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New Liberal Arts Lab Architecture Design for Universities Driven by Digital Intelligence Convergence

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Abstract. Digital-intelligence convergence promotes the construction of a new paradigm of intelligent education and is the core driving force for the construction of the New Liberal Arts lab. Driven by the digital-intelligence convergence technology, the New Liberal Arts lab presents new morphological characteristics, and its architectural design mainly includes five parts: a digital-intelligence convergence experiment platform based on 5G and cloud architecture; a multidisciplinary experimental big data center; an intelligent computing center providing arithmetic support, algorithmic models and intelligent control; a virtual simulation experiment center embodying panoramic rendering, holographic interaction, and virtual-reality coexistence; an experimental data sensing and monitoring system covering all nodes, objects, and processes; and an experimental intelligence system meeting the requirements of accurate evaluation and personalized learning. This architecture provides a reference for the construction of New Liberal Arts labs in colleges and universities at the technical level.

Keywords. Digital intelligence integration; New Liberal Arts; Liberal arts lab.

1. Introduction

Implementing the national education digitalization strategy and promoting the application of big data and AI in education and teaching is an important strategy for building a strong education nation. The construction of New Liberal Arts is an important issue in the current innovation of higher education, and the New Liberal Arts lab is the key carrier of the cross-fertilization of digital intelligent technology and disciplines and professions, the core place to cultivate students' knowledge integration and application and innovation and practice ability, and an important basic project for the construction of New Liberal Arts [1]. At present, the construction of liberal arts labs is facing contradictory problems such as weak functions, insufficient technology, and insufficient sharing, and so on [2]. The rapid development of digital intelligence technology provides new concepts, technologies, and methods, and promotes the

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transformation of the architectural design of labs.

2. Digital Intelligence Integration and New Liberal Arts Lab

2.1. Transformation of Higher Education under the Integration of Data and Intelligence

Currently, society is entering an era of digital-intelligence integration, where "digital-intelligence + education" is becoming a new educational model and norm [3]. In this context, "digital" refers to datafication, digitization, and big data, while "intelligence" refers to intelligentization, wisdom-based systems, and AI [4]. "Digital-intelligence integration" represents a higher level of digital transformation. In this process, AI becomes a key player in the digital transformation [5].

The concept of "digital-intelligence integration" refers to the integration of big data and AI, supported by key technologies such as data mining, the Internet of Things (IoT), cloud computing, learning analytics, machine learning, and natural language processing. This integration enables capabilities such as data perception, understanding, reasoning, and prediction. It is manifested through the continuous enhancement of personalization and intelligence via data mining, and by achieving intelligent decision-making and services through data-driven processes and deep learning [6].

The integration of digital intelligence has driven the construction of a new paradigm of smart education, presenting new connotations at different levels such as philosophical foundation, methods, techniques, and tools [7]. As shown in Table 1:

Table 1. The New Paradigm of Smart Education under the Integration of Digital Intelligence

Level	Function	Connotation
Philosophical foundation	Provide conceptual guidance for smart education	Centered on human-machine collaborative intelligence
Methods	Provide new intelligent teaching methods	Construct support structures for intelligent teaching methods through collaboration with humans, empowering personalized learning, automated services, and intelligent strategies.
Techniques	Provide intelligent machine assistants	Possess capabilities in perception, cognition, emotion, values, aesthetics, and cultural computing, promoting the "personalization" of teaching models.
Tools	Provide new infrastructure for smart education	Includes the innovative construction of intelligent systems, smart learning tools, intelligent learning companions, smart environments, and intelligent assessment.

2.2. The Integration of Digital Intelligence Drives the Construction of New Liberal Arts Lab

The core content of the "New Liberal Arts" is the philosophy and social sciences with Chinese characteristics. It represents a new form of knowledge production and reproduction in the humanities in the post-industrial era, based on the high integration, informatization, and digitization of knowledge [8]. This paradigm emphasizes amplifying China's voice, interdisciplinary collaboration, integration of information technology, and innovation in talent cultivation models. It advocates for synchronization with history and the world, cross-disciplinary integration, practice

orientation, and the merging of new technologies [9]. Against the backdrop of current digital economy construction, the "New Liberal Arts" should integrate "digital intelligence" technology to drive its development in practice, reflecting a diversified and panoramic integration and interaction between the humanities and technology.

