, paradigms are searched by their names and the results are sorted according to their relevance. Using Google Scholar as a single source of literature seems to be valid approach according to [16] and [17], as it not only may be used to identify the most highly-cited articles, but also provides a more comprehensive coverage of relevant literature when compared to Scopus or Web of Science. For the definitions, starting with the first hit, all accessible results that were available in English were considered until an appropriate saturation was reached. Saturation is assumed when five sources do not provide new criteria for the definition of the respective paradigm.

Based on these definitions the paradigms are distinguished in chapter three. For this purpose, Euler diagrams are used, which have their origin in set theory. They show all relations between the considered definitions. Finally, the results are discussed in chapter four and lastly a conclusion is given.

2. Foundations

In this section the term and characteristics of Ubiquitous Manufacturing, Distributed Manufacturing and Cloud Manufacturing are enlightened.

2.1. Ubiquitous manufacturing

First of all it is important to note a small deviation from the mentioned literature-searching approach stated previously. [7] was included after carefully inspecting [6], where the former was stated as a comprehensive state-of-the-art survey of UM-literature. It is moreover interesting to note, that [7] wouldn´t have been included otherwise with our procedure.

As already mentioned in the introduction, the literature regarding UM seems to be fragmented. Firstly, it is interesting to note that there is no definition-aspect, onto which all inspected authors do agree – thereby already neglecting a uniform definition and a restrictive definition. Secondly, there are aspects onto which a majority of authors do agree, namely: collection of logically distributed, free accessible and independent intelligent devices which are using ubiquitous computing technology. In order to be ubiquitous, manufacturing events have the necessity of market orientation as well as a certain frequency of occurrence higher than a specific threshold. For the following, this definition is treated as the major definition. Highlighting the fragmentation of the literature, there are several characteristics which are neither shared by every author nor by the majority of authors, which leads to the expensive definition of UM.

Hence, the expansive definition of UM is the combination of the major definition stated above, as well as all of the other criteria in the following table one, as they are non-contradictory.

Table 1. Criteria for ubiquitous manufacturing and their utilization

Criterion	Mentioned In	Cnt.
collection of logically distributed, free accessible and independent intelligent devices	[18-20, 23]	4
market oriented with frequency of occurrence greater than a specific threshold	[18,20-22]	4
utilization of ubiquitous computing technology	[18-19,21,23]	4
provision of real time data	[18,21,23]	3
events on the lowest level of hierarch	[20, 22-23]	3
utilization of product life cycle (PLC) information	[21,23]	2
provisioning through information and communications technology (ICT)	[18,23]	2
design, make and sell anywhere at anytime	[18,20]	2
fusion of utilization and cloud technologies with traditional manufacturing systems	[20-21]	2
automatic identification and localization via sensor technology	[18]	1
change dynamically and reconfigure automatically for new manufacturing tasks	[18]	1
supported by semantic tools for communication	[18]	1
utilization of micro electrical, chemical and radio frequency technology	[18]	1
service-orientation	[20]	1
is a practical an approximate term	[20]	1
utilization of material process, information processing and knowledge resources	[20]	1
managed by meta organization via 'chaos and complexity'	[20]	1
based on industrial location and central place theory	[22]	1
seamless information exchange	[23]	1

2.2. Distributed manufacturing

Whereas the literature in UM was uncertain regarding a uniform characteristic, it is a little bit different for DM. All of the inspected literature agreed on the following, which will serve as a restrictive definition of DM: It is a collaboration within a cluster or network of cross-border relationships in carefully developed supply chains, within loosely coupled production units.

When further looking for a major definition, most of the authors do agree onto increased flexibility of a plant, partly with the same manufacturing capability in different locations or varying quantity. Furthermore, they are engaged on a decentralized, sometimes fully distributed heterarchical control system, while retaining a minimal amount of global information for the highest possible production efficiency.

Likewise in UM, the literature in DM seems to be fragmented, as there are several mentioned characteristics which are solely shared by a minority or even just a single author within the inspected literature. These characteristics in total do form the expansive definition of DM (whilst including the restrictive and major characteristics stated above), as they are non-contradictory, see the following table two.

