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Chapter 1: Understanding the convergence of artificial intelligence, big data, and cloud technologies in shaping the future of education and energy systems

1.1 Introduction

Education and energy sustain economic growth and development of a prosperous society and are essential to maintain readiness and capabilities for the nation (Annapareddy, 2022; Chava & Rani, 2023; Kannan, 2022). Higher education is an integral fabric of a society. In the United States, research performed by colleges and universities plays a dominant role in the development of new technology and hence contributes to the sustainable growth of the economy. Land-grant universities often have significant responsibilities for extension and outreach programs, enriching society, and empowering agricultural, economic, and social advancement. Therefore, research and education are tightly coupled through a proper academic and outreach faculty working closely to advance our understanding of fundamental principles and to accelerate the application and transfer of transformative technologies to support societal and economic well-being.

In the new age of the big data era, which directs the renaissance of artificial intelligence as the computing framework, machine learning becomes the tip of the spear of artificial intelligence research to address a wide range of applications in a people- and data-driven demand world. Over the past few decades, machine learning has revolutionized many fields by enabling machines to learn from data and experience. The mainstream approach of adapting artificial neural networks, also known as deep learning, as the learning models, and scaling the models up using sophisticated mathematical theorems, also known as big model mathematics, has produced an explosion of feasibility for machine learning for a wide range of applications in information technology over computing platforms. The majority of today's computing infrastructure for enabling AI development and deployment is powered by cloud technologies. The convergence of AI, big data, and cloud technologies has reshaped and will continue to shape how we produce, distribute, and enrich educational instruction and content in the post-pandemic future, and redefine the discourse of energy systems vital for the economic stability and military readiness of the nation.

1.1.1. Overview of Educational Technology Innovations

"Computer-based training (CBT)" refers to instruction or training delivered via a personal computer, generally over a local area network. It is interactive. The computer may be used as a tutor, guide, adviser, or even as a surrogate teacher. The program presents, guides, and monitors the progress made by the trainee. The goal of CBT is to facilitate learning via the use of computers, serving as the mediator between the information and the learner. Successful CBT, then, would be learning that is faster, more complete, and more accurate.

In computer-based training, users do learn, and they do so just as they learn from their teachers. There is a significant body of knowledge that explains how students learn and how to design materials. Computer-assisted instruction is subordinate to the computer, whereas with CBT, the computer is our servant. The primary points raised by this definition are: a CBT application is for schools, groups with common interests, or individual students; interaction is guided by the computer, and program interaction is under computer control; tasks are performed in self-motivated or self-directed mode and within a prescribed time frame or session-defined times.

1.2. The Role of Artificial Intelligence in Education

The dynamic nature of the world we live in requires that education be responsive not only to current needs but also to the continuously changing ideals and relations that make up human society. Recent discussions focus on exploring novel methods to support educational institutions and educators in the provision of learning opportunities that leverage digital technologies, such as learning analytics, cloud computing, content delivery systems, and mobile platforms, which are enabling policymakers to overcome some of the traditional limitations of educational systems regarding inclusiveness, quality, and relevance. The wave of digital transformation drives changes in some of the fundamental paradigms in educational strategies. One such change is a shift from a process-driven, informational perspective of education to a focus on knowledge-driven activities. Although still a matter of investigation and debate, knowledge-centric approaches rely on the promise that technology can play a critical role in separating content to be assimilated from the process to get there.

At the center of changes to the traditional educational processes is the use of data to enable better decision-making across faculty, curricula, and administrative bodies, looking for correlation patterns in educational data rather than intuitive expertise. In a world of information-technology-driven public and private life, digital natives live in a virtual world tightly integrated with the urban environment, where quantity and access to continuous feeds of data play a critical role. Digital technologies, particularly cloud computing and big data analytics, are changing the way we perceive and organize, and are valuable tools in shaping future education strategies. Proposed actions range from supporting curricula with online lecture delivery to organizing data-driven, flexible adaptive recommendations for students. Data under this perspective ceases to be a problem in itself—fast access and analysis rely on the widespread availability of big data cloud analytics services—or becomes a learned artifact of explorative activities represented and made accessible by the development of novel data representation methods.

Fig 1 . 1 : Understanding the AI/Cloud Convergence

1.2.1. AI-Powered Personalized Learning

The development of information and communication technologies has fostered research that can stimulate humans' learning skills. The development of advanced gaming software, hardware, and simulation environments allows the emergence of intelligent tutoring systems that can constitute personalized learning environments. The latest developments in artificial intelligence have allowed the creation of machines with the best human skills. The use of the big data that these systems produce is necessary to train these intelligent systems by those who created them. The use of remote servers to store data and run machine learning algorithms is possible through the use of cloud computing technology. The use of cloud technology over the internet is changing how education and work are undertaken. The use of machines to teach is possible through the use of chatbots that simulate humans when they take on the role of teachers. These initiatives are possible through the use of artificial intelligence techniques, large data, and cloud computing technology. The combination of the aforementioned technologies constitutes the main subject of this chapter. The integration of these technologies is essential for the creation of devices that allow the stimulation of students to carry out learning actions, anytime, anywhere.

The realization of personalization of education is still a challenge due to the high cost associated with providing individual attention to students without considering the places where learning actions can be taken. This is possible by translating a gamified and immersive learning environment into e-learning platforms. The use of chatbots makes online learning platforms gamified due to the possible simulation of humans and the ease with which students can establish communication. The use of computer simulation allows the assessment of intellectual actions, regardless of where they occur. Due to the significant use of the internet in e-learning platforms, cloud services enabled by the shared resources with which to store or run large data are often possible. The technological integration of advanced game software, big data, and cloud computing allows the establishment of a variety of new methodologies to teach natural science disciplines in engineering courses. These methodologies use games with gamified educational content that are usually assessed by cloud services that are part of platforms where educational data can be stored. One of the most important gamified educational trends foresees the installation of intelligent tutoring systems that use artificial intelligence techniques to act as genuinely stimulating and inspiring private teachers to guide students to achieve their learning objectives.

