INTERNATIONAL JOURNAL OF RESEARCH AND INNOVATION IN APPLIED SCIENCE (IJRIAS)
ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume IX Issue VIII August 2024

Technologies that are Anchored on Event Driven Architecture and their Impact on the Digital Economy

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DOI: https://doi.org/10.51584/IJRIAS.2024.908050

Received: 23 August 2024; Accepted: 30 August 2024; Published: 16 September 2024

ABSTRACT

Event-Driven Architecture (EDA) has emerged as a pivotal framework in the digital economy, revolutionizing how systems are designed, implemented, and operated. By focusing on the production, detection, and reaction to events, EDA enables systems to be more responsive, scalable, and flexible. This research paper explores various technologies anchored on Event-Driven Architecture and examines their profound impact on the digital economy. Key technologies such as artificial intelligence (AI), the Internet of things (IoT), big data, block chain, 5G, 3Dprinting, robotics and drones are analyzed to understand their roles in enhancing real-time data processing, enabling micro services, and facilitating seamless integration across diverse systems. The study highlights how these technologies contribute to operational efficiency, customer experience, and business agility, while also addressing challenges related to implementation and management. The findings provide insights into how leveraging EDA can drive innovation and competitiveness in the digital economy, offering a roadmap for organizations aiming to harness the full potential of event-driven systems.

Keywords Frontier technologies, event-driven architecture, service-oriented architecture, Internet of Things

INTRODUCTION

In today's digital economy, where quick responses to market shifts and customer needs are essential, traditional monolithic architectural models are being increasingly replaced by more adaptable and flexible approaches. Event-Driven Architecture (EDA) has emerged as a key paradigm that meets the demands for real-time data processing and agile system design. EDA revolves around the creation, detection, and consumption of events—significant state changes that trigger automated responses or actions within a system. This type of architecture is particularly beneficial in environments that require high scalability, responsiveness, and integration across diverse systems.The shift towards EDA is driven by the need to support complex, distributed applications across various sectors, such as finance, e-commerce, and telecommunications. Technologies like artificial intelligence (AI), the Internet of Things (IoT), big data, blockchain, 5G, 3D printing, robotics, and drones are central to EDA, each bringing unique capabilities for real-time event handling, microservices orchestration, and the integration of disparate systems. These technologies enable the development of systems that are not only more adaptable but also capable of delivering improved user experiences and operational efficiencies.

The objective of this study is to explore technologies based on Event-Driven Architecture and evaluate their impact on the digital economy. By examining the features and applications of leading EDA technologies, the study aims to understand how they enhance business agility, innovation, and competitiveness. Additionally, the paper will address the challenges of adopting EDA technologies, such as issues related to system complexity, data consistency, and performance. Through a thorough analysis, this research will offer valuable insights into how organizations can effectively leverage EDA to succeed in the digital age, ensuring they remain responsive and resilient in a rapidly changing technological environment.

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LITERATURE

The transition towards a circular economy (CE) is increasingly becoming a strategic priority for organizations around the globe. CE is seen as an alternative to the traditional linear economy, which operates on a "take–make–waste" model. Instead, CE is based on the principles of regeneration, maintaining continuous use of materials, reducing waste, and minimizing pollution (Ellen MacArthur Foundation, 2013). In this approach, the conventional 'end-of-life' concept is replaced by strategies that prioritize reducing, reusing, recycling, and recovering resources. However, shifting from a linear to a circular economy is often impeded by challenges such as data shortages and difficulties with integration at both the firm and ecosystem levels. Researchers argue that a successful transition to CE is closely linked to digital transformation (Ajwani-Ramchandani et al., 2021; C. Chauhan et al., 2019; Ingemarsdotter et al., 2019), which involves utilizing technologies like big data, artificial intelligence (AI), block chain, the Internet of Things (IoT), and cloud computing. There is a consensus among scholars that adopting CE is inherently connected to digitalization, as it facilitates predictive analytics, tracking, and monitoring throughout the product lifecycle (C. Chauhan et al., 2019).

Problem of the Study

With the rapid advancement of technology, it is essential to comprehend the effects and possible impacts these developments may have on different industries and economic sectors.