Table 2. Criteria for distributed manufacturing and their utilization

Criterion	Mentioned In	Cnt.
collaboration within network of cross-border relationships in carefully developed supply chains	[6, 24-28]	6
increased flexibility of plant	[6, 25-28]	5
decentralized control type	[6, 24-25,28]	4
retention of minimal amount of global info for highest possible production efficiency	[24,26-28]	4
geographical dispersion of production locations	[6, 27-28]	3
concurrent production systems	[25,28]	2
redistribution of value or manufacturing	[6,28]	2
digitalization of product design, production control and demand or supply integration	[6,28]	2
personalization of products	[6,28]	2
process plan according to near optimal	[26,28]	2
blurring boundaries between consumer and producer	[6]	1
diverse or disparate stakeholders	[6]	1
just in time (JIT) production	[28]	1
human influent complex system for decision making	[28]	1
focus on core competencies	[28]	1
enabled via service-oriented architecture (SOA) or agent concept	[28]	1

2.3. Cloud manufacturing

When searching for the most relevant papers with the keyword Cloud Manufacturing in Google Scholar, a strong dominance of some authors and thus the similarity of the content between the papers is striking. When it comes to the content-related discussion of CM, many authors agree on one point, that there seems to be no shared definition [29–32]. However, all of the consulted agree in one criterion that has to be fulfilled for CM, that manufacturing resources can be accessed on demand, that they are considered as services. Table three gives a complete overview of all the mentioned criteria, their origin and the frequency of their appearance. Additional to this consensus criterion, the majority of the authors demand orchestration as well as resource management functionality and the utilization of network technology, at least half of the authors the utilization of virtualization technology. The demanded orchestration functionality focuses on customers and describes the ability to form temporary, reconfigurable production lines out of dedicated manufacturing services. The demanded resource management functionality focuses on the service providers.

Table 3. Criteria for cloud manufacturing and their utilization

Criterion	Mentioned In	Cnt.
resources-as-a-service	[29-38]	10
orchestration functionality	[30,33,36,32,37-38]	6
resource management functionality	[29-30, 33, 34,35,37-38]	6
utilization of network technology	[29,31,33–36]	6
utilization of virtualization technology	[31,33–36]	5
capabilities-as-a-service	[30-31,35,38]	4
participation of multiple suppliers	[30-31,34,38]	4
utilization of cloud computing	[33–36]	4
utilization of IoT technology	[33–36]	4
manufacturing execution functionality	[37]	1

Beyond this, some authors demand that not only resources but also further technical as non-technical capabilities to be available on demand and that multiple supplies need to share their resources for the CM paradigm to be fulfilled. Furthermore, the utilization of cloud computing and IoT technology is partly required. A single author explicitly demands that the manufacturing services can not only be allocate but also has to be directly executable. Based on this analysis, the following common definition can be derived, which includes all criteria mentioned by the majority of authors: In CM solutions, resources are managed, offered as a service via network technology and can be orchestrated by the end customer as required. A restrictive definition, which is consistent with all authors, is limited to making resources available as a service. An expansive Definition can include all of the above criteria, since they are non-contradictory.

3. Distinction of the Paradigms

In the following, the definitions of the three production paradigms UM, DM and CM are distinguished. The distinction is based on the previously developed restrictive, major and expansive definitions. Euler diagrams are used for presentation.

3.1. Placement of restrictive definitions

As mentioned above, there is no consensus regarding a restrictive definition for UM. Hence, the following Euler diagram shows the relationship between CM and DM.