1.2.2. Automated Assessment and Feedback

Some of the simple cognitive tasks gradually vanished as they were automated (Sriram, 2022; Suura, 2025). These tasks, such as computation, translation, information retrieval, and manufacturing, were just a part of the nearly complete set of knowledge domains that AI once considered out of reach for machines. These advances enabled machines, either physical or virtual, to execute a wide range of tasks, leading to a new wave of digital transformation. In this new landscape, machines operate in a vast networked infrastructure, and the data is the fuel and the glue of digital services. They are transforming many areas of society, mainly economics, safety, ethics, and fairness. These machines have evolved, as well as the way data is collected, assimilated, and exploited. Regarding data management, the increasing number of data sources, such as radar signals, GPS inertial data, sensor networks, cameras, meters, vehicle and facility configurations, together with the increasing data volume, velocity, variety, and veracity, have led to an exponential explosion of different types of data.

The increasing digital transformation, associated with the massive production of data, has also reached the education ecosystem, leading to the concept of digital education. Digital education is providing excellent student experiences while creating data dividends—new insights from the growing wealth of analytics. It allows individual student needs, strengths, and goals to drive learning moments, provides individualized mentoring and coaching for students, personalizes content and programs, and increases student engagement with interactive learning experiences. Educational institutions that offer blended and online courses capture the experiences of learners along with the digital footprints they leave behind and leverage data from these rich experiences to engage and support students. These student experiences are the product of the ecosystem they are embedded in, including the modern learning technologies based on AI, big data, and cloud computing. These technologies are currently used or being developed in educational institutions for a broad set of tasks, such as understanding students' characteristics, behaviors, and interactions, improving instructional content or the environment to address student needs and strengths, and facilitating real-time, tailored feedback and educational interventions. They can be seen in the digital learning infrastructure as well as in the practically limitless number of digital courseware tools and the emerging software products used to develop and deliver integrated digital learning experiences.

1.2.3. AI in Educational Administration

AI is transforming educational administration for a more student-centered, responsive, and personalized educational experience (Chava & Rani, 2023; Kannan, 2022). Advances in AI have promising implications for advancing equity. AI technologies are being applied to facilitate intuitive and rewarding interactions among students, their classmates, peer educators, and the broader university environment. AI is impacting all aspects of university administrative structure, including student administration, finance, human resources, and research. It is impacting businesses, non-profit, and government agencies. Hyper-governance is reflective of the extensive integration of AI into the decision-making environment, which results from AI penetration areas beyond human expertise. The unique capabilities of AI that allow it to learn, interpret complex interactions, and make real-time decisions on complicated or unforeseen searches are a boon for administrators. Hyper-governance points to AI's capacity for creating direct value for students in educational administration. These new tools use natural language processing and cognitive capabilities to automate conversations that increase the quality of interactions between AI and humans, ultimately enriching the student-administrator experience. These tools arrive at decisions informed by their insights on individual students' academic records, including independent variables like socioeconomic demographics.

1.3. Big Data Analytics in Education

Education reform is typically justified on economic grounds. In a world where digital globalization of economies is creating unprecedented pressures for workers to upgrade their skills, education reform has become all the more important. The digital economy rewards those with high skills who can use advanced tools and information effectively. Experts are warning of sharp changes in labor markets, with weak demand for low-skilled workers and a premium put on experts and especially custom work. It is against this background that we consider the role of big data and analytics. If the future of the knowledge economy is predicated on high skills and education, we need to reconsider the role of analytics in finding patterns that can help train. In fact, education is one of the facets of people-facing services that big data is beginning to transform. There are many apps and companies trying to bring big data into the classroom or company training programs. With good data, we can obtain answers to many of the most pressing educational questions, from how individual students are progressing to the effectiveness of reforms, to equity in educational opportunity, to the necessary skills for the future. What is much less clear is how to harness data to answer that evaluation in a way that is credible and generalizable. Principals, districts, states, and education boards face constant streams of financial decisions regarding curriculum, achievement, quality of instruction, and the technical setting in which the school operates.

1.3.1. Data-Driven Decision Making

Organizations in the digital economy are embracing data-driven decision making. As organizations deal with rapidly increasing volumes of disparate, complex, high-velocity data, it becomes difficult to make insightful and effective decisions in many business areas without support. Big data applications, especially in business analytics and marketing, are further depleting the ranks of those with deep expertise in analytics. Hence, data-driven decision making is spreading in organizations of all sizes at an accelerated rate and shifts the role of the business analyst in these organizations. Due to this trend, the market for data skills is strong and hiring is active.

Data-driven decision making is becoming an essential part of all modern business and services, and will be essential for all business domains in the 21st century. Big data analytics technologies are developing rapidly and are replacing and changing decision-making processes in various domains. Today, the decision-making role of organizations is changing as analysis methods and tools are becoming increasingly popular. Organizations that embrace business analytics to realize their long-term strategic goals will benefit from increased top-line revenue, confidence in decision making, and improved risk management. Organizations are using business analytics to power their growth and industry transformation. High-performance manufacturers in the private sector use business analytics to create a competitive edge in their production tests.

