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The Future of Electronic Commerce in the IoT Environment

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Abstract: The Internet of Things (IoT) was born from the fusion of virtual and physical space and became the initiator of many scientific fields. Economic sustainability is the key to further development and progress. To keep up with the changes, it is necessary to adapt economic models and concepts to meet the requirements of future smart environments. Today, the need for electronic commerce (e-commerce) has become an economic priority during the transition between Industry 4.0 and Industry 5.0. Unlike mass production in Industry 4.0, customized production in Industry 5.0 should gain additional benefits in vertical management and decision-making concepts. The authors' research is focused on e-commerce in a three-layer vertical IoT environment. The vertical IoT concept is composed of edge, fog, and cloud layers. Given the ubiquity of artificial intelligence in data processing, economic analysis, and predictions, this paper presents a few state-of-the-art machine learning (ML) algorithms facilitating the transition from a flat to a vertical e-commerce concept. The authors also propose hands-on ML algorithms for a few e-commerce types: consumer–consumer and consumer–company–consumer relationships. These algorithms are mainly composed of convolutional neural networks (CNNs), natural language understanding (NLU), sequential pattern mining (SPM), reinforcement learning (RL for agent training), algorithms for clicking on the item prediction, consumer behavior learning, etc. All presented concepts, algorithms, and models are described in detail.

Keywords: electronic commerce (e-commerce); Internet of Things (IoT); artificial intelligence (AI); machine learning (ML); fuzzy logic; Industry 4.0; Industry 5.0

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1. Introduction

The world around us is changing at an alarming rate. We are currently in a transition period between Industry 4.0 and Industry 5.0. The Internet of Things (IoT) is a critical enabler of Industry 4.0, playing a key role in the transformation of traditional industries into smart, connected, and data-driven ecosystems. Industry 5.0, as the next phase of industrial development, should involve a more advanced integration of AI technologies into all social and technological branches.

In a broader sense, the IoT has a significant impact on electronic business (e-business) and electronic commerce (e-commerce). The integration of IoT into e-commerce is an ongoing trend shaping the business landscape. By leveraging the power of artificial intelligence, e-commerce can be significantly improved in the online marketplace.

In a narrow sense, artificial intelligence should improve online product selection, price prediction, customer behavior analysis, digital marketing, market trend analysis, supply chain management, etc.

This work is composed of several parts to indicate some directions for the future development of electronic commerce. The IoT concepts for e-commerce needs are analyzed. Vertical data processing and edge, fog, and cloud computing are explained in detail. It is pointed out that there is a need to improve the decision-making process by introducing new fuzzy logic algorithms. Several models and algorithms based on neural networks and deep learning are presented.

2. Background and Related Work

Big data processing, market monitoring, stock prediction, and customer behavior analysis are some hot e-commerce issues. Therefore, there is a need for fast data processing and comprehensive data analysis to improve the existing decision-making methods and develop novel ones in the e-commerce space.

The term Internet of Things was coined to highlight the fusion of virtual and physical spaces. The IoT implementation should improve existing services and provide new ones [1]. The IoT is a virtual space composed of networked smart devices, virtual–physical assets, information technologies, and computer platforms. Since the end of the 20th century, cyber–physical space fusion has become pivotal in improving communication and business. The frequent mismatch between IoT and large datasets requires better and faster IoT technologies and AI software tools [2].

Industrial revolutions, unlike social revolutions, achieve their progress through evolution, not revolution. We have not yet been fully involved in the Industry 4.0 era, and it is already being said that the Industry 5.0 era is beginning. Industry 5.0 originates in the concept of Industry 4.0 [3]. To understand these paradigms, we have to understand their characteristics. The key drivers of Industry 4.0 are the following [4]: Internet of Things, cloud computing, cyber–physical systems, artificial intelligence, augmented reality, decision-making tools, and autonomous robots. The key features of Industry 4.0 are the following: smart technology, smart environment, mass production, machine-to-machine communication (M2M), a full practical implementation of IoT with edge, fog, and cloud computing, artificial intelligence (machine learning, big data, fuzzy logic, cognitive computing, collaborative robots, etc.), augmented reality, hierarchical data, information processing, and automated decision making [5,6].

Edge computing is performed close to the data source or "edge" of the network, typically on devices such as smart sensors and monitoring systems [7]. This computing is ideal for low-latency and real-time data processing [8]. Fog computing can provide increased reliability compared to edge computing and is suitable for applications with slightly relaxed latency requirements [9,10]. Cloud computing provides a vast array of online services over the internet and networked communication systems [11]. Cloud computing encompasses three distinct service models: infrastructure as a service (IaaS), platform as a service (PaaS), and software as a service (SaaS) [12]. These services encompass a broad spectrum of application servers, database servers, and powerful software tools for analysis, planning, and decision making.

Using big data analytics on unstructured data can be challenging but rewarding. The IoT was the development driver of Industry 4.0. Therefore, it is realistic to expect continued development in Industry 5.0. To meet expectations, it is necessary to understand the weaknesses and limitations. The limitations of Industry 4.0 are the following [13,14]:

- High dependence on technology.
- Full hands-on IoT implementation. Development of IoT derivatives for better implementation in various industrial, business, and commerce branches: Industrial Internet of Things (IIoT), Military Internet of Things (MIoT), Green Internet of Things (GIoT), Green Industrial Internet of Things (GIIoT), etc.
- Unevenness of mandatory initial investments in related economic branches.
- Demands for rapid progress cause disruptions in the industry due to inconsistency in the growth of some industrial branches.
- The uninterrupted update can cause disruptions in sustainable economic development.
- An economic gap exists between traditional and business models adapted to Industry 4.0 requirements.
- The need for highly skilled experts.
- Increased unemployment is due to a reduced need for a labor force (automated machines, unmanned vehicles, etc.).

