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Harmonising humans and technology: Exploring the dynamics of cognitive production, artificial intelligence and social communication in cybernetic systems

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Abstract

Agile cognitive production systems mark a manufacturing paradigm shift, propelled by the demand for accelerated product development and the adoption of digitalised production systems across extensive supply networks. Cognitive manufacturing emphasises the role of technology and automation in the learning and adaptation process. These systems independently analyse data, make real-time adjustments and optimise processes, sometimes minimising the need for human intervention.

Based on a conceptual framework that draws on the diversity of living systems and cognitive processes, cybernetics provides a solid theoretical background. It explores the intricate connections between cognition, self-organising systems and the challenges arising from the autonomy of such systems. The concept of "cognition" in "agile cognitive systems" moves away from the conventional understanding of purely technical processes and towards human thought processes.

This departure fosters a dynamic exchange where individual thoughts resonate in social communication. Addressing the role of artificial intelligence (AI), the article emphasises examining computers from a social science standpoint, exploring the relationship between computers and mental systems, capturing human faculties such as cognition, utterance, and understanding.

The integration of AI into computer-mediated communication leads to the question how AI-equipped computers intersect with societal intelligence notions. The inherent intransparency of AI, often viewed as a black box, prompts queries about the potential black-box nature

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of an autonomously controlled AI factory or supply chain. In this hypothetical scenario, the idea of the supply chain as a communication network is challenged, emphasising the importance of human involvement.

Research on human-centric cognitive production emphasises explainable AI and human-in-the-loop. This orientation goes beyond the technical dimensions and incorporates social science considerations, which emphasises the holistic nature of current research. In essence, research in the field of cognitive production is a comprehensive exploration of the complex interplay between human cognition, artificial intelligence and the evolving landscape of modern production systems.

Keywords
Agile cognitive production systems, Digitalisation, Cybernetics, Human thought processes, Artificial intelligence, Computer-mediated communication, Autonomy, Human-centricity

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Introduction

Cognitive production systems mark a significant evolution in the world of manufacturing[1,2]. It responds to the growing pressures placed on companies to expedite their product development and release cycles. This transformation is primarily driven by the increasing reliance on data-driven performance and the widespread adoption of digitalised production systems[3,4].

At its core, cognitive production aims to create production systems that are not only adaptive and self-organising but also quasi-autonomous[5]. These systems are designed to meet the surging demand for customised products in a highly competitive market. They are the result of a fundamental shift in the way manufacturing processes are conceived and executed[1,6].

Cognitive production aligns with the principles of fifth industrial revolution by emphasising human-technology orientation, flexible and adaptable manufacturing regimes, which contrasts with the more rigid, efficiency-driven focus of previous industrial revolutions. While Industry 4.0 centered on automation, digitalisation and interconnected systems, cognitive production integrates intelligence with advanced technologies, such as artificial intelligence (AI) and robotics, to create systems that are not only efficient but also adaptable and resilient, the first three industrial revolutions focused on mechanization, mass production and automation respectively (Figure 1).

This produces a pressing need for harmonising human and technological interactions. As a result, the author explores the dynamics of social communication, AI and advanced production regimes, grounding the paper in a selective review of recent literature on smart, learning, and cognitive production systems, as well as communication in social systems, informed by cybernetics and AI. These insights are further complemented by experiences from working on the European knowlEdge project, which the author coordinated, offering also a case description that highlights practical applications and recent advancements in these fields.

Cognitive production, as a transformative approach to manufacturing, redefines traditional processes. It advocates for the adoption of flexible and adaptable systems, moving away from the constraints of linear manufacturing[7,8]. At its core, cognitive production relies on connected sensors to gather real-time data from various production stages, enabling continuous monitoring and adjustment for optimal efficiency. This approach excels in analyzing diverse data types from various sources, fostering data-driven decision-making in the dynamic manufacturing environment. By seamlessly integrating data from internal and external sources, cognitive production provides a holistic understanding of the production environment. Notably, it introduces the concept of a learning organization, extending adaptability and evolution beyond human learning to encompass machines and automation. This multifaceted approach shapes a manufacturing landscape characterized by flexibility, data-driven precision, and adaptive organizational learning[9,10]. What sets cognitive production apart is its capacity to transcend human involvement. It emphasises the role of technology and automation in the learning and adaptation process. These systems can autonomously analyse data, make real-time adjustments, and optimise processes, reducing the need for continuous human intervention[9,11].

Such production regimes promise a revolution in manufacturing efficiency, the integration of technology and human involvement poses unique challenges. The evolution toward quasi-autonomous systems raises pertinent questions about the role of humans in this technologically advanced landscape[12–14].