Labs are regarded as the most critical spaces for fostering students' innovation and practical abilities, often referred to as the "heart of the modern university". Compared to traditional humanities labs, the New Liberal Arts lab focuses on disciplinary reorganization and interdisciplinary integration, embedding new technologies into humanities experimental courses, and providing students with comprehensive, cross-disciplinary practice environments [10]. The New Liberal Arts lab is logically consistent with the connotations of the New Liberal Arts and serves as a practical foundation for its construction. The integration of digital intelligence drives the construction of New Liberal Arts lab, perfectly aligning with the concept of "philosophy and social sciences intersecting with the new technological revolution". It enhances the intellectual and technological empowerment of these labs, making digital-intelligence integration the core driving force for their construction.

Its connotations and value are primarily reflected in the following aspects: Firstly, digital-intelligence technology provides scenario support for the New Liberal Arts Lab, leading to quality upgrades in Lab tools and methods. Secondly, digital-intelligence applications represent the transformation direction of the New Liberal Arts lab's disciplinary content**,** bringing comprehensive innovation to the lab's focus and scope. Thirdly, digital-intelligence platforms provide foundational support for the organization and resource sharing within New Liberal Arts lab**,** driving innovation in research methods and paradigms [11].

3. The Formative Characteristics of New Liberal Arts Lab in Universities Driven by Digital-Intelligence Integration

The construction of New Liberal Arts lab driven by digital intelligence occurs against the backdrop of rapid digital-intelligence development and application. This process supports, drives, and guides the reform and transformation of lab content, environment, and management through technology. It promotes research exploration from data analysis to method innovation and intelligent development, pushing for structural adjustments, interdisciplinary integration, and the enhancement of talent cultivation capacity.

Deep Integration of Technology and Humanities: by using technology to address challenges in humanities exploration and allowing the humanities to guide the application of technology, a scientific and technological mindset is applied to address the major real-world needs of social sciences, creating an experimental content system characterized by interdisciplinary integration [12].

Immersive Experimental Scenarios with a Fusion of Virtual and Real Elements: by integrating holographic classrooms with XR (VR, AR, MR) technologies and the synesthetic internet, students' visual, auditory, taste, smell, and tactile senses are engaged, expanding the interactive space for teaching and learning through multimedia.

Student-Centered Personalized Experimental Spaces: an experimental virtual space is built based on digital twin technology, while AI's pervasive computing power is used for intelligent analysis, updating, or reconstructing experimental scenarios to meet the personalized learning needs of students.

Human-Machine Collaborative Experimental Community: the integration of digital twin technology with educational agents facilitates multi-directional interaction between the educational agent, the experimenter, and the experimenter's digital twin, forming a new type of community, that is the "experimenter—educational agent—experimenter twin". This setup enables deep human-machine communication and multi-directional information exchange [13].

Open and Shared Digital-Intelligence Experimental Platform: based on "5G + cloud + holographic technology," the platform facilitates the sharing of experimental projects, courses, resources, and teaching processes, while blockchain ensures data security and enables open communication across regions and cultures [14].

Experiment Management Controlled by the "Smart Brain": by comprehensively sensing and collecting experimental data and utilizing AI computing power for deep data analysis and intelligent mining, the system enables intelligent control and management of the experimenter and experimental process.

4. Architectural Design of New Liberal Arts Lab in Universities Driven by Digital-Intelligence Integration

Centered around the characteristics and target positioning, university-based New Liberal Arts lab integrate modern technologies such as 5G, big data, cloud computing, AI, the Internet of Things, visual immersion technology, and blockchain to innovatively construct the basic architecture of New Liberal Arts lab in universities. As shown in Figure 1.

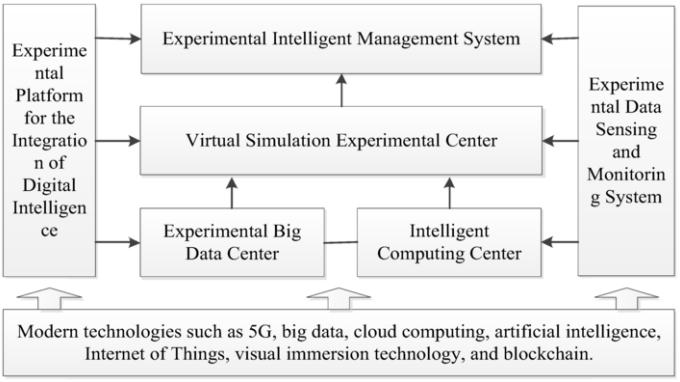

Figure 1. Architectural Design of New Liberal Arts Labs in Universities Driven by Digital-Intelligence Integration