Fuzzy logic applications showcase their versatility in addressing real-world problems across diverse domains where precise and deterministic decision making may not be feasible or appropriate. The fuzzy decision-making process is the focus of fuzzy logic systems in particular [15]. Fuzzy logic can be utilized in decision making within electronic commerce for the following product–customer relationships [16]: product recommendation, dynamic pricing, customer satisfaction assessment, fraud detection, inventory management, user experience optimization, intelligent decision making, and recommender systems [17].

There are high expectations for Industry 5.0 to overcome these disadvantages and reduce existing limitations. Industry 5.0 is human-centric and reorients priorities from shareholders to stakeholders. Three key drivers of Industry 5.0 are the following [4]:

- Human-centric approach to the production process.
- Sustainability, which implies waste reduction, waste recycling, and resource reusing.
- Resilience, which implies robustness in industrial production.

If Industry 4.0 revolves around digitalization, Industry 5.0 should center on collaboration between the digital realm and the creative thinking capacities of humans [18]. This collaboration should respond to future market challenges and sustainability requirements. In Industry 5.0, custom-oriented production should decrease mass production and increase environmental awareness. It will be easy to carry out the planning and implementation of the green agenda under these circumstances. The initial actors in Industry 5.0 objectives should be manufacturers and consumers. The future environment should enable the interaction of human creativity and artificial intelligence in machines and robots, e-commerce, e-business, medicine, etc. The following challenges and opportunities should encourage the implementation of Industry 5.0:

- Vertical and semi-vertical IoT concepts with clearly defined hierarchical computing at the edge, fog, and cloud levels [19].
- Flexible business and commerce models.
- Future collaborative robots can take on and perform boring, tiring, and dangerous tasks.
- Readily available custom software.
- Future technologies should bring people back to the focus of production.
- Real-time monitoring by smart sensors and systems should ensure better environmental protection.
- Cognitive IIoT.
- Energy-harvesting techniques.
- The mass application of artificial intelligence in decision-making algorithms should ensure timely decision making, faster planning, and better maintenance.
- Better cyber security systems, based on in-depth strategies with customized machine learning algorithms, for faster and better detection of sophisticated intrusion.
- Green machine learning.

There are the following prospective technologies of Industry 5.0 [20]: advanced IoT concepts (Internet of Everything—IoE; Artificial Intelligence of Things—AIoT, etc.), augmented reality (AR), digital twins (DTs), blockchain technology, cognitive computing, smart sensors and collaborative robots, 6G cellular networks and beyond, etc.

Convolutional neural networks (CNNs) play a significant role in various applications within the e-commerce industry, leveraging their capabilities in image processing, pattern recognition, and feature extraction. Thanks to CNNs, many practical applications of machine learning in e-commerce have been achieved. CNNs efficiently utilize vast datasets, automatically extracting features from the original data, thereby empowering enhanced versatility.

There are many ML models and algorithms based on different CNN architectures. Convolutional autoencoders, the YOLO (You Only Look Once) algorithm, and recommender systems currently belong to the group of cutting-edge algorithms and models commonly used in e-commerce [21–23].

Numerous challenges await us. Uncontrolled mass production generates a lot of industrial waste, unsold products, and storage problems. All this harms the environment. From the social aspect, unfortunately, dependence on robots and technology will not be avoided in the future. However, fortunately, custom-oriented production should decrease mass production and increase environmental awareness. It will be easy to carry out the planning and implementation of the green agenda under these circumstances.

3. Electronic Commerce in the IoT Environment

IoT technology has penetrated all branches of electronic business [24]. E-commerce must seamlessly blend into different economic sectors, fostering global e-commerce as a pivotal driver of economic growth. E-commerce in the IoT should bring benefits in the following areas [25]: quality monitoring, information flow, supply chain management, etc. The IoT highlights and shapes the main aspects of Industry 4.0. Today's e-commerce strategies and theories should adequately respond to the IoT by adapting to all hierarchical computing and management levels (edge, fog, and cloud).

E-commerce into the flat IoT structure fully meets the requirements imposed by mass production and consumption. Consequently, IoT completely redefines the e-market with great business opportunities. Two main IoT concepts, flat and vertical, are shown in Figures 1–3 [26].

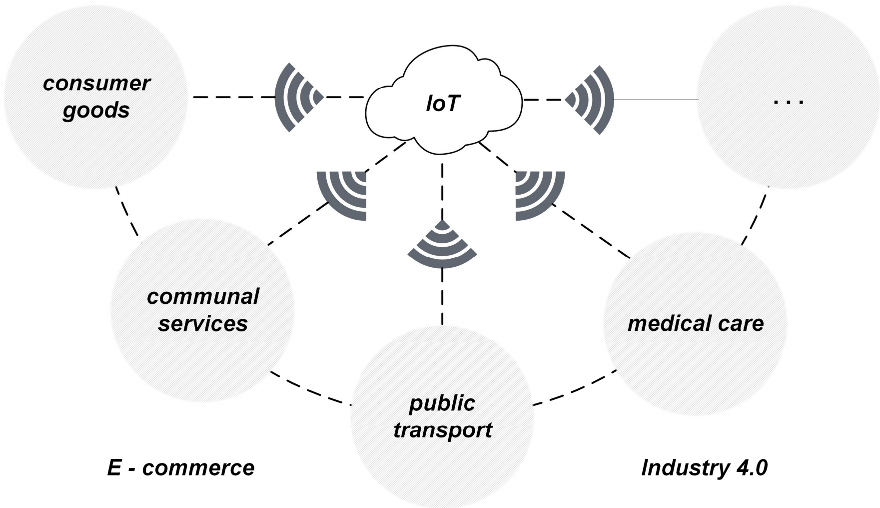

Figure 1. General flat IoT concept.