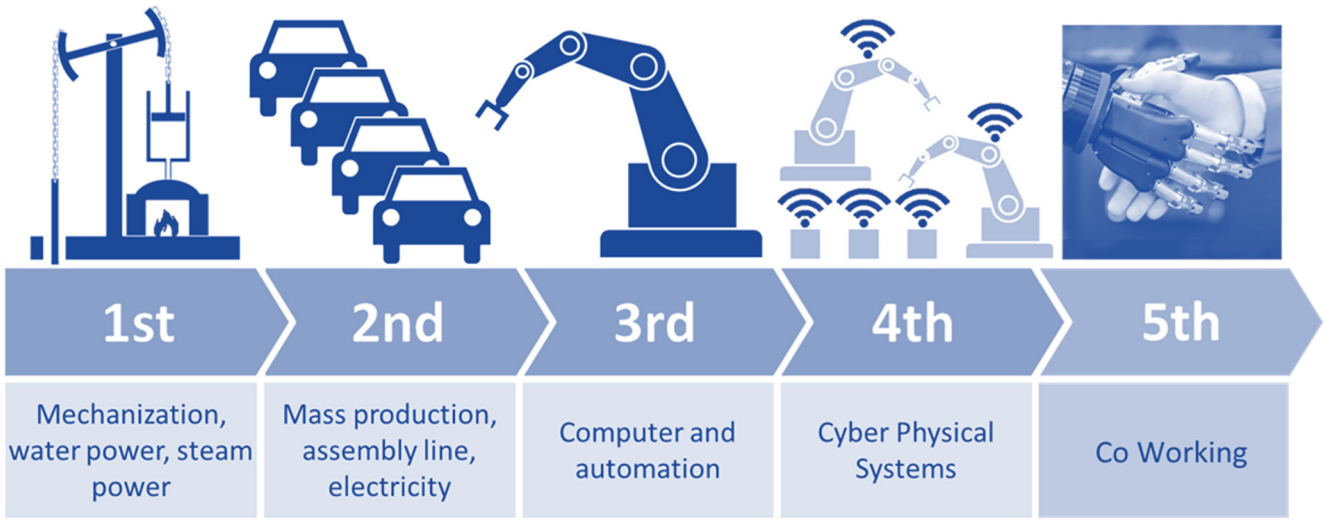

Figure 1. Stages of industrial evolution, from the beginnings of mechanization (First industrial revolution) to the collaboration of humans and technology (Fifth industrial revolution or Industry 5.0).

Typical aspects that come to mind include skills and training and ethical considerations in the context of human-AI collaboration. While transparency in decision-making is the goal, it may conflict with security and data confidentiality issues and demand explanation and trust[15,16]. This requires greater flexibility than may be visible in current organisations and may very well result in significant cultural shifts in organisational management[17].

The concept of cognitive production introduces both possibilities and challenges in achieving shared understanding in meaning when it comes to human-technology collaboration[18,19]. Thus, harmony in the human-technology relationship involves a holistic approach that encompasses for example design thinking, cognitive science and a deep understanding of the intricacies of human cognition. By focusing on mutual learning, transparent communication and adaptive design, cognitive production systems can become powerful tools that amplify human capabilities while respecting the unique cognitive attributes of both parties.

Challenges, on the other hand, may stem from different ways of conceptualizing and categorizing information, keeping up with the increasing levels of complexity that come from the continuous adaptation of cognitive systems, and lack of understanding about cognition or learning operates in the systems[20,21]. This prevents a comprehensive understanding of how decisions are reached. Overcoming these challenges and creating fruitful outcomes produces heightened focus on communication. This may also involve strategic design choices, which can create greater insights, if not full transparency, when engineering technology for cognitive production systems[22].

The paper describes agile cognitive production systems, particularly emphasising their transformative influence on manufacturing processes, also including supply chain dynamics[23,24]. It shows how these systems reshape traditional manufacturing, leveraging real-time data analysis, autonomy and adaptation to optimise supply chains.

Furthermore, it endeavours to clarify the theoretical underpinnings of agile cognitive production systems, giving prominence to the field of cybernetics. By exploring the intricate connections between cognition, self-organising systems, and the challenges stemming from their autonomy, the paper aims to shed light on how these theoretical foundations shape the design and functioning of manufacturing processes. Additionally, the emphasis on the departure from conventional technical processes to a framework grounded in human thought processes highlights the paradigm shift in conceptualising and implementing agile cognitive systems in manufacturing.

In addition, the paper takes a critical stance on the integration of artificial intelligence (AI) into social communication within the context of agile cognitive production systems. It delves into the inherent intransparency of AI, often perceived as a black box, and raises thought-provoking questions about its potential black-box nature when autonomously controlling systems like factories or supply chains. In emphasising the importance of human involvement, the paper advocates for a balanced approach rather than relying on AI alone within manufacturing processes. Thus, the paper highlights the holistic nature of current research, focusing on the interplay between human cognition, AI, and the evolving landscape of modern production systems.

The paper is structured to logically progress through several interconnected topics, beginning with this introduction, followed by discussions on cognitive production systems, the principles of cybernetics and cognitive systems, and the importance of standardisation. Further sections address the coupling of psychic and social systems, the role of computers in communication, and the conceptualisation of supply chains as forms of social communication. As mentioned already, the narrative integrates the European knowlEdge project to illustrate recent advancements and to show how human knowledge can be integrated with computer systems. The paper concludes with urging stakeholders to consider more inclusive and transparent approaches to integrating human and technological systems, especially in the context of evolving supply chain dynamics and communication processes.

Agile, cognitive production systems

As described in the introduction, agile factories are essentially a paradigm shift in manufacturing characterised by a fusion of advanced technologies and human collaboration[25]. These transformative facilities are characterised by several features.

Firstly, real-time data processing takes centre stage and is the linchpin of agile factory operations[26]. The associated dynamic processing capability enables immediate analysis and response and promotes agility and responsiveness in production. This is also of great importance with regard to unexpected conditions that could jeopardise the functioning of supply chains.

Secondly, the functioning of these factories is highly dependent on intricate networks that connect different players[27]. These networks form the backbone of collaboration and enable seamless communication and the exchange of information. In contrast to traditional production structures, where processes often run in isolation, the agile cognitive approach builds on the vision of networking to improve efficiency and adaptability. Figure 2 shows an example of a supply chain. In addition to the direct suppliers and customers, the suppliers of the suppliers and all trade and customer levels are also considered in the entire supply chain. This means that the supply chain is based on a holistic approach, with all companies in the cross-company value chain working together. The concept of integration is emphasised, which means that supply chain management is aimed at linking various partners with the help of information technologies.

In addition, artificial intelligence (AI) is becoming a central component that is seamlessly integrated into decision-making processes[28]. AI algorithms equipped with learning capabilities contribute to informed decision-making and optimise production processes based on real-time data and historical data