4.1. Digital-Intelligence Integrated Experimental Platform Based on 5G and Cloud Architecture

The digital intelligence integrated experimental platform is an experimental service platform built upon hardware and software resources, providing computing, network, and storage capabilities. It primarily relies on technologies such as 5G and cloud computing. Virtual simulation experiments and human-machine-object interconnection require a stable and smooth network environment, and 5G technology can provide the network infrastructure needed for large-scale user participation, reflecting the demand

for interconnectedness in the construction of the New Liberal Arts. The cloud platform, with its computing and storage functionalities, can offer users comprehensive cloud-based services.

The digital intelligence integrated experimental platform consists of six main modules: The computing virtualization module virtualizes computing resources such as the CPU and memory on servers within the cluster, providing computing virtualization functionality. The distributed storage module virtualizes storage resources such as SSDs and HDDs on servers within the cluster, offering a unified storage resource pool service. The network and security module uses software-defined methods to provide network and security functions for the infrastructure, enhancing the internal network security of the data center. The backup and disaster recovery module uses both native and third-party backup and disaster recovery features to provide data protection and disaster recovery capabilities for running workloads. The container management and services module enables one-stop construction and management of clusters based on computing, storage, and network resources. The resource management and usage module centrally manages and utilizes computing, storage, and network resources. As shown in Figure 2.

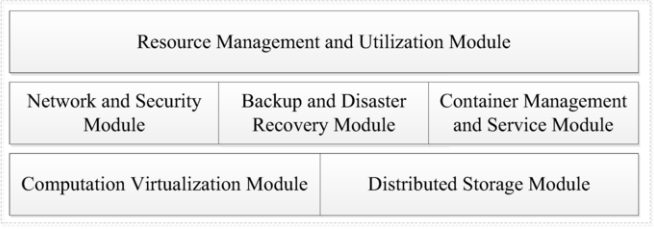

Figure 2. Structure Diagram of the Digital-Intelligence Integrated Experimental Platform

4.2. Multidisciplinary-Oriented Experimental Big Data Center

Data resources are at the core of experimental teaching and scientific research, and the aggregation of massive amounts of data is the nucleus of New Liberal Arts lab construction in universities. It provides essential support for disciplinary experiments and research and are considered vital "infrastructure" in the construction of New Liberal Arts lab in universities. Universities should establish a multidisciplinary-oriented big data center, integrating various information channels, systems, and scattered data resources. The structure of the big data center is shown in Figure 3.

This center would form a massive data network composed of data collection layers, data processing layers, data storage layers, data service layers, and data application layers, creating a highly scalable and open visual database. The center would become a core hub for data storage, exchange, usage, and sharing, promoting cross-regional, cross-level, and cross-departmental data sharing and exchange. This would enable the digital transformation of the humanities and social sciences. Additionally, the center should coordinate multiple forces and focus on solving major national and regional real-world issues by providing multidisciplinary research teams with a data platform, lowering the difficulty and cost of data acquisition and usage, and improving research efficiency.

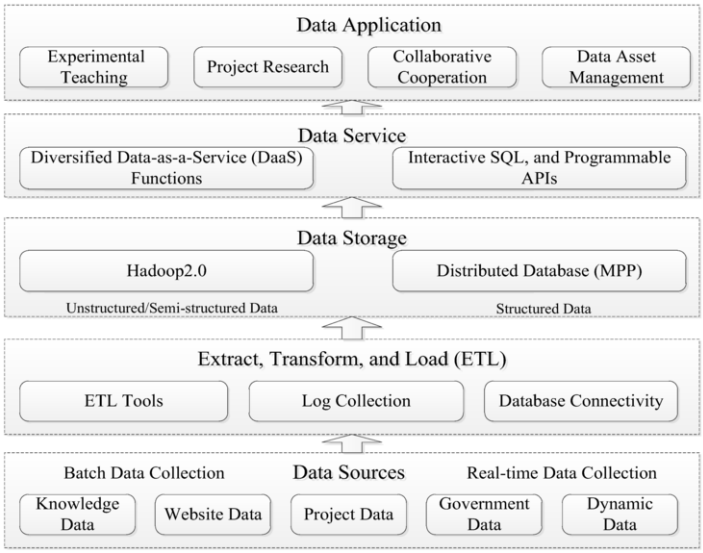

Figure 3. Structure Diagram of the Experimental Big Data Center

4.3. Intelligent Computing Center Providing Computational Power, Algorithm Models, and Smart Control

The Intelligent computing center is the primary computing power production center in the digital-intelligence era. It operates on a converged architecture computing system platform and uses data as a resource. With powerful computational power, it drives AI model algorithms for deep data processing, continuously generating various smart computing services that are delivered to organizations and individuals via the cloud as network services [15]. Its structure is shown in Figure 4.