1.3.2. Predictive Analytics for Student Success

Student success is a priority for higher education institutions since it reflects the preparation of the future workforce and their reputation. In the absence of live intervention, teaching and enhancing scholarship may be negatively affected. Those universities that do not utilize learning analytics to enhance the experience and support of students risk underachieving, which may impact reputation and business. Predictive analytics for student success is a broad field of educational data mining, influencing student retention, progression, and completion. It consists of four functional areas: reporting and visualization, early warning/alert, profiling and patterns such as activities, events, or learning styles, and behavior intervention.

The demand for learning analytics research has been growing while predictive models of academic performance have received increasing attention, being the most frequently used methods such as logistic regression, decision tree, and artificial neural networks. A system of learning analytics developed using big data to predict students' academic performance used Random Forest, an established machine learning algorithm. The results show that the developed system could be used in various universities as a pioneering tool in higher education settings for providing decision support to university administrators, academic advisors, and instructors. However, predictive analytics for student success and learning analytics have generated less practical and social impact in part due to the lack of transparency in the data that feed the models.

1.3.3. Challenges of Data Privacy

The prominent role of data in machine learning and AI techniques for educational systems brings new challenges, the most important of which is data privacy. In recent years, big data technologies have made detailed and micro-scale data processing, retrieval, and analytics a reality. Linking multiple datasets from different domains further enhances the impact of big data analytics in providing new insights and creating new opportunities. However, these new opportunities have been countered by challenges of data privacy. Data privacy refers to one's ability to keep their data hidden and secure. As new machine learning and AI techniques are developed to extract more useful information from a certain dataset, these same techniques might also be used to undermine the privacy protection in the datasets.

Building an intelligent tutor system leverages machine learning and big data technologies to uncover personalized learning patterns from the interaction of students in a learning environment. This personalized learning profile is highly sensitive, as it could reveal significant information about the student's knowledge level, interests, attitudes, and personal life. It is important for the intelligent tutor system to keep such data confidential. An open discussion about where the line should be drawn and how to draw the line in data privacy is necessary so that researchers from different research disciplines can collaborate to benefit from big data analytics. After the students' data is collected, we seek to minimize the authority of a single data holder by applying corresponding cryptographic tools to prevent a single breach from affecting all data holders.

1.4. Cloud Technologies in Education

Students are the cream of education. Their satisfaction results in the satisfaction of educational institutions. The level of student satisfaction may differ according to age, major, marital status, gender, internet usage frequency, and technological equipment available around them. These criteria are important aspects that provide an overview of the level of using cloud technologies in educational settings. It seems that our students are dissatisfied with what is offered to them by the educational departments. The management of the educational institutions appears to be using the current policy of charging the highest acceptable level of tuition to maximize profit for their own budgetary expansion, rather than using the surplus to expand the facilities available to deprived students. Educational technology, i.e., the utilization of learning resources, such as information and communication systems for maximizing the efficiency and effectiveness of education, could be the only source that will predict future educational gains and economic potential for the technological advancement of new cloud computing systems. The management of the university sector will face stiff competition and will have to adjust its academic management strategies to attract better students by offering preferred programs. The employees who work, help, assist, control, and evaluate in an effort to demonstrate the required competencies perform the new technological assignments needed in the leadership of future global models to satisfy the needs of these higher educational standard institutions in the university departments' services. These organizations accept, use, help, and support the efficient educational institutions' appropriate learning resources as new, flexible, and modern technological structures, options, and uses in the educational system to determine the graduate curriculum achievement level performance and global reputation.

Cloud computing, both as large-scale collections of technology and embodying the cloud services that control the cloud-based processing of applications from the server side, is a highly optimized, resource-saving technology that is multidisciplinary and multi-objective. Subsequently, cloud computing focuses on the factors necessary to allocate physical and, later, reservable technological resources before developing personalized and scalable educational cloud data infrastructures for delivering structured learning and assessment via the available educational technology. These new educational cloud computing structures, options, and uses depend on the benefits and efficiency of the educational technology provided by the educational content, to include real-time adoption of synchronous models. Later, the educational technology practice starts to use the basic strengths of cloud technologies, including value computing, distributed computing, virtual reality, plug-in cloud computing, ultraviolet light storage technology, and middleware services, to allow an immediately scalable educational technology network to incorporate generic cloud computing, permitting both students and teachers to hold the necessary educational support knowledge. Each of the subscribed individuals plays different roles in the described educational digital ecosystem. They have adapted the educational technology content to include the fast-selling color and support used by the change in a model of business delivery, services provided, and casual customers produced.

1.4.1. Scalability and Accessibility

Among the distinctive features of the advanced cloud AI services are the scalability that enables computation workloads to automatically scale up or down, along with the ability to perform complex AI tasks that can be easily exposed, leveraged, and consumed as cloud-based services through easy-to-access and well-documented API calls. The workflows performed from consuming these advanced AI services generally do not require the existence of local AI expertise or data science skills. In many cases, client applications using these professional AI services neither necessarily involve any form of cloud AI powered real-time computation services nor possess any direct access to physical AI computing devices at all. A client application hosted on a standalone isolated or local server may be engaging in AI offshore batch computing but can still effectively utilize these mature cloud AI tools to undertake complex tasks without any constraints imposed regarding the cloud computing unit or local hardware infrastructure. In contrast, traditional AI technologies rely on the resources only available close to the application to perform where the data resides.