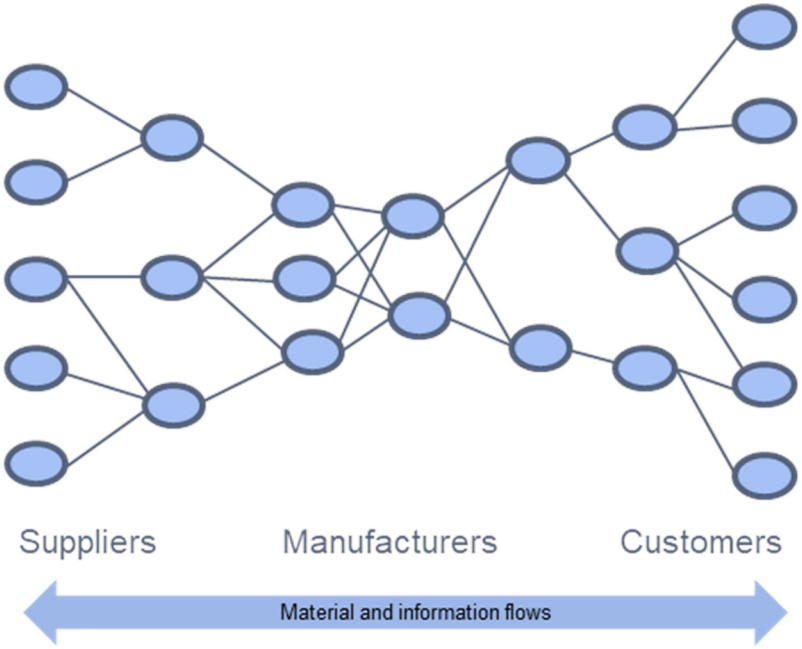

Figure 2. Generic supply chain, showing nodes and arcs ranging from suppliers tiers to customer tiers, and illustrating the network character of supply relationships.

from databases. This use of AI brings a level of intelligence to production that goes beyond the capabilities of conventional manufacturing systems.

As already emphasised, one striking difference to conventional production methods is the extensive collaboration between humans and machines. Instead of a dichotomy between manual and automated tasks, agile cognitive factories emphasise the mutual benefits of this relationship. Humans and machines work together and utilise each other's strengths to achieve optimal efficiency. This collaborative approach not only increases productivity, but also opens up new opportunities for creativity and problem solving[29].

As a result, the fusion of real-time data processing, networked systems, artificial intelligence and human-machine collaboration leads to greater complexity in the manufacturing process. This integrated approach goes beyond the sum of its parts and creates a dynamic and adaptable production environment that can respond quickly to market demands, changing preferences and unforeseen challenges[6].

Here, it is important to understand that the concept of cognitive manufacturing systems is a multi-faceted approach driven by a comprehensive set of goals that transcend traditional manufacturing paradigms. This is because, at its core, cognitive manufacturing is a strategic response to the changing industrial landscape, designed to achieve a spectrum of goals that redefine the purpose and impact of manufacturing processes[25]. This also addresses increasing complexity. This approach is particularly relevant for supply chains. These often extensive and interlinked supply chains have become the basis of modern production processes, where they pass through various stages from the raw material supplier to the end consumer[30,31].

This means that responsibility for production is spread across numerous companies, often on a global scale. Globalisation reflects the networked nature of today's production, where the different stages of production are seamlessly interwoven across geographical boundaries. The result is a global web of collaboration and coordination that contributes to the complexity and diversity of today's supply chains[32,33].

However, as supply chains grow in size and complexity, so does the challenge of managing them effectively[34]. Complexity increases with the proliferation of nodes and communication links. Each node represents a critical point in the supply chain, from raw material extraction to production facilities and distribution centres. Human and technical communication links facilitate the flow of information, materials and products between these nodes. The intricate web of nodes and connections leads to a level of complexity that requires new management strategies.

One of the main objectives of cognitive production is to improve the economic sustainability and competitiveness of companies[2]. This is about more than just efficiency gains; it is about the strategic integration of advanced technologies and intelligent

systems to optimise the use of resources, reduce costs and increase overall economic performance. In line with the goal of sustainable development, it is not just about maintaining competitiveness in the market, but also about promoting growth with strategic foresight. In view of increasingly complex global situations, this is fraught with growing uncertainty.

Adapting to market requirements is another important goal of cognitive production. Today's market is characterised by dynamic changes in consumer preferences and an increasing demand for personalised, individualised products. Cognitive manufacturing addresses this demand by utilising its adaptability to design manufacturing processes in such a way that products meet specific consumer needs and preferences. This personalised approach not only increases customer satisfaction, but also fosters brand loyalty in an ever-changing market landscape. Adaptive supply chains can be designed and manufacturing goals such as small-batch manufacturing can be realized[1].

Beyond purely economic considerations, the concept of cognitive production also takes a holistic perspective by recognising wider social and environmental concerns. Social issues, including challenges related to interoperability and collaboration between different systems, are recognised and addressed within the framework of cognitive production. In addition, environmental sustainability is an important pillar, emphasising the responsible use of resources, waste prevention and environmentally friendly practices. This approach goes beyond the traditional boundaries of manufacturing and recognises the interconnectedness of production processes with wider social and environmental ecosystems.

In addition, as briefly mentioned earlier, cognitive manufacturing plays a crucial role in promoting resilience to change, particularly in the context of risk management. The adaptive nature of learning, cognitive manufacturing systems enables organisations to deal with uncertainty, whether due to market fluctuations, supply chain disruptions or unforeseen challenges. This resilience improves an organisation's ability to withstand shocks and uncertainties, contributing to long-term continuity and sustainability.

Advanced management requires this holistic understanding and a strategic approach. Cognitive production systems, with their real-time data processing capabilities, networked systems and artificial intelligence, play a central role in overcoming the challenges posed by complex production networks. They bring adaptability and responsiveness to a system that is inherently dynamic and subject to constant change and fluctuation.

Cybernetics and cognitive systems

The need for effective management adaptation is therefore a critical factor in managing the increasing complexity of modern production and supply chains[35]. This adaptation enables the establishment of robust control structures, the management of intricate communication networks and the implementation of strategic management practices. This is where cybernetics becomes the central science that provides insights into the dynamics of communication, the design of effective control mechanisms and the principles of efficient management strategies. As a systems and governance science, cybernetics plays a fundamental role in equipping management with the tools and understanding required to manage the complexity of today's industrial landscape[36–40].

The conceptual framework of cognitive production builds on the theoretical foundations of living and cognitive systems. This theoretical foundation addresses the relationships between cognition, self-organisation and the challenges arising from operational closure, an important characteristic of living systems[41].

Living systems, which are often regarded as cognitive systems, thus form the cornerstone of this foundation within the framework of cybernetics. According to this view, the essence of life is closely linked to cognition. The process of life is not just a biological phenomenon but is understood as a cognitive process in which systems continuously engage with and respond to their environment[42].

