Heliyon 10 (2024) e25722

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Augmented reality-assisted cloud additive manufacturing with digital twin technology for multi-stakeholder value Co-creation in product innovation

Shengyang Xu [a,b], Yuan Lu [c], Chunyang Yu [a,*]

[a] Design-AI Lab, China Academy of Art, China
[b] School of Art & Design, University of Illinois Urbana Champaign, USA
[c] Department of Exhibition and Education, Zhejiang Science and Technology Museum, China

ARTICLE INFO

Keywords:
Augmented reality
Cloud manufacturing
Additive manufacturing
Value Co-Creation
Digital twin

ABSTRACT

Industry 4.0, boosting the integration of sophisticated computational and manufacturing technologies, has profoundly reshaped the way to deal with market dynamics. It increases the capabilities of multi-stakeholders to engage in value co-creation for product innovation. Nonetheless, it also poses challenges to operation efficiency, i.e., surged requirements meeting expedited delivery times, in account of stakeholders' diverse backgrounds and goals. To respond, by applying the technology of Digital Twin (DT), this study proposes an Augmented Reality-assisted Cloud Additive Manufacturing (AR-CAM) framework, establishing a sophisticated cyber-physical interface to cater to various coordinating interactions. By this means, it attempts to give a consistent understanding to multi-background stakeholders. A case study involving the fabrication of a speed rear derailleur is applied, thereby underscoring the validity of the AR-CAM framework.

1. Introduction

Industry 4.0 has significantly transformed the operations of market systems. The demand for customized products has continuously surged [1] while meeting an incessant quest for heightened productivity [2]. Consequently, to harmonize the contradiction between them, stakeholders—including retailers, consumers, suppliers, and manufacturers—must re-evaluate their value chain collaborative strategies, transitioning towards a paradigm of value co-creation [3]. It requires comprehensive engagement of the stakeholders, although their heterogeneous knowledge backgrounds might be prone to misinterpretations. For instance, designers' conceptualizations may remain confusing to others until they are tangibly represented, and most of the stakeholders lack the specialist knowledge possessed by their engineering counterparts. Such disparities can hinder swift consensus, posing challenges to production efficiency [4].

To mitigate these challenges and augment the efficacy of value co-creation endeavours, a majority of research has pivoted towards bolstering the digital proficiencies of stakeholders [5,6]. These digital competencies encompass intelligence, connectivity, and analytics [7], with a core emphasis on devising sensing and feedback mechanisms for holistic integration. By this means, stakeholders can adeptly discern, evaluate, and address the specific requirements of their counterparts, ensuring sustained responsiveness throughout

---

[*] Corresponding author.
E-mail address: yuchunyang@caa.edu.cn (C. Yu).

https://doi.org/10.1016/j.heliyon.2024.e25722
Received 24 August 2023; Received in revised form 1 February 2024; Accepted 1 February 2024

the co-creation process [8]. Numerous studies have proposed agile management frameworks and technological interventions, such as service design frameworks [9], communication methodologies [10], and information applications [11]. However, many of these investigations offer piecemeal solutions, lacking a radical approach.

Concurrently, Industry 4.0 has heralded the mature applications of emergent technologies in manufacturing like Augmented Reality (AR), Cloud Manufacturing (CMfg), and Additive Manufacturing (AMfg), while their potential for synergistic integration to foster value co-creation for product innovation remains largely untapped. For instance:

- AR enhances real-world interactions by superimposing virtual elements onto tangible environments [12], facilitating unambiguous multi-stakeholder communications by visualizing "cyber-physical" products from diverse perspectives [13,14].
- CMfg, a pioneering manufacturing service paradigm [15], harnesses the "manufacturing-*as*-a-service" ethos, aggregating distributed manufacturing resources via a robust shared network [16], thereby amplifying collaborative opportunities for value co-creation.
- AMfg offers a versatile rapid prototyping solution, facilitating design and manufacturing processes that are multi-scale, multi-material, and multi-functional, all while ensuring cost-efficiency [17].

Despite the individual applications of these technologies to enhance value co-creation, there is a paucity of research exploring their integrative potential. Addressing this gap, an Augmented Reality-assisted Cloud Additive Manufacturing (AR-CAM) framework is proposed in this paper. This framework employs the Digital Twin (DT) as a nexus for data exchange, combining AR, CMfg, and AMfg to offer a tailored cyber-physical interface for diverse interactions among stakeholders to converge their consistent understandings. For example, visualizing the process information through DT helps to obviate comprehension barriers in product definition. Moreover, the AR-CAM framework synergizes the inherent strengths of the incorporated technologies, while concurrently addressing their limitations. For instance, the precision of AR image overlay, when integrated with rapid prototyping via AMfg, ensures product evaluation in both accurate and efficient ways.

The subsequent sections of this paper are structured as follows: Section 2 overviews the aforementioned technologies and reviews their potential applications. Section 3 proposes the AR-CAM framework, targeting challenges in value co-creation during product innovation phases. Section 4 illustrates the methodologies and technologies in support of the AR-CAM framework. A practical application is presented in Section 5, detailing the fabrication of a speed rear derailleur to validate the framework. Finally, Section 6 offers concluding remarks and outlines directions for future research.

2. Related works

The increasing adaptability and efficiency of networked collaborations have promoted the value co-creation of multi-stakeholders. Meanwhile, cutting-edge technologies, including AR, CMfg, and AMfg, have expanded the foundational capabilities underpinning these collaborations, attracting tremendous scholarly interest.

2.1. Value co-creation

Value co-creation has emerged as a pivotal paradigm across various domains, including service management, B2B marketing, and broader business management practices [18]. The establishment of value co-creation relationships fosters collaborative interactions between enterprises and their customers, enhancing their capacities to address genuine market demands. Such collaborative dynamics, motivated by active customer participation, can lead to mutually beneficial outcomes, thereby promoting an enterprise's brand identity and competitiveness [19].

Fundamentally, the process of value co-creation among multi-stakeholders is underpinned by a service-oriented logic. For instance, as customers engage with a company's offerings—perceived as a service—they are often inclined to share expectations and provide feedback, aiming to optimize their experiences [20]. Consequently, the incorporation of value co-creation strategies can amplify comprehensibility, accessibility, risk mitigation, and transparency within multi-stakeholder collaborative contexts [21]. In spite of this, value co-creation might also inadvertently confuse roles, complicate operational dynamics, and even cause value erosion [22]. For instance, customers, perceiving an elevated role within the co-creation process, might demand heightened recognition, potentially leading to friction with professional stakeholders [23]. To navigate these complexities, numerous frameworks around service design and management have been proposed, such as the integration of "enterprise sustainability theory" into value co-creation [24], interaction-centric creation frameworks [25], and multi-platform business models [26]. However, limited research has explored the potential of leveraging integrated technologies to harmonize individual benefits and collective values within intricate multi-stakeholder partnerships [27].