The intelligent computing center consists of four key structural layers: infrastructure layer, computational power layer, algorithm layer, and service layer. The infrastructure layer provides hardware, power supply, and other necessary conditions for the center, with a focus on energy-saving technologies. The computational power layer emphasizes open computing with integrated software-hardware collaboration, building a diverse and converged architecture that integrates general-purpose CPUs with heterogeneous chips, combining various computing power types to fully unleash their value. The algorithm layer offers preset industry algorithms, constructs pre-trained large models, facilitates continuous algorithm model upgrades, and provides specialized data and algorithm services, enabling more experimenters to benefit from accessible and inclusive intelligent computing services. The service layer, through low-code or even no-code development, offers experimenters feature-rich, easy-to-use intelligent computing and algorithm services, as well as personalized development support.

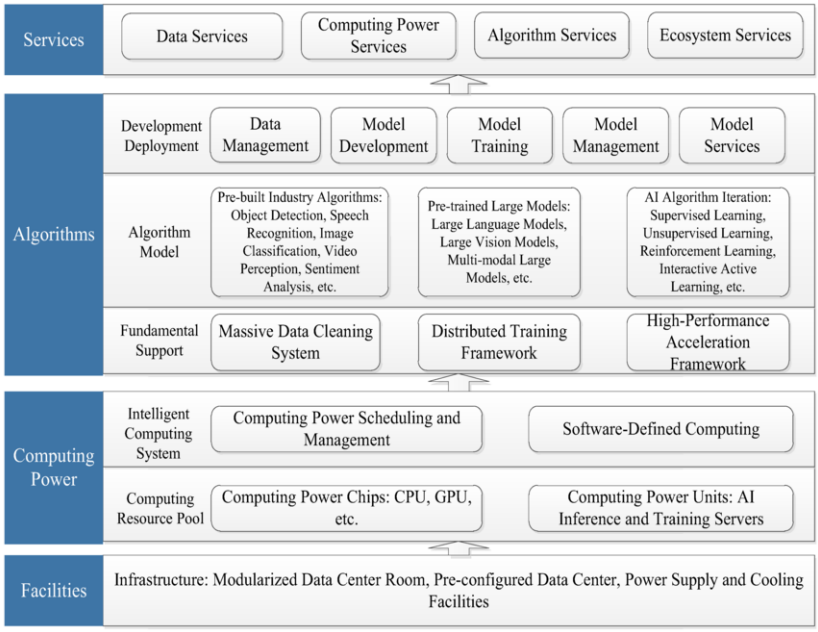

Figure 4. Structure Diagram of the Intelligent Computing Center

4.4. Virtual Simulation Experimental Center with Panoramic Presentation, Holographic Interaction, and Virtual-Real Coexistence

The Virtual Simulation Experimental Center integrates virtual simulation experimental course resources and deeply combines next-generation information technologies such as VR, AR, MR, human-computer interaction, dynamic environment modeling, real-time 3D graphics generation, stereoscopic display, sensor technology, and system integration control. This enables experimenters to experience realistic socio-economic operating scenarios and provides an immersive experimental and teaching model [16]. As shown in Figure 5.

The construction of the Virtual Simulation Experimental Center primarily includes experimental software, experimental resources, hardware equipment, and a management service platform. Experimental software provides objectified, realistic experimental scenarios, forming the foundation for conducting virtual simulation experimental projects. Experimental resources consist of five categories: a theoretical knowledge base, teaching materials library, model tools library, practical case library, and business database, all of which represent the content of the experiments. Hardware equipment includes intelligent wearables, holographic projection, display terminals, interactive devices, and smart capture equipment, providing mediums for comprehensive human-machine interaction. The management service platform integrates course experimentation, teaching management, and shared services. Internally, it manages virtual simulation course resources, while externally it connects with national, provincial, and external university virtual simulation platforms for resource sharing.