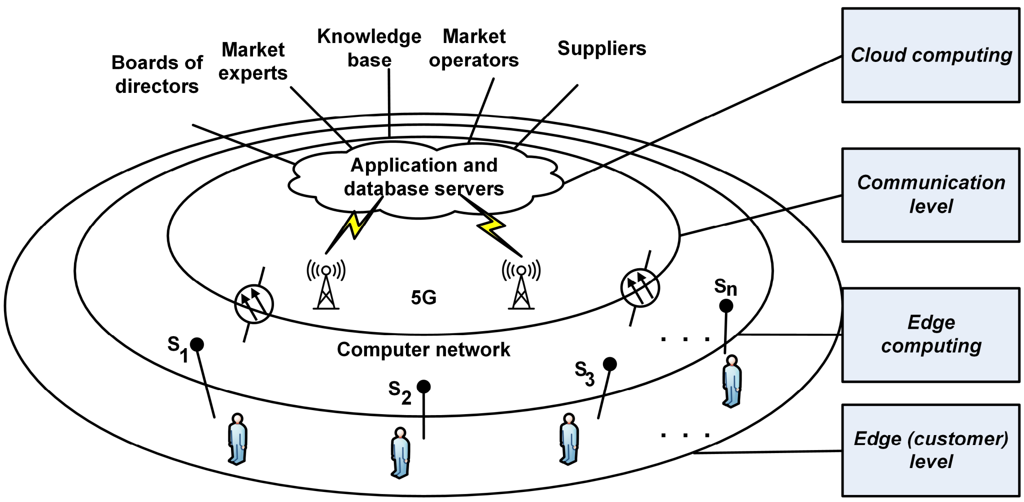

Figure 2. Flat IoT concept composed of cloud and communication levels.

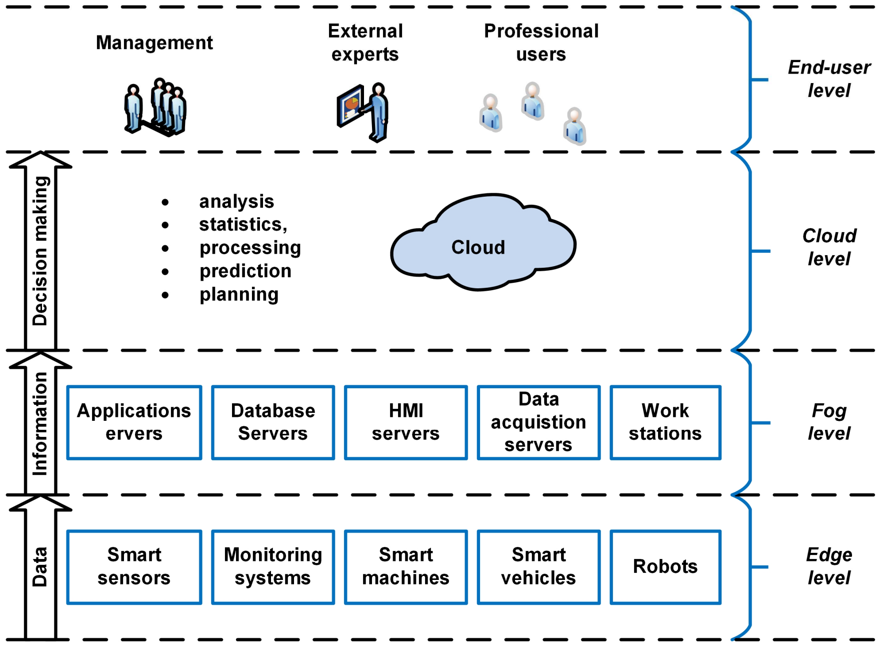

Figure 3. Vertical IoT concept.

When it comes to e-commerce, the IoT has numerous advantages [27]. Online orders create opportunities for better management of production and inventory. Some authors believe that the main advantage of IoT is inventory management and supply chain management over precise product tracking and locating [28]. The hands-on IoT applications enable the following improvements:

- High-quality commodity management (reducing warehouse costs and shortening delivery times).
- More efficient distribution and transport (goods tracking in real-time).
- Solving the problem of asymmetric information.

One of the significant drivers of the evolution of Industry 4.0 into Industry 5.0 is the need for environmental protection in a sustainable and human-centered industry in the digital age [29]. Commerce sustainability in Industry 4.0 depends on many factors and requires a combination of several scientific fields [30]. The evolution from Industry 4.0 to Industry 5.0 represents a fundamental shift from mass production to customized production.

The IoT vertical concept (Figure 3) is defined according to the process data $\rightarrow$ information $\rightarrow$ decision-making flow direction [31]. The end-user is a customer who uses the cloud services or information from cloud computing.

In Industry 5.0, customized production should be seen as a one-directional, multiphase process from customer needs to the final product. The need to focus on the end user should narrow the scope of a flat business. In addition to the "brick and mortar" stores, e-commerce in Industry 5.0 requires a vertical organization of IoT.

Several practical case studies have shown that the Industrial IoT (IIoT) vertical concept represents a well-ordered hierarchical framework for management, control, monitoring, and "in-depth" cyber security [31,32]. The following five steps define the vertical concept of IIoT:

1. Measuring;
2. Data gathering;
3. Data processing;
4. Information processing;
5. Decision making.

In light of the aforementioned, the e-commerce transformation requirements should be addressed through a transition from the flat IoT to the vertical IoT, leveraging machine learning models and algorithms. The IoT vertical structure implies hierarchical data and information processing distributed by IoT levels (edge, fog, and cloud). Even though an IoT environment produces a large amount of data, it is questionable how much can be directly used for IoT services [33]. From the "knowledge cycle value chain" aspect at the edge level, raw data transformation can be divided into four stages [34]: find, filter, format, and forward.

