Digital & Cognitive Corporate Reality

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Abstract—**As part of the most recent developments in human co-evolution with information and communication technologies, the increasing complexity of our digital realities, as well as the expanding capabilities of omni-present artificial intelligence, are having profound implications. This transformative shift leads to a new era in many fields, including corporate management and business. Newly co-evolved cognitive capabilities, both natural and artificial, are emerging, necessitating a paradigm shift in our understanding and approaches to corporate management and business science. This paper introduces the concept of Digital and Cognitive Corporate Reality (DCR) to establish a new broader view for higher-level conceptual discussion, adopting a holistic perspective that encompasses related scientific fields. Following this definition, the paper briefly explores how different scientific disciplines can be expected to contribute to the development of DCR. Use case examples are also provided to demonstrate the benefits of the holistic perspective adopted in DCR.**

Index Terms—**corporate management; business science; digital and cognitive corporate reality; internet of digital & cognitive reality; cognitive infocommunications**

I. Introduction

The European Union is committed to driving growth digitally; hence the Digital Agenda was developed by the European Parliament. A Digital Compass was created in 2021 to suggest actions in four fields (skills, businesses, infrastructure, and public services) [1]. The Digital Compass 2030 highlights the role of digital transformation (DT) in Europe's resilience, while President von der Leyen emphasizes some key areas of digitization, a European Cloud, leadership in ethical artificial intelligence, secure digital identity for all, and vastly improved data, supercomputer, and connectivity infrastructures [2].

The Digital Compass identifies four key fields; two are focused on digital capacities in infrastructures and education and skills, and the other two are concentrated on the digital transformation of business and public services [2]. Whilst action programs and tenders are created to enhance the national strategies derived from the EU's digital strategy, many companies hesitate to embrace the technologies and lag in the competition in the new digital reality [3]. Researchers elaborated several digital maturity assessment or readiness models to facilitate the transition of companies with practical insights about their digital status. The framework of Digital Maturity Technical Architecture built based on 28 digital maturity models encompasses the pillars of ICT, organization, and people [4]. Nevertheless, digital transformation literature in business and management also emphasizes that education has a significant role in DT. Education and training can benefit from the topics investigated in this field in an evidence-based way. The literature revolves around alternative or new forms of value creation; structural changes in companies, sectors, and industries; technological viewpoints in B2B or customer perspective in the B2C sector; digital capabilities, big data and their role in strategy development [5]. The human factor is also unquestionable in digital transformation [6]. Disruptive or ICT technologies have effects on not just the companies, but also the cognitive system of people. Both people and companies as a collaborative network are part of the digital transformation journey towards digital reality, supported by infocommunications and other disruptive technologies. This fact provided us with a new perspective based on which the concept of Digital & Cognitive Corporate Reality was derived.

This paper proposes the following definition for Digital & Cognitive Corporate Reality (DCR):

Definition 1. *Digital & Cognitive Corporate Reality is a scientific discipline integrating Corporate Management and Business Science, Internet of Digital & Cognitive Reality and Cognitive Infocommunications leading to a higher conceptual level, adopting a holistic view. DCR includes all corners of co-evolved natural and artificial cognitive capabilities, spanning the entire range of individual and social levels as well as network aspects. DCR research aims to explore interactions among the areas of digital corporate ecosystems (including processes, infrastructure, digital assets, organizational & human competencies, governance, regulatory and information security), and various approaches to the Internet of Digital & Cognitive Reality (including ICT, AI & data science, 2D / 3D digital environments and network science), all within a conceptual framework of hybrid human, organizational and artificial cognitive capabilities. Within these areas, DCR targets the development of both theoretical frameworks and practical solutions towards applications.*

The paper is structured as follows. Sections II-V introduce the contributions of and potential synergies with various fields from the perspective of DCR. Thus, section II presents digital corporate ecosystems that emerged from the intersection of corporate management and business science; section III focuses on the field of Cognitive Infocommunications with special focus on artificial and natural cognitive capabilities of cognitive entities, whereas section IV approaches DCR from viewpoint of the holistic systems forming an Internet of Digital & Cognitive Reality surrounding cognitive entities. Section V focuses on the breakthrough and disruptive technological enablers of artificial intelligence (AI) and spatial computing (VR/AR/MR). Finally, Section VI describes some use cases to better highlight the systemic, holistic viewpoint enabled by DCR.