2.2. Augmented reality in manufacturing

Rapid advancements in AR solutions within industrial contexts can be attributed to their multifaceted applicability in manufacturing processes [28], notably in domains such as visual inspection, error detection, and assembly guidance. Empirical research highlights AR's potential to not only amplify workforce proficiency but also to mitigate errors stemming from human oversight [29]. For instance, by rendering product standards and procedural guidelines, AR has demonstrated effectiveness in diminishing product sorting discrepancies [30] and reducing deviations in quality assurance protocols [31]. Within assembly operations, AR technologies are frequently employed to project nuanced technical directives onto the subjects of operation [32,33].

At its core, AR represents a sophisticated paradigm of human-computer interaction, predicated on forging an innovative interface between human operators and manufacturing assets. Illustratively, an AR-infused user interface, when integrated with eye-tracking devices, offers a more instinctive modality for driving electric wheelchairs [34]. Similarly, an AR-driven cyber-physical machine tool enables a more holistic interaction between personnel and machinery [35]. It is evident that the degree of manufacturing digitalization profoundly influences the effectiveness of AR deployments. Consequently, DT-integrated AR interfaces tend to emerge as focal points of future technological exploration [36]. Significantly, the proliferation of AR equips non-specialist individuals, such as consumers, with the tools to decipher the intricate architectures or functionalities of complex industrial products. This, in turn, holds promise for broadening stakeholder engagement and motivating collaboration in the realm of value co-creation.

2.3. *Additive manufacturing*

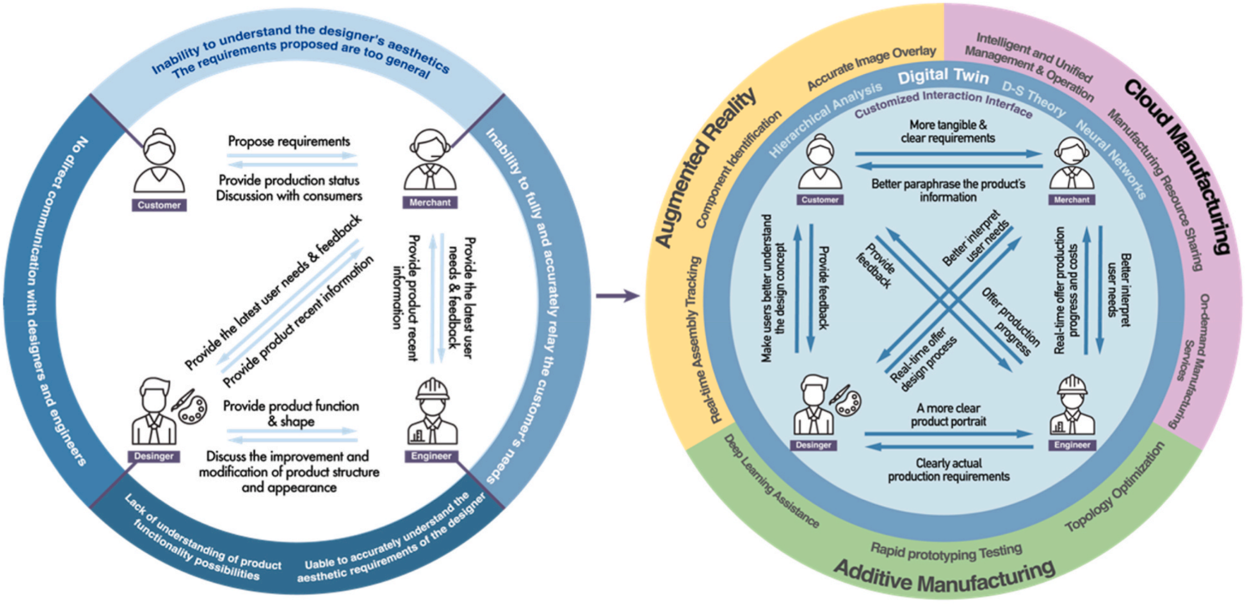
Over recent decades, AMfg has witnessed significant advancements. Nevertheless, it grapples with persistent challenges, including material extrusion inaccuracies, dimensional discrepancies, and inefficient capacities [37]. These challenges underscore the imperative for the integration of cutting-edge technological solutions. For instance, deep learning technologies have been applied for the fast detection and categorization of printing exceptions, aiming to optimize material allocation [38]. Additionally, topology optimization, such as determining the ideal product thickness, emerges as a useful strategy to enhance material utilization and printing efficiency without compromising the manufacturing quality [39]. The principles of distributed control also hold relevance for AMfg optimizations, particularly when contemplating the enlargement of collaborative AMfg machines to increase manufacturing throughput [40,41].

It is evident that, despite the comparatively streamlined operation and management of AMfg equipment relative to traditional manufacturing tools (e.g., CNC machines), the domain still necessitates expertise. Hence, independent applications of AMfg maintains a barrier to entry for the non-specialist, such as consumers, limiting their potential contributions to value co-creation.

2.4. *Cloud manufacturing*

CMfg draws inspiration from cloud computing, offering on-demand manufacturing resources and capabilities within a service-centric paradigm. It is recognized that the inception of the CMfg platform not only amplifies the collaborative efficiency between enterprises and consumers but also economizes their investments in manufacturing resources. Moreover, it engenders avenues for intimate interconnections and agile configuration of diverse manufacturing infrastructures, thereby deepening product customization and augmenting the adaptability of enterprises [42,43]. For instance, a CMfg platform empowers consumers to directly modulate and parameterize product components while maintaining oversight of corresponding data streams [44].

CMfg's foundation rests upon a suite of advanced technologies, encompassing cloud computing, the Internet of Things, and enterprise engineering, and it also shows good interoperability with state-of-the-art industrial technologies. For instance, integrating AR



a) Traditional Value Co-creation Scenario

b) Post-promotion Value Co-creation Scenario

Fig. 1. The promotion of the value co-creation scenario by the AR, AMfg and CMfg: (a) Traditional Value Co-creation Scenario; (b) Post-promotion Value Co-creation Scenario.

within CMfg can render shared data across dispersed physical terrains [45]. Furthermore, AMfg can synergize with CMfg, bolstering customization capabilities [46]. Such inherent versatility positions CMfg as exceptionally adaptable within integrated environments, helping to address the value co-creation challenges.

In summary, AR, AMfg, and CMfg have ascended to pivotal roles within Industry 4.0, contributing significantly to value co-creation through enhanced decision support, intelligent monitoring, process visualization, and expedited prototyping, among other facets. However, a conspicuous lacuna persists: extant literature seldom examines these technologies in a holistic manner, and there remains a dearth of comprehensive integration solutions tailored to the specific needs of diverse stakeholders. In response, this paper endeavours to integrate AR, AMfg, and CMfg to investigate their collective impact on value co-creation, proffering a structured framework to harmonize multi-stakeholder collaborations.