The term "cognition" in the context of "agile cognitive systems" is deeply rooted in this perspective. It represents a departure from the conventional understanding of cognition, which is limited to human perception. Instead, it embraces a broader concept in which cognitive processes are inherent to the structure of living systems and extend the cognitive domain beyond the boundaries of human consciousness.

A key concept in this theoretical framework is autopoiesis, a term used by Luhmann in the social domain. Autopoiesis refers to the self-generation or self-creation of living systems. These autopoietic systems are essentially cognitive systems that have the ability to differentiate themselves from their environment through constant self-production[43]. Although this operational closure is fundamental to the autonomy and identity of cognitive systems, it also has a remarkable consequence, namely incompatibilities between systems. Since systems establish their own identity through operational closure, they inherently create differences that may not connect seamlessly with other systems. This phenomenon becomes particularly relevant when it comes to questions of standardisation and interoperability in communication.

In the context of cognitive production, where communication and interoperability are of paramount importance, the incompatibilities resulting from operational closure become even more apparent. The challenge is to close the gaps between systems with different identities, a task that is at the heart of the quest for standardisation and seamless communication. Theoretical

reflections on autopoiesis and operational closure shed light on the complexity involved in promoting compatibility and communication within the intricate web of cognitive production systems[43–46]. In relation to cognitive production, a crucial aspect therefore arises from the overlap between technical and engineering contexts, where the conventional understanding of information is subject to a paradigm shift. Here, the influence of Shannon's information theory is omnipresent, which assumes that information is a universal entity that is the same in all contexts and environments[47,48].

However, the teachings of cybernetics provide a contrast that challenges this prevailing view. Cybernetics does not view information as an independent and universally applicable construct but assumes that information is inherently context-dependent. It exists and acquires meaning within the specific context of a particular system, which redefines the nature of information theory[41,49].

When we look at the concept of standardisation, we understand that it is closely linked to the pursuit of interoperability and seamless communication within the complex network of production systems[50]. The reference to Shannon in this context clarifies the nature of signal transmission and reception. Following the vision of cognitive production, information flows dynamically between different nodes, so the ability to send and receive signals is crucial. However, this leads to key issues of semantics and syntactics[51]. These are crucial in the transmission and understanding of information.

Semantics refers to the meaning or interpretation of symbols in a particular context. In our context, that of cognitive production, semantics determines the correct interpretation of data, which is important for decision-making, for example. Syntactics, in turn, determines the rules for the arrangement of symbols. Only with the help of syntax can the data be transferred in the first place, as it is used to define the common language or structure. This then enables the aforementioned interoperability, both in the integration of different devices, systems and platforms and in the collaboration between humans and artificial intelligence.

With regard to the field of information technology, the possibility of networking machines and their data exchange, division of labour and collaboration is a given. However, the scenario develops further when confronted with the enormous networking of devices on the Internet. This is where the importance of standards, both industry-specific and open standards, becomes particularly clear. These standards, as mentioned, serve as a common language that enables different devices and systems to communicate effectively.

To overcome the problem of the diversity of devices and systems, the aim of standardisation is to create a framework that enables effective communication, collaboration and interoperability. This harmonisation is not just a technical matter, but the foundation on which the agility and adaptability of cognitive production systems is built[52–55]

The knowlEdge project

The EU research project *knowlEdge - Towards Artificial Intelligence powered manufacturing services, processes, and products in an edge-to-cloud-knowledge continuum for humans [in-the-loop]*[56]. focuses on the creation of agile factories through the strategic integration of artificial intelligence algorithms. The overarching aim of the project is primarily to improve process efficiency and optimisation, as well as to eliminate errors.

What sets the knowlEdge project apart from others is its consistent focus on explainable artificial intelligence. In a typical environment where artificial intelligence is often treated as a black box, this initiative is a signal of transparency and comprehensibility. The project goes beyond the traditional approach of introducing AI without a clear understanding of how it works. Instead, it seeks to provide concrete use cases that illuminate the outcomes of AI processes and make them accessible and understandable to human stakeholders[56].

The project contributes to developing a one-stop-shop digital platform, where different AI-related services can be made available to companies. The knowlEdge platform is designed to enhance the entire AI lifecycle, from problem identification to deployment and maintenance, with a strong emphasis on human-AI interaction. Central to the platform are two components: the knowlEdge Discovery component and the AI Model Generation component, which together create AI solutions that capture and process data from various sources, including crucial human input. In agile manufacturing, one of the biggest challenges is integrating domain knowledge into AI systems, particularly when contextual information is limited, and AI models lack transparency[28].

The knowlEdge platform addresses this challenge by facilitating a seamless human-AI interaction that combines two types of knowledge: (i) learned knowledge, generated by the AI model, and (ii) engineered knowledge, provided by domain experts. It allows subject matter experts to interact with AI models in three key ways: (i) rejecting learned knowledge if it's incorrect, (ii) accepting it if it's correct, or (iii) adapting it when it's accurate but requires modification[28].

This interaction ensures that AI models are continuously refined and aligned with expert insights, enabling a deeper understanding of data and a more thorough evaluation of the AI lifecycle. Ultimately, the knowlEdge platform serves as an interface that bridges the gap between AI systems and domain experts, such as machine operators and managers, facilitating human feedback and enhancing the overall effectiveness of AI in complex, real-world scenarios[28].

By enabling human intervention and understanding, the knowlEdge project strives to bridge the gap between advanced algorithms and the humans who work with and oversee these systems. This intentional effort to avoid the AI black box paradigm of AI is consistent with a broader vision of technological advancements that put humans at the centre[28,56].

Importantly, the influence of the knowlEdge project goes beyond the boundaries of computer science and technology application and extends to social science research. This interdisciplinary approach recognises that the impact of cognitive production systems goes far beyond technological considerations. The project recognises the complex interplay between technology and society and encourages a holistic investigation that encompasses both the technical and social dimensions[28,56].

Standardisation

Research efforts in the field of cognitive production can therefore be described with reference to two main directions as far as harmonisation is concerned.