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II. Digital Corporate Ecosystems

A. Corporate Management and Business Science in the Digital Age

Corporate Management and Business Science is concerned with the economics, strategy, management, and decision-making of corporations of various sizes, operating in diverse fields. The recent developments in information technology are fundamentally transforming how these corporations operate, enabling new artificial and natural cognitive capabilities towards working, competing, and collaborating. Business ecosystems are emerging that are characterized by groups of interacting firms, leading to vertical specialization and tight networked collaborations [7], forming Digital & Cognitive Realities [8], [9] of corporations. Organizational boundaries will blur both horizontally and vertically as a result of this turbulent business environment [10]. Digital technologies can enhance existing and create new cognitive infocommunications [11] capabilities (involving both an artificial and human side) of digital realities (DRs), which will play a key role in this business transformation:

- Connective capabilities: Network technologies and the Internet have laid the foundation for connecting sensors, equipment, customers, and suppliers, enabling the sharing of data and information. These technologies have not stopped evolving: RFID enables the automated identification of objects, location technologies make it possible to obtain accurate geospatial-temporal information about customers or transportation, while 5G infrastructure will enable low latency, high speed, real-time connectivity. Smart sensors, the Internet of Things (IoT) will provide data about the environment, the business processes and the products taking information availability to the next level. This will result in a new level of connectivity and an immense volume of data that could be used to build new analytical and intelligence capabilities.
- Analytical capabilities: the volume of data that is generated through the interaction with customers, suppliers as well as collected from IoT, RFID or location technologies, will enable us to understand better the behavior of the business environment, the stakeholders and the equipment. New analytical methods and technologies, utilizing Big Data can support data-driven decision-making to increase organizational efficiency and effectiveness.
- Intelligence capabilities: artificial intelligence as a scientific discipline has experienced enormous growth in the last decades. Current AI methods already provide endless business application possibilities for decision support: image recognition, process optimization, route planning, recommendation systems, or content creation generative AI techniques to name but a few. The capabilities of these AI methods are often superior to what humans can do. In addition, 3D spatial technologies like virtual and augmented reality (VR / AR) also enable humans to communicate with and interface to digital realities at a structurally higher level.

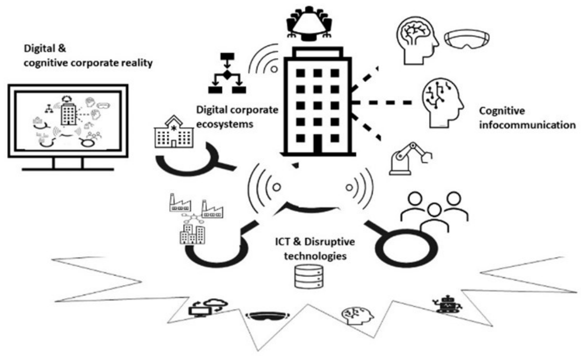

Fig. 1. Digital & Cognitive Corporate Reality

AI could play an especially pivotal role in helping users and digital systems to "brainstorm" new solutions together in a corporate and management environment, thereby transforming business processes and decision making. AI could enable building business applications that have either brand new or superior capabilities to existing ones. AI can help perform routine tasks, monitor processes within the environment, detect anomalies and defects, forecast demand for the planning of activities, and optimizing processes to enhance their efficiency and effectiveness [12].

There could be numerous applications to perform routine tasks of monitoring processes or the environment. Data generated as business activities are performed could be pre-screened through digital capabilities, and therefore more efficiently monitored by humans to identify deviations from what is desired. This information can be based on, inter alia geospatial-temporal data in logistics and transportation, network traffic from the computing infrastructure, IoT sensor data from manufacturing or transaction data from sales. Machine vision is one of the emerging artificial monitoring capabilities supporting routine applications, where machine learning algorithms are used to recognize pre-trained images or patterns and to perform business rules-based actions. Such methods can screen through millions of images, something that circumvents the limitations of human capabilities, while maintaining the quality of performance. However, based on this digital capability, humans can analyse the pre-screened and clustered images, to gain insights and to use them for building new applications – a synergy which demonstrates well the viability of hybrid cognitive capabilities.

The routine monitoring of processes or the environment is often used to detect anomalies, defects, and deviations from normal operation. Various AI models are capable of and can be trained to generate alerts if the data is different from what is deemed to be normal. Such models can use multiple sources of information simultaneously to increase detection capabilities, again augmenting human capabilities.