3. Formulation of the augmented reality-assisted cloud additive manufacturing

In traditional product customization scenarios within the value co-creation paradigm, as depicted in Fig. 1(a), communication among various stakeholders occurs within a linear chain structure. Here, the sequential communication modality, while straightforward, often proves inefficient, considering the complexity of customized product development. Communication barriers, delays (due to awaiting feedback), and potential conflicts can frequently arise in such an environment. To mitigate these challenges, we try to propose an innovative approach, integrating Digital Twin (DT) technology into the value co-creation scenario. Based on this, with the help of AR, AMfg, and CMfg technologies, this approach can enhance the clarity of communication and strengthen the interconnectedness among stakeholders across all stages of the value chain, as illustrated in Fig. 1(b).

To actualize this vision, we propose an Augmented Reality-assisted Cloud Additive Manufacturing (AR-CAM) framework, as depicted in Fig. 2. This framework is predicated on the five-dimensional DT model [47], which encapsulates the physical product, its virtual counterpart, data, the service system, and their connections.

In the AR-CAM framework, all data generated during value co-creation activities are meticulously recorded and processed in real time via DT technology. This includes data related to product design, manufacturing processes, user feedback, operational performance, etc. These data are centralized and shared in the CMfg platform (usually for service matching), facilitating a comprehensive overview of the manufacturing process and enabling efficient resource allocation. Despite this centralized sharing, the specific data executions of stakeholders (i.e., interacted with DT through AMfg and AR services) are in distributed locations, which enhances not only the efficiency of data processing but also the security of unexposed data.

The DT technology is the core to ensure a genuine integration of AR and AMfg services, creating accurate digital replicas of the physical objects, not only the appearance but also the functionality. Such an integration invents a “tangible” AR experience, which facilitates to mutual understanding of stakeholders by visualizing the manufacturing processes. As a result, the varying requirements of stakeholders across multiple contexts can be addressed in an on-demand, customized manner throughout all stages of value co-creation.

Moreover, the AR-CAM framework also promotes a networked and augmented knowledge base in support of value co-creation. This enables all relevant stakeholders to interact and exchange knowledge directly and equitably, fostering a deeper understanding within

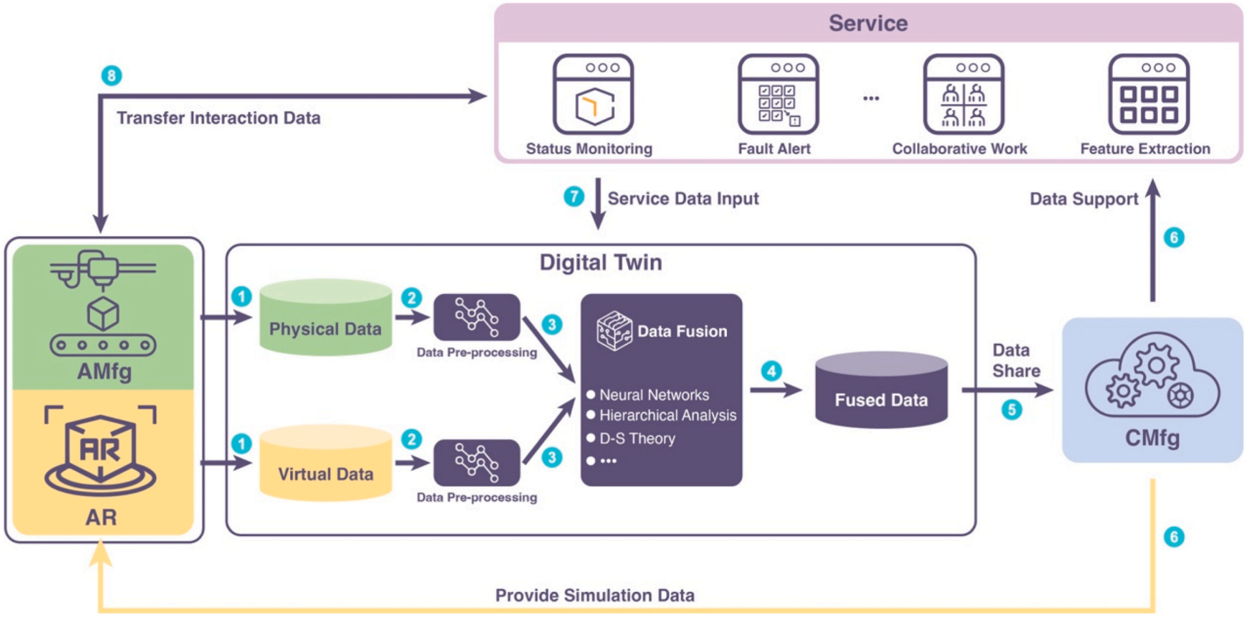


Fig. 2. The framework of augmented reality-assisted cloud additive manufacturing.

collaborative teams. In detail, the CMfg platform operates as a knowledge hub, managing various data sources to support integrated AR and AMfg operations. AR functions as a multi-dimensional (e.g., multi-spatial-temporal scales) knowledge visualizer for product descriptions in the digital space. AMfg facilitates rapid testing, evaluation, and iteration of physical product prototypes, accelerating the updating of product and production knowledge, thereby enhancing the efficiency of demand response.