The first line of research focuses primarily on technical standardisation and communication. This direction deals with the intricacies of establishing standardised protocols and effective communication channels. It is not only about establishing uniformity, but also about the potential impact and changes that can result from these concerted efforts. Standardisation in the dynamic landscape of cognitive manufacturing addresses the need for interoperability, seamless data exchange and efficient communication between the various elements in the manufacturing ecosystem. It is also about understanding the impact and outcomes of standardisation on the evolving manufacturing landscape.

Standardisation roadmaps play an important role in enforcing standardization[57]. These roadmaps can be used to address the challenges and intricacies associated with achieving interoperability within the network of production systems. The purpose of standardisation roadmaps is to initially define common standards and protocols that enable different parts and systems to work together. In this way, they set the direction of development and significantly reduce the complexity that would otherwise exist. This enables coordination, which includes adherence to agreed rules and compliance and long-term strategic planning[58].

Part of this effort to develop standards are architectures or frameworks such as the RAMI 4.0 reference architecture model, which encompasses multiple levels and hierarchies. From business levels to functional levels to communication structures, this model serves as a roadmap for establishing standards that permeate the various facets of the cognitive manufacturing value stream. Each level corresponds to different aspects of the manufacturing process and contributes to the overall framework[59].

RAMI 4.0 thus provides a reference architecture that outlines the relationships and interactions between different components within a manufacturing ecosystem. This includes information technology platforms, machines, devices, sensors and communication protocols. The architecture serves as a blueprint for the development and implementation of standardised and interoperable systems. By defining clear standards at each level of the architecture, RAMI 4.0 ensures that different components and systems can communicate and work together seamlessly. RAMI 4.0 supports this by providing a structured approach to information flow and data exchange across different levels and components, facilitating real-time decision making.

The details of interoperability become clear by analysing the individual levels and aspects. As a consequence, the standards defined within the framework of the model cover the networked flows of value creation that contribute to the development of cognitive production systems.

Another example to implement standardisation across organisations is the Asset Administration Shell (AAS) concept. This concept is pivotal in the realm of Industry 4.0, particularly concerning the implementation of digital twins. In this context, an asset embodies the physical component, while the administration shell represents its digital counter-part. Through the AAS, organizations can effectively bridge the physical and digital worlds, creating virtual replicas of their assets enriched with comprehensive data regarding identity, properties, behaviors, relationships, and lifecycle information[60].

Standardization efforts within the AAS framework focus on establishing common standards, protocols, and data models for representing and exchanging asset information in a standardized manner. This entails standardizing interfaces, communication protocols, and data formats to ensure seamless interoperability across different AAS implementations and industrial systems. By adhering to standardized AAS specifications, organizations can facilitate smooth integration and collaboration among digital twins and various Industry 4.0 technologies, thereby enabling data-driven decision-making and enhancing operational efficiency[61].

Essentially, standardisation is a necessity for companies to reap the benefits of digitalisation. The transition from physical to digital assets should not only be seen as a technological change but has profound implications for the structure of organisational structures and processes. It requires a reassessment of how companies manage and organise their assets in this digital age where the boundaries between the physical and the digital are blurring. This will also lead to a realignment of organisational strategies and processes.

Information, utterance and understanding

A second line of research arises from the origins of communication. It ties in with the exploration of artificial intelligence in the context of cognitive production. This explores the possibility of categorising increasingly autonomous machines as cognitive systems, drawing on the principles of cybernetics. The topic is the complicated relationship between machines and cognition as well as the role of AI in the design and control of production processes. The research goes beyond the conventional understanding of AI as a tool and tries to find out whether these machines can really be regarded as cognitive systems in the cybernetic sense. This research dimension is at the frontier of understanding the evolving synergy between human cognition and technical intelligence in the context of cognitive production.

At the centre of both social science considerations and the technology-oriented concept of cognitive production is a fundamental unity of information, utterance and understanding. This unity forms the foundation of communication. Within this framework, communication is a dynamic interplay of three essential elements, all of which contribute to the transmission and interpretation of data or messages.

The element of information is linked to an utterance through which the information takes form, be it in spoken words, written text or another communication medium such as a computer. The recipient in turn decodes the utterance, which gives meaning to the information. The meaning of the message is not inherent, but is actively constructed by the recipient, which emphasises the dynamic and participatory nature of communication.

In particular Niklas Luhmann's theory of social systems provides valuable insights into this conceptualization of communication. Luhmann emphasises the role of communication in the social construction of reality. He argues that communication is a self-referential system characterized by the recursive interplay between information, communication media and social structures. Luhmann's theory underscores the dynamic nature of communication and the active role of individuals in the processes of creating meaning[43].

In the context of AI, and due to the fact that AI systems are designed to facilitate understanding, this conceptual framework becomes even more important. Depending on the specific AI function, transmission in the sense of communication consists of data processing, pattern recognition and decision making that mirror the cognitive processes of human understanding[62]. The success of AI systems depends on their ability to effectively manage this entity and transform information into meaningful outcomes through sophisticated algorithms.

Coupling of psychic and social systems

By focusing on the social science aspects of cognitive production, the concept of structural coupling emerges as a guiding principle that highlights the pervasive interconnectedness between psychological or mental systems and their social counterparts[43]. This framework describes the connection between thought processes and communication. This allows conclusions to be drawn about the relationship between individual cognition and collective social dynamics.

At the centre of this interaction is the concept of language as the pivotal point that enables the coupling of mental and social systems[63]. Language serves here as a medium through which mental processes are expressed in the social sphere. Language bridges the gap created by the inherent limitations of the human mind, namely the inability to read the thoughts of others or to communicate one's own thoughts directly to others.

The result is a dynamic exchange in which individual thoughts find resonance in the fabric of social communication. It is in this communicative sphere that the shared understanding of concepts, beliefs and values takes shape. This shapes the way in which individuals within a particular community or society perceive and respond to each other. It forms the basis for the construction of shared meanings and norms and serves as a mechanism for resolving the inherent challenge posed by the opacity of individual thought.