3.1. Frameworks and Concepts

According to MESA International, smart manufacturing indicates a composition of the business, physical, and digital processes that make up the value chain. Companies should reshape their electronic business (e-business) and offer better digital services to support economic growth in the Industry 5.0 era.

To beat the competition, many trading companies tailor their approaches to e-commerce and e-business, consequently causing market confusion. Sustainable development includes novel branches such as internet trade, online merchandising, electronic commerce, and electronic business. The authors developed a common framework for e-commerce in the IoT environment to harmonize different commerce strategies, methods, and models. E-commerce is a part of e-business that supports money transactions and information exchange. Nowadays, e-business is progressing rapidly because of the following fulfilled conditions: fast internet, a large flow of data and information, and the fusion of a few e-commerce types supported by artificial intelligence. Additional conditions include a stable social, economic, and business environment. The main advantages of e-commerce are the following: expanding the market, reducing business costs, greater efficiency, and 24/7 interaction with consumers. Below are the nine basic types of e-commerce:

1. G_2G—Government to Government;
2. G_2B—Government to Business (Government to Company);
3. G_2C—Government to Consumer (Government to Citizen);
4. B_2G—Business to Government (Company to Government);
5. B_2B—Business to Business (Company to Company);
6. B_2C—Business to Consumer (Company to Consumer/Citizen);
7. C_2G—Consumer to Government (Citizen to Government);
8. C_2B—Consumer to Business (Consumer/Citizen to Company);
9. C_2C—Consumer to Consumer (Citizen to Citizen).

Figure 3 shows the spatial allocation of consumer, business, and government e-commerce following the flat IoT concept that is the trademark of Industry 4.0. All these commerce types are arranged in three circular rings (levels) separated by two communication zones (Figure 4).

Figure 4 depicts three independent concentric rings defined by the same groups of users (C_2C, B_2B, and G_2G). Defining basic e-commerce rules is much easier to achieve among the same groups of consumers. It is much more difficult to establish rules and mutual relations between consumers who belong to different groups.

The IoT concept improves e-commerce by applying the following steps (procedures, tasks, and activities): data and information processing; tracking and logistics; manufacturer and customer interactions and experiences; supply chain and inventory management; market and goods analytics; maintenance and warranties; and reducing costs and increasing revenue.

The consumer and business levels should be viewed as flat (IoT) concepts (as circular disks in vertical order) with clustered sets of the same or similar companies and consumers. The communication level serves as the link between these two levels. The communication level is composed of fiber-optic, Wi-Fi (router connection), cellular (4G LTE and 5G), and GPS telecommunication networks. Business and government levels belong to the fog level and represent a vertical structure due to the strictly defined market positions of the companies and government organizations. These two levels are also interconnected by the communication level. The technical solutions for the upper communication level imply the application of fiber-optic, cellular (4G LTE and 5G), and GPS telecommunication networks, while Wi-Fi networks are less prevalent.

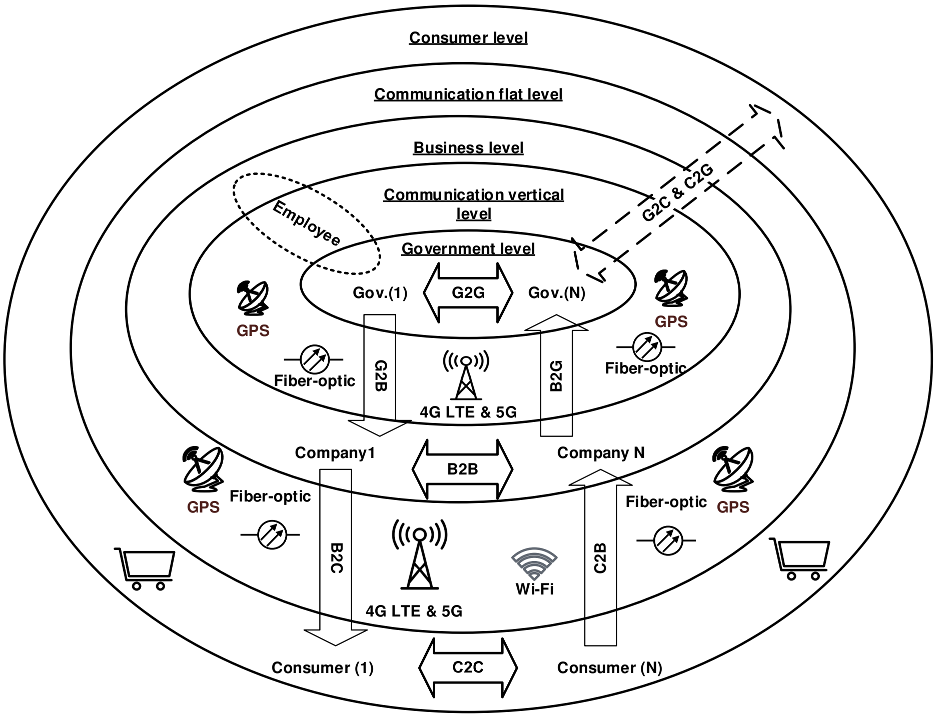

Figure 4. E-commerce and IoT (Industry 4.0)—flat concept.