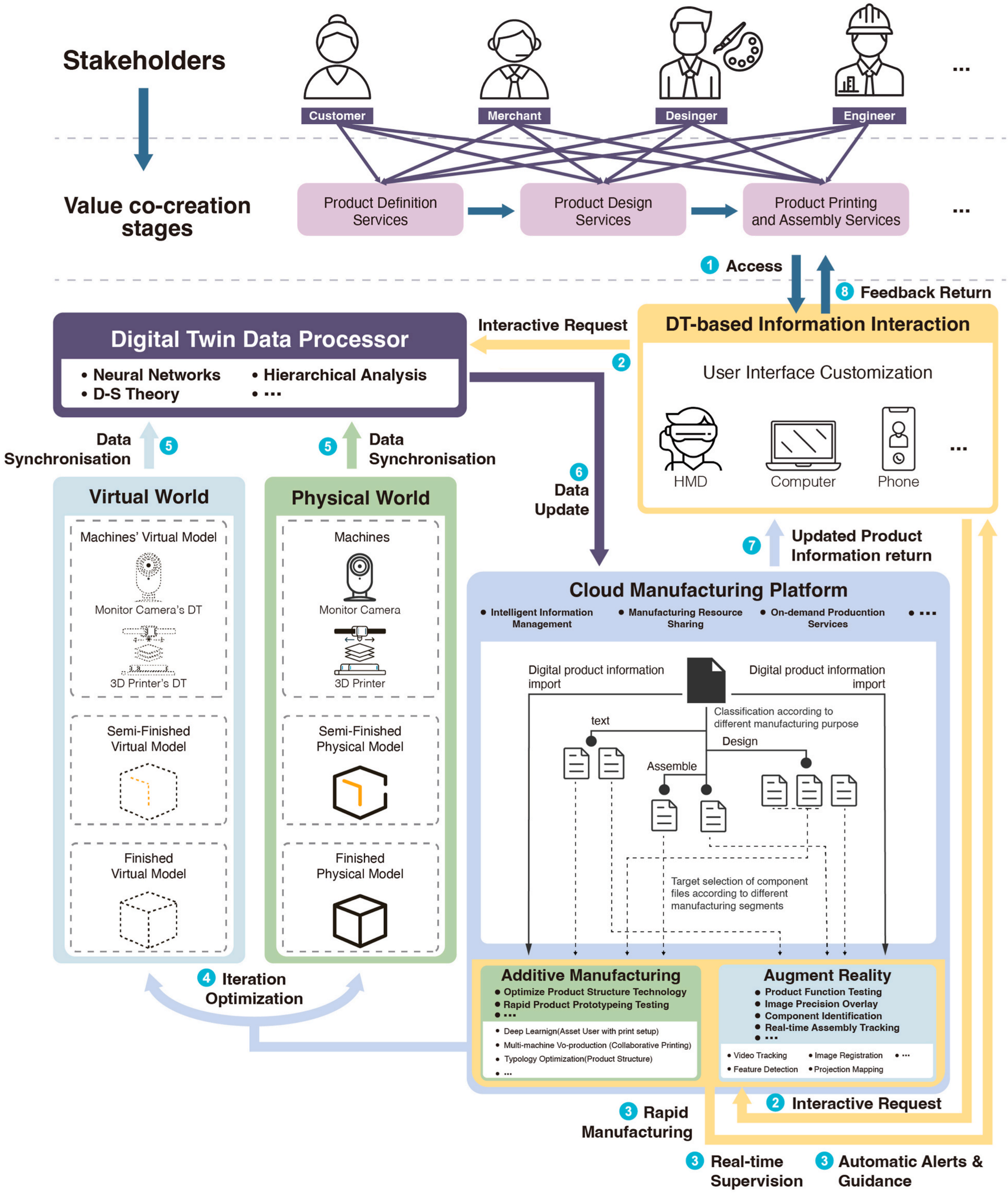


Fig. 3. Implementation of the augmented reality-assisted cloud additive manufacturing.

4. Implementation of the augmented reality-assisted cloud additive manufacturing

The implementation of the AR-CAM framework is delineated in Fig. 3. This schematic representation illustrates the coordination between various associated technologies across the process of value co-creation. As depicted, the DT technology formulates a data processor to ensure the efficient perception, accessibility, and utilization of life-cycle manufacturing data, including the value co-creation stages such as product definition, product design, and product printing and assembly.

4.1. Product definition

The process of product definition permeates the entire manufacturing process. A user interface for product requirement management is furnished to each stakeholder, interacting with real-time feedback via the data shared to the CMfg. Within this user interface, AR facilitates a rich visual dimensionality of the product concept, while concurrently working in tandem with AMfg to expedite the prototyping of digital models.

This mixed (the physical and virtual) information interface enables stakeholders to concurrently engage in in-depth communications regarding the product's aesthetics, structure, mechanics and functionality with minimum misunderstandings. In this process, all the generated data, such as stakeholders' intentions, available resources, and technical requirements, are synchronized by the DT processor, to maintain the product requirement meeting expectations in effective and efficient.

4.2. Product design

During the design process, the product concept undergoes effective iterations and optimizations. The product simulation data, such as product blueprints, 3D models, and dimensional parameters, need to transfer to AR for process via CMfg. These data can be superimposed onto the real environment using AR's projection mapping technology. This approach provides the stakeholders with an intuitive three-dimensional representation of the product concepts, which can be referenced during the design process within the interactive interface, thereby enhancing the stakeholders' capabilities of design perception.

In such a mixed reality environment, the physical product's functionalities can be evaluated by its digital replica, which reduces the effort to develop intricate but insignificant mechanical or electromechanical components only for the purpose of visualization. Simultaneously, the DT processor synchronizes both the virtual and physically interacted data in real time. These data are further processed in the CMfg platform to support the iterative optimization of the product.

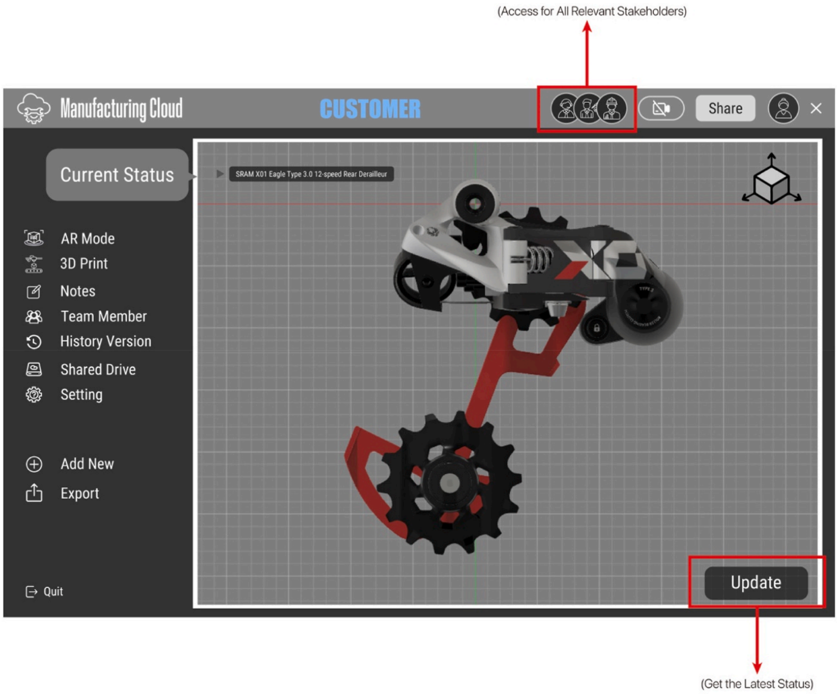


Fig. 4. The home page interface: The 3D model of the "SRAM X01 Eagle Type 3.0 12-Speed Rear Derailleur" for this study was obtained from GrabCAD (an open-source platform).

4.3. Product printing and assembly

The product printing and assembly data, such as the part installation sequence, steps and instructions, should be created and uploaded to the CMfg platform by engineering specialists in advance. These data along with the AR display construct a uniformed visual assembly tutorial for distributed stakeholder themselves. By this means, it can assure every involved stakeholder a tangible product experience with minimum manufacturing effort.

For example, the assembly progress can be detected by computational vision algorithms to stimulate the relevant assembly data in the CMfg platform. Subsequently, these data are precisely screened onto the pre-determined position referring to the physical product, to provide stakeholders with detailed assembly guidelines. Simultaneously, the stakeholders' operating data (e.g., assembly gestures and component movements) are handled in real-time by the DT processor, to synchronize the assembly status of the physical products. This visualized human-machine interaction is friendly to the non-specialists, enhancing their technical involvement.