Forecasting is an important capability in running a business, enabling the future to be predicted, and thereby supporting preparation with resources, and optimized plans. AI can bring forecasting to a higher level [13] by using tailored models for each application field. Both the accuracy of the forecasts and their ability to cater to differences in patterns can be enhanced by using AI capabilities. Thus, AI has the capability of optimizing business processes [14] and creating plans for situations with many dimensions, constraints, and changes. The results of these optimizations are not only the most efficient ones but robust too. There are various exact and heuristic optimization methods available, whose performance could be significantly improved using AI methods, evolutionary computing algorithms being one of them.

Meanwhile DCR also entails companies embracing new technologies where several legal, ethical, cybersecurity issues emerge, especially in the case of AI. Robots driven by AI, autonomous vehicles can make decisions without external control. Questions arise about responsibilities, how to characterize new norms, apply human regulations on machines or modify them [15]. These issues need to be handled not just at governmental or international, but at an enterprise level as well. Corporate Digital Responsibility, as an analogy to Corporate Social Responsibility [16], is defined as "The set of shared values and norms guiding an organization's operations with respect to four main processes related to digital technology and data. These processes are the creation of technology and data capture, operation and decision-making, inspection and impact assessment, and refinement of technology and data" [16].

B. Digital Corporate Ecosystems

Under the DCR concept, Corporate Ecosystems, as a prominent organizational structure, focus on emerging capabilities of a dynamic group of largely independent economic players that create products or services that together constitute a coherent solution [16]. A Corporate Ecosystem can be defined as a "loose network of corporate actors; customers, suppliers, distributors, outsourcing partners, makers of related products and services, technology providers, and a host of other organizations that affect and are affected by the creation and delivery of a company's offering". Based on Moore (Moore, 1996, 2006), a Corporate Ecosystem is "an economic community supported by a foundation of interacting organizational units and individuals - the 'organisms of the company'. This economic community produces goods and services of value to customers, who are members of the ecosystem" [17]. In this context, the term 'ecosystem' is used as a biological metaphor that highlights the interdependence of all actors in the business environment, who "coevolve their capabilities and roles" [17]. Control capabilities of Corporate Ecosystems are not fully hierarchical, but there is some coordination mechanism.

The Digital Corporate Ecosystem (DCE) is a digital representation of the Corporate Ecosystem. DCE is a socio-technical environment of individuals, organizational units and digital technologies with collaborative and competitive cognitive capabilities to co-create value through shared digital platforms [17]. In digital platforms, coordination is generally achieved through access and interaction, that is generally regulated by a set of application programming interfaces (APIs) in the related Digital Corporate Reality. DCE includes collective intelligence achieved through tools for the formalization of knowledge built on top of a distributed persistent storage layer hosting digital organisms: business models, training modules, skill descriptions, digital contracts, software services, ontologies, dynamic semantic networks and taxonomies, folksonomies, tag clouds [18]. Nachira et al. [18] describe an isomorphic model between biological behavior and the behavior of the software, based on theoretical computer science implications and leading to a DCR having the capabilities of evolutionary self-organization and self-optimization (Evolutionary Environment or EvE). In our approach, connective, analytical and intelligence capabilities are core enablers of DCE. These can contribute to DCE boosting productivity and improving competitiveness, in the case of SMEs for the foreseeable future of at least 20 years [19]. Instead of a full business view, we put the focus on the corporate view, so we use Digital Corporate Ecosystems as an umbrella term.

III. Cognitive Infocommunications

Cognitive Infocommunications (CogInfoCom) is a research initiative proposed in 2010, which focuses on the analysis and synthesis of new cognitive capabilities – that are neither purely human, nor purely artificial – arising in co-evolved human-digital ICT environments. Since it was first proposed, an IEEE conference has been held focusing on relevant topics on a yearly basis, as a result of which CogInfoCom is widely regarded as a scientific discipline today.