The AIaaS design enables unique characteristics due to its reliance on customized and high-quality AI-specific services operating at large scales. These AI services generally come with good quality guarantees in terms of accuracy, performance, reliability, security, and privacy, without directly demanding any client application or service to be an expert in dealing with AI domain-specific issues. From the client's perspective, it does not need to worry about the security of AI model artifacts, the scalability and provisioning of computing resources used during AI workflow execution, the hosting and operational management of AI model artifacts, or the unique data annotation functionalities and skills required for different AI task domains. The cloud AI services provide the ability to consume AI capabilities and, more importantly, champion the simplification of complex AI capabilities and the democratization of AI talents, democratization of domain knowledge, democratization of model and data serving capabilities, and the establishment of business ecosystems through efficient collaboration and monetization. The structured, intelligent, and automated tools avoid individual application developers from having to understand and correctly manipulate the intricate nature of the algorithms, the models, and the data, which make AI more accessible to clients of different technical and business backgrounds. Introducing a parallel of AI knowledge and assistance ecosystem, where recognition tasks can also be performed, shared, and executed among distributed edge devices and the cloud, assists in further democratizing model knowledge and capability, thereby enabling inclusive AI knowledge distribution and AI fairness, and expanding the widespread usage of AI capabilities in resource-starved communities and industries. With the developments in AIaaS, the education and public sectors, as well as non-profit organizations, embrace opportunities in the AI ecosystem and appreciate the benefits of AI without being significantly challenged by AI proficiency, expense, and operating capability concerns.

1.4.2. Collaborative Learning Environments

The modern practice of solution-oriented education encourages a constructivist-based atmosphere where the active search for problem solutions is performed. This implies the mastering of competencies and intellectual skills together with key information and the ability to execute specific forms of classroom activity. Advanced techniques supported by innovative technical tools and communication means such as multimedia methods, consistent technical software tools, and special computer-coded models that execute contingent analysis and, in most cases, game-world cases that support the development of actions online through a digital workspace are transforming the traditional didactic process. The instructional processes are evolving in order to promote investigation, interpretation, and argumentation. Consequently, new technological possibilities have an effect on educational courses.

Especially for engineering or economics courses, suitable methods use a diverse category of digitally immersive technology, thus enhancing the learning process of basic knowledge. The term digital immersion includes augmented and virtual reality, collaborative and flying prototyping techniques, intelligent digital infrastructure, smart objects, and cloud robotics systems; all these systemized techniques are used in the courses. However, especially these days, an advanced collaborative digital instructive environment always creates a blend of resources and instruments, both stepping onto high and low levels of semi-structured multimedia documents for educational purposes; an improvement based on human–computer methods increases multidisciplinary symbol manipulation. These methods are typical for teaching technical and soft skills. According to expert definitions, through a digital environment, it is a five-stage system: initially, at the base platform level, the initial iteration of the system's educational assemblies is built. As soon as this first step is completed, the implementation of superstructure functions that allow the system to form distinct iterated sets of educational objects is reached. Next, at the next level, the system is upgraded in order to evaluate, analyze, and design efficient pedagogical programs that guide the assumed series of educational applications. Subsequently, once the system is able to form a series of iterations and educational applications, the system implements an operational level for suitable testing and feedback generation. Besides the roadmap for the development of the digital educational environment, it should be noted that students appreciate falling into four categories within classical institutions: (a) personal edition—individual digital resources used for an elementary learning process, leading to personnel skill improvement; (b) individual digital media rehabilitation—educational procedures used for one-to-one tutoring with a teacher, in order to help the child advance, organized for special educational needs; (c) class digital mediums; and (d) mixed digital setting.

1.4.3. Cost-Effectiveness of Cloud Solutions

There are numerous studies that compare the costs of implementing on-premises and cloud solutions. Most studies do not take into account costs associated with raw data processing and time, with the benefit of computing using AI, which comes from big data. We argue that if we incorporate the costs of data acquisition and manipulation, all studies on the cost-effectiveness of the cloud should have the same conclusion, i.e., implementing AI using an on-premises solution would be much more expensive.

Fig 1 . 2 : NeuroClass 2125: The Future of Immersive Learning

For example, a thorough financial analysis prepared for both cloud and on-site solutions claims that the cloud-based solution yields a 19-month payback from efficiency improvements in user management, device management, lower help desk costs resulting from improved self-service capabilities, and total annual benefits of $9.5 million, $2.6 million of which resulted from the IaaS/PaaS stack. To ensure that AI applications are feasible, and in most cases only feasible for very large academic centers, one would have to incorporate a detailed analysis on variable data acquisition and preparation costs and tie all cloud resources into on-premises solutions. Leasing solutions are also not scalable and would require buying dynamic datacenter capabilities as they would be charged by the megawatt or quadrupling of capacity from a battery backup infrastructure perspective at a fraction of the speed if needed for an on-premises solution.

1.5. Integrating AI, Big Data, and Cloud in Educational Systems

In the last two decades, the information world has changed more than ever before. Computer and mass data storage technologies changed from the server-client model of data processing to cloud-based, and the use of mobile devices greatly reduced the requirements for graphic display. The development of computer technologies has also opened the doors for the use of intelligent computer programs in various applications. Under the trend of big data, computers are now more widely used to connect broadband data sources as a platform for data analysis in the fifty years since the construction of the first personal computer, which is the generation that people call the age of big data.

In order to meet the requirements of matching the situation of the 21st century, the essence of education is to cultivate students' comprehensive ability of independent thinking, team cooperation, and lifelong learning, and to enable them to adapt to the era of globalization with high competitiveness. The aim is to make a smooth transition to the information-based industrial environment and continue to be innovative and make breakthroughs. Therefore, how to lay down a firm foundation of core competence has become very important. To achieve educational goals, in addition to being able to make changes to a class environment to increase the breadth and depth of learning, efficient personalized learning is extremely important. With the advantages of small class teaching, there also come disadvantages, such as difficulties in arranging students' study time. It is difficult to meet every student's individual differences and styles of diverse teaching performed. Whether online learning is positive for students' learning is also a question. How to cultivate students' independent thinking and problem-solving abilities? This paper states that by means of cloud computing and artificial intelligence to assist with the analysis of big data, a display and suggestion mechanism can help instructors understand the learning situations for different students. After analyzing students' learning situations, an assessment and evaluation mechanism can provide feedback to students to enable them to improve their study behavior at any time and discover effective learning strategies. Therefore, instructors can give students feedback at the right time and teach the students' learning methods in addition to modifying teaching strategies, which in turn guides their teaching and improves the effectiveness of teaching.