Fig. 1: Euler diagram for CM and DM

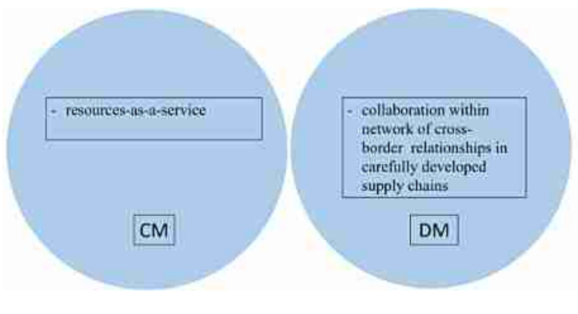
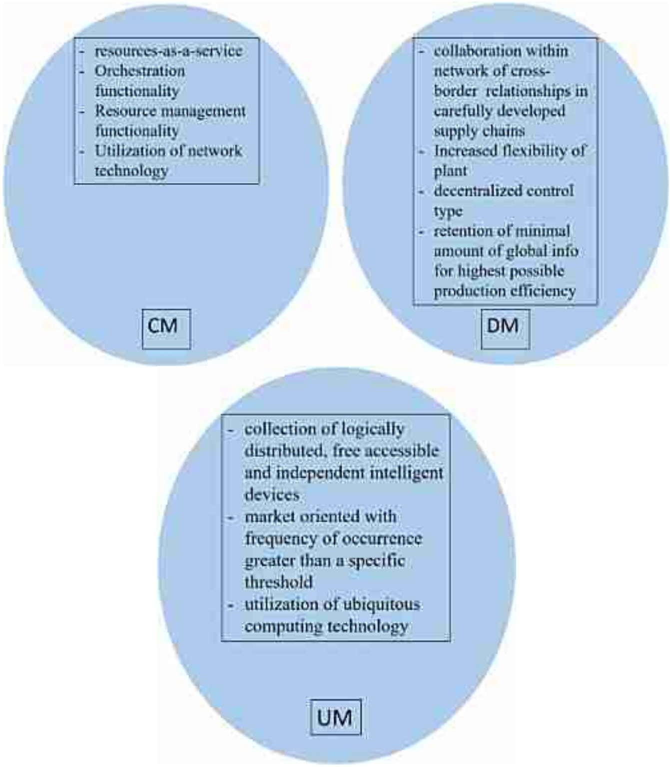


Fig. 2: Euler diagram for CM, DM and UM



3.2. Placement of major definitions

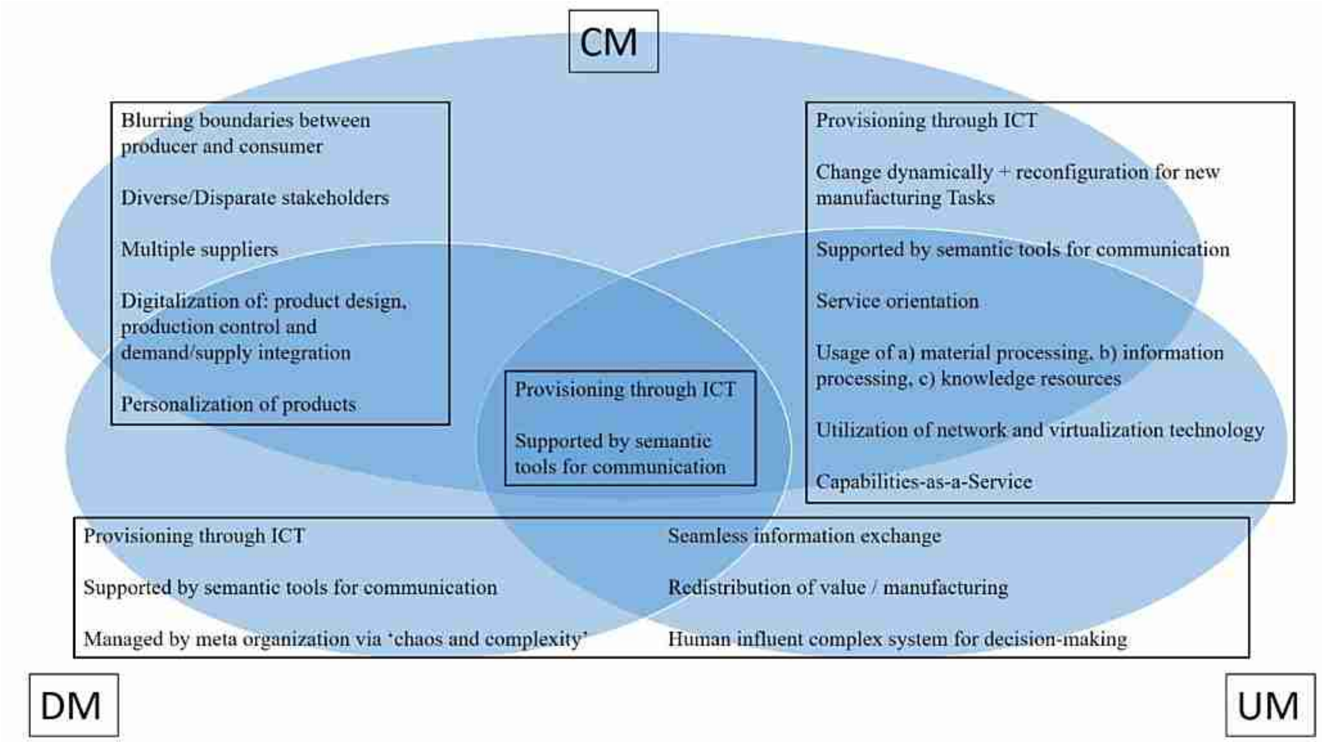
Figure two is showing the Euler diagram for the relationship between CM, DM and UM.