5. Case study - a prototype developed for applying the AR-CAM framework to the product print and evaluation

5.1. Product view/design/printing

A series of foundation interfaces for product customization are developed for consumers. A home page interface is depicted in Fig. 4, in which the label "Current Status" tracks the product development progress, and it can be updated manually. Besides this, the stakeholders are allowed to switch views for specific information (e.g., from the "AR mode" view to the "3D print" view), to understand the situation of value co-creation in its totality.

Moreover, a design studio interface is specifically tailored for designers. As depicted in Fig. 5, it provides an "AR preview" function for 3D modeling, by which the designers can perceive the product panorama while working on specific features.

Fig. 6 presents a 3D print parameter setting interface for engineers, to visualize the print processes according to the particular parameters. Under this condition, when other stakeholders initiate a print request, as shown in Fig. 7, the engineers have the responsibility to submit the completed engineering files to the CMfg platform.

Finally, benefiting from the CMfg, stakeholders can easily find nearby available 3D printers. In this environment, to optimize manufacturing efficiency, the printing task can be decomposed and assigned to multiple machines for concurrent executions, as shown in Fig. 8.

5.2. AR-enabled collaborative product configuration

In this paper, it takes the collaborative configuration of a speed rear derailleur as an example, and the digital and physical products are illustrated in Fig. 9 (a), respectively. Fig. 9 (b) showcases a collaborative product configuration interface by displaying AR projection information (i.e., the digital product) in the workplace. Every stakeholder (e.g., consumers, merchants, designers, and engineers) can get involved in this process, with the help of interaction tools, for example, the video conference tool shown in Fig. 10 (a), and the product data projection tool displayed in Fig. 10 (b).

5.3. AR-enabled product function simulation

The application of AR technology enables a paradigm of "testing while doing" in product development, which improves the

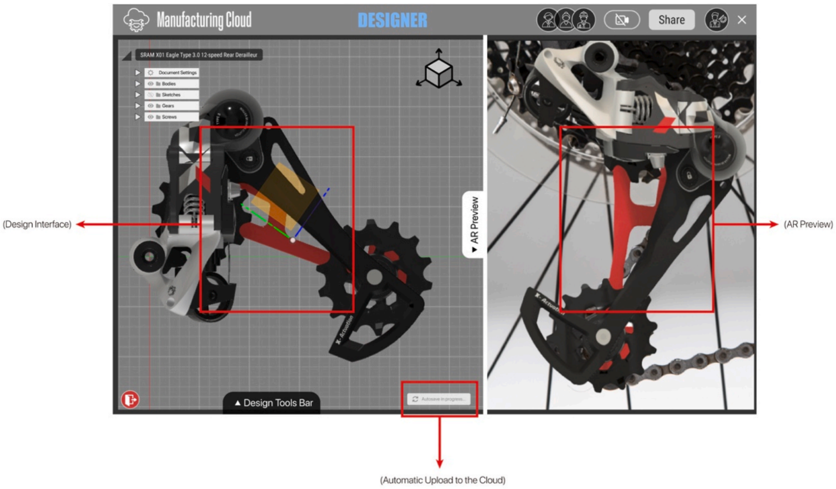
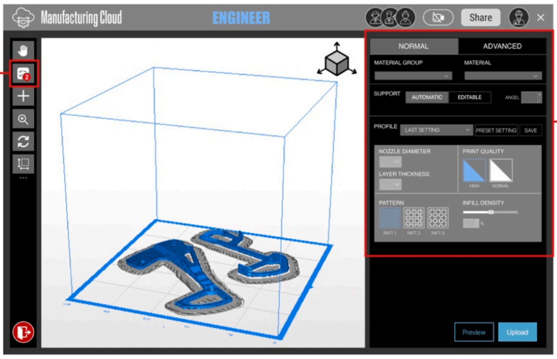


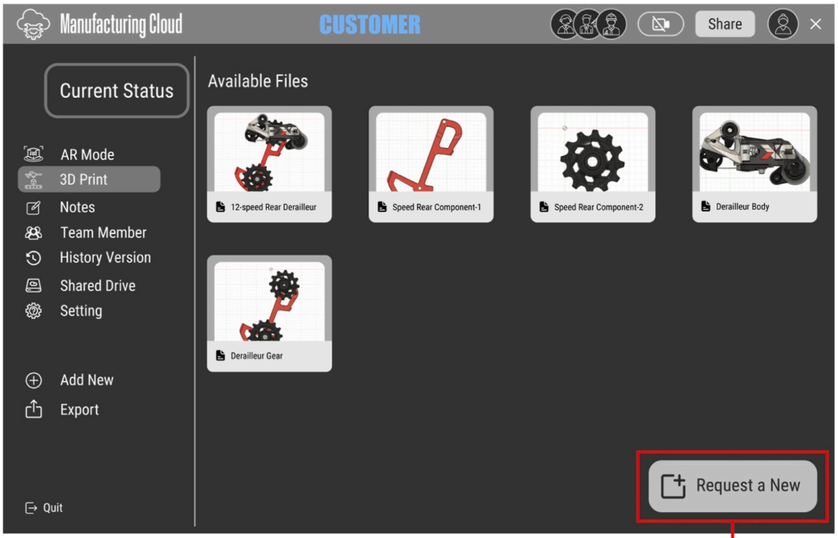
Fig. 5. The design studio interface.



(New Print File Setup Request)

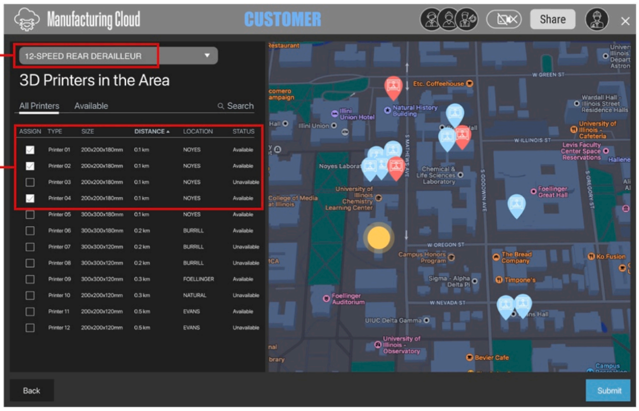
(File Parameter Setting)

Fig. 6. The interface for 3D print parameter setting.



(Request a New Set Up Print File)

Fig. 7. The interface for 3D print request.