The question of individual perceptions and social interactions inevitably prompts reflection on the consequences of these patterns in the evolution of systems and interactions. It deals with the subtleties of human behaviour in response to evolving systems. The effects of these behavioural patterns have an impact on various contexts, where they are particularly evident in the area of social media, for example. The observable impact of user behaviour, emerging patterns and subsequent adaptations of certain social platforms are evidence of the profound influence of behavioural dynamics. Although there are parallels between social media and industry and connected supply chains in terms of these dynamics, such as a volatile fluctuation in demand that can lead to short-term price and supply risks, the question of the consequence of deeper behavioural changes in industry remains open. The industrial context brings with it a different set of variables and dynamics that require a more nuanced examination of how behavioural patterns manifest themselves in the intricate web of cognitive production systems. This will become increasingly important as technological progress leads to wider change in industry.

For example, it is conceivable that the increasing interaction between humans and artificial intelligence and the use of immersive technologies will lead to more comprehensive changes in behaviour, which will be reflected in various aspects such as learning ability, motivation and concentration, dependency and social interaction. On the other hand, in a corporate setting, the increasing interaction can shift decision-making away from the centralised management to the user of AI systems. This has the potential of significantly empowering users[29].

So, what about computers?

It is also important to examine the role of the computer from a social science perspective. In particular, the relationship between computers and mental systems representing human abilities such as cognition, understanding, learning and expression should be understood.

The central task is to analyse the role of computers in bridging the gap between mental systems. This means reducing the psychological distance between people's mental worlds. In this perspective, computers are seen not only as tools or devices, but rather as mediators that enable a more direct connection between people's complex thought processes[64]. Viewing the computer as a communication medium opens up new dimensions of understanding how these technological interfaces are interwoven with human cognition. This perspective emphasises that computers are not just passive tools, but actively contribute to changing the way people think and communicate[64]. This should be understood in the sense that the computer is, which intervenes on the information part of the communication process. In comparison, a book spreads information to others. The computer, however, processes the information[65]. It, thereby, also removes the unity of utterance and understanding

within the same process, since one user who entered the data in the computer does not know what another user is retrieving.

The connection between artificial intelligence and computer-mediated communication adds another fascinating layer. It raises the fundamental question of how computers equipped with AI functions can interact with society's understanding of intelligence. Not only the technological aspects, but also the implications of AI and computer-mediated communication in relation to the human understanding of intelligence need to be analysed in future research. Generally, knowledge is inherently social. This challenges the notion that intelligence could be defined solely in terms of symbols and representations[66,67].

Thus, computers cannot be fully understood within traditional frameworks guided by what has been called first-order semantics. First-order semantics refers the advance in describing an observation, e.g. through language. This enables second-order observations, e.g. reading a description or communicating about something. Rather, the role of computers in shaping communication, knowledge, and intelligence necessitates a reevaluation of conventional notions. Computers disrupt traditional concepts by challenging the dynamics of knowledge production, distribution and intelligence.

When computers function as mediums that intervene in information processing, the resulting elaboration are beyond the control of individuals, such as those who provided the data input[68]. The essence is not about computers enabling correct observations and evaluations for decision-making. Instead, it is about fostering communication forms detached from the need for unifying different observation perspectives[69]. From a sociological perspective, computers disrupt unitary semantics by facilitating forms of communication that explode contingency rather than providing a correct observation of the world. While mass media already initiated the decline of unitary semantics involving utterance and understanding, computers are an even more radical step from it[70].

The supply chain as social communication

To return to the starting point of the considerations on cognitive production systems and agile supply chains, the question now arises as to whether the vision of an AI-controlled autonomous supply chain is a realistic goal. This problem is central to the management of networked cognitive production systems.

Interactions with AI within the supply chain are not comparable to communication patterns in the social sense, despite the common definition of a supply chain as a communication network. Essentially, it is recognised that the application of AI within the supply chain involves complex interactions and processes, but these are fundamentally different from the way humans communicate socially.

This highlights the unique challenges and characteristics associated with integrating AI into supply chain management. Unlike human communication, where there is a shared understanding of social cues and contextual nuances, AI interactions within the supply chain focus more on data processing, decision-making and optimisation based on algorithms and machine learning.

It is important to bear in mind that artificial intelligence (AI) is often perceived as a black box. This perception stems from a lack of clarity about how the inner workings of an AI system function and what results can be expected. The uncertainty associated with AI functioning as a black box raises the critical question of whether a supply chain would exhibit similar black box characteristics if it were autonomously controlled by AI.

In this hypothetical scenario, where the supply chain is operated as a black box under autonomous AI control, the nature of the supply chain as a communication network would become meaningless. This emphasises the potential challenges and paradigm shifts that autonomous AI control brings to supply chain management. These considerations once again emphasise the complexity and profound issues surrounding the implementation of AI in supply chains.

Information technology solutions like the platform developed by the EU knowlEdge project may have the potential to fundamentally transform supply chains by integrating human-AI collaboration into the very fabric of these complex social networks. As stated, supply chains are inherently collaborative, relying on continuous communication and coordination among a diverse array of stakeholders, including suppliers, manufacturers, distributors and customers. By introducing explainable AI through the knowlEdge platform, these stakeholders gain access to transparent and comprehensible insights generated by advanced algorithms.

The platform's design ensures that AI does not operate in isolation but actively involves human expertise at critical junctures. Through its dual knowledge approach – combining engineered knowledge from AI models with learned knowledge from domain experts – the platform enables nuanced decision-making that reflects both data-driven insights and human experience. Subject matter experts can accept, reject, or adapt AI-generated recommendations, ensuring that decisions align with practical realities and contextual nuances of the supply chain and keeping the human in the loop.

By continuously refining AI models with human feedback, the platform ensures that AI evolves in tandem with the changing dynamics of the supply chain. This way, the black box nature of AI could be avoided. As a result, human intelligence and artificial intelligence synergistically drive supply chains. This can have interesting repercussions for the adaptability and innovative capacity found in such a network. This fusion of technology and human insight potentially cultivates greater more resilient and responsiveness and, as mentioned already, can shift decision-making away from the centralised management to the user of AI systems.

