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Application of Robotics in Intelligent Libraries: A Case Study of Linguistic Topic Models

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With the rapid development of artificial intelligence technology, the application of intelligent robotics technology in the field of library services is becoming increasingly widespread. This paper systematically reviews key advancements in robot recognition technology, path planning, service innovation, and the development of smart libraries. By leveraging neural networks and deep learning technologies, combined with image recognition and data processing techniques, it is possible to achieve accurate book identification, rapid localization, and intelligent path planning, thereby optimizing the library's circulation management system. Research indicates that intelligent robot technology can effectively drive the intelligent transformation and upgrading of university libraries, providing theoretical references and practical pathways for the development of smart libraries.

Keywords: artificial intelligence robot, recognition technology, path planning, smart library, linguistic topic model

Introduction

Research Background

The rapid development of artificial intelligence (AI) technology is profoundly reshaping the forms of social production and public services. Breakthroughs in neural networks and deep learning are driving the evolution of libraries from *smart libraries* to *intelligent libraries* (Lu, 2017). Currently, the construction of a national smart library system has been incorporated into the national cultural digitization strategy, and the *AI+* initiative has become the core engine for the high-quality development of public libraries (Huo, 2026). In the field of library services, the integrated application of robotics and image recognition technologies has become a key driver for service transformation and upgrading (He, 2018). In particular, the deep integration of intelligent robotics and computer vision technologies has played a significant role in enhancing the efficiency of library reference services, book management, and reader services (Guo, 2017). However, traditional library services still face efficiency bottlenecks: manual book inventory error rates reach 3%–5%, service hours are limited to fixed opening times, and it is difficult to accurately respond to readers' personalized needs. Against this backdrop, intelligent robot technology, with its 24/7 uninterrupted service, high-precision recognition, and proactive interaction capabilities, has emerged as a key technological pathway to resolving these challenges in library services.

Through literature review and technical analysis, this study systematically examines the current state of intelligent robot applications in library services, promotes the integration of library science and artificial

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intelligence technology, and provides replicable technical solutions and implementation pathways for the development of smart libraries.

Core Application Scenarios of Intelligent Robotics Technology in Library Services

By leveraging advanced technologies such as intelligent robots, image recognition systems, and deep learning algorithms, libraries can achieve automated and precise management of services (Cao, 2019). Intelligent robot technology supports functions such as real-time reference consultation, book navigation, shelf arrangement, and personalized services, effectively enhancing service efficiency and the reader experience (Yao et al., 2011). Image recognition technology based on OpenCV and deep learning holds significant application value in the automatic collection of book information, detection of misplaced books, and precise location tracking (Li, 2019). In addition, technologies such as voice interaction, robotic limbs, and data storage have played a significant supporting role in optimizing human-robot collaboration models and reducing the workload of library staff (Cao, 2019). The services provided can be summarized as follows:

Collaborative Services

As collaborative partners for library staff, intelligent robots have been deeply involved in restructuring the operational models of basic tasks such as book shelving, organization, and inventory. Represented by the "Tuke robot" developed by Professor Chen Lijun's team at Nanjing University, this device uses radio frequency positioning and computer vision technology to achieve precise book localization, with an accuracy rate of up to 97%. It can inventory approximately 20,000 books per hour, with a missed-reading rate controlled below 1% (Fan, 2018). The three inventory robots deployed at the Sino-Singapore Tianjin Eco-City Library and Archives operate autonomously every night after closing. Working in conjunction with 15 AGV sorting robots and two transport robots, the system can sort 1,500 books per hour, achieving an efficiency ten times that of traditional manual labor (Xie, 2025). This human-machine collaboration model effectively addresses the issue of insufficient recognition robustness caused by object occlusion in complex environments through automated feature extraction and multi-pose recognition technology (Chen, 2015), significantly improving operational accuracy and collection management efficiency while reducing labor costs.

Consultation Services

An intelligent consultation bot based on natural language processing (NLP) technology has established a functional framework for 24/7 reader services. The system integrates core technologies such as speech recognition, semantic understanding, dialogue management, and speech synthesis, and utilizes a Seq2Seq model to enable multi-turn dialogue modeling and detection of invalid outputs (Wang, 2024). In FAQ response scenarios, the consultation bot leverages a semantic network built on a knowledge graph to accurately identify user intent and match the optimal answer path; in borrowing guidance and spatial navigation scenarios, by combining target pose recognition methods based on convolutional neural networks (Zhou, 2019), the bot can achieve real-time positioning of book shelf areas and service counters, as well as dynamic path planning. The intelligent data service robot system proposed by Su (2024) effectively resolves the issue of system resource overload caused by large-scale model traversal through key feature data extraction and business scenario adaptation, significantly enhancing service stability in continuous demand scenarios.