The definition of the CogInfoCom is as follows [20]:

Definition 2. *"Cognitive Infocommunications investigates the link between the research areas of infocommunications and cognitive sciences, as well as the various engineering applications which have emerged as the synergic combination of these sciences. The primary goal of CogInfoCom is to provide a systematic view of how cognitive processes can co-evolve with infocommunications devices so that the capabilities of the human brain may not only be extended through these devices, irrespective of geographical distance but may also be blended with the capabilities of any artificially cognitive system. This merging and extension of cognitive capabilities are targeted towards engineering applications in which artificial and/or natural cognitive systems are enabled to work together more effectively."*

One of the key motivations behind DCR, from the perspective of CogInfoCom, is to develop a holistic view of how digital realities and humans can co-evolve, both at an individual and a social level, and how this co-evolution can provide new, entangled combinations of artificial and natural/social cognitive systems leading to newly integrated cognitive capabilities which cannot be explained at separate cognitive levels.

From a CogInfoCom perspective, the border between the natural and artificial cognitive capabilities of the present and the coming generations are becoming fuzzy or even disappearing. The CogInfoCom scientific discipline considers this "Human & ICT" combo as one Cognitive Entity (CE) with new cognitive capabilities instead of viewing it as a set of features emerging from human–ICT interactions [11].

Taking the view of CEs and their social level as a higher-order conceptual component, the development of scientific theories in Corporate Management and Business Science can based on new paradigms leading to a higher conceptual level, adopting a holistic view. For instance, in a corporate management environment, considering the CEs instead of sets of features and capabilities built on human–ICT interactions can allow researchers to focus on formalizing the cognitive capabilities of the management itself without investigating the structure of the interaction elements that may present a lower-level layer of abstraction ill-suited to describing high-level management issues.

IV. Internet of Digital & Cognitive Reality

The concepts of Digital Reality (DR) and Internet of Digital Reality (IoD) have recently been proposed to describe, analyse and synthesize 2D / 3D and augmented digital environments with digital content management and artificial intelligence in networked settings, enabling domain-driven digital environments centred around some coherent aspect.

The definition of IoD is as follows [8]:

Definition 3. *"Digital Reality (DR) is a high-level integration of virtual reality (including augmented reality, virtual and digital simulations and twins), artificial intelligence and 2D digital environments which creates a highly contextual reality for humans in which previously disparate realms of human experience are brought together. DR encompasses not only industrial applications but also helps increase productivity in all corners of life (both physical and digital), thereby enabling the development of new social entities and structures, such as 3D digital universities, 3D businesses, 3D governance, 3D web-based digital entertainment, 3D collaborative sites and marketplaces. Beyond the concepts of the Internet of Things and Internet of Everything, the Internet of Digital & Cognitive Realities (IoD) already encompasses the networking of the widest range of digital & cognitive entities to be managed, transmitted and harmonized, focusing on a higher level of user accessibility, immersiveness and experience with the help of virtual reality and artificial intelligence."*

A definition of "digital reality" has first been proposed by Deloitte Consulting LLP and the Consumer Technology Association as a trademarked term to refer to "technologies and capabilities that inhere in AR, VR, MR, 360deg video, and the immersive experience, enabling the simulation of reality in various ways" as described in [11]. In [9], this definition was extended through the addition of more context and a wider perspective focusing not only on the "3D visualization" but also highlighting the presence of "2D digital environments" and artificial intelligence-related, capability-oriented and social cognition aspects. The paper (Baranyi et al., 2021) also considered the Digital Reality concept in the emergence of a new kind of interconnectedness, referred to as the Internet of Digital Reality [8], based on a strong analogy with the Internet of Things (IoT). The paper [8] discusses the combination of VR / AR / XR and 2D windows like human environments in which virtual simulations, virtual twins and digital twins are integrated.

In the concept of IoD, the meaning of Reality plays a crucial role. Different definitions and understandings exist to explain the meaning of Reality. In [8], the authors characterize the meaning of this concept as a set of highly entangled natural and artificial cognitive capabilities that serve a common goal. In the case of corporate and business management, even existing solutions rely to a large extent on digital environments and personalized (human) digital capabilities, i.e., on cognitive entities (CEs) [11] being mapped onto corporate divisions. However, all of the general and specialized capabilities reflected in the systems being used ultimately serve the goals of - for instance - management. That is, all capabilities of the entire cognitive network of capabilities that have the purpose of serving management goals, can be considered as a part of the emergent Management Reality.