The implementation of the vertical IoT concept implies the existence of a hands-on vertical e-commerce framework (Figure 5). The advantages of the proposed concept are the following: better business security, reliable information, faster decision making, and better ML algorithm selection.

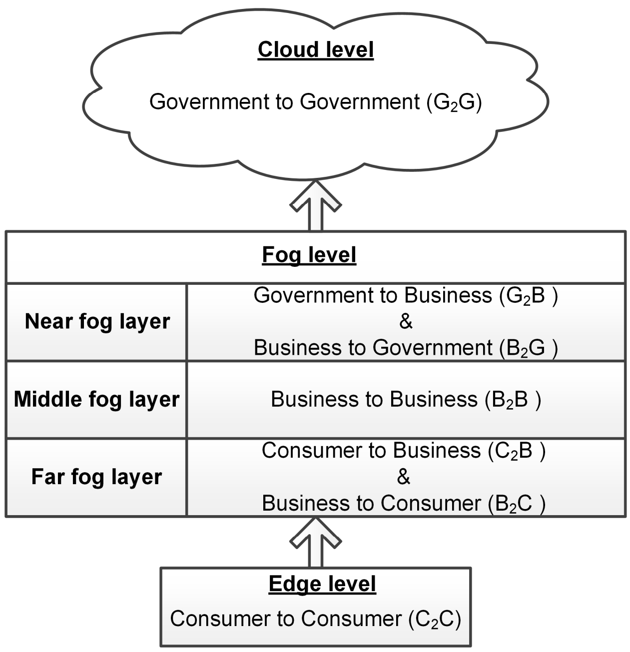

Figure 5. Vertical e-commerce framework in Industry 5.0.

The main disadvantage of information and communications technology (ICT) is cyber-attack vulnerability. Consequently, all types of electronic businesses are exposed to security risks. Data and information protection should be a key security target of any commerce organization [35]. Sustainability is not attainable without personal data protection and wellorganized e-commerce security. GDPR (General Data Protection Regulation) is a regulation enshrined in human rights and privacy laws and should be a security roadmap for conducting business in Industry 5.0. In addition to well-known hardware and software protections against cyber-attacks, e-commerce in the vertical IoT concept is additionally protected thanks to the frequent use of private clouds and an in-depth security strategy [19].

3.2. Cross-Border E-Commerce

Digital trade is defined by the US International Trade Commission as a transaction based on internet technology. The internet's emergence facilitates 24/7 global online electronic commerce. E-commerce overcomes the many challenges existing in traditional commerce: a unique online marketplace, global product accessibility, cost-efficiency of parcel delivery, mitigation of language barriers, overcoming currency differences, reliable and simple online payment methods, protection of personal data, etc. Online customers are motivated (by lower prices, a wide product range, etc.) to purchase across borders. This type of e-commerce, known as cross-border e-commerce (CBeC), has been rapidly growing in recent years [36]. CBeC is the youngest (tenth) type of e-commerce, involving buyers and sellers from all over the world [37]. Given the importance of e-commerce in smart environments and the digital market, the European Union has an interest in promoting CBeC.

4. Artificial Intelligence in E-Commerce

Business and commerce are the silent drivers of social and technical progress. Strategies for achieving sustainable development goals depend on market trends, the financial climate, and modernization. These strategies rely on economic methods and decision-making algorithms based on artificial intelligence. Artificial intelligence uses models, methods, and algorithms for prediction, classification, clusterization, object detection, object segmentation, control, management, monitoring, tracking, and decision making. Therefore, AI development encourages the development of a global smart environment and electronic market.

4.1. Fuzzy Logic in E-Commerce

The decision-making process depends on different sources, many data categories, and various linguistic formalisms. The influence of unpredictable external factors (pandemics, war, natural disasters, etc.) also makes it difficult.

Fuzzy logic has widespread applications in e-commerce. The fuzzy rules are created based on the opinions of market experts. Due to their frequent disagreements and different points of view on market trends, it is very convenient to use fuzzy logic models based on fuzzy logic systems—type 2. Figure 6 shows a fuzzy logic system type 2 (FLS-T2) that is improved and adapted for e-commerce.

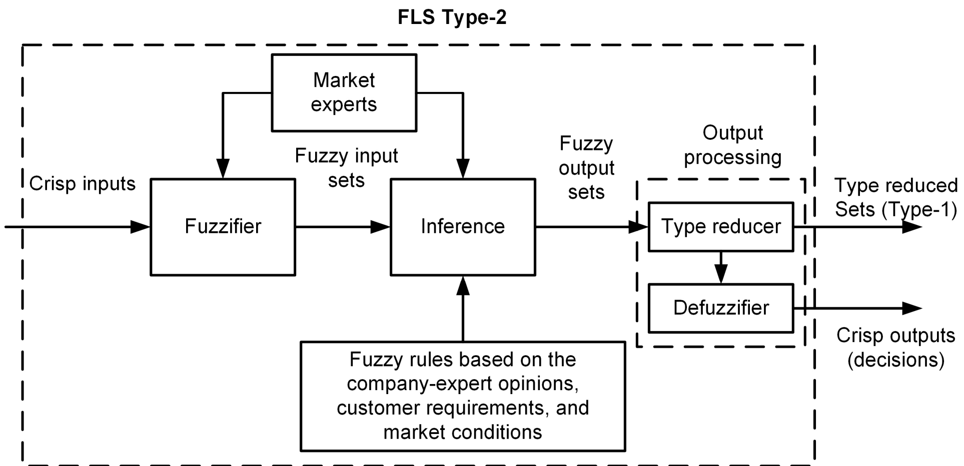

Figure 6. Improved fuzzy logic system type 2.