1.5.1. Framework for Integration

Evolving technology has allowed for capturing and analyzing large amounts of data. Artificial intelligence and machine learning can harness big data to analyze systems to improve capabilities and better understand and manage new cost-effective outputs. Cloud computing acts as an interface between big data and AI/ML platforms and also helps avoid upfront capital investment in infrastructure. Consider the convergence of AI, big data, and cloud technology as a powerful tool for managing the future of renewable energy and consolidating renewable energy processes. Introducing a bifacial solar module using ML technology. For the day-ahead forecasting tasks to be performed, forecast target values such as power production, module backside transmittance, and ambient temperature values have been determined in the first step. Conventionally, the most important forecasts in the solar energy sector are day-ahead forecasts. Many energy system operators can make their capacity or their energy deficit very expensive due to higher energy costs and price irregularities if the capabilities are not prepared effectively. AI-based technologies are capable of computing energy and pricing supervisions. This additional data will improve the quality of many applied forecasts and should be utilized more effectively for energy optimization.

1.5.2. Case Studies of Successful Implementations

As it is demonstrated in our previous section, big data and artificial intelligence are helpful for educators to grasp student learning needs and learning behavior accurately and quickly. Traditional educational systems can be redesigned and improved based on the instructional innovations that these technologies have brought. As a complement to these technologies, we provide a case study in this section with another powerful technology, namely cloud computing, that synchronizes with AI technology. We will see firsthand how the combination of AI and cloud computing technologies can design new instructional models and run a pervasive educational program.

The cloud-based contemporary educational model has improved the drawbacks of traditional educational modes. It enables learning within the students' physiological and psychological margins while simultaneously adopting the modern concept of personalized learning. AI can cope with the huge amount of diversified data, help educators gain a deeper understanding of student learning, and contribute to the construction of a smart modeling-based educational model in addition to the cloud computing service to satisfy individual differences in physiological and psychological states. The intelligent content service management system proposed extends the targeted offerings that enable the adjustment of the dynamic model, referring to the interface and content highlighting features in accordance with personalized requirements such as learning interest, personality traits, hobbies, and academic performance.

1.6. The Role of Artificial Intelligence in Energy Systems

The power industry is one of the main elements in the growth of a modern economy, and it is a critical part of the economic structure of a country. Artificial intelligence technologies can be used in energy systems for numerous purposes, but to obtain the most profit, they should be used correctly. Electrical power systems are becoming highly complicated in the deregulated atmosphere because of the ongoing development toward liberalization, the growing number of units participating in markets, and the increasing standardization of power distribution. This growth is usually credited to two different causes: the evolution of communication and information technologies and the growth of the operational paradigms of several quality services.

The Internet of Things and big data-related technologies have made it clear to understand the information created in many steps of the power interchange process, therefore providing powerful solutions to the computational logic at discrete points in time to ensure that the security and quality of the associated services are achieved regarding complex conditions such as the continuous solution of the related optimization problems. Although these results are indeed remarkable, converting from the driver function to the actual control actions in a real-time condition, such as the stability of grid frequency or physical flow management, may not be an economic, practical, or secure method in power systems. Since it is difficult to utilize such powerful techniques' extensive power at the actual operative speed of the physical world, the prevailing operations of many power systems have largely been considered feasible due to known designs and related expertise.

1.6.1. Smart Grid Technologies

Unlike the current power grid, the smart grid is a multifaceted, integrated electrical system that can optimize different aspects of the usage and management of the electrical infrastructure. Smart grids combine digital generation, control, protection, and communication systems to improve the efficiency, reliability, economic structure, flexibility, and sustainability of the entire system. In terms of generation, renewable energy, distributed power, and demand response are combined to help meet objectives of demand response, integration, and optimization while minimizing and often reversing the environmental impacts of the electrical system. A more active and attentive space is managed by distribution systems and the development and implementation of fault isolation and restoration systems to prevent the overall system from experiencing more impact due to faults and natural disasters. Furthermore, by introducing more automated systems, commercial and industry users are offered advantages that were once only available to utilities or large industrial users. With more advanced and cost-effective distribution automation solutions, the concept of smart grids can be used throughout the home to provide consumers with the knowledge and means to make real-time decisions to increase energy efficiency and reduce overall carbon footprint without compromising existing electrical grid services or personal convenience. To achieve these smart grid implementations and objectives, technologies such as digital meters, integrated communication systems, advanced sensors, and measurement and control systems, together with sophisticated software and algorithms, have already been realized as commercial solutions. The implementation of enabling technologies results in increased data flow, communication needs, and high-speed networking and computing needs.

1.6.2. AI for Energy Management

In the past few years, there has been a growing interest in using AI-driven models for load forecasting, energy consumption predictions, and other energy management applications that include energy market bidding, electricity price forecasting, and performance optimization of energy conservation and renewable generation efforts. To effectively harness the unique benefits and remove the limitations of AI technologies, it is critically important to understand the general principles and recent developments in AI techniques and then apply them in appropriate ways to analyze and make sense of the ever-growing amounts of data available from different sources in the context of power systems. The introduction of AI technologies to various functions of power and energy business operations has disrupted conventional practices in several ways. AI has given rise to new capabilities that exploit patterns in the data and facilitate newer and meaningful insights that help in understanding and decision-making processes. Such technologies lead to the design of new and sophisticated data architectures that employ features and classifiers derived from AI models to discover different kinds of problems. AI applications in power systems come in many flavors, and it does not take long to recognize the potential impact of these applications that are becoming increasingly important with every passing day. Given the growing emphasis on environmental sustainability, load shaping, and management of high penetration of renewable resources on the grid, AI is making positive contributions and helping stakeholders to avoid expensive and complicated decisions through products and smart services.