As an analogy, consider a garage and a car service. Both contain cars, repair tools, and human resources, but the integrated set of capabilities and the varying quality of those capabilities within the set highlight the different overall purposes of a garage versus a car service. It is the combination of these capabilities that creates a distinction. In a similar fashion, when artificial cognitive capabilities such as those provided by AR, VR, XR, 2D, Digital Twin, and AI are intertwined with natural cognitive capabilities to serve a shared objective, they create a Digital & Cognitive Reality. This is the connection between Digital Reality and the reality of management or corporate operations.

V. Breakthrough and Disruptive Technological Enablers

In this section, we provide a brief overview of the evolution of artificial intelligence (AI) and 3D spatial technologies, with special focus on how such technologies can be expected to influence DCRs.

A. Artificial intelligence (AI)

Founded in the 1950s, AI is a field focusing on the implementation of human-like intelligent behaviors in computer systems. In a document written by the pioneers of the field, McCarthy et. al. in 1955, the authors envision a "2 month, 10 man study", in an attempt "to find how to make machines use language, form abstractions and concepts, solve kinds of problems now reserved for humans, and improve themselves" [21].

In retrospect, it is evident that the expectations set within the given timeframe were overly optimistic. However, it's also clear that they were perhaps broadly defined. As a result, the field of AI has been characterized by the emergence of a myriad of sub-fields, including knowledge-based systems, machine learning, soft computing, natural language processing, evolutionary computing and others. Also, the field has been characterized by an alternating sequence of booms and busts, with each boom precipitated by the maturation of different approaches, such as logical inference, statistical machine learning, training of artificial neural networks using backpropagation, or reinforcement learning.

1) Evolving conceptualizations of intelligence: Additionally, one can observe that the definition of what it means for a digital reality to be intelligent has also evolved – both in public perception, and among researchers.

Within the realm of public perception, when asked whether spell checking and grammar checking in word processing software, or human face recognition in digital camera software should be regarded as AI, no doubt users would have answered differently depending on whether they were asked in the 1980s, 1990s or early 2010s. This can only be expected, as the emergence and maturation of all technologies leads to a continuous re-evaluation of how they can best be put to use.

At the same time, AI is also somewhat unique in that there is no real consensus even among researchers as to what a truly intelligent system should look like. Not only public intellectuals and philosophers, but also researchers in AI as well as in various fields focusing on the relationship between humans and computers have adopted different, sometimes conflicting views on what it means for a machine to be intelligent and how best to support human intelligence via digital realities.

For example, some have criticized current widespread generative AI solutions as being purely statistical in nature, thereby not having a "real" understanding [22], [23]. Others have argued that to do statistical inference well, a real understanding has to implicitly emerge. For example, Hinton has argued that to translate the sentence "*the trophy doesn't fit into the suitcase because it is too small*" to French, a large language model has to understand that it must generate the subject pronoun "elle (la valise)" instead of "il (le trophée)" because it is the suitcase that is too small, not the trophy; in contrast, if the sentence read "*the trophy doesn't fit into the suitcase because it is too big*", this would be the other way around.

Within the field of Human-Computer Interactions (HCI) in particular, Winograd and others have noted that a deep divide runs across the AI and HCI communities as to whether computers should behave like and be talked to as humans, or if making a clear distinction between artificial and human intelligence has practical and philosophical benefits [24] - an observation that was also one of the motivating factors behind CogInfoCom. These tensions have led to new definitions and conceptualizations of what is expected of intelligent digital realities, focusing on a broader perspective than the goal of optimizing some cost functions. In [25], a definition of "interactive human-centered AI" is presented, which focuses not only on interactivity and explainability, but also on levels of abstraction and granularity of control. In CogInfoCom, a hybrid viewpoint has been adopted that focuses on longer-term co-evolution and hybrid, or merged cognitive capabilities, thereby leaving the question of purely artificial intelligence aside [11].

2) An alternative view of implied deliberative intelligence: In this paper, we adopt an alternative perspective from those described above, with individual elements combined from different existing perspectives.

First, we propose to view the artificial cognitive capabilities extending human capabilities – as a component of new cognitive entities (CEs) [11] – towards vision and speech, whether in the direction of input (image recognition, speech recognition) or in the direction of output (image generation, text generation) as a kind of reflexive process as opposed to a deliberative one in AI systems. In much the same way as perception in humans is a more direct, lower-level process than high-level thinking, current generative AI solutions operate by passing an input through a feed-forward network in order to generate the next token, or the next iteration of noise to be removed (as in the case of diffusion-based image generation). Of course, such operation is far removed from the kind of iterative, deliberative reasoning-based process in which we as humans refine our work through self-critique, through the critique of others, or through other impulses that can be explained at a different level such as human psychology and neuroscience. The key point here is that a large language model like GPT-4 cannot go back and refine output that it has already generated.