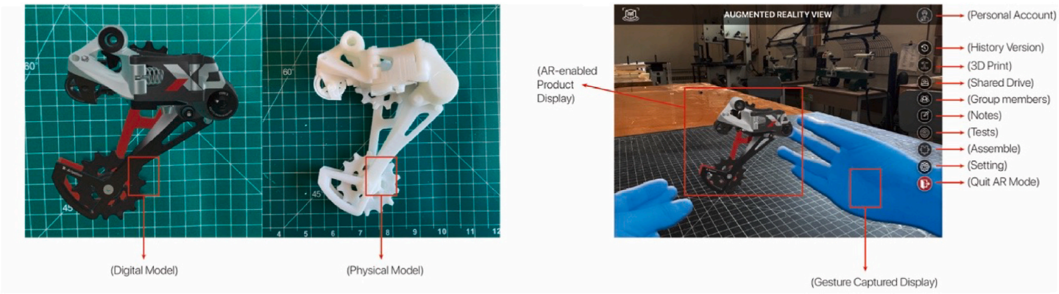
(Selected Print File)

(Multi-machine synchronous printing)

3D Printers in the Area

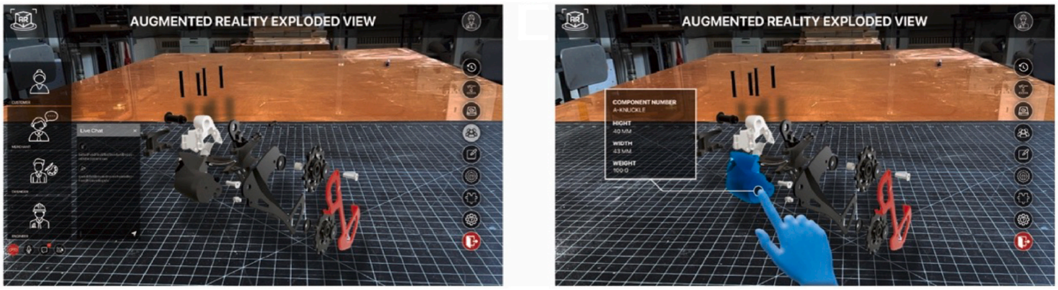
ASSIGN	TYPE	SIZE	DISTANCE ▲	LOCATION	STATUS
☑	Printer 01	200x200x180mm	0.1 km	NOYES	Available
☑	Printer 02	200x200x180mm	0.1 km	NOYES	Available
☐	Printer 03	200x200x180mm	0.1 km	NOYES	Unavailable
☑	Printer 04	200x200x180mm	0.1 km	NOYES	Available
☐	Printer 05	300x300x180mm	0.1 km	NOYES	Available
☐	Printer 06	300x300x180mm	0.2 km	BURRILL	Available
☐	Printer 07	300x300x120mm	0.2 km	BURRILL	Unavailable
☐	Printer 08	300x300x120mm	0.2 km	BURRILL	Unavailable
☐	Printer 09	300x300x120mm	0.3 km	FOELLINGER	Available
☐	Printer 10	200x200x120mm	0.3 km	NATURAL	Unavailable
☐	Printer 11	200x200x120mm	0.5 km	EVANS	Available
☐	Printer 12	200x200x120mm	0.5 km	EVANS	Unavailable

Fig. 8. Available 3D printers' page.



a) Digital and Physical Products **b) AR Configuration Interface**

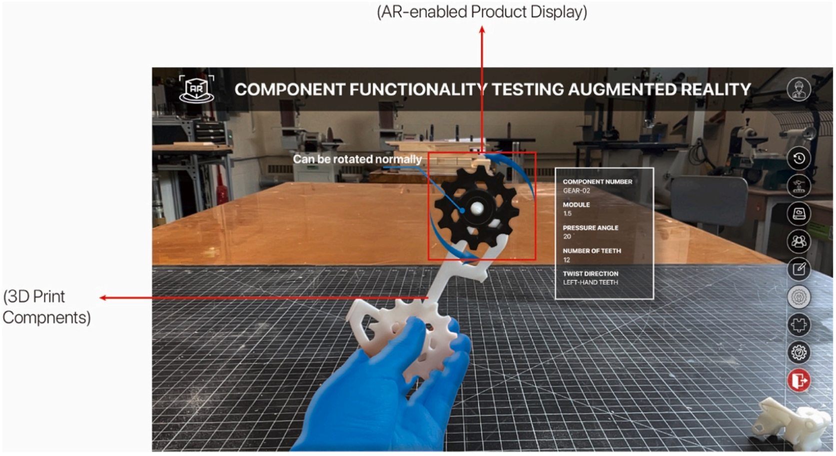
Fig. 9. Mixed visualization interface: (a) Digital and Physical Products; (b) AR Configuration Interface.



COMPONENT NUMBER
A-KNUCKLE
HIGHT
40 MM
WIDTH
43 MM
WEIGHT
100 G

a) Video Conference Tool **b) Product Data Projection Tool**

Fig. 10. AR interaction tools: (a) Video Conference Tool; (b) Product Data Projection Tool.



COMPONENT NUMBER
GEAR-02
MODULE
1.5
PRESSURE ANGLE
20
NUMBER OF TEETH
12
TWIST DIRECTION
LEFT-HAND TEETH

Fig. 11. AR-enabled components function simulation test.

reliability of the final product. As depicted in Fig. 11, a digital wheel is projected onto the physical product to simulate a "rotating" function. It offers an operating standard for assembling the actual wheel.

AR-enabled product function simulation is also applied in creating a setup wizard for product assembly according to the pre-defined installation information. For example, the physical part will be highlighted by AR projection once it prepares to install, and a reference product is projected in the same view, to achieve a visualized assembly process, as shown in Fig. 12.

6. Conclusion and future work

Applying the DT technology, this paper proposes an AR-CAM framework for value co-creation with multi-stakeholders. It enhances the cooperation efficiency, and the primary contributions of the paper are concluded as follows:

Fig. 12. AR-enabled component installation guide.

(1) The AR-CAM framework implements a technical architecture for value co-creation, in which advanced technologies (e.g., DT, AR, CMfg and AMfg) are integrated to produce a comprehensive solution to reduce the understanding barriers among multi-stakeholders, fostering a more effective collaborative partnership.
(2) Within the integrated technologies, this study proposes a novel cyber-physical interface for distributed human-machine interaction. This interface can be customized to support efficient collaborations among multi-stakeholders, irrespective of their distinct knowledge backgrounds and professions.
(3) It applies a human-centric approach, contrasting with the traditional machine-centric or production-centric methods. Hence, the innovative cyber-physical interface integrates advanced technologies in both frontend and backend. It not only improves the user experience (i.e., frontend integration) but also enhances the manufacturing efficiency (i.e., backend integration).

However, the study still needs improvement. The paper presents the AR-CAM framework in a conceptual way, and it requires further technical and practical research. For example, this study has not gone deep into the technical details, e.g. mechanism studies to react to AMfg errors. In addition, the case study are carried out on the scenario of iterative design and prototype evaluation, i.e., a part of the value co-creation process. More processes tend to be included in future.

To sum up, future work could focus on upgrading the AR-CAM framework. For example, the user interface can be optimized to adapt to more manufacturing scenarios, and more user and process data could be collected (e.g., applying dynamic eye tracking into AR application) to analyse and understand the operation behaviour of the proposed AR-CAM framework to detect the improvement directions.