3.3. Placement of expansive definitions

Due to visualization arguments, in the following Euler Diagram the major and restrictive definitions are excluded, as they were already previously shown. Moreover, figure one and two already implied that there are no intersections or overlappings between the three paradigms regarding the former two definitions. It is moreover important to note, that figure three only included the overlappings between the concepts, illustrated as rectangles, whilst the “non-overlapping” characteristics remain hidden to ensure a more suitable illustration of the actual results. Those “non-overlapping” characteristics are nevertheless logically included in the distinctive logical sets of CM, UM and DM, according to the characteristics respectively defined in table one, two and three.

An observation of figure three is implying that a) there are common sets of characteristics between CM and UM, CM and DM as well as UM and DM and that b) there are two characteristics which are shared by the three production paradigms.

Fig. 3: Euler diagram for CM, DM and UM



4. Discussion

For the following, the results of figure one, two and three as well as table one, two and three are considered.
The very first obvious implication is that CM, DM and UM are definitely not equal to each other, contradicting the stated ambiguity in the introduction where several authors did imply some equality. Namely, we strongly reject the statements from [10] and [11]. Additionally, we reject the implied stated equality of DM and CM in [13].

The rejections become clear when looking at figure one and two, where either a restrictive (all of the authors do agree) or a major (more than 50% of authors agree) is used. Looking at both, there are not overlappings of the production paradigms.
If and only if the expansive definitions are used, some overlappings emerge. Nevertheless, those shared characteristics have to be treated with caution, as the expansive definitions itself are already implying some kind of ambiguity due to their nature.

Additionally, even within the expansive characteristics, the non-overlapping characteristics are superior regarding the actual amount. Last but not least, it is important to note that all of the three production paradigms have the same origin, as stated in the introduction. Thus, even if looking at the relaxed expansive definitions and the respective overlappings within the three production paradigms, the equal characteristics have to be treated with caution. There are two characteristics which are shared by CM, DM and UM, namely provisioning through ICT and the support by semantic tools for communication.
Having the same motivation regarding their invention and being finally enabled by the latest developments in information communication technology and the internet, those two overlapping characteristics are becoming quite evident.

More interestingly, the following hypotheses are formulated based on our results:

H_1: The literature in DM and UM is highly fragmented based on the sole number of expansive characteristics in both topics.
$H_{2.1}$: The literature in UM is even more fragmented than DM, as there is no possibility to formulate a restrictive definition and the amount of expansive definitions is clearly outnumbering.
$H_{2.2}$: UM is not a production paradigm, but rather a manufacturing approach due to $H_{2.1}$ and due to the literature found within the actual screening process. Most of the literature "somehow" uses the concept of UM in a variety of contexts implementation-wise, whereas one would expect to gather 'theory-anchoring' papers within the first results when using Google Scholar. Additionally, the actual concept has its roots in geography, already neglecting a one-to-one transformation into manufacturing literature.
H_3: The focus of CM is to enable lot size one, while the focus of DM and UM is related to enhance existing production efficiency.
H_4: An implementation of DM is possible via an implementation of CM, but not vice versa.
H_5: An implementation of UM is possible via an implementation of CM, but not vice versa.

With the stated hypotheses H_5, we can now also reject the stated relationship in [7] – CM is not an implementation of UM, but vice versa.

5. Conclusion

In order to account for the rapidly changing manufacturing environment, several production paradigms have been proposed previously.