Unlike the well-known framework of the fuzzy logic system type 2 (FLS-T2) [38], Figure 6 shows an improved FLS-T2 framework emphasizing the influence of market conditions and expert opinions. FLS-T2 has a "footprint of uncertainty" (FOU). The Takagi–Sugeno–Kang fuzzy model, which is characterized by high precision and few fuzzy rules, is most often used.

4.2. Machine Learning in E-Commerce

Currently, the prediction accuracy obtained through conventional methods is generally deemed unsatisfactory [39]. The functional relationship between historical data and online data is a current issue that should be addressed with the help of data science and machine learning. The efficiency and performance of ML models depend on the quality and quantity of the training features [40,41]. Data preparation focuses on data identification, while data pre-processing refers to data selection, cleaning, and transformation [42]. There is a trend toward mass application of machine learning models and algorithms due to the need for fast real-time data processing. Some of them are widely used for their excellent performance.

Customer relationship management is defined as a mutual interaction between companies and customers using data integration from various sources [43,44]. E-commerce mostly relies on the market–customer–product relationship, based on which the databases are created [45,46]. E-commerce requires a continuous improvement on the order-to-delivery process by using omnichannel and multichannel marketing strategies.

Since Industry 5.0 focuses on the consumer, this paper proposes ML algorithms that are used in C_2C, C_2B, and B_2C business models. Figure 7 shows a vertical framework of four unified processes: data collection, data processing, information processing, and decision making.

The proposed vertical framework enables e-commerce sustainability by applying intelligent solutions that should meet the following requirements:

1. Customer segmentation;
2. Customer behavior analytics;
3. Intelligent demand forecasting;
4. Intelligent pricing;
5. Competitor price monitoring;
6. Automated content generation;
7. Product image analytics;
8. Quality of cross-border import e-commerce (CBeC) services;
9. E-commerce site search.

The success of C_2C commerce depends mainly on advertising. ML is used to predict target consumers and their purchasing behavior. Successful online C_2C e-commerce is based on a user-centric approach (behavioral targeting and user profiling) or a content-centric approach (real-time bidding and contextual advertising). The most commonly used algorithms for advertising are the following [47,48]:

1. Sequential pattern mining (SPM) algorithm for extracting keywords from online content.
2. Click-through rate (CTR) set of algorithms for clicking on the item prediction. Most of these algorithms are based on deep neural networks (DNNs).
3. The following algorithms are used to predict the audience attributes (gender, age, etc.): support vector machine (SVM), naive Bayes, and a few linear regression algorithms.

For behavior learning, the following algorithms are used: the Limited-Memory Broyden–Fletcher–Goldfarb–Shanno (LM-BFGS) algorithm, Boosted Decision Trees (BDTs), and some hybrid algorithms.

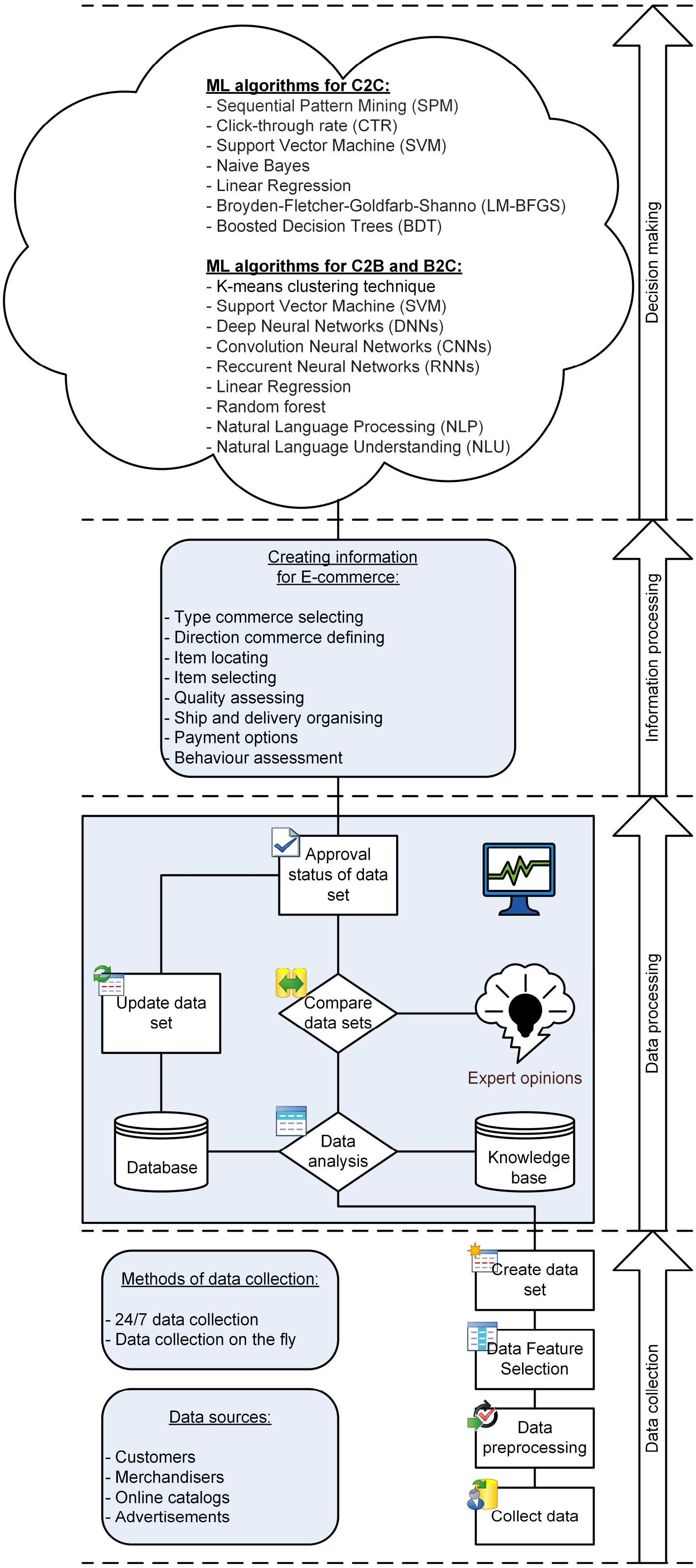

Figure 7. A vertical framework of four unified processes: data collection, data processing, information processing, and decision making.