Thus, the integration of human judgement and decision-making into automated systems involving AI ensure that AI outputs are interpretable, align with human values and expectations and can be adjusted based on context. Relating the concept of human-in-the-loop to the concept of "double contingency" in sociology offers an intriguing perspective. Double contingency describes a fundamental problem in social interaction: each person in a social exchange must consider the other person's potential reactions to their own actions. Since individuals cannot directly access each other's thoughts (i.e., each mind is a "black box"), they must rely on communication to coordinate actions and achieve mutual understanding[43].

In this context, the human-in-the-loop approach can be seen as a way to bridge the communication gap between humans and AI systems. While computers and AI do not "communicate" in the sociological sense – since they do not possess cognition or volition (i.e. consciousness, intentions, or the ability to interpret meaning) – they process information and produce outputs based on that information. This process lacks the inherently social and interpretive aspects of human communication.

Human-in-the-loop effectively replaces the need for computers to engage in true "communication" with humans. Instead, humans interpret and contextualize the AI's outputs, injecting the necessary social and cognitive elements into the decision-making process. This allows for a form of collaboration where humans resolve ambiguities, apply ethical considerations and ensure that AI-driven actions align with human goals and societal norms.

Conclusion

These final considerations conclude the discourse on the interplay between interoperability, human cognition and artificial intelligence. The elaborations emphasise the conditions necessary to achieve seamless interoperability in cognitive production.

A key aspect that deserves special attention is the profound impact of interoperability on the cognitive landscape of human thought processes, communication patterns and knowledge bases. The intertwining of interoperability with the way people think and communicate shapes mental models and influences the exchange and reception of information.

In this context, the question arises as to the evaluation of machines that process information without engaging in real communication as cognitive production systems, especially if they are equipped with artificial intelligence. These questions, as shown, require a critical examination of the nature of cognitive production, questioning assumptions and exploring the core characteristics that define authentic cognitive systems.

The previous comments also covered the area of autonomy and questioned whether authentic cognitive production systems require human involvement to go beyond pure automation. The realisation that the practical focus in AI research is often on human support underlines the symbiotic relationship between artificial intelligence and human collaboration.

Research and development projects should therefore be guided by the ethos of human-centred cognitive production and emphasise aspects such as explainable AI or human-in-the-loop. This orientation emphasises not only the technical, but also the sociological and social science dimension and highlights the holistic nature of such efforts.

Data availability

No data are associated with this article.

Acknowledgements

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Open Peer Review

Current Peer Review Status: ? ✗ ?

Version 1

Reviewer Report 17 October 2024

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?

Sotiris Makris
University of Patras, Patras, Greece

This article presents aspects of human interaction with advanced, AI-driven, production systems. The focus is on harmonizing interactions between humans and technology via AI and social communication in cybernetic systems.

The topic address by the paper is important and well aligned with the Horizon Europe vision. It is well structured, the use of English language is good and the information well presented. It could serve as a complement to existing literature.

Several sections of the paper have been generated/written by the use of AI tools. It is encouraged to limit the use of such tools and the authors to express their personal findings.

The paper would take advantage of a more clear concept, avoiding inconsistent arguments, as it includes several key concepts without proper definition e.g. "cognitive production systems", "human-technology interactions".

The paper is structured as a conceptual one and could take advantage of a more detailed explanation of how the literature was selected and reviewed.

Newly released publications in the field need to be taken into account and included in the paper.

The conclusion section could be enhanced in order to make clear connection with the earlier arguments.

The addition of informative graphics could allow the authors to convey the findings in a more intuitive way and make the information easier to digest.

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Is the rationale for the Open Letter provided in sufficient detail? (Please consider whether existing challenges in the field are outlined clearly and whether the purpose of the letter is explained)
Yes

Does the article adequately reference differing views and opinions?
Yes

Are all factual statements correct, and are statements and arguments made adequately supported by citations?
Partly

Is the Open Letter written in accessible language? (Please consider whether all subject-specific terms, concepts and abbreviations are explained)
Yes

Where applicable, are recommendations and next steps explained clearly for others to follow? (Please consider whether others in the research community would be able to implement guidelines or recommendations and/or constructively engage in the debate)
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: collaborative robotics, human-robot collaboration, human augmentation, human-robot interaction, virtual reality in manufacturing

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 08 October 2024

https://doi.org/10.21956/openreseurope.19903.r44442

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Godfrey Mugurusi
Norwegian University of Science and Technology,, Trondheim, Norway

This research addresses a highly fascinating part of the newly emerging human-centered manufacturing area. The research focuses on three dimensions: cognitive manufacturing, artificial intelligence, and social communication in cybernetic systems. The author attempts to reconcile the tensions in these concepts hence the title of the paper: “Harmonizing humans and technology.....” However, because the paper's purpose is unknown (i.e. undefined), it struggles greatly with conceptualization, resulting in an absence of critical and consistent arguments or assumptions. Even the operationalization of the central concepts in the paper are not tied together with any theoretical or conceptual framework. This is why the paper appears to go in several directions. Below, I outline some of these issues and offer some suggestions on how to improve them.

Abstract
The abstract is unusually long and does not explain what the purpose of the paper is. As it stands, it merely gives a broad summary of the article, with scattered indications of what the study is about. I would therefore suggest that the revised version presents first, the purpose of the “open letter”, then a short summary of methods, results, and then the significance. It should represent a "stand-alone" snapshot of the complete document.

Introduction section
The study begins with a thorough dive into "cognitive production systems," which is linked to industry 4.0, before focusing on "agile, cognitive production systems". Later, seemingly out of nowhere, the concept of supply chain management is introduced (what is the logic here?).
It is difficult to determine the purpose of the paper based just on this section. What problem or research topic does the study aim to answer, and why? The "why" here question is the most significant one because it should explain why this article is important and who the target audience is.
The study claims that there is "a pressing need for harmonizing human and technological interactions" (page 3). That's why the article "explores the dynamics of social communication, AI and advanced production regimes, grounding the paper in a selective review of recent literature on smart, learning, and cognitive production systems, as well as communication in social systems, informed by cybernetics and AI" - 3, page 3.
First and foremost, it is not clear why there is a need to harmonize human and technological interactions. In fact, what are these “human and technological interactions”? First and foremost, it is unclear why there is a need to coordinate human and technical interactions. So, what exactly are these "human and technological interactions"? Why are they so important to study? Second, how are the core concepts discussed above defined and related to one another? I'm talking about "social communication", "AI", "advanced production systems", and so on. What do you mean by "smart, learning, and cognitive production systems" or "cybernetics"? It is counterproductive to throw about complicated terms without clarifying them. For example, what do you mean by “learning organization”, “flexible and adaptive systems”, “supply chain dynamics”, “standardization”, “semantics versus syntactics”, etc.