Of course, in a sense such reflexive AI is an essential component of general intelligence, without which further progress would be difficult to imagine. For example, without the ability to generate grammatically correct text, or text that "makes sense" in view of earlier parts of a dialogue, it would be difficult both to interact with users at a high level, and to generate content in the first place that can later be refined. In this sense, basic visual and linguistic skills can be seen as prerequisite cognitive capabilities to high-level reasoning.

The task now, in our view, is to organize and embed these capabilities into a broader networked environment, consisting of individuals using them, of organizations with constituent individuals using them, and of other artificial capabilities that can be put to use in semi-automated workflows. This leads to a kind of implied deliberative intelligence embedded in DCR, as depicted on Figure 2.

B. Spatial technologies

We refer to all digital technologies that utilize spatial properties and relationships to present content to users as spatial technologies. Spatial technologies derive their significance from their ability to employ spatial metaphors that human cognition has become accustomed to in the physical environment through millions of years of evolution. Thus, instead of adopting file-folder hierarchies to structure information, a spatial technology might present documents in a way that reflects their topic, relative importance and context of use, thereby boosting the effectiveness of the human brain at various cognitive levels [26]–[30].

1) The benefits of realistic visualization: Visualization, simulation, and 3D graphical rendering are somewhat overlapping yet distinct concepts that can be used to enhance the efficiency of corporate realities at various levels. Central to these approaches is the notion that the more spatially and geometrically accurate the digital reality in which users receive feedback, the faster and more effective the interventions that they can make. For instance, in industrial settings, it may be the case that all of the pertinent feedback – including status messages, and alerts – can be provided to users as a text-based digital capability; still, a growing number of companies now use digital twins,

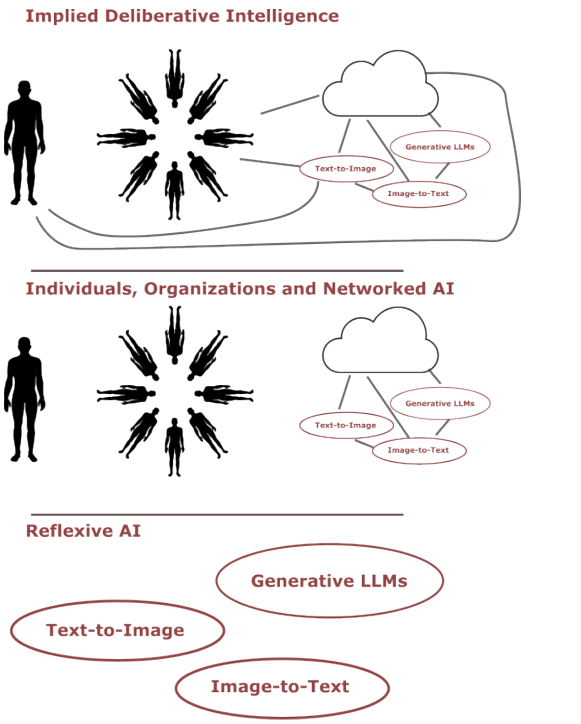

Fig. 2. Implied deliberative intelligence arising from reflexive AI, networked AI, individuals, and organizations.

which mirror the physical environment and its events on a digital interface that shows a similar geometry and a similar spatial structure to the physical environment. While sometimes counter intuitive, such high-fidelity feedback methods can be highly effective since users implicitly know where to look for what kind of information and are less likely to experience cognitive overload resulting from feedback messages that have no semantically relevant distinguishing features [31].

More recently, in part based on such successes, researchers have turned towards the use of 3D virtual environments, as opposed to 2D simulations with spatial aspects. Several authors have highlighted that virtual worlds have a unique potential to foster creativity in a way that the traditional Web cannot (see e.g., [32]). For example, it has been shown that the ability to explore spatial locations as users are able to have discussions with teammates, while in the meantime accessing supplementary information enable users to create associations between experiences that would normally belong to separate realms [30], [32]. Creativity improvements have also been observed by others in multimodal avatar scenarios [30].