RESEARCH METHODOLOGY

The researcher conducted an integrated literature review to identify relevant research articles and projects on emerging technologies worldwide. A total of 300 scholarly articles on event-driven architectures were reviewed, using open-access repositories or databases that offer free access to research publications. A critical analysis of these scholarly articles and reports was performed to evaluate the global impact of these technologies on the digital economy and to predict future user adoption trends

Event-Driven Architecture

According to L. Riberio et al. (2010), an event-driven architecture (EDA) is a framework where components are activated by events. In a business setting, an event represents a change in the state of a business process element that affects the process's outcome. Events, being abstract constructs, are represented as event objects. These objects enable machines to process, calculate, and manipulate the events. The primary components of an EDA include event sources or generators, event recipients or consumers, event sensors, and event processors. Event sources and consumers can be linked either directly (point-to-point) or through middleware or a broker (bus). An event source might be an application, business process, internal or external stakeholder, or any other entity that observes data changes (Magoutas et al., 2013). Event recipients are all the interested subscribers. Event capturing and delivery must adhere to compatibility standards and can be managed by an additional component known as the event agent. The event processor handles the logic for gathering and directing events. Incoming events are processed and then sent to event consumers in real-time, either predefined or flexible ("soft" real-time). An event consumer reacts to received events by executing its function or issuing an alert according to Krumeich et al, (2014).

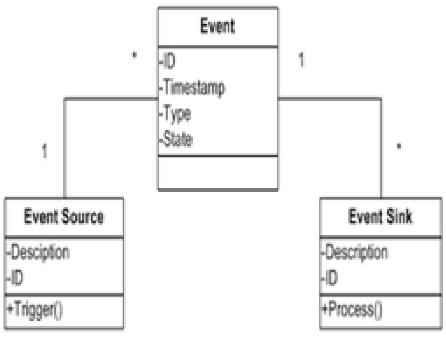

Figure 1: Event-Driven Architecture **source**: **Smith, J. (2014).**

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Based on this understanding, there are three types of events that need to be handled: single events, event streams, and complex events. Processing these events involves operations on event objects such as creation, transformation, reading, or deletion. Furthermore, the complex event processing (CEP) technique summarizes the algorithms for handling multiple or interconnected events. CEP improves the identification and extraction of structured information from message-based systems. It involves analyzing and correlating events to deliver information that triggers decisions. CEP defines relationships between events using business rules, patterns, maps, and filters, as described by Clark et al. (2012). Event monitoring is supported by business activity monitoring (BAM) tools, which are typically part of a business process management suite. These tools are currently more focused on detecting events and displaying them on a dashboard rather than making automated decisions, thus requiring less computational intelligence.

DISCUSSION OF FINDINGS

ICT Technologies Based on Event-Driven Architectures and Their Impact on the Digital Economy. Frontier technologies refer to a set of emerging technologies that leverage digitalization and connectivity to amplify their effects. These technologies include artificial intelligence (AI), the Internet of Things (IoT), big data, block chain, 5G, 3D printing, robotics, and drones. According to Grunwald (2018), these frontier technologies already form a $350 billion market, which could expand to over $3.2 trillion by 2025. To provide context, the current global market for laptops stands at $102 billion, while the smartphone market is $522 billion. Although some projections for frontier technologies might be overly optimistic and may involve significant double-counting, their potential impact on the digital economy is considerable.

