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THE CONSTRUCTION PATH OF SMART CAMPUS DRIVEN BY ARTIFICIAL INTELLIGENCE AND BIG DATA

JiaoJiao Sun[1], Fei Wang[2*], QuanDe Dong[2], Cui Wang[1], Yaliu Yang[1]
[1]Business School, Suzhou University, Suzhou 234000, Anhui, China.
[2]Network and Information Center, Suzhou University, Suzhou 234000, Anhui, China.
Corresponding Author: Fei Wang, Email: cumtwf@126.com

Abstract: With the rapid development of artificial intelligence—especially Large Language Model (LLM)—and big data technologies, smart campus construction in universities faces new opportunities and challenges. This paper proposes a system architecture based on "data governance + model services + application integration" and conducts a benchmark analysis of its feasibility and effectiveness using representative university cases. The study also outlines a four-stage construction path: top-level design, driven by Data Middle Platforms, empowered by intelligent applications, and safeguarded by institutional mechanisms.In addition, it establishes a supporting framework composed of organizational coordination, institutional regulation, and data security compliance.The findings of this study provide both theoretical guidance and practical reference for system planning, technology selection, and scenario deployment in the construction of smart campuses in higher education.
Keywords: University informatization; Large language model; Data middle platform; Digital transformation; Construction path

1 INTRODUCTION

With the continuous breakthroughs in artificial intelligence (AI), especially Large Language Model (LLM) technology, the education sector is undergoing profound changes. In recent years, LLM systems represented by ChatGPT, DeepSeek, Claude, etc., have demonstrated excellent performance in natural language processing, cross-modal understanding, and automatic programming, accelerating the evolution of university smart campuses towards intelligence and integration [1]. Domestic LLM represented by DeepSeek have prominent advantages in Chinese understanding, code generation, and educational Q&A, and have gradually become an important technical engine for smart teaching and management in universities. At the same time, as the scale of data accumulated by universities becomes increasingly large, how to synergistically integrate big data with LLM to build an intelligent, efficient, and secure smart campus system has become a new topic in informatization construction. This is not only an inherent requirement for the modernization of the university governance system but also a key path in response to the national "Education Digitalization Strategy Action"[2].
This study introduces open-source LLM into university smart campus scenarios. It focuses on exploring their empowerment paths in intelligent services, behavior analysis, and personalized teaching. This approach aims to expand the boundaries of current smart campus research and fill the application research gap in the context of AI and big data integration. [3,4]. By constructing system models for multi-dimensional scenarios such as teaching, research, and management, and clarifying the technical path for university smart campuses, it helps improve resource allocation efficiency, enhance educational equity and service personalization, and support the construction of a student-centered smart governance system [5,6].
This study, based on LLM and university big data platforms, focuses on the construction path of smart campuses in universities under the background of the integration of AI and big data, mainly including:
(1) Clarifying the connotation and evolution trends of university smart campuses, and defining their functional positioning in the education digitalization strategy [7,8];
(2) Exploring typical application scenarios of LLM in smart campuses, including teaching assistance, research support, campus governance, and service optimization;
(3) Constructing a smart campus system architecture supported by "AI + Big Data", and designing key technical paths and integration logic;
(4) Selecting representative universities for case analysis, summarizing successful experiences, and extracting suggestions for construction paths and governance mechanisms.
This study adopts the following research methods:
(1) Literature Research Method: Systematically review domestic and international research results in smart campus construction and the integration of educational LLM to lay a theoretical foundation;
(2) Case Analysis Method: Select representative smart campus practice samples such as Nankai University, Tongji University, and Shenzhen University for systematic case analysis[9,10];
(3) Architecture Modeling Method: Combine the technical characteristics of LLM and big data platforms to build an implementable overall architecture for the smart campus system, forming a technical support plan[11,12].

(4) Construction and Verification Method [13,14]: System Architecture Design: Centered on the core needs and technical characteristics of the smart campus, construct a layered architecture model composed of "Perception Layer — Data Middle Platform Layer — LLM Layer — Application Layer "; Evaluation Model Construction: Based on literature and policies (such as the "Education Digital Transformation Strategy Guide"), extract four major dimensions: technology maturity, data governance, intelligent services, and organizational guarantee, to form an evaluation framework; Preliminary Verification: Use the expert consultation method to optimize the architecture and indicator design, and through case benchmarking analysis, use practical data from Tongji University, Nankai University, and Shenzhen University (such as response time, service coverage, and user satisfaction) to verify and adjust the weights of the model.