1.6.3. Predictive Maintenance in Energy Infrastructure

As the energy infrastructure ages, it becomes imperative to diagnose and resolve potential issues before they have even materialized. In doing so, human lives and money will be saved. With the help of comparatively cheap sensors or actuators, the correct readings are taken and stored in a central location; for example, turbine data is stored and analyzed. We can learn over time when turbines are likely to fail, and at that point, operators can take the necessary preventative maintenance steps without disrupting generation. If done successfully, this sort of advantage can add up to significant cost reductions, energy savings for both power operators and consumers, and improved reliability for the grid infrastructure.

By being able to predict the chance of failure for different grid segments, it becomes possible to prepare in advance and have the right personnel in the right place. This lowers costs for energy companies and customers and prevents hostilities from mounting. Importantly, for policymakers around the globe, the increased ability to predict the state of their energy infrastructure will support the integration of more renewable power, which lowers overall CO2 emissions, increases energy independence, and provides several other trilateral benefits in the most conscientious possible way.

1.7. Big Data in Energy Systems

Some of the major energy data reported include technical and economic data, energy statistics, market data, and geospatial data. Among these, geospatial data becomes increasingly relevant due to the growing impacts and benefits of GIS in energy systems across the value chain. This report provides a literature review summarizing common data-driven models related to renewable energy technology deployment, operation, and reliability. Models discussed are capable of solving specific problems such as estimating the levelized cost of energy, forecasting renewable energy resources, optimizing power system operations, and evaluating energy storage system performance. Research frontiers and challenges in this subdomain are also identified and presented. Recommendations for integrating data-driven tools with domain experts are provided to accelerate technology adoption in the energy industry.

Advancements in generation data provide monitoring, control, and predictive and prescriptive capabilities. While technical and economic data include standardized data, data analytics, and market data including short-term and long-term modeling with data such as forecasting of supply and maintaining grid reliability, integration of stochastic variability, financial modeling through a suite of financial management services, energy policy, and penetration of GHG emission-free resources and participation of demand-side resources. Finally, other data such as geospatial data includes analysis and reporting ability, business intelligence tools, solar power satellite prototypes, solar forecasting environmental impacts and tracer releases, climate and weather prediction, energy forecasts, fuel cycle dynamics, and risk analysis with economic and non-economic factors.

1.7.1. Real-Time Data Analytics

Data-Based Models for Power System Configuration In general, data-based models avoid semi-physical limitations, simplify the design, and reduce the number of coefficients that need to be optimized. Moreover, time-consuming offline computation reduces the need for real-time data processing. These benefits make the flexibly integrated modern applications, such as real-time energy data processing and online Power System State Estimation, possible and affordable. The real-time Power System State Estimation is a core function of power grid operations and controls. Its accuracy and responsiveness directly affect the stability, reliability, and continuity of energy services. Applying data-based models to real-time Power System State Estimation is neither an essential guarantee of the real-time response nor does it make it operationally feasible for smart grids containing complex systems and data sets.

Our Data Analytics and Modeling Goals We aim to develop real-time, region-based, highly accurate, and scalable data analytics and modeling tools to fuse synchronous PMU data with the distributed sensor data streaming from components, and other monitoring or communication systems such as energy management systems, Transmission Operator Information Management Systems, distribution management systems, energy markets, and power grid operators, to enable seamless regional Power System State Estimation in restructured power systems. As a key novelty, we approach this problem from the standpoint of data analytics and blended theories. We will then develop advanced cyber-power system analytics for energy fusion, dynamic monitoring and evaluation, dynamic deviation capture, and real-time Power System State Estimation. Our new data-driven tools and concepts will be validated and demonstrated in real-time, large-scale power systems parallel to other physical measurements, and will enable ASU to lead cutting-edge, practical research in next-generation data analytics, data processing, smart grid monitoring, and cybersecurity verification.

1.7.2. Energy Consumption Forecasting

Development and implementation of AI technologies have enabled the development of innovative approaches and solutions in fast-evolving fields like the energy sector to provide higher energy efficiency, enable advanced data analysis, and create tools for responsible consumption and advanced energy management, matching production and consumption for sustainable development. In energy, the use of AI technologies is particularly relevant for predicting the demand for electricity. Throughout the years, different methods have been used with similar goals, such as autoregressive moving average, seasonal autoregressive integrated moving average, and neural networks using weather as an input feature. In recent years, different works have been using advanced deep learning models with exogenous features to predict electrical consumption. Our work presented a deep learning model that includes the exogenous feature of weather, with better results than the baseline models used independently of exogenous features.

Electric energy consumption forecasting is a real challenge that brings a lot of attention from the community due to its relevance. Developing accurate predictive models of electricity consumption in urban contexts helps to design viable policies for energy saving. Advertising actions may be promoted by releasing alerts to citizens when the forecast for a certain date is significantly out of the expected range, and city energy management can adjust supply and demand. In a point-of-sale scenario, an adequate forecast avoids excessive storage that leads to unnecessary energy waste. Conversely, suboptimal predictions could create disastrous situations: in point-of-sale, the concern is under-stocking, which leads to energy scarcity and a negative impact on quality of life, whereas in the urban scenario, the correct balance of supply and demand is relevant. Our discovery of a different usage pattern for energy in February, possibly related to the Mardi Gras week in Brazil, potentially constitutes social relevance to the best of our knowledge, and our paper addresses a gap in the literature on predictive analysis of electrical energy consumption specific to Brazil using weather data. With an accuracy of 0.9533 in energy consumption at a 24-hour forecast horizon and 0.7633 at 30 minutes, the proposed model outperforms different models in the literature.