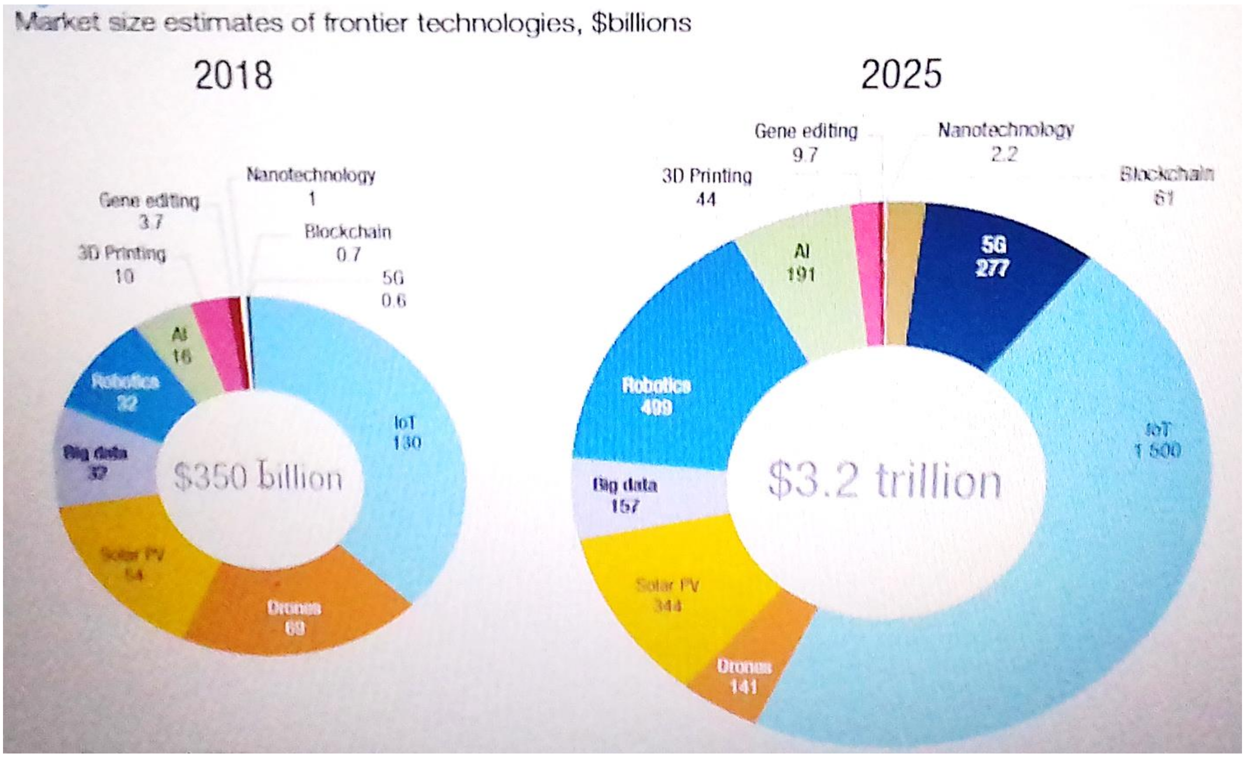

Figure 6.1: Statistics of the impact of “Frontier Technologies” on the digital Economy

Source: (Technology & Innovation Report, 2023)

Block chain

Block chain is a technology that uses an immutable, time-stamped series of data records managed by a network of computers, with no single entity owning the entire network. It is the foundational technology for cryptocurrencies, facilitating peer-to-peer transactions that are transparent, secure, and quick. As outlined by Walport (2016), block chain allows for the easy collection, integration, and sharing of transactional data from various sources, including cloud services. When someone requests a transaction, it is verified and then

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represented as a new block. Verified transactions can include cryptocurrency exchanges, contracts, records, or other types of information. The new block is subsequently added to the existing block chain. The requested transaction is broadcast to a peer-to-peer network consisting of computers known as nodes, which validate the transaction using cryptographic methods. Cryptocurrency functions as a medium of exchange, like the US dollar, and is created and stored electronically within the block chain. Encryption techniques are employed to manage the creation of new monetary units and to verify fund transfers, as explained by Anwar (2019).

The Statistics

U.S. companies are the leading providers of block chain services. Among the top block chain-as-a-service providers are Alibaba (China), Amazon, IBM, Microsoft, Oracle, and SAP (Germany) (Oxford Business Group, 2016). The finance, manufacturing, and retail sectors are the top users of block chain technology, measured by spending (IDC, 2019b). Block chain is a feature-specific technology, so the final cost depends on the particular project requirements, with development costs typically ranging from $5,000 to $200,000.

Although the block chain market was relatively small compared to other frontier technologies, valued at $708 million in 2017, it is expected to grow rapidly (Market Research Future, 2019). block chain applications have expanded beyond financial transactions, such as online payments and credit/debit card payments, to include IoT, healthcare, and supply chains. However, potential market constraints include issues with scalability and security, uncertain regulatory standards, and challenges integrating block chain with existing applications.