Embedded Services

The integration of robotics technology into research support and disciplinary services represents an

innovative pathway, manifested in the transition from a resource-centric to a knowledge-service-centric model. Research on hot topics using the LDA topic model indicates that the core trend in AI-enabled smart libraries lies in deep business integration (Yang, 2021). Intelligent transport robots can deliver 25,000 books daily, freeing librarians from routine tasks and enabling them to focus on high-value-added services such as subject-specific intelligence analysis and reading promotion planning (Li, 2021). This embedded service model reconfigures the library's value chain and accelerates the intelligent upgrading of the knowledge service ecosystem.

Robot Image Recognition and Intelligent Book Retrieval Technology

Image Recognition Mechanism Based on Convolutional Neural Networks

Convolutional Neural Networks (CNNs) achieve efficient recognition of book images by simulating the hierarchical abstraction processing mechanism of the human visual system. This network consists of multiple convolutional layers, pooling layers, and fully connected layers. Lower layers extract primary visual features such as edges and textures, while higher layers progressively combine these to form semantic object representations, ultimately achieving an end-to-end mapping from pixel-level input to class classification (Yang, 2017). This hierarchical architecture enables robots to automatically learn discriminative features in complex bookshelf environments, avoiding the subjectivity and limitations of traditional manually designed features. The core advantages of applying CNNs to book recognition tasks stem from three key technologies. The local receptive field mechanism ensures that each neuron responds only to visual stimuli from a specific region, effectively capturing local structural information from book covers and spines; the weight sharing strategy, which traverses the entire image using the same convolutional kernel, significantly reduces the number of model parameters and enhances robustness against translational deformations; and spatial sampling operations, which achieve down sampling of feature maps through pooling layers, gradually expanding the receptive field of subsequent layers to balance the integration of global context and local details (Wang, 2017). The synergy of these three techniques enables the CNN to maintain high recognition stability even in library settings characterized by varied book orientations and complex lighting conditions.

The synergistic effects of function optimization accelerated the model's convergence rate by approximately 30% in the book classification task, achieving a recognition accuracy of over 97% (Zhu, 2021), thereby ensuring the computational efficiency required for robots to process massive collections of images in real time.

Book Recognition and Practical Applications

CNN-based image recognition technology enables robots to capture book information from multiple dimensions. The system uses high-definition cameras to capture images of the covers of linguistics books, extracting visual features such as the title, author, and publisher; simultaneously scans the spine area to obtain the call number and collection label of the linguistics books; and invokes an OCR module to parse the ISBN barcode, generating structured bibliographic data.[1] This process automates the mapping from physical objects to digital records.

In specific operational scenarios, image recognition technology demonstrates significant effectiveness. During book inventory, the robot traverses the shelves at a rate of approximately 20,000 books per hour, achieving 97% positioning accuracy and keeping the misreading rate below 1%; the misplaced book detection function

[1] Intelligent Book Inventory Robot [EB/OL]. (2024-01-01) [2025-01-01]. https://baike.baidu.com/item/智能图书盘点机器人/53968471.

automatically flags misplaced books by comparing real-time captured images with standard collection location data; The intelligent sorting system allocates returned books to designated bins based on recognition results and rules such as category and floor, achieving a sorting efficiency more than three times higher than manual methods.[2]

Analysis of Research Hotspots and Development Trends Based on the LDA Topic Model

Research Methods and Data Sources

This study employs the Latent Dirichlet Allocation (LDA) topic model for semantic mining of literature. This method generates topics based on the probability of term co-occurrence and offers good generalization ability and interpretability (Lin, 2019). Technically, the Gibbs sampling algorithm is used for parameter estimation (DU et al., 2017), and the number of themes is determined based on the perplexity metric, selecting the optimal number at the inflection point to avoid semantic ambiguity or theme fragmentation (Wang, 2018). The data was sourced from CNKI (China National Knowledge Infrastructure) literature related to topics such as “Smart Libraries” and “Intelligent Robots”, and a corpus was constructed after preprocessing.

Identification of Research Hotspots in AI-Empowered Smart Libraries

Theme clustering based on the LDA model indicates that research on AI-empowered smart libraries can be categorized into five major thematic domains: intelligent service systems, knowledge organization and discovery, user behavior analysis, intelligent spatial renovation, and robotics applications. The study introduced the Dynamic LDA (DTM) model to track thematic evolution, revealing a significant increase in the prominence of robotics-related topics, which have expanded from single navigation functions to diverse scenarios such as collaborative services and emotional interaction (Qi, 2016). Additionally, improved models such as TIF-LDA and MB-WLDA optimize thematic identification accuracy by incorporating time-weighted factors or integrating user dimensions, thereby providing support for precise service delivery.