2 SMART CAMPUS AND LARGE LANGUAGE MODEL TECHNOLOGY SYSTEM

2.1 Smart Campus Development Stages

The current development of smart campuses can be roughly divided into the following three stages (see Table 1):

Table 1 Smart Campus Development Stages

Stage	Characteristic Description
Digital Campus Stage	Complete preliminary information system construction, achieve digitization of basic data and system integration.
Intelligent Campus Stage	Apply AI, big data, etc., to promote automation of business processes and personalization of services, improving management and teaching efficiency.
Smart Campus Stage	Fully integrate LLM (GPT, DeepSeek, etc.), knowledge graphs, multimodal AI, etc., to achieve a closed-loop governance and personalized empowerment system of "Ubiquitous Perception - Intelligent Cognition - Autonomous Decision-Making - Precise Services", realizing truly personalized education and refined management.

Currently, university smart campuses are accelerating their evolution from "system parallel connection" to an integrated, intelligent ecosystem driven by "Data Middle Platform + Intelligent Core", showing a transformation trend from tool integration to intelligent collaboration, and from information aggregation to data governance [15].

2.2 Core Technology System Supporting Smart Campus

The evolution towards the 'Smart Campus' stage is underpinned by a sophisticated technology ecosystem. The core supporting technologies include:
(1) Big Data Technology: Used for storing, processing, and analyzing massive campus data, enabling student profiling, behavior prediction, management decision support, etc. [16];
(2) Artificial Intelligence Technology: Including natural language processing, knowledge graphs, machine learning, etc., used for intelligent Q&A, teaching evaluation, research assistance, etc.;
(3) Internet of Things (IoT) Technology: Enabling perception and control of physical campus spaces such as classrooms, laboratories, dormitories, and libraries;
(4) Edge Computing and Cloud Computing: Providing high-performance computing resources to support high concurrency and low latency requirements of the system;
(5) Blockchain Technology: Ensuring the security and traceability of teaching certifications, student records, and digital certificates.

3 APPLICATION SCENARIOS OF LARGE LANGUAGE MODELS IN SMART CAMPUS

With the increasing maturity of LLM technology, smart campuses are entering a new stage of leapfrogging from "digitalization" to "intelligence". LLM (such as the DeepSeek series), by virtue of their advantages in Chinese understanding, code generation, multi-turn dialogue, etc., deeply integrate with university big data systems, providing diversified intelligent support in teaching assistance, research support, campus governance, and service optimization.

3.1 Application in Smart Teaching Scenarios

To leverage the empowering role of LLM in smart higher education teaching, this study systematically categorizes three typical teaching application scenarios and integrates them with technical pathways. Table 2 illustrates three smart teaching scenarios, detailing the technical pathways from data platform construction to LLM integration, which highlights the model's role in enhancing teaching precision and interactivity.

Table 2 Smart Teaching Scenarios

Scenario	Technical Path
Personalized Learning Recommendation	Student Profile (Data Middle Platform) → LLM generates learning path → Precise resource push. Utilizes the powerful semantic understanding and generation capabilities of LLM, combined with knowledge graph association reasoning, to dynamically generate personalized learning paths and resource combinations that match individual cognitive levels and interest preferences.
Intelligent Q&A Teaching Assistant	Access course knowledge base → Cross-modal Q&A (text/image/voice). Accesses teaching management systems and course knowledge bases to build a digital teaching assistant, providing 24/7 Q&A support, improving teacher-student interaction efficiency.
Teaching Content Generation	Automatically generate question bank/lecture notes → Prompt engineering controls difficulty → Knowledge graph logic verification. Leverages LLM to quickly generate lecture notes, PPTs, question banks, and case discussion materials, improving teaching content quality and reducing preparation burden.

3.2 Research Assistance Scenarios

As shown in Table 3, typical application scenarios of LLM in university research activities and their technical paths, covering the entire process from research assistance writing, literature processing to topic selection decision support, demonstrating the application value of LLM in improving research efficiency, enhancing text quality, and optimizing topic selection direction.

Table 3 Research Assistant Scenarios

Scenario	**Technical Path**
Literature Review Generation	Engineer research intent → Generate code → Connect to experimental platform for visualized results.
Paper Translation and Polishing	Template adaptation → Professional terminology consistency correction → Semantically enhanced translation.
Research Topic Assistance and Hotspot Identification	Build domain knowledge graph → Access journal/fund databases → LLM analyzes research trends and keywords → Outputs topic suggestions.

3.3 Campus Governance Scenario Applications

As shown in Table 4, typical application scenarios of LLM in the field of university governance and services and their technical implementation paths, covering key links such as intelligent approval, behavioral safety warning, and digital guide, reflecting the model's comprehensive capabilities in text understanding, behavior recognition, and multimodal interaction, providing intelligent support for the construction of a smart governance system.

Table 4 Campus Governance Scenarios

Scenario	Technical Path
Intelligent Approval	Embed LLM into OA system → Automatically generate official documents/forms.
Behavioral Safety Warning	Multi-source data fusion → Abnormal behavior classification → Linkage intervention mechanism.
Digital Guide	Multimodal interaction (OCR + Voice + Map) → Multi-language support.