According to Market Research Future (2019), growth in demand is mainly driven by the increase in online transactions, digitization of currencies, secure online payment gateways, rising interest from the banking, financial services, and insurance sectors, and the growing number of merchants accepting cryptocurrencies. Grand View Research (2019) notes a significant increase in the block chain job market, with demand for block chain engineers in the U.S. growing by up to 400% between 2017 and 2018, translating into market sizes of $708 million in 2017 and an estimated $61 billion by 2024. Rodriguez (2018) points out that block chain engineers earn an average salary of $150,000-$175,000 per year, compared to the $135,000 average salary for software engineers. Major technology companies such as Facebook, Amazon, IBM, and Microsoft, which are actively recruiting talent in this field, have been significant drivers of this trend (Rodriguez, 2018)

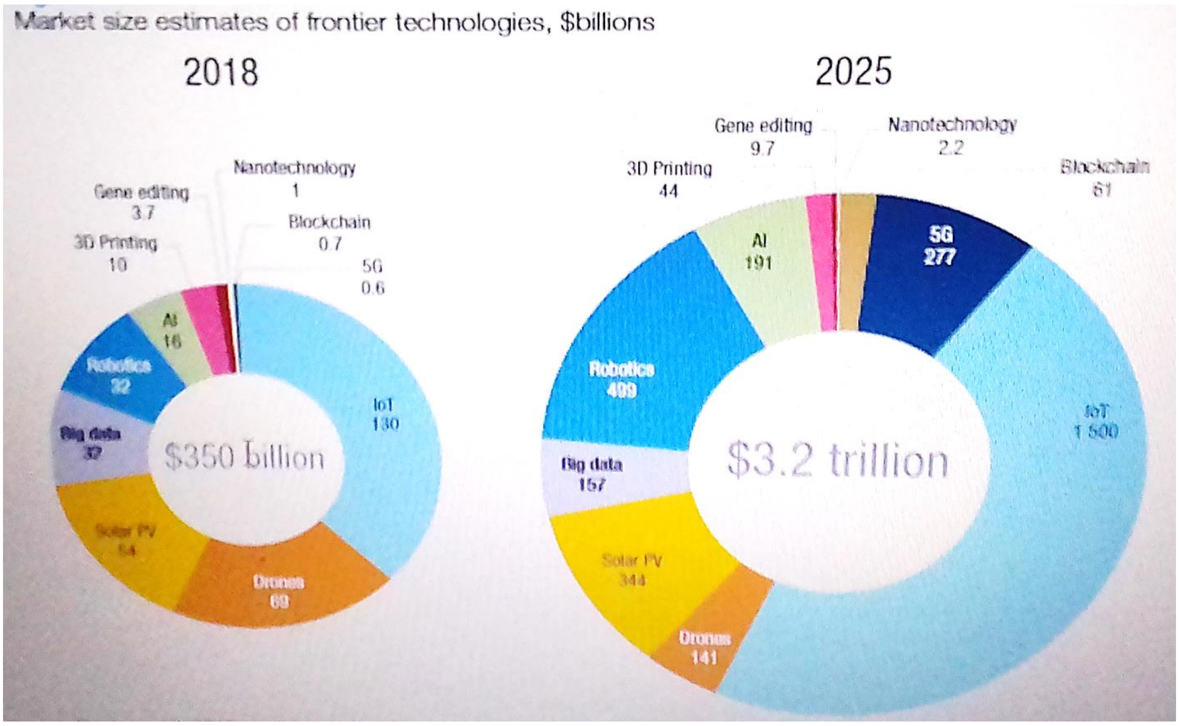

Figure 6.1: Statistics of the impact of "Frontier Technologies" on the digital Economy

Source: (Technology & Innovation Report, 2023)

Big Data

Big data refers to datasets that are too large or complex for traditional database systems to handle effectively. This technology allows computers to access and utilize data that was previously inaccessible or unusable, leveraging business intelligence techniques to extract value. Adopting big data technology offers several advantages, including more precise pricing, enhanced customer targeting, and a shift in insurers' roles from reactive claims processors to proactive risk advisors. This also suggests a potential gap between companies that effectively utilize data and those that do not. Companies that leverage data will be able to price products based on a more profound understanding of risk, while those that do not will compete primarily on price, resulting in lower profit margins and higher payouts (Manyika et al., 2011).