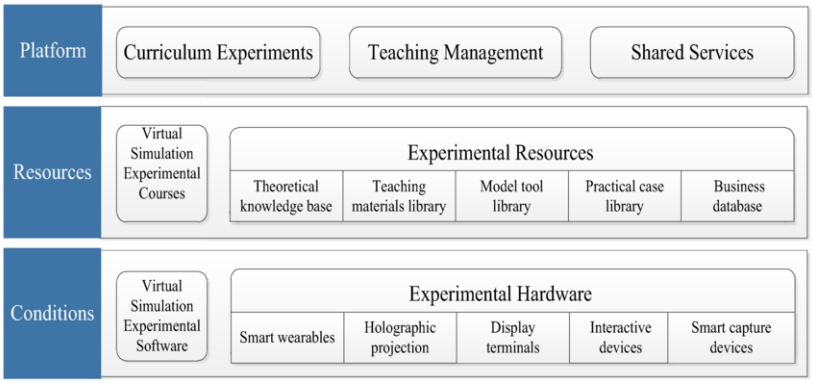

Figure 5. Structure Diagram of the Intelligent Computing Center

4.5. Experimental Data Sensing and Monitoring System Covering All Nodes, Objects, and Processes

The New Liberal Arts labs in universities utilize Internet of Things (IoT) technology to gather information from experimenters or the experimental process through various physical sensing devices embedded in the environment. By leveraging intelligent sensing technology that simulates human sensory capabilities, the system provides highly sensitive insights into the experimental environment. It then uses categorized data transmission technology for real-time data transfer, which is further analyzed and processed to enhance intelligent situational awareness.

The main functions of the experimental data sensing and monitoring system include: First, integration with the experimental system, recording and extracting students' behavioral data and performance data during the experimental process, and monitoring their experimental status. Second, connection with intelligent hardware terminals, enabling real-time data collection to support the analysis of the experimental process and results. This is based on adding sensing nodes to experimental hardware for intelligent upgrades. Finally, it can comprehensive monitor of Lab personnel, facilities, equipment, and material consumables, and ensure the safety of the Lab.

4.6. Intelligent Experimental Management System to Meet the Requirements of Precise Evaluation and Personalized Learning

An AI-driven experimental course system is constructed based on digital knowledge maps and competency maps, clearly displaying the relationships between knowledge points, and providing personalized learning paths and competency development routes. Leveraging the behavior data of experimenters and experimental equipment data, university-based New Liberal Arts lab can use intelligent analysis technology to accurately assess the needs of experiment participants. By deeply analyzing experimental data, the system can capture experimenters' preferences and value demands, enabling precise evaluation of experimental outcomes and real-time monitoring. This allows for the on-demand customization of personalized plans, providing refined experimental services [17]. The intelligent experimental management system is primarily manifested through intelligent learning companions, intelligent teaching assistants, and intelligent research assistants.

Intelligent learning companions: with the support of generative AI, it generates or adjusts experimental scenarios for students, flexibly builds experimental processes, pushes experimental auxiliary resources, controls experimental progress, organizes experimental collaboration, and provides guidance and answers.

Intelligent teaching assistant: assists teachers in experimental design, resource generation and integration, learning situation analysis, real-time Q&A, etc., guiding students to collaborate and explore with generative AI.

Intelligent research assistance: provides experimental design and optimization tools to assist experimental researchers in complex data analysis and processing. Through reinforcement learning, it can continuously respond to the evolving environment.

5. Conclusion

Under the influence of digital-intelligence fusion technology, the construction of New Liberal Arts lab exhibits new characteristics and architectural designs. In the overall architecture, the digital-intelligence integrated experimental platform facilitates the integrated operation and platform-based sharing of New Liberal Arts lab. The data support, computational power, and algorithmic support provided by the experimental big data center and the intelligent computing center have become core elements of New Liberal Arts lab. The virtual simulation experimental center, characterized by panoramic presentation, holographic interaction, and virtual-real coexistence, has built a bridge between the Lab and the real world, offering possibilities for better understanding, and addressing complex real-world issues. Real-time sensing, monitoring, and intelligent analysis of experimental state data, which continually improve the intelligence level of the experimental management system, represents an important aspect of the digital-intelligence transformation of New Liberal Arts lab.

Currently, generative AI is experiencing explosive growth and will continue to have a lasting impact on the construction of New Liberal Arts lab. In this context, how to promote the reform of experimental teaching content and methods, the development of experimental course resources, and the innovation of experimental research paradigms are critical issues that require in-depth and ongoing exploration.

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