Here, I recommend that the introduction portion of the paper give an entrée into the topic by demonstrating why harmonizing human-machine interactions is an essential issue, followed by outlining the manuscript's aim. It is also critical that the introduction presents a logical justification and context for the topic being addressed. Here, a well-articulated conceptual framework might be beneficial. Indeed, a basic, well-stated research question could help reorient the entire structure of the paper. Then, ensure that the variables under investigation are clearly identified and defined.

The methods section
As observed, the paper has no clear methodological framework. Even if this is an “open letter”, it is molded as a conceptual paper. Conceptual papers too have a methodological basis. One would expect that the paper provides some basic arguments on how the author selected the literature to review or some basic data collection techniques, analytic procedures, or regulatory statements associated with the project being discussed. Earlier in the introduction section of the paper, it was proposed that paper is based on “selective review of recent literature” – page 3. Which literature is this, and how was it selected and reviewed.
While the paper builds its case around the EU research project “*knowlEdge”,* one would have expected this part would have provided more details of the project, the key actors, what they do, their demographics and expected results etc. and then link this to the purpose of the paper. This way at least the basic canons of the methods sections such as reliability/validity, trustworthiness, and absence of bias are fulfilled. These details are missing.
I was mostly concerned with the "pick and choose" theoretical angles considered in the study without any clear reasons or arguments to support the advancements made in the paper. Most of these came from IT, management cybernetics, sociology, operations management to name but a few. For example, “living/biological systems”- page 6, “Shannon’s information theory”- page 7, “Niklas Luhmann’s theory of social systems” – page 9, etc.
To remedy the methodological challenges noted here, I would propose that the paper consider explaining the methodology in such a way that the new section gives sufficient detail so that others may appreciate how the project's conclusions are important in the broadest sense.

Key observations
I strongly propose that the article include a section on results and discussion, preferably with some interpretation of the findings from the project.
On page 10, its written that “Information technology solutions like the platform developed by the EU *KnowlEdge* project may have the potential to fundamentally transform supply chains by integrating human-AI collaboration into the very fabric of these complex social networks”. Where in the paper is platform described? How does it look like? How was it developed? What can one make of this platform from the cognitive production systems lens? I am sure more readers would like to know more about the concept of “dual knowledge approach” that’s been developed on the platform “combining engineered knowledge from AI models with learned knowledge from domain experts” – page 10
Because the paper is based on the EU research project “knowledge”, I would propose that results of this project, if those are to be reported in a consistent way, are organized in a way that is easy to understand. As it stands, the majority of these are scattered across the paper. The results should then be contextualized, that is, addressed wisely and in accordance with the text.

The conclusion
Here I expected that paper to describe and interpret their main stand out points or arguments

instead of the sweeping statements such as “These final considerations conclude the discourse on the interplay between interoperability, human cognition and artificial intelligence” – page 11. “The intertwining of interoperability with the way people think and communicate shapes mental models and influences the exchange and reception of information” - page 11. What exactly does the author mean here? I am not sure that such inferences are supported any observations made earlier.
Generally, the paper has so many statements in the paper that are difficult to understand. For example, at the end: “The intertwining of interoperability with the way people think and communicate shapes mental models and influences the exchange and reception of information” – page 11. What does this exactly mean?
I would therefore recommend that the conclusion section of the paper considers both the both the empirical interpretations as well as the personal perspectives to these interpretations given that the author is the one of the project’s coordinators. Here observe the limitations of this on the paper, i.e. bias. Also, the practical significance or theoretical implications should be discussed and some more detailed guidance for future studies should be offered.

Good luck with the improvements.

Is the rationale for the Open Letter provided in sufficient detail? (Please consider whether existing challenges in the field are outlined clearly and whether the purpose of the letter is explained)
No

Does the article adequately reference differing views and opinions?
No

Are all factual statements correct, and are statements and arguments made adequately supported by citations?
Partly

Is the Open Letter written in accessible language? (Please consider whether all subject-specific terms, concepts and abbreviations are explained)
No

Where applicable, are recommendations and next steps explained clearly for others to follow? (Please consider whether others in the research community would be able to implement guidelines or recommendations and/or constructively engage in the debate)
No

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: (Digital) supply chain management, AI Governance, Human-centered manufacturing

I confirm that I have read this submission and believe that I have an appropriate level of

expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

Reviewer Report 07 October 2024

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The paper is well-written and straightforward. Most of the highlights are already discussed in the literature and more exhaustive works exist. However, it could complement existing works providing a few food for thought. I would suggest the following:
- update some citations. Many citations are more than 5 to 10 years old. Some are great reference points, but more recent works should be prioritized.
- add a picture summarizing the results, the two highlighted research directions and subdomains that, from my point of view, should be better motivated.- the two pictures currently in the text are a dime a dozen. They do not add any value to the work.

Is the rationale for the Open Letter provided in sufficient detail? (Please consider whether existing challenges in the field are outlined clearly and whether the purpose of the letter is explained)
Partly

Does the article adequately reference differing views and opinions?
Yes

Are all factual statements correct, and are statements and arguments made adequately supported by citations?
Partly

Is the Open Letter written in accessible language? (Please consider whether all subject-specific terms, concepts and abbreviations are explained)
Yes

Where applicable, are recommendations and next steps explained clearly for others to follow? (Please consider whether others in the research community would be able to implement guidelines or recommendations and/or constructively engage in the debate)

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Human centred production systems, collaborative robotics and human digital twins

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.