Interestingly, there was a heavy ambiguity between three of them: CM, DM and UM. This article clarified their relationship by looking at the restrictive, major and expensive definitions of those and made their distinction clear. Although there are similarities when comparing the expansive definitions, they actually differ obviously. UM cannot be considered as a production paradigm anymore. The limitation of this study remain with the chosen methodology. Although there are sound arguments for solely using Google Scholar regarding this kind of research, we cannot deterministically exclude the possibility of slightly other restrictive, major and expansive definitions. In the future it is planned to integrate our results more precisely within existing manufacturing literature.

Acknowledgements

This work was partly supported by the Federal Ministry of Economics and Energy on the basis of a decision of the German Federal Parliament (Deutscher Bundestag) - ZF4328612P08.

References

[1] Wright, K. 21st century Manufacturing. 1st edition. Prentice Hall; 2011.
[2] Kwon, K., Choi, B., Lee, S. CEO information: The Web 2.0 centric change of society and enterprise. Technical report, Samsung economic research institute 2007; p. 588.
[3] Wiendahl, H.-P., Scholtissek, P. Management and control of complexity in manufacturing. Annals of the CIRP 1994; 43(2), 533-540.
[4] Gunasekaran, A. Agile manufacturing: a framework for research and development. International Journal of Production Economics 1999; 62, 87–105.
[5] Bamber, L., Dale, B.G. Lean production: a study of application in a traditional manufacturing environment. Production Planning and Control 2000; 11 (3), 291–298.
[6] Srai, J.S., Kumar, M., Graham, G., Phillips, W., Tooze, J., Ford, S., Beecher, P., Raj, B., Gregory, M., Tiwari, M.J., Ravi, B., Neely, A., Shankar, R., Charnley, F., Tiwari A. Distributed manufacturing: scope, challenges and opportunities, International Journal of Production Research 2016; 54:23, 6917-6935.
[7] Wang, X., Ong, S.K., Nee, A.Y.C. A comprehensive survey of ubiquitous manufacturing research, International. Journal of Production Research 2018; 56:1-2, 604-628.
[8] Li, B. H., Zhang, L., Wang, S.L.,Tao, F., Cao, J.W., Jiang, X.D., Song, X., Chai, X.D. Cloud manufacturing: a new service-oriented networked manufacturing model. Computer Integrated Manufacturing Systems 2010; 16(1), 1-8.
[9] Zhang, L., Luo, Y., Fan, W., Tao, F., Ren, L. Analyses of cloud manufacturing and related advanced manufacturing models. Computer Integrated Manufacturing Systems 2011; 17(3):458-468.
[10] Dubey, R., Gunasekaran, A., Chakrabarty, A. Ubiquitous manufacturing: overview, framework and further research directions. International Journal of Computer Integrated Manufacturing 2017; 30:4-5, 381-394.
[11] Putnik, G. Advanced manufacturing systems and enterprises: Cloud and ubiquitous manufacturing and an architecture. Journal of Applied Engineering Sciences 2012; 10 (3),127–143.
[12] Liu, Y., Wang, L., Wang, X.V., Xu, X., Jiang, P. Cloud manufacturing: key issues and future perspectives. International Journal of Computer Integrated Manufacturing 2019; 1-17.
[13] Esmaeilian, B., Behdad, S., Wang, B. The evolution and future of manufacturing: A review. Journal of Manufacturing Systems 2016; 39, 79-100.
[14] Lu, Y., Morris, K.C., Frechette, S. Current standards landscape for smart manufacturing systems. National Institute of Standards and Technology 2016; NISTIR, 8107, 39.
[15] Ka´da´r, B., Monostori, L., Szelke, E. An object-oriented framework for developing distributed manufacturing architectures. Journal of Intelligent Manufacturing 1998; 9, 173–179.
[16] Harzing A.W., Alakangas S. Google Scholar, Scopus and the Web of Science: a longitudinal and cross-disciplinary comparison. Scientometrics 2016; 106:787-804.