Statistics

According to Verma (2018), U.S. companies are leaders in the big data market, with major providers of big data services including Alphabet, Amazon, Dell Technologies, HP Enterprise, IBM, Microsoft, Oracle, SAP (Germany), Splunk, and Teradata. The top sectors based on big data service spending are banking, discrete manufacturing, and professional services. IDC (2019d) notes that the cost of big data systems varies based on their purpose; for instance, maintaining data warehouses can cost between $19,000 and $25,000 per terabyte (TB) annually. Thus, a data warehouse with 40TB of data (a typical size for many large enterprises) would require an annual budget of around $880,000, assuming a cost of $22,000 per TB. Aziza (2019) projects that the big data market, valued at $31.93 billion in 2017, is expected to grow rapidly to between $32 billion and $157 billion by 2026. Market Watch (2019a) attributes growth on the supply side to increased internet usage, cloud services adoption, and rising data volumes and mobile devices. However, Market Watch (2019) also points out that a shortage of skilled workers is hindering market growth. On the demand side, growth is driven by the finance sector's adoption of big data for risk management and customer service, along with rising demand for real-time analytics across various sectors. Nonetheless, the lack of awareness about big data benefits, along with privacy and security concerns, could impede market growth (Market Watch, 2019).

Internet of Things (IoT)

The Internet of Things (IoT) refers to a vast network of internet-enabled physical devices that collect and exchange data. Kevin Ashton first introduced the term "Internet of Things" in 1999 to describe a set of interoperable objects connected through radio-frequency identification (RFID) technology (Gawali & Deshmukh, 2019). Similarly, Oberländer et al. (2018) explain that IoT involves the connectivity of physical objects, including sensors and actuators, through data communication technologies powered by the internet. This rapid growth and widespread adoption of IoT are largely due to the increased use of smart devices over the past decade. The advancement and ubiquity of internet technology have created a world where devices can connect to the internet, providing access to information anytime and anywhere. IoT represents a major innovation in pervasive computing, contributing to a global network of information that supports new and complex services (Patel & Cassou, 2015). For instance, universities use IoT technologies like campus-wide Wi-Fi to allow students and staff to access information and services based on their location, such as finding lost students via interactive maps or checking the availability of study rooms.

Statistics

According to DA-14 (2018), U.S. companies are leading providers of IoT services, with major IoT platform providers including Alphabet, Amazon, Cisco, IBM, Microsoft, Oracle, PTC, Salesforce, and SAP (Germany). In 2018, the top sectors in terms of IoT spending were consumer, insurance, and healthcare. Business Wire (2018) notes that the cost of IoT systems varies by application; for example, ECG monitors range from $3,000 to $4,000, environmental monitoring systems start at $10,000, energy management systems begin at $27,000, and building and home automation systems start at $50,000. The IoT market, valued at $130 billion in 2018, is expanding rapidly and is projected to reach $1.5 trillion by 2025 (Froese, 2018). On the supply side, growth is driven by advancements in semiconductor technology, which enable more efficient and lightweight devices. Research Nester (2019) attributes demand-side growth to factors such as rising demand for advanced consumer electronics, increasing adoption of smart and internet-enabled devices, the growth of tele-healthcare services, and the rise of automation technology across various sectors. Despite this growth, Verified Market Research (2019) highlights concerns about cybersecurity risks and privacy, which could hinder market expansion, as well as a shortage of skilled workers. Research Nester (2019) reports that in 2017, the global IoT industry comprised 2,888 companies employing around 342,000 people, struggling to find skilled professionals to keep pace with rapid growth. Bjorlin (2017) notes that in 2017, the companies with the largest number of IoT-related employees were IBM (4,420), Intel Corporation (3,044), Microsoft (2,806), Cisco (2,703), and Ericsson (1,665).

Robotics

Robots are programmable machines capable of performing tasks and interacting with their surroundings through sensors and actuators, either autonomously or semi-autonomously. They come in various types, including disaster response robots, consumer robots, industrial robots, military/security robots, and autonomous vehicles (Broussard, 2018).