Besides creativity, VR has also been observed to have a positive influence on cognitive capabilities in many respects. Thus, it has been shown that even a desktop VR platform is capable of generating more salient memories [27], to enable a higher degree of context awareness [26] and generate new cognitive capabilities towards obtaining a holistic overview of multimodal content [26]–[28].

2) 3D spatial technologies from a DCR perspective: VR and AR are core technologies contributing to both Digital Reality and Internet of Digital Reality; hence, they are also closely linked to DCR.

A key notion behind the corporate use of these technologies is that users are able to organize and access their digital content more effectively and at a lower cognitive load if their semantic relationships are encapsulated in 3D spatial metaphors. In practice, this means that documents that are related appear closer together in space, documents that contain key insights as opposed to supplementary materials appear relatively larger, and often documents are placed in the proximity of objects whose identity conveys some kind of meaning. For example, in a factory, management type documents would more likely be placed in the office spaces above the shop floor, whereas documents pertaining to the operation of individual machines would be accessible in the area where the machines are located.

From the holistic perspective of DCR, 3D spatial technologies together with AI solutions can provide solutions where the necessary information is available to users in a context-sensitive way and through an interface that enables them to achieve more with less effort.

C. AI and VR enablers from the perspective of Gartner Emerging Technologies in 2023

The 2023 Gartner Emerging Technologies and Trends Impact Radar emphasizes four key areas [33]: neuromorphic computing; self-supervised learning, metaverse, and human-centered AI (HCAI). Neuromorphic computing offers a new approach to modeling the operation of a biological brain using digital or analog processing techniques more accurately. Its use cases cover event detection, pattern recognition, and small dataset training. Self-supervised learning provides an automated approach to annotating and labeling data. It has special importance in the field of computer vision and NLP. Metaverse adds an immersive digital environment to Digital Reality. It contributes to the physical world real-time through decentralized, collaborative, interoperable, and spatially organized digital content. Human-centered AI suggests a model, where people and AI work together enriching cognitive performance, like learning and decision-making. HCAI deals with transparency and privacy and manages AI risks. It focuses on ethical, responsible behavior, and adds to AI a human touch [33].

VI. The Central Role of DCR in Practical Use Cases

A. CogInfoCom capabilities in cognitive entities and DCR

The field of CogInfoCom considers cognitive entities (CEs) as emergent human-digital systems with complex hybrid capabilities that are both natural and artificial but cannot be separated into natural and artificial components in a clear-cut way.

Depending on the context, both CEs and DCR can have natural cognitive capabilities and CogInfoCom capabilities in this hybrid sense. Conceptually, this results in a matrix, the rows of which distinguish between natural and CogInfoCom capabilities, and the columns of which distinguish between CE and DCR capabilities. Of course, such distinctions are not always crisp, but can have overlaps in a fuzzy sense. Nevertheless, it is often possible to associate a given example with one specific quadrant of this matrix. For example:

- When the focus is on a CE having CogInfoCom capabilities in a general environment not necessarily in corporate or management settings – such as using everyday AI and infocommunication devices, or collaborative or social knowledge sharing – the resulting capabilities can be seen as CogInfoCom capabilities of CE.
- When the focus is on a DCR having CogInfoCom capabilities specifically in a corporate or management environment, the resulting system can be seen as a CogInfoCom capability of DCR, where the human is extended as a component of newly emergent CEs.

B. Advanced collaborative capabilities of DCR

In the most general, abstract sense, collaborative capabilities can be seen as advanced CEs that can lead to the loosening of temporal, spatial and other contextual constraints that would be hard constraints without the formation of such CEs. Therefore, collaborative capabilities of DCR are supported by the enhanced CogInfoCom capabilities of such new CEs.

For example, new CEs involving human teamwork within computer networks loosen the constraint of having to work in the same physical location at the same time. Thus, online collaborative networks such as GitHub and Clickup and many others enable the collaboration of larger teams due to the loosening of physical and temporal constraints.

In a more radical sense, not only physical location and temporal requirements, but also contextual requirements such as whom to work with can be loosened in the context of new DCR CEs, as suggested by terms such as the 'platform economy' or the 'gig economy' [34]. A unifying feature of these platforms is that they apply new organizational methods in value creation, made available by a new kind of CE comprised of a flexible and dynamic workforce and computer networks. These either usurp existing markets or services or create entirely new ones that were not available previously [34].