[17] Martin-Martin, A., Orduna-Malea, E., Harzing A.W., López-Cózar E.D. Can we use Google Scholar to identifiy highly-cited documents? Journal of Informetrics 2017; 11:152-163.
[18] Chen, T., Tsai, H. R. Ubiquitous manufacturing: Current practices, challenges, and opportunities. Robotics and Computer-Integrated Manufacturing 2017; 45, 126-132.
[19] Wang, X., Ong, S.K., Nee A.Y.C. A comprehensive survey of ubiquitous manufacturing research. International Journal of Production Research 2018; 56:1-2, 604-628.
[20] Putnik, G. Advanced manufacturing systems and enterprises: Cloud and ubiquitous manufacturing and an architecture. Journal of Applied Engineering Science 2012; 10(3), 127-134.
[21] Dubey, R., Gunasekaran, A., Chakrabarty, A. Ubiquitous manufacturing: overview, framework and further research directions. International Journal of Computer Integrated Manufacturing 2017; 30(4-5), 381-394.
[22] Foust, J. Ubiquitous Manufacturing. Annals of the Association of American Geographers 1975; 65(1), 13-17.
[23] Suh, S.H., Shin, S.J., Yoon, J.S., Um, J.M. UbiDM: A new paradigm for product design and manufacturing via ubiquitous computing Technology. International Journal of Computer Integrated Manufacturing 2008; 21(5), 540-549.
[24] Duffie, N.A. Heterarchical control of highly distributed manufacturing systems. International Journal of Computer Integrated Manufacturing 1996; 9(4), 270–281.
[25] Ka, B., Monostori, L., Szelke, E. An object-oriented framework for developing distributed manufacturing architectures. Journal of Intelligent Manufacturing 1998; 9(2), 173-179.
[26] Li, L., Fuh, J.Y.H., Zhang, Y.F., Nee, A.Y.C. Application of genetic algorithm to computer-aided process planning in distributed manufacturing environments. Robotics and Computer-Integrated Manufacturing 2005; 21(6), 568–578.
[27] Matt, D.T., Rauch, E., Dallasega, P. Trends towards Distributed Manufacturing Systems and Modern Forms for their Design. Procedia CIRP 2015; 33, 185–190.
[28] Kühnle, H. Distributed manufacturing: paradigm, concepts, solutions and examples. Springer Science & Business Media; 2009.
[29] He, W., Xu, L. A state-of-the-art survey of cloud manufacturing. International journal of computer integrated manufacturing 2015; 28 (3), 239–250.
[30] Ren, L., Zhang, L., Tao, F., Zhao, C., Chai, X., Zhao, X. Cloud manufacturing: from concept to practice. Enterprise Information Systems 2015; 9 (2), 186–209.
[31] Ren, L., Zhang, L., Wang, L., Tao, F., Chai, X. Cloud manufacturing: key characteristics and applications. International journal of computer integrated manufacturing 2017; 30 (6), 501–515.
[32] Wu, D., Greer, M.J., Rosen, D.W., Schaefer, D. Cloud manufacturing: Strategic vision and state-of-the-art. Journal of Manufacturing Systems 2013; 32 (4), 564–579.
[33] Tao, F., Cheng, Y., Xu, L.D., Zhang, L., Li, B.H. CCIoT-CMfg: cloud computing and internet of things-based cloud manufacturing service system. IEEE Transactions on Industrial Informatics 2014; 10 (2), 1435–1442.
[34] Tao, F., Zhang, L., Venkatesh, V.C., Luo, Y., Cheng, Y. Cloud manufacturing: a computing and service-oriented manufacturing model. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture 2011; 225 (10), 1969–1976.
[35] Tao, F., Zuo, Y., Xu, L.D., Zhang, L. IoT-based intelligent perception and access of manufacturing resource toward cloud manufacturing. IEEE Transactions on Industrial Informatics 2014; 10 (2), 1547–1557.
[36] Wang, X.V., Xu, X. An interoperable solution for cloud manufacturing. Robotics and computer-integrated manufacturing 2013; 29 (4), 232–247.
[37] Xu, X. From cloud computing to cloud manufacturing. Robotics and computer-integrated manufacturing 2012; 28 (1), 75–86.
[38] Zhang, L., Luo, Y., Tao, F., Li, B.H., Ren, L., Zhang, X., Guo, H., Cheng, Y., Hu, A., Liu, Y. Cloud manufacturing: a new manufacturing paradigm. Enterprise Information Systems 2014; 8 (2), 167–187.