Statistics

According to Technavio (2019), much of the robotics research is centered in the United States. From 1996 to 2018, leading manufacturers of industrial robots included ABB (Switzerland), FANUC (Japan), KUKA (China), Mitsubishi Electric (Japan), and Yaskawa (Japan). Major players in humanoid robotics are Hanson Robotics (Hong Kong, China), Pal Robotics (Spain), Robotis (Republic of Korea), and Softbank Robotics (Japan). For autonomous vehicles, leading manufacturers are Alphabet/Waymo (United States), Aptiv (Ireland), GM (United States), and Tesla (United States). Mitrev (2019) highlights that the top sectors in terms of robotics spending are discrete manufacturing, process manufacturing, and resource industries. IDC (2019c) notes that robot prices vary by type; industrial robots cost between $25,000 and $400,000, while humanoid robots range from $500 to $2,500,000. The robotics market is projected to grow significantly, with estimates reaching $32 billion in 2018 and $499 billion by 2025. Growth in robotics is moderate, with the U.S. having 132,500 robotics engineers in 2016 and a projected job growth rate of 6.4% from 2016 to 2026. Career Explorer (2020a) identifies various robotics careers, including Robotics Engineer, Software Developer, Technician, Sales Engineer, and Operator

5G

5G is anticipated to surpass ultra-broadband networks and integrate existing technologies such as the Internet of Things (IoT), cloud computing, big data, artificial intelligence, and blockchain to foster innovative services. Besides enhancing speed, 5G is notable for its significantly lower latency, with delays of less than one millisecond (ms), which is nearly instantaneous in real-world terms. Unlike current IoT services, 5G is expected to enable a vast expansion of IoT capabilities due to its high bandwidth, extensive coverage (approaching 100%), and ability to connect numerous devices. This will create an ecosystem where "smart networks" can be employed for large-scale medical devices and real-time interactions (Khan et al., 2019).

Statistics

Auchard and Nellis (2018) indicate that various global companies will be major suppliers of key 5G components, including network equipment and chips. Leading 5G network equipment suppliers are Ericsson (Sweden), Huawei (China), Nokia (Finland), and ZTE (China). Major chipmakers in this field include Huawei (China), Intel (United States), MediaTek (Taiwan), Qualcomm (United States), and Samsung Electronics (Republic of Korea). According to La Monica (2019), the largest 5G-enabled sectors by 2026 are expected to be energy utilities, manufacturing, and public safety. Reichert (2017) notes that in the early stages around 2017-2018, 5G technology prices were limited, with Verizon charging $10 more per month compared to 4G, AT&T charging $20 more for mobile hotspots, and T-Mobile maintaining its prices. Horwitz (2018) highlights that the early adopters of 5G technology are expected to be the Republic of Korea, China, Japan, and the United States. The 5G market, valued at $608 million in 2018, is projected to double annually until 2025 (SDxCentral, 2017). Raza (2019) mentions that achieving broad 5G coverage will take about five years, with infrastructure upgrades such as microcell towers and base stations posing potential cost barriers. MarketWatch

(2019) reports that demand growth is driven by the rising need for mobile broadband, increasing smartphone and smart wearable use, greater mobile video consumption, advancements in IoT, and the development of smart cities and cloud-based solutions. Business Wire (2019) estimates that by 2035, the global 5G value chain will support 22 million jobs worldwide, with China leading at 9.5 million jobs, followed by the United States with 3.4 million, and Japan with 2.1 million.

3D Printing

Also known as additive manufacturing, 3D printing creates three-dimensional objects from a digital file. This technology allows for the production of complex shapes using less material compared to traditional manufacturing methods. It can produce very thin layers made from materials like plastic or metal. Initially termed Rapid Prototyping, 3D printing was first used to create small models that would later be scaled up. However, with advancements, 3D printers are now capable of producing larger objects by using CAD designs to print separate parts that are then assembled. Additionally, 3D printing is now utilized in fields such as nanotechnology and biological engineering to fabricate robots and tissues. The integration of computational technologies like machine learning, artificial intelligence, and programming languages such as Python has enhanced the quality and versatility of 3D printing, making it valuable for various scientific applications (Akio et al., 2012).