4 SYSTEM ARCHITECTURE AND KEY TECHNOLOGY PATH DESIGN

4.1 System Overall Architecture Diagram

To achieve the goals of "intelligent perception, data-driven, model empowerment, scenario implementation" for university smart campuses, the system should build a trinity architecture system of "Data Governance + Model Services + Application Integration", meeting requirements such as ubiquitous access, unified scheduling, high availability, and scalability. This architecture adopts a layered and decoupled design: the underlying IoT devices achieve omnidirectional perception; the Data Middle Platform layer aggregates core data assets such as educational administration and behavior; the AI Large Model layer provides intelligent engines such as general-purpose LLM, multimodal, and fine-tuning components; ultimately supporting four major application scenarios including teaching assistance, research support, campus governance, and service optimization. This design, through vertical collaboration of "Perception-Data-Model-Application", builds an intelligently driven closed-loop governance system, see Figure 1.

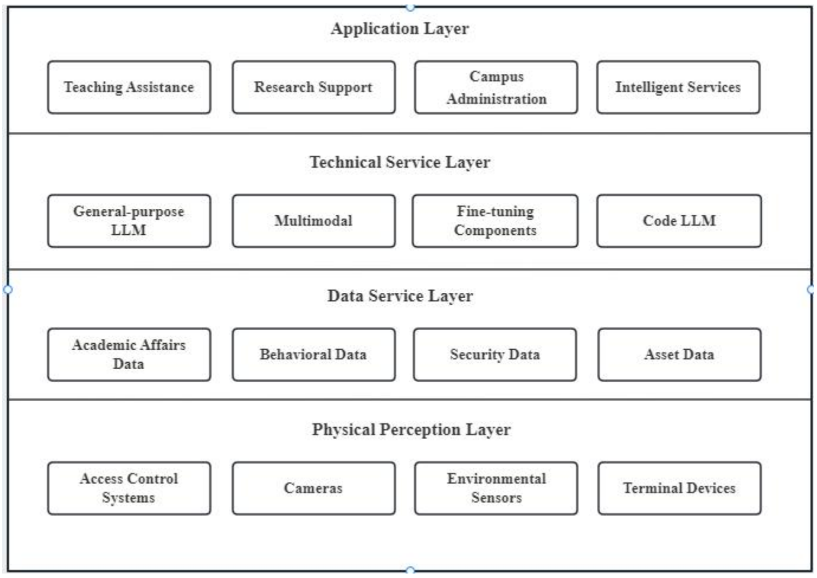

Figure 1 Smart Campus System Architecture

4.2 Core Modules and Key Technology Paths

The system construction of the smart campus relies on the collaborative linkage of three core modules: Data Middle Platform and Governance Technology, Model Deployment and Application Technology, and Scenario Application Integration and Service Portal. The technical implementation paths for each module are as follows:

4.2.1 Data Middle Platform and governance technology

The Data Middle Platform is the foundational platform for achieving the integration, governance, and servitization of educational data. Its key technology system includes:

(1) Multimodal Data Collection: Supports unified access and management of structured (e.g., educational administration system tables), semi-structured (JSON/log files), and unstructured data (teaching videos, audio, text);

(2) Entity Profile Construction: Through Master Data Management and tag systems, integrate multi-source data to build 360° panoramic profiles of core educational entities such as students, teachers, and courses;

(3) Data Governance and Standardization: Establish data cleaning, deduplication, quality verification, and standardization processes to ensure the accuracy, consistency, and reliability of educational data;

(4) Data Servitization and Opening: Provide data support for teaching, research, and management applications through methods like RESTful API and GraphQL interfaces, promoting the efficient reuse of data resources.

4.2.2 Model Deployment and application technology

(1) Diversified Deployment Modes: Local Private Deployment: For sensitive scenarios, ensuring data compliance and closed-loop flow within the campus; Cloud-Edge Collaborative Deployment: Deploy lightweight models on edge nodes such as teaching terminals and IoT devices, with the central cloud scheduling full models, achieving low-latency response and unified management;

(2) Servitization and Enhanced Inference: Model Servitization Encapsulation: Encapsulate model capabilities as high-availability, high-concurrency API services, supporting dynamic batch processing and multi-version management; RAG Enhanced Retrieval Mechanism: Build a campus knowledge retrieval system based on FAISS + BERT, retrieving relevant content from databases such as educational regulations and academic literature, enhancing the accuracy and factuality of model responses.

(3) Scenario Application Integration and Service Portal: Build a user-centered integrated intelligent service entry. Key integration technologies include: unified identity and permission management, multi-terminal adaptive support, microservices and elastic architecture, educational knowledge graph empowerment.