From a DCR perspective, key differentials on the platform of work arise according to two dimensions. First, some of these operate on local markets that offer works that have to be provided on site, e.g., cleaning or delivering, while others on a global scale, such as online labor market platforms. Second, the autonomy of workers, is different, ranging from relatively high for creative projects present at online labor market platforms to very low in the case of drivers that are routed by the applications [35]. While online platforms promise the freedom of choice to workers in terms of time and amount of work that promises increasing inclusion (e.g., of workers from developing countries or ones doing family care work that excludes from traditional markets), structural constraints, such as worker dependence on the work and cultural constraints seriously limit this [36].

C. Emerging corporate roles in a DCR context

From a DCR perspective, many new opportunities are available to corporations to solve tasks that previously required countless hours of human labor, or which were simply impossible to achieve. However, an understanding of how these opportunities can best be brought to bear is still incomplete.

On the one hand, given the data sensitivity constraints, as well as the growing availability of open-source, self-hosted AI solutions, we envision that many companies will employ their own AI models in the coming years. This implies upfront costs and some degree of iteration in developing new infrastructures. However, it also implies that it will become necessary to train individuals to better understand the scope and limits of current AI solutions, given that the emergence of new, previously non-existent lines of work can be expected.

In addition, companies can be expected to leverage 3D spatial digital capabilities more and more, making areas of digital computing that had previously been reserved to gaming enthusiasts a central part of corporate infrastructure.

Based on the above, some possible newly created roles might include:

- Data curation: the collection of relevant data based on which AI models can be further refined, with a preference towards one-shot learning episodes for increased flexibility.
- Prompt engineering: the formulation of useful inputs to AI systems for specific use cases
- AI operator tasks: the use of the previously mentioned prompts within a given workflow to obtain output from AI models and to refine those outputs iteratively.
- Spatial environment management tasks: the curation of results from AI operators, in an increasingly automated fashion, and the furnishing of 3D spatial computing environments with the components and documents necessary for work to be effectively carried out within a given workflow.
- Human-AI Workflow engineering: making decisions as to what parts of a given workflow to implement through human labor, what parts to implement using AI, and what parts to implement in a human-supervised-AI mode. This role also includes establishing and monitoring protocols to ensure that human operators are able to intervene at optimal points in a workflow, and that the AI methods that are employed have access to the optimal external tools at the right time
- AI quality control: involves the monitoring of the performance of the system as a whole, and finding modes of operation that are increasingly performant, in close collaboration with Human-AI workflow engineers.

We note that a growing number of challenges can be expected such that they can be best solved at an organizational rather than an individual level of AI tools or human operators. Thus, the output of the organization as a whole needs to be considered, and often empirical methods can be expected to be amenable to the goal of improving the organizational performance. For example, the roles listed above are often strongly intertwined, with decisions made at some point influencing the work of several other roles. Therefore, we can expect that new methods of management will emerge to tackle functional issues at this holistic scale.

VII. Conclusions

In this paper, we discussed and proposed a definition of DCR. By reviewing relevant aspects of Digital Corporate Ecosystems, Cognitive Infocommunications, and Internet of Digital Reality, we showed that in accordance with recent trends within European research and development initiatives, the definition covers a new set of capabilities. EU's Digital Compass, digital maturity models and digital transformation literature review also highlighted that a new holistic viewpoint is required in that digital technologies, humans and organizations are investigated together. Digital corporate ecosystems were defined as loose networks of corporate actors; customers, suppliers, distributors, outsourcing partners, makers of related products and services, technology providers, and a host of other organizations that affect and are affected by the creation and delivery of a company's offering. Connective, analytical and intelligence capabilities are core enablers of DCE.

The primary goal of CogInfoCom is to provide a systematic view of how cognitive processes can co-evolve with infocommunications devices so that the capabilities of the human brain may not only be extended through these devices, irrespective of geographical distance but may also be blended with the capabilities of any artificially cognitive system. The Internet of Digital Reality is a high-level integration of virtual reality (including augmented reality, virtual and digital simulations and twins), artificial intelligence and 2D digital environments, which creates a highly contextual reality for humans in which previously disparate realms of human experience are brought together. Corporate ecosystems and cognitive ecosystems are influenced and transformed by digital technologies on the road towards digital reality. This synergy led to the concept of Digital & Corporate Cognitive Reality.

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