Statistics

Neufeld (2019) reports that American companies lead the 3D printing industry, with major manufacturers including 3D Systems, ExOne Company, HP, and Stratasys. The primary sectors using 3D printing technology, based on spending, are discrete manufacturing, healthcare, and education. The cost of 3D printers has decreased, with entry-level models available for around $200 and high-end industrial printers costing over $100,000. The average consumer 3D printer is priced at approximately $700 (PwC, 2020). Once a niche market, 3D printing is now expanding rapidly, with the market size growing from $9.9 billion in 2018 to an estimated $44.39 billion by 2025, reflecting a compound annual growth rate of 24% (Sawant & Kakade, 2018). This growth is driven by advancements in technology, which have increased the variety of printable materials (shifting from plastic to metal), improved production speed, expanded the size of printable objects, reduced errors and costs, and enabled customization. The rise in demand is largely due to its applications in healthcare, consumer electronics, automotive, dentistry, food, fashion, and jewelry. Grand View Research (2018) highlights that the growing market is creating a demand for skilled professionals, including engineers, software developers, material scientists, and business support roles such as sales and marketing specialists

Artificial Intelligence (AI)

AI refers to a machine's ability to perform cognitive tasks typically handled by the human brain (Colom et al., 2010). Today, AI is commonly used for specific applications such as online shopping recommendations, virtual assistants on smartphones, and detecting spam or credit card fraud. Modern AI implementations leverage machine learning and big data.

Statistics

According to Botha M. (2019), the United States leads in AI service provision, with major players including Alphabet (with its subsidiaries Google and DeepMind), Amazon, Apple, IBM, and Microsoft. The primary sectors utilizing AI, based on spending, are retail, banking, and discrete manufacturing. While the cost of AI varies depending on the application, it is generally becoming more affordable (IDC, 2019c). The AI market was valued at $16 billion in 2017 and is expected to grow significantly, reaching $191 billion by 2024 (MarketsandMarkets, 2018). MarketWatch (2019i) notes that supply-side growth is driven by the expansion of big data, enhanced productivity, diverse application areas, substantial government funding, and advancements in image and voice recognition. On the demand side, growth is fueled by increased adoption of cloud-based services, rising demand for intelligent virtual assistants, and higher client satisfaction.

Drone

A drone, also known as an unmanned aerial vehicle (UAV) or unmanned aircraft system (UAS), is a flying robot that operates without a pilot or passengers on board. It can be controlled remotely via radio waves or autonomously using software with sensors and GPS (Rouse, 2018). While drones are often associated with military applications, they also serve various civilian purposes including videography, agriculture, delivery services, weather forecasting, waste management, mining, and telecommunications (Frey, 2014; Mahashreveta, 2018). The term "drone" originated from its early use in a 1935 play called "Queen Bee," which involved a pilotless target drone controlled by radio waves (Staff, 2018). John (2010) describes drones as Unmanned Aircraft Systems (UAS) that are controlled either by a human operator or onboard computer and may also be referred to as Unmanned Aerial Vehicles (UAV), Remote Pilot Vehicles (RPV), or Uninhabited Combat Aerial Vehicles (UCAV).

Statistics

U.S. companies lead in military drone manufacturing, while commercial drone production is dominated by firms from other countries. Key manufacturers of commercial drones include 3D Robotics (U.S.), DJI Innovations (China), Parrot (France), and Yuneec (China), while major military drone producers are Boeing (U.S.), Lockheed Martin (U.S.), and Northrop Grumman Corporation (U.S.) (Technavio, 2018a). The primary sectors investing in drones are utilities, construction, and discrete manufacturing. IDC (2018) forecasts modest growth for the drone market, which had a revenue of $69 billion in 2017 and is expected to reach $141 billion by 2023. TechSci Research (2018) attributes supply-side growth to advancements in digital technology, camera quality, drone specifications, mapping software, and sensory applications. However, privacy concerns and national security regulations may pose challenges. Lanjudkar P. (2017) notes that increased demand for GIS, LiDAR, and mapping services from sectors like agriculture, energy, and tourism is driving demand. The drone job market is expanding rapidly, with over 100,000 drone-related jobs expected to be created in the U.S. between 2013 and 2025 (Jenkins D. and Vasigh B., 2013).

CONCLUSION

Event-driven architectures hold the promise to transform the technologies of the fifth industrial revolution and the digital economy by facilitating real-time responsiveness, scalability, integration, event-driven data processing, innovation, and improved customer experiences. By harnessing these advantages, organizations can secure a competitive advantage, propel digital transformation, and excel in the fast-paced technological environment.

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