1.7.3. Data Security in Energy Systems

The data security in energy systems is built on several measurement levels through processing, including data collection, data storage, data sharing, data disposal, data transformation, and more. As the energy data are usually stored in and processed by cloud environments, users have to share their private information with cloud providers in order to obtain suitable energy services. Such sensitive energy data are usually distributed among different entities, in spatially separated domains, and are stored and maintained by third-party service providers. This raised high concerns about how to protect the confidentiality of the outsourced data. Furthermore, the energy data usually have to be combined with other heterogeneous data such as climate, geospatial, and topological data. The data fusion, mining, analysis, and sharing processes of energy data usually take place in the cloud services, which further raise concerns about data privacy. Although some encryption algorithms could be employed to encode the sensitive energy data with high protection, the running speed of the encryption algorithms is not suitable for the usually high-intensive energy data service requirements.

As energy data could provide a realistic blueprint of users' daily routines and life habits, the privacy of energy data has to be taken into stricter scrutiny. Unfortunately, many service providers still lack the appropriate protection levels and regulations for those. The existing legislation widely focuses on the data generated by social media platforms, Internet of Things devices, websites, and other internet-based services. The goal is to ensure the safety and privacy of big data, but energy service providers are still outside current scopes. The energy data then become handy objects for other service providers that follow their users' daily activities, such as insurance, financial, social media, and healthcare service providers. With the advancements of artificial intelligence and big data analytics, the self-generated data in smart grids are quickly monetized and analyzed for unexpected business benefits. Therefore, the trackers and applications of privacy abusers are growing quickly for this purpose. Due to the complex research background, there is still largely an insufficient understanding of the connections between privacy and energy data in computing, legislation, and the market. More privacy-preserving techniques and efficient operational frameworks could improve the interrelated state of the research and practice to ensure users' meaningful consent and data privacy. The anonymous techniques and unlinked operations and data could be implemented to provide privacy protection without revealing the raw data. As the energy-related studies involve people's lives, owners and users, especially taking simultaneous roles, should be given additional rights even in distributed energy data processing activities. Transparent management is required to ensure fairness and build trust at the social and technical levels. As an efficient way, when necessary, any entity participating in the service delivery could, on behalf of their own duties and responsibilities, fulfill privacy protection for the authorized person/data with public-oriented measures. Different stakeholders follow their own intended privacy settings to maximize public awareness, protect sensitive information, add pertinent expert knowledge, and preserve human rights and fundamental internet protocols. Institutions funded by the certification of telecommunication information are most effective for the work of certifications and authorizations, including metadata.

1.8. Cloud Computing in Energy Systems

How cloud computing can be a solution to the big data problem? Over the past few years, cloud computing has emerged not only as a means of providing computing infrastructure and services based on ideology and design that emerged from AI and efficient algorithms, leading to the leverage of significant advances made in AI for providing significant and affordable resources of service with access to domain applications. Most AI services, like machine learning workloads and infrastructure services that host AI services, are carried out in and by cloud computing data centers. Thus, cloud computing is a direct beneficiary of advances made in AI, including machine learning; however, it also has a critical role to play in making AI technology scalable. In essence, cloud computing is keeping up with sustained strong demands for AI services by offering increasingly better, refined, and faster resources than Moore's Law.

Energy system choices drive both environmental and social outcomes. Transforming these systems to meet national and global sustainability goals is a form of social contract that generates inequities and externalities. However, constant change in technology and new insights create the opportunity to continuously improve our energy systems. Cloud computing is now an integral part of the landscape of future energy systems, propelling demand for information, communication, and computation. Our growing reliance on digital tools, inherent uncertainties in predicting the future, and rapid changes emerging in both energy systems and in the cloud infrastructure that will support these systems suggest new research goals. The energy community has an opportunity to work with the computing community at this point to encourage shifts in research direction that will support the future needs of both communities.

Consumers and businesses increasingly turning to cloud computing and infrastructure as a service is not surprising. Declining prices and the rapid proliferation of devices with internet access have led to an explosion of data, making the cloud the proverbial elephant in the room. Organizations can cheaply store and analyze vast amounts of data to gain new insights unavailable from mere fingertips. Meanwhile, dedicated facilities help businesses avoid the exposure that comes with owning and maintaining capital-intensive servers, while related services have drastically lowered the amount of time and money businesses must spend on system management. The energy required to power and cool these computer systems in data centers is substantial but has been stable as a fraction of global electricity use over the past decade. The blueprint, along with low and stable energy costs and what has been perceived as a near endless supply of electricity, has led companies down an energy-intensive path. It is important to appreciate, though, that electricity creates IT infrastructure costs in both data centers and end devices, air emissions associated with electricity generation, and environmental impacts. These have the potential to foil society's desire to harness the cloud for addressing important public policy challenges. These costs are growing with both an increase in the use of and in the requirements for cloud services, exacerbated by cloud services not being shared equally among different populations or across geographic locations.

