Chapter

Introductory Chapter: Opportunities and Challenges on the Convergence of Blockchain and Artificial Intelligence

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1. Introduction

According to a PwC global study presented in 2019, Artificial Intelligence (AI) has the potential to contribute up to $ 15.7 trillion to the global economy by 2030 [1]. In a report of 2020, the same company predicted that blockchain (BC) applications will boost global Gross Domestic Product (GDP) in 2030 by $ 1.76 trillion (1.4% of global GDP) [2]. Such a boost in economic value in the next decade shows the potential of both technologies as key drivers of the current digital transformation.

AI, specifically the most used techniques today, Machine Learning (ML), Deep Learning (DL) or Reinforcement Learning (RL) can create learning models that process and analyze data, perform tasks or make predictions for diverse real-world problems that were previously thought to be impossible to be solved by nonhumans. However, the use of AI comes with social concerns related to issues like the possibility of data tampering due to data centralization, the rise of fake news and deep fakes [3], the invasion of privacy or the bias in data training.

Distributed Ledger Technology (DLTs) and specifically BC, can create trust and consensus among a group of participants removing the need for intermediaries. On the one hand, BC can help to establish the data provenance for explainable AI and to ensure the authenticity and reliability of the data sources used in techniques [4]. In addition, decentralized computing for AI enables decision-making on secured shared data in a decentralized manner without intermediaries. Furthermore, autonomous systems that make use of smart contracts can learn over time and make trusted decisions [5]. On the other hand, AI can help to face some of the current limitations in BC implementations like scalability or security, privacy-preserving personalization, automated refereeing, and governance mechanisms [6].

Both AI and BC are increasingly being used in similar and even in the same applications. Therefore, it is expected that AI and blockchain converge into BC-AI systems in the near future, paving the way for major innovations in areas like smart grids for electric vehicles [7], Industry 4.0 automation [8], critical infrastructure (e.g., gas systems for smart cities [9]), 6G networks [10], the Internet of vehicles [11] or data security [12]. Moreover, such advances can also be enabled by the joint use of other Industry 4.0/Industry 5.0 enabling technologies like Internet of Things (IoT), Edge Computing or Augmented Reality (AR), Mixed Reality (MR), or Virtual Reality (VR) [13].

Previous research outlined potential opportunities for convergence of AI and BC [5, 6]. Nonetheless, as indicated by Pand et al. [14], most current research only provides a theoretical framework to describe the upcoming integration of AI and BC. In addition, most available research focuses on one-way integration (i.e., how BC integrates into AI or how AI integrates into BC) without considering its reciprocal nature, and, in general, it does not take into account the existence of DLTs different from BC that can be more appropriate for specific scenarios like IoT.

This book aims to help AI and BC researchers to develop systems that overcome current challenges and allow the convergence of both technologies.

2. Opportunities and challenges

The full development of BC-AI systems presents numerous opportunities for innovation. Despite the promising foreseen future of such an integration, it is also possible to highlight some open challenges that must be faced by future researchers. The following paragraphs summarize some aspects to be considered:

1. **Current BC and AI maturity levels**

   The adoption of BC-AI systems opens a wide range of potential applications in the short and medium-term. Nevertheless, it is a fast-paced field and there are several potential research topics that would be involved in a full deployment: BC scalability or security, smart contract vulnerabilities, and deterministic execution, trusted oracles election or AI-specific consensus protocols.

2. **Innovation driven by BC-AI systems used jointly with Industry 4.0/ Industry 5.0 Enabling Technologies**

   - IoT. On-device IoT data training is possible thanks to decentralized AI algorithms and mobile edge computing [15]. However, the use of BC in IoT applications still has to face some open challenges [16].

   - Fog and Edge Computing. IoT devices can offload training tasks to fog or edge computing devices to enable AI at the network edge [17]. In addition, such nodes can have a BC module, which allows fog nodes to execute localized data management, access and control. Those distributed edge intelligence frameworks pose advantages in terms of latency and network resource consumption, but impose certain additional challenges such as user privacy and data security [18].

   - Augmented Reality (AR), Mixed Reality (MR), and Virtual Reality (VR) (Metaverse). Such technologies provide new ways to interact with digital content and to create new worlds where it will be possible to engage in different activities that will be accelerated by the use of trusted technologies like BC, thus transforming digital content in valuable assets [19].

3. **Quantum computing**

   - In the coming quantum computing era, new attacks against classic cryptosystems will be developed, therefore researchers will have to pay attention to the quantum computing scene and its advances [20].

4. **Reduction of carbon footprint and energy efficiency optimization**

   - Researchers will have to study how to minimize the environmental impact and maximize energy efficiency [18] when deploying BC-AI systems. Specifically, researchers will have to develop novel approaches to optimize cryptosystems and reduce the energy consumption of AI techniques.

5. **Standardization and regulations**

   - Although standards for BC technology are already currently being developed [21], regulations for BC deployment in the context of AI applications need to be established at local and global levels. In addition, compliance with current legislative directives implies the cooperation of a wide range of global stakeholders and the creation of proof-of-concepts to define the correct set of technical standards for ensuring interoperability.

6. **Corporate governance, corporate strategy, and culture**

   - The ability of organizations to experiment with new business strategies and to make long-term investments will be important in the adoption of BC-AI innovative systems, as a collaborative approach is necessary to incorporate all stakeholders and to establish new ways of creating value while lowering carbon emissions.

3. Conclusions

This chapter summarizes the most relevant issues that will have to be faced by AI and BC during their convergence. Such issues will be addressed in the different chapters of this book, which shows the potential of the integration of AI and BC. Thus, this book includes state-of-the-art and future research opportunities of the convergence of AI and BC.

The book also deals with the technological and practical limitations to be addressed regarding scalability, privacy, smart contract security, trusted oracles, consensus protocols, interaction with Industry 4.0/Industry 5.0 technologies, quantum computing resiliency, reduction of carbon footprint, standardization, interoperability, regulations, and governance. The results obtained from the described analyses will allow for guiding the future developers of interdisciplinary AI and BC applications and/or the convergence of such fields, and to contribute to the development of the next generation of innovations based on BC-AI systems.

Conflict of interest

The authors declare no conflict of interest.

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