Additional information

No additional information is available for this paper.

CRediT authorship contribution statement

Shengyang Xu: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Yuan Lu:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Chunyang Yu:** Writing – review & editing, Visualization, Validation, Supervision, Software, Project administration, Methodology, Investigation, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

This work is supported by the Zhejiang Provincial Philosophy and Social Science Planning Project (No. 22NDJC175YB).

References

[1] C. Yang, S. Lan, W. Shen, G.Q. Huang, · Xianbin Wang, Tingyu Lin, X. Wang, T. Lin, Towards product customization and personalization in IoT-enabled cloud manufacturing 20 (2017) 1717–1730, https://doi.org/10.1007/s10586-017-0767-x.

[2] D. Mourtzis, V. Siatras, J. Angelopoulos, N. Panopoulos, An augmented reality collaborative product design cloud-based platform in the context of learning factory, in: Procedia Manuf, Elsevier B.V., 2020, pp. 546–551, https://doi.org/10.1016/j.promfg.2020.04.076.

[3] V.G. Duffy, Modern human-robot interaction in smart services and value co-creation, lecture notes in computer science (including subseries lecture notes in artificial intelligence and lecture, Notes in Bioinformatics) 9745 (2016) 399–408, https://doi.org/10.1007/978-3-319-40247-5_40/FIGURES/3.

[4] L.M. Camarinha-Matos, H. Afsarmanesh, R. Fornasiero, Collaboration in a Data-Rich World IFIP AICT 506, 2017. http://www.springer.com/series/6102.

[5] D. Beverungen, C.F. Breidbach, J. Poeppelbuss, V.K. Tuunainen, Smart service systems: an interdisciplinary perspective, Inf. Syst. J. 29 (2019) 1201–1206, https://doi.org/10.1111/ISJ.12275.

[6] C. Raddats, C. Kowalkowski, O. Benedettini, J. Burton, H. Gebauer, Servitization: a contemporary thematic review of four major research streams, Ind. Market. Manag. 83 (2019) 207–223, https://doi.org/10.1016/J.INDMARMAN.2019.03.015.

[7] J. Pyun, J.S. Rha, Review of research on digital supply chain management using network text analysis, Sustainability 13 (2021), https://doi.org/10.3390/SU13179929, 9929 13 (2021) 9929.

[8] S. Lenka, V. Parida, J. Wincent, Digitalization capabilities as enablers of value Co-creation in servitizing firms, Psychol. Market. 34 (2017) 92–100, https://doi.org/10.1002/mar.20975.

[9] E. Yu, D. Sangiorgi, Service Design as an Approach to Implement the Value Cocreation Perspective in New Service Development, (n.d.) https://doi.org/10.1177/1094670517709356..

[10] M. Krishnan, J. Ahmad, Proposing stakeholder communication framework for business positioning among manufacturing-based small and medium enterprise: adopting a public relations approach, Humanities and Social Sciences Reviews 7 (2019) 450–464, https://doi.org/10.18510/hssr.2019.7461.

[11] A. Barbu, G. Militaru, Value Co-creation between manufacturing companies and customers. The role of information technology competency, in: Procedia Manuf, Elsevier B.V., 2019, pp. 1069–1076, https://doi.org/10.1016/j.promfg.2019.02.323.

[12] Z. Zhu, C. Liu, X. Xu, Visualisation of the digital twin data in manufacturing by using augmented reality, in: Procedia CIRP, Elsevier B.V., 2019, pp. 898–903, https://doi.org/10.1016/j.procir.2019.03.223.

[13] U. Urbas, R. Vrabič, N. Vukašinović, Displaying product manufacturing information in augmented reality for inspection, in: Procedia CIRP, Elsevier B.V., 2019, pp. 832–837, https://doi.org/10.1016/j.procir.2019.03.208.

[14] E.C. Crofton, C. Botinestean, M. Fenelon, E. Gallagher, Potential applications for virtual and augmented reality technologies in sensory science, Innovative Food Sci. Emerging Technol. 56 (2019), https://doi.org/10.1016/j.ifset.2019.102178.

[15] J. Delaram, M. Houshamand, F. Ashtiani, O. Fatahi Valilai, A utility-based matching mechanism for stable and optimal resource allocation in cloud manufacturing platforms using deferred acceptance algorithm, J. Manuf. Syst. 60 (2021) 569–584, https://doi.org/10.1016/j.jmsy.2021.07.012.

[16] Y. Liu, L. Wang, X.V. Wang, X. Xu, P. Jiang, Cloud manufacturing: key issues and future perspectives 32 (2019) 858–874, https://doi.org/10.1080/0951192X.2019.1639217.

[17] Z. Jin, Z. Zhang, G.X. Gu, Autonomous in-situ correction of fused deposition modeling printers using computer vision and deep learning, Manuf Lett 22 (2019) 11–15, https://doi.org/10.1016/j.mfglet.2019.09.005.

[18] R.R. Sinkovics, O. Kuivalainen, A.S. Roath, Value co-creation in an outsourcing arrangement between manufacturers and third party logistics providers: resource commitment, innovation and collaboration, J. Bus. Ind. Market. 33 (2018) 563–573, https://doi.org/10.1108/JBIM-03-2017-0082/FULL/PDF.

[19] V. Lember, T. Brandsen, P. Tõnurist, The potential impacts of digital technologies on co-production and co-creation 21 (2019) 1665–1686, https://doi.org/10.1080/14719037.2019.1619807.

[20] P. Zaborek, J. Mazur, Enabling value co-creation with consumers as a driver of business performance: a dual perspective of Polish manufacturing and service SMEs, J. Bus. Res. 104 (2019) 541–551, https://doi.org/10.1016/J.JBUSRES.2018.12.067.

[21] P. Zaborek, J. Mazur, Exploring Links Between Engaging Customers in Value Co-Creation and Product Innovativeness, Int. J. Manag. Econ. 53 (n.d) 82–106. https://doi.org/10.1515/ijme-2017-0020..

[22] D. Sjödin, V. Parida, M. Kohtamäki, J. Wincent, An agile co-creation process for digital servitization: a micro-service innovation approach, J. Bus. Res. 112 (2020) 478–491, https://doi.org/10.1016/J.JBUSRES.2020.01.009.

[23] K.W. Chan, , C.K. (Bennett) Yim, S.S.K. Lam, Is Customer Participation in Value Creation a Double-Edged Sword? Evidence from Professional Financial Services across Cultures 74 (2010) 48–64, https://doi.org/10.1509/Jmkg.74.3.048.

[24] B. Aquilani, C. Silvestri, G. Ioppolo, A. Ruggieri, The challenging transition to bio-economies: towards a new framework integrating corporate sustainability and value co-creation, J. Clean. Prod. 172 (2018) 4001–4009, https://doi.org/10.1016/J.JCLEPRO.2017.03.153.