1.8.1. Cloud-Based Energy Management Systems

To use the real-time energy consumption data at the device level and optimize an energy management system under different constraints, the local devices need high computational resources and the capability of running complex algorithms. Cloud computing is capable of providing customers with affordable and scalable computing services. Using cloud computing to manage the dynamic energy consumption and other demands of devices such as air conditioning, electric vehicle charging, and energy storage, which need to be completed with low latency and quick response, can enhance the flexibility and reliability of an energy management system. In addition, more advanced algorithms can be applied to these energy management systems on the cloud to optimize system performance under the consideration of different constraints. However, the application of cloud technologies in energy management systems must consider the reduction of total energy consumption and the increased computing consumption by the cloud platform.

With the development of artificial intelligence and big data technologies, the capability of energy forecasting with high precision has been provided to improve the feasibility of using renewable energy as the main energy supply. However, complex network architecture and large-scale data processing during the deep learning model training stage consume a large amount of time and computing resources. In order to enhance the agility of the energy management system, the forecasting analysis model can be deployed on the cloud to generate predictions in advance and can be cached on the local devices to be used at the prediction moment.

Big data can be applied to pattern recognition and further optimize and analyze the large-scale energy data collected by different sensors on the smart grid. This big energy data can be stored and analyzed on the cloud to provide a batch of important and valuable information, not suitable for real-time energy management system usage. In addition, edge computing can be designed to compress the big energy data, reduce storage consumption, and achieve fast and cost-effective data transfer. Important and valuable knowledge can be targeted, stored, and retained for further analysis or summarization. However, in the application of big data technologies in smart grid energy data, data security and privacy issues should be given more attention. The analytical results based on big data technologies should be utilized effectively, and the unseen relationships between different data should be utilized to benefit the network on the smart grid.

1.8.2. Integration with IoT Devices

The increased adoption of Internet of Things (IoT) devices has allowed AI to be easily integrated with the infrastructure, with the intention to adopt the solutions. In the continuing discourse, IoT begins to impact the core outcome on big data; hence, AI integrates big data and cloud services in response. Many fields are taking advantage of these advances in the next generation. The electrical energy structure is associated with educational institutions, taking advantage of IoT devices in the areas of smart education and smart management. To have a better understanding of utilizing capabilities, universities could build their campuses as mini-smart cities.

IoT devices facilitate a rich set of teaching services; thus, in an interactive manner, optimized operational management improves students' learning and energy consumption as a matter of university management. Not only in the colleges of energy, engineering, medical, social sciences, and humanities do smart campus measures increasingly stand out. The trend for smart campus creation in the real world implies the easy application of various emerging IoT technologies to many areas. Higher education institutions consolidate all IoT data of equipment through big data analysis. By using innovative AI tools, they can analyze key indicators of action, thereby achieving good educational outcomes. Educator-oriented curriculum tailoring and timely stage information recommendations are proposed. Additionally, the feedback process is developed to allow operational instructors to understand the students' degree of professionalism accurately. The abundant educational application content turns university campuses into lively virtual intelligent tutoring platforms.

Fig 1 . 3 : Smart Campus Technology Adoption & Impact (2018-2024)

1.9. Conclusion

The convergence of artificial intelligence, big data and cloud technologies in shaping the future of education and energy systems is one of the fundamental areas of attention for sustained growth and continued intellectual capital accumulation. At the current juncture, with the education and energy sectors straining under conflicting pulls from digitization and demand for decarbonization, generating robust evidence seems current priority. For this to succeed, however, much work is needed in developing and testing what implementable policies and reform models that can be used to guide the transition to the digital energy and education sectors. Policymakers also need practical guidance on designing and delivering change management programs that can help overcome the diverse challenges facing the transition. Much remains uncertain in this regard because of a lack of adequate theory and empirical work on the uptake of digital technology in the industry.

We are living through a period where the convergence of big data and cloud with artificial intelligence technology promises to fundamentally reshape and revolutionize the energy and education sectors, their growth potential and their relationship as well as the establishment of decentralized/distributed and the transition towards digital learning systems. Encouragingly, early inklings suggest that, after some delay, these new technologies will enable the energy and education sectors to enter a new age of competition, dynamism and growth. Such innovation and digital disruption can provide an incredible boost to the productivity of the education and energy systems. These radically different sectors will require radically different policies if the promise of lower costs, improved quality, and greater access is to be realized; as our exploration shows, it can be realized, and systems can play a central role in making this happen.

1.9.1. Final Thoughts and Future Directions

The era of digital transformation—exemplified by the convergence of artificial intelligence, big data analytics, and cloud technologies—has the potential of transforming traditional classroom teaching into personalized learning experiences. Major service players in the space are making significant strides in developing products by implementing advanced algorithms such as deep learning and reinforcement learning. The television industry, on the other hand, with its well-developed analytical tools and big-data capabilities augmented by increased connectivity along with advances in graphics, audio and holography, can shape up to be a new platform for offering these modern educational experiences. In this chapter, we introduce future learning experience powered by next-generation broadcasting services, and show the end-to-end network architecture. We also present results on key technologies, including adaptive bitrate video streaming, low-latency multiview streaming, data-driven learning experience optimization, and student engagement analysis.

The future learning experience is leveraging new technologies from advanced, next generation broadcasting and cross-connected multi-domain intelligent networks. Within an educational institution, the sensitive nature of educational content requires massive local storage, while providing access to streaming educational video content on a network within an educational institution requires transmission support of a multicast capability to reduce the bandwidth load. Scalability is another important issue. While several computing environments can be established using the current multicasting technology, scalability becomes a significant problem when the users increase. Broadcasting services that are capable of introducing the features those students experience in live educational environments have tremendous potential to deliver learning with higher student engagement. With the progress in AI, AR, MR, VR, graphics, and 5G, TV broadcasting will be established as a new learning platform. By enabling students to interact with remote students and broadcast from a point in classroom views of the teacher, TV will create new educational content and provide new learning experience.

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