C_2B and B_2C depend mainly on the e-commerce relationships between companies and consumers. First, it is necessary to understand global customer requirements and then their specific product customization requirements to achieve e-commerce sustainability [49]. Companies often use online services and smart devices and systems for better business:

1. Trust management technologies offer advanced solutions for e-commerce on an edge level. These solutions refer to the following algorithms: 1—ML models for clustering (K-means clustering technique); 2—ML models for classification using models to identify the nonlinear boundaries of trustworthy and untrustworthy interactions (support vector machine—SVM).
2. Online recommender systems for C_2B and B_2C business models predominantly use deep neural networks (DNNs) and convolutional neural networks (CNNs). CNNs can work with unstructured data obtained from the available online database.
3. Natural language understanding (NLU) algorithms and reinforcement learning (RL for training agents) algorithms for creating a chatbot or a personal assistant of natural language processing (NLP) are useful for C_2B and B_2C commerce [50]. Recurrent neural network (RNN) and reinforcement learning (RL) algorithms are principally used for these needs. Reward-focused RL algorithms are ideal for dynamic online tracking of consumer behaviors.
4. Company forecasting models use the following ML algorithms [51]: linear regression, random forest, support vector machine, deep neural networks, recurrent neural networks, convolutional neural networks, and transformers (TensorFlow library) for natural language processing.
5. The application of neural networks is for improving the quality of CBeC services, personal privacy, and shortening the delivery time [52].

The utilization of ML models and algorithms enhances the efficiency of the processes outlined in Figure 7, representing a positive feedback loop of accelerated development.

4.3. Convolutional Neural Networks (CNNs) in E-Commerce

Convolutional neural networks (CNNs) have many hands-on applications in electronic commerce, leveraging their image processing and pattern recognition capabilities. Algorithms for image processing, classification, and online tracking of user behaviors provide excellent predictions of user needs. A convolutional network is trained to minimize the output errors for a given training image set. CNNs are widely applicable in extracting features from e-commerce data, facilitating product classification, customer behavior analysis, and product sales forecasting [53–55]. CNNs have significantly improved the online processes of searching, classifying, and clustering products.

During the CNN training process, filters (kernels) are learned that perform adequate transformations on the input image. It is necessary to define the CNN architecture, which must be tested on a large dataset. The following Python pseudocode demonstrates the use of basic TensorFlow libraries and functions to create the CNN model (Figure 8).

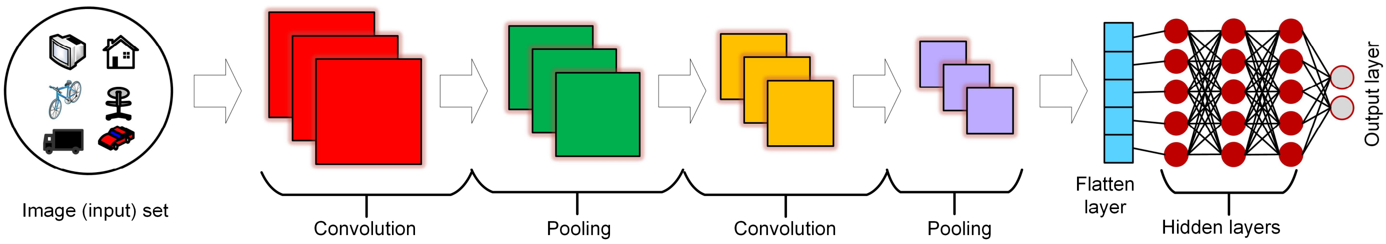

Figure 8. Convolution neural network (CNN).

Model Convolution Neural Network
Import libraries:
TensorFlow library, Keras, Sequential model, Dense layers
Defefine 2D model:
model = Sequential
First layer:
2D Convolutional 1. layer: (filters, kernel_size, activation, input_shape)
2D Pooling 1. layer: (pool_size)
Second layer:
2D Convolutional 2. layer (filters, kernel_size, activation, input_shape)
2D Pooling 2. layer (pool_size)
Flatten layer: flatten the 3D output to 1D array
Hidden Dense layers:
Dense 1. layer (neurons, activation)
Dense 2. layer (neurons, activation)
Dense 3. layer (neurons, activation)
Output classification layer:
Dense layer (units, activation)

E-commerce 24/7 portals are generating plenty of data and much information from customer reviews. Online CNN models and algorithms use these data and information to extract features with high availability.

4.4. E-Commerce Sustainability

Real-time data and information exchange have significantly improved all e-business branches [56]. E-commerce is the buying and selling of goods and services, or the transmitting of funds or data, over an electronic network, primarily the internet. The following four factors affect the long-term sustainability of e-commerce in the IoT [57,58]:

1. Quality of IoT services;
2. Security of IoT services;
3. Operating cost of IoT services;
4. IT knowledge of users.

Search site engines should enable fast database searching and answers to questions about companies, products, and services. Flexible, intuitive, and quickly executable site-searching algorithms are very important for boosting visitor experience and building customer loyalty. The development of state-of-the-art complex algorithms often implies the aggregation of several ML models. E-commerce in the future e-market ultimately requires never-ending improvements in ML models and algorithms. It is necessary to emphasize that future customer-oriented e-commerce in Industry 5.0 should create the ultimate conditions for better cyber protection.