[25] V. Ramaswamy, K. Ozcan, What is co-creation? An interactional creation framework and its implications for value creation, J. Bus. Res. 84 (2018) 196–205, https://doi.org/10.1016/J.JBUSRES.2017.11.027.

[26] D.T. de Oliveira, M.N. Cortimiglia, Value co-creation in web-based multisided platforms: a conceptual framework and implications for business model design, Bus. Horiz. 60 (2017) 747–758, https://doi.org/10.1016/J.BUSHOR.2017.07.002.

[27] V. Lember, R. Kattel, P. Tõnurist, Technological capacity in the public sector: the case of Estonia, Int. Rev. Adm. Sci. 84 (2018) 214–230, https://doi.org/10.1177/0020852317735164.

[28] E. Bottani, G. Vignali, IISE Transactions Augmented Reality Technology in the Manufacturing Industry: A Review of the Last Decade Augmented Reality Technology in the Manufacturing Industry: A Review of the Last Decade, 2019, https://doi.org/10.1080/24725854.2018.1493244.

[29] J. Egger, T. Masood, Augmented reality in support of intelligent manufacturing – a systematic literature review, Comput. Ind. Eng. 140 (2020), https://doi.org/10.1016/j.cie.2019.106195.

[30] G. Plakas, S.T. Ponis, K. Agalianos, E. Aretoulaki, S.P. Gayalis, Augmented reality in manufacturing and logistics: lessons learnt from a real-life industrial application, in: Procedia Manuf, Elsevier B.V., 2020, pp. 1629–1635, https://doi.org/10.1016/j.promfg.2020.10.227.

[31] M. Mengoni, S. Ceccacci, A. Generosi, A. Leopardi, Spatial Augmented Reality: an application for human work in smart manufacturing environment, in: Procedia Manuf, Elsevier B.V., 2018, pp. 476–483, https://doi.org/10.1016/j.promfg.2018.10.072.

[32] Z.H. Lai, W. Tao, M.C. Leu, Z. Yin, Smart augmented reality instructional system for mechanical assembly towards worker-centered intelligent manufacturing, J. Manuf. Syst. 55 (2020) 69–81, https://doi.org/10.1016/j.jmsy.2020.02.010.

[33] M.D. Mura, G. Dini, An augmented reality approach for supporting panel alignment in car body assembly, J. Manuf. Syst. 59 (2021) 251–260, https://doi.org/10.1016/j.jmsy.2021.03.004.

[34] S. Ishida, M. Takimoto, Y. Kambayashi, AR based user interface for driving electric wheelchairs, in: Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) 10278 LNCS, 2017, pp. 144–154, https://doi.org/10.1007/978-3-319-58703-5_11/FIGURES/11.

[35] C. Liu, S. Cao, W. Tse, X. Xu, Augmented reality-assisted intelligent window for cyber-physical machine tools, J. Manuf. Syst. 44 (2017) 280–286, https://doi.org/10.1016/j.jmsy.2017.04.008.

[36] C. Li, P. Zheng, S. Li, Y. Pang, C.K.M. Lee, AR-assisted digital twin-enabled robot collaborative manufacturing system with human-in-the-loop, Robot. Comput. Integrated Manuf. 76 (2022) 102321, https://doi.org/10.1016/J.RCIM.2022.102321.

[37] Z. Jin, Z. Zhang, J. Ott, G.X. Gu, Precise localization and semantic segmentation detection of printing conditions in fused filament fabrication technologies using machine learning, Addit. Manuf. 37 (2021) 101696, https://doi.org/10.1016/J.ADDMA.2020.101696.

[38] H. Elhoone, T. Zhang, M. Anwar, S. Desai, Cyber-based design for additive manufacturing using artificial neural networks for Industry 4.0, Int. J. Prod. Res. 58 (2020) 2841–2861, https://doi.org/10.1080/00207543.2019.1671627.

[39] I. Ntintakis, G.E. Stavroulakis, N. Plakia, Topology optimization by the use of 3D printing technology in the product design process, HighTech and Innovation Journal 1 (2020) 161–171, https://doi.org/10.28991/hij-2020-01-04-03.

[40] R. Srinivasan, V. Giannikas, D. McFarlane, A. Thorne, Customising with 3D printing: the role of intelligent control, Comput. Ind. 103 (2018) 38–46, https://doi.org/10.1016/j.compind.2018.09.003.

[41] A. Awad, S.J. Trenfield, A. Goyanes, S. Gaisford, A.W. Basit, Reshaping drug development using 3D printing, Drug Discov. Today 23 (2018) 1547–1555, https://doi.org/10.1016/J.DRUDIS.2018.05.025.

[42] A. Simeone, A. Caggiano, L. Boun, B. Deng, Intelligent cloud manufacturing platform for efficient resource sharing in smart manufacturing networks, in: Procedia CIRP, Elsevier B.V., 2019, pp. 233–238, https://doi.org/10.1016/j.procir.2019.02.056.

[43] Y. Lu, X. Xu, Cloud-based manufacturing equipment and big data analytics to enable on-demand manufacturing services, Robot. Comput. Integrated Manuf. 57 (2019) 92–102, https://doi.org/10.1016/j.rcim.2018.11.006.

[44] M. Hasan, B. Starly, Decentralized cloud manufacturing-as-a-service (CMaaS) platform architecture with configurable digital assets, J. Manuf. Syst. 56 (2020) 157–174, https://doi.org/10.1016/j.jmsy.2020.05.017.

[45] R. Yasmin, M. Salminen, E. Gilman, J. Petajajarvi, K. Mikhaylov, M. Pakanen, A. Niemela, J. Riekki, S. Pirttikangas, A. Pouttu, Combining IoT deployment and data visualization: experiences within campus maintenance use-case, in: Proceedings of the 2018 9th International Conference on the Network of the Future, NOF 2018, 2018, pp. 101–105, https://doi.org/10.1109/NOF.2018.8598127.

[46] J.P. Rudolph, C. Emmelmann, A cloud-based platform for automated order processing in additive manufacturing, in: Procedia CIRP, Elsevier B.V., 2017, pp. 412–417, https://doi.org/10.1016/j.procir.2017.03.087.

[47] F. Tao, W. Liu, M. Zhang, T. Hu, Q. Qi, H. Zhang, F. Sui, T. Wang, H. Xu, Z. Huang, X. Ma, L. Zhang, J. Cheng, N. Yao, W. Yi, K. Zhu, X. Zhang, F. Meng, X. Jin, Z. Liu, L. He, H. Cheng, E. Zhou, Y. Li, Q. Lyu, Y. Luo, Five-dimension digital twin model and its ten applications, Jisuanji Jicheng Zhizao Xitong/computer integrated manufacturing systems, CIMS 25 (2019) 1–18, https://doi.org/10.13196/J.CIMS.2019.01.001.