4.2.3 Technical implementation roadmap suggestions

We propose a four-stage roadmap to promote construction: as shown in Table 5:

Table 5 University Smart Campus Construction Stages and Implementation Path

Stage	Core Tasks	Time Cycle
Step1	Build the Data Middle Platform, complete unified data governance system	1-3 months
Step2	Privately deploy LLM, complete scenario-specific fine-tuning and adaptation	3-6 months
Step3	Integrate key application scenarios, such as intelligent Q&A, teaching recommendation, intelligent administrative Q&A, etc.	6-9 months
Step4	Expand diverse application scenarios, establish unified portal and service orchestration system	9-12months

5 TYPICAL CASE ANALYSIS

5.1 Case Selection and Research Approach

This chapter selects three universities with representative practical achievements in empowering smart campuses with AI and big data: Tongji University, Nankai University, and Shenzhen University. These three have different focuses in technical paths,Application Effect, and Management Mechanism, which can well reflect the diversity and advancement of smart campus construction in China. By analyzing their technical implementation, application effects, and management mechanisms from multiple dimensions, successful experiences are summarized to provide replicable and promotable path references for other universities.

5.2 Core Achievements and Technical Paths

5.2.1 Tongji University: data-driven teaching quality evaluation system

Technical paths: Multi-source data integration (educational administration/teaching evaluation/classroom video) → Machine learning for academic risk identification → BI visualization platform;
Application Effect: Teaching evaluation coverage increased by 24%, covering over 90% of courses;
Management Mechanism: Three-level linkage between Academic Affairs Office + Information Center + Colleges, establishing data quality responsible persons.

5.2.2 Nankai University: artificial intelligence research assistant system

Technical paths: Integrate DeepSeek/GLM LLM→ Build research knowledge graph → Natural language interaction interface;
Application Effect: Research topic selection efficiency improved by 60%, over 90% user satisfaction.
Management Mechanism: Led by the library for development, introducing AI ethics guidelines + behavior log auditing.

5.2.3 Shenzhen University: campus-wide intelligent governance platform

Technical paths: Unified Data Middle Platform accesses security/logistics/energy consumption systems → Face recognition behavior warning → Fault self-reporting and dispatching;
Application Effect: Event response ≤ 3 minutes, risk index decreased by 38%, service satisfaction 94.2%;
Management Mechanism: School-level construction task force promotes, "One Governance Map" realizes visualization of authority, responsibility, and processes.

5.3 Summary of Successful Experiences and Promotable Paths

Based on the in-depth analysis of the cases of Tongji, Nankai, and Shenzhen University, combined with cross-evaluation of multi-school experiences in expert consultations, this paper extracts five key dimensions for smart campus construction and their successful experiences (as shown in Table 6). Experts generally agree that the "Unified Data Middle Platform + AI Core Model" architecture of the technology system is the foundational support (confirmed by Shenzhen University case); the "multi-department collaboration + clear responsibilities" (Tongji's three-level linkage mechanism) in the organizational governance dimension and the "introduction of ethical norms + behavior auditing" (Nankai's AI ethics guidelines) are key guarantees to avoid "emphasizing technology over management", which is consistent with the conclusions of literature. Experts particularly pointed out that deep user participation (e.g., Shenzhen University's high satisfaction stems from the closed-loop of teacher-student feedback) and the bottom line of security and compliance (all three universities have established graded protection) are core elements for project sustainable development.

Table 6 Summary of Successful Experiences in Five Dimensions of Smart Campus Construction

Dimension	Successful Experience
Technology System	Build a unified Data Middle Platform, integrate AI core models, and promote business intelligence collaboration.
Application Scenarios	Effective implementation in multiple fields such as teaching quality evaluation, research assistance, and logistics & security governance.
Organizational Governance	Implement multi-department collaboration mechanisms, clarify data responsibility boundaries, and introduce ethical norms.
User Participation	Teachers and students deeply participate in system feedback, achieving positive interaction and continuous optimization.
Security&Compliance	Establish AI usage security boundaries and behavior audit mechanisms to ensure the system is trustworthy, controllable, and traceable.

6 CONCLUSION

This paper systematically constructs an overall framework for smart campus construction driven by artificial intelligence and big data, clarifies the system logic centered on "Top-Level Design - Middle Platform Drive - Intelligent Applications", and points out that the integration of AI and big data is the core engine for promoting the intelligent reconstruction of campus management, teaching, research, and service models. Research shows that the effective implementation of technology must rely on sound institutional guarantees, collaborative organizational mechanisms, and continuous development of teacher-student digital capabilities, forming a long-term mechanism for the positive interaction of "Technology-Mechanism-Culture". Although this study preliminarily proposes a construction path and evaluation model, its applicability still needs to be empirically tested on a larger scale in different types of universities; in the future, based on multi-university research and longitudinal data support, we will further explore the dynamic evolution mechanism and sustainable governance path of smart campuses.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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