5. Discussion

Today's social trends are rapidly opening up a large number of economic issues. The authors recognized the necessity of a hierarchical concept of e-commerce to meet the strict requirements of Industry 5.0. In the context of transformation toward Industry 5.0, the development of technology is oriented toward the following: networked sensors, digital twins, artificial intelligence, and greener and more sustainable environmental and social criteria.

The second chapter deals with the place and role of e-commerce in IoT and smart environments during the transition from Industry 4.0 to Industry 5.0. The main similarities and differences between Industry 4.0 and Industry 5.0 are given in Table 1 [59–61].

The IoT has attracted great global attention and successfully unified almost all e-commerce flows, becoming a driver for many smart industrial and social entities: smart cities, smart factories, intelligent medical, intelligent transportation, intelligent justice, intelligent agriculture, etc. The key drivers of most future technologies are the following: cloud computing, cyber–physical systems, artificial intelligence, augmented reality, decision making, tools, and autonomous robots.

Table 1. Similarities and differences between Industry 4.0 and Industry 5.0.

Similarities	Differences
AI technologies and robotics	Ind. 4.0—technology-driven Ind. 5.0—human-centered
Data-driven decision making	Ind. 4.0—automation and machine-centric operations Ind. 5.0—human–machine collaboration
IoT and smart devices	Ind. 4.0—economic efficiency and productivity Ind. 5.0—environmental and social sustainability
Flexibility and adaptability	Ind. 4.0—intelligent products Ind. 5.0—intelligent production

Sections 3 and 4 focus on hands-on implementations of fuzzy logic and machine learning algorithms, targeting three key e-commerce types (B_2B, C_2C, and C_2M) within the vertical IoT architecture. Artificial intelligence is a form of intelligence that involves machines being programmed to possess problem-solving and decision-making abilities and carry out tasks that are similar to humans. IoT is used for many business activities in Industry 4.0. The presented four unified processes (data collection, data processing, information processing, and decision making) are the logical and conceptual basis for e-commerce sustainability in the future with an orientation toward consumers. Machine learning (ML) can be integrated into various computing paradigms, including edge computing, fog computing, and cloud computing. ML algorithms and models for hierarchical computing on edge, fog, and cloud levels are necessary for the hands-on vertical e-commerce concept. The authors emphasize that the benefits of using ML in e-commerce models should be expected in the following applications:

1. Product recommendations;
2. Personalized marketing;
3. Improved search and navigation;
4. Fraud detection and security;
5. Dynamic pricing;
6. Customer segmentation;
7. Behavioral and sentiment analysis;
8. Inventory management;
9. Sales forecasting;
10. Real-time trend monitoring.

Fuzzy logic plays a significant role in electronic commerce by addressing the inherent uncertainties, imprecisions, and complexities in decision-making processes. Fuzzy logic type 2 can find a valuable place in electronic commerce by addressing the higher levels of uncertainty and different expert opinions in decision-making processes. The choice of fuzzy logic type should align with the characteristics of the data and the complexity of the decision-making process in the e-commerce context [16]. The presented type-2 fuzzy logic system emphasizes the role of market experts (human experts, expert systems, or AI agents) in two important processes: the creation of fuzzy rules and inference.

Artificial intelligence is rapidly developing. This paper provides strategic frameworks and presents AI tools for e-commerce in a future smart environment. A few new technologies, in addition to artificial intelligence, are greatly enhancing e-commerce. Blockchain is a method of recording information that makes it impossible or difficult for the data to be changed or hacked. It operates through a distributed ledger that copies and distributes transactions throughout the computer networks. Fifth-generation mobile communication (5G) technology represents the following benefits: high speeds, low latency, increased network capacity, and support for massive IoT deployments. The synergy of these technologies has the potential to create a solid and secure foundation for a wide range of e-commerce applications.

6. Conclusions

Economic sustainability takes on a new dimension in the Industry 5.0 era. The development of e-commerce models requires multidisciplinary knowledge from different scientific fields (economics, mathematics, artificial intelligence, information technologies, telecommunications, etc.).

This paper deals with hot e-commerce issues and the Internet of Things through the transition between Industry 4.0 and Industry 5.0. The presented vertical data processing and decision-making concepts should support and accelerate the transition from mass production to customized production. The fundamental differences between the flat and vertical IoT concepts are explained.

There are three main contributions in this paper.

One of the ongoing challenges with Industry 5.0's strategic approaches to e-commerce in a future smart environment is how to conceptualize e-commerce within a multi-level vertical Internet of Things framework. The conceptualization of e-commerce in a multi-level vertical IoT framework is the first contribution of this paper. Trend monitoring, multi-parameter analysis, and real-time prediction have become essential for timely decision making. The paper shows a comprehensive analysis of the vertical IoT concept and the vertical placement of data science and machine learning algorithms and models in the proposed framework.

E-commerce classification requires a methodical approach in terms of appropriate ML algorithms and models. The second contribution is the classification of ML algorithms according to the nine basic types of e-commerce.

Given the increased dimensionality of market demands, finding the best commercial model is a very demanding and never-ending process. Large companies are continually searching for the best business model. The third contribution is the selection of the e-commerce type according to the flat (concentric rings) and vertical levels.

Data collection occurs at the edge level, the most vulnerable to cyber-attacks. In future work, the authors' research will focus on online data sources and cyber-security AI tools at the edge level of the IoT.

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