Taking Linguistics Books as an Example

The results of topic clustering based on the LDA model show that research on linguistics books can be categorized into five core thematic domains: corpus construction and annotation, computational linguistics methods, dictionaries and lexical knowledge bases, language teaching resource development, and natural language processing applications. Among these, the corpus theme covers annotation standards, retrieval tools, and multimodal corpus integration; the computational linguistics theme involves syntactic analysis, semantic computation, and machine learning algorithms; and the lexicography theme focuses on headword segmentation, example sentence selection, and knowledge graph construction. By applying the Dynamic Topic Model (DTM) to track topic evolution, we found that content related to the “deep learning + linguistics” fusion theme has shown a significant upward trend, expanding from early rule-based methods toward neural network models and pre-trained language models.

Conclusion

This study systematically explores the core applications and future trends of intelligent robotics and image recognition technology in library services. The research indicates that the integration of these technologies has

[2] So Advanced! Zhejiang Library Launches Robot Librarian [EB/OL]. (2025-01-01)[2025-01-01]. https://baijiahao.baidu.com/s?id=1832319039188913246&wfr=spider&for=pc.

driven significant improvements in library efficiency across three key scenarios: collaborative operations, intelligent consultation, and embedded services.

In Terms of Core Application Outcomes, Efficiency Far Exceeds That of Manual Labor

Technology enables high efficiency: Image recognition mechanisms based on convolutional neural networks have enabled high-precision automation of tasks such as book inventory and misplacement detection, with recognition accuracy reaching 97%. This has led to a profound restructuring of service scenarios: Intelligent robots not only handle basic tasks such as shelving and organizing books but also provide 24-hour consultation through natural language processing technology, freeing librarians from repetitive labor and allowing them to focus on high-value-added services.

Research Hotspots and Trends

The intensity of research on this topic continues to rise, with application scenarios expanding from simple navigation to diverse areas such as collaboration and emotional interaction. The evolution of research themes is clear: through LDA topic modeling analysis, five core research domains have been identified, including intelligent service systems and knowledge organization. Dynamic analysis indicates deepening convergence in the field of robotics: taking linguistics books as an example, research paradigms are evolving from traditional methods toward deep integration with deep learning and pre-trained models.

Summary and Outlook

In summary, the deep integration of intelligent technologies with library operations is an inevitable path toward enhancing management efficiency and service quality. In the future, with the further development of technologies such as multimodal large language models, smart libraries will evolve toward greater personalization and precision, ultimately achieving a fundamental transformation of service models.

References

Cao, G. (2019). A library reference service robot: China. CN201920345678.9 [P]. 2019-05-20.

Chen, W. (2015). A method for door recognition based on deep convolutional neural networks in robot navigation and its application. Doctoral dissertation, Guangdong University of Technology.

DU, H. et al. (2017). Parameter estimation of LDA model based on Gibbs sampling. *Computer Science, 44*(4), 1-6.

Fan, H. L. (2018). Innovative practices and reflections on intelligent robot-assisted book inventory—A case study of Nanjing University library. *Library, 9*, 1-5.

Guo, S. (2017). Application of intelligent robot technology in real-time reference consultation services in public libraries. *Library Science Research, 10*, 69-73.

He, N. (2018). Research on navigation and path planning technologies for service robots. *Mechanical Design and Manufacturing*, *10*, 39-42.

Huo, R. J. (2026). The national smart library system: Charting a new vision for high-quality development of public libraries through "AI+". *Library Theory and Practice*, *1*, 1-6.

Intelligent Book Inventory Robot [EB/OL]. (2024-01-01) [2025-01-01]. https://baike.baidu.com/item/智能图书盘点机器人/53968471

Li ,Y. (2021). Research on robot service strategies in Chinese libraries and prospects for the future. *Library Work and Research, 5*, 1-8.

Li, J. N. (2019). Research and design of a deep learning-based intelligent shelving recognition system for libraries. Doctoral dissertation, Beijing University of Posts and Telecommunications.

Lin, L. L. (2019). Discovery and evolution analysis of research themes in domestic library and information science based on the LDA model. *Information Science*, *37*(12), 176-183.

Lu, T. T. (2017). From smart library to intelligent library: The transformation of library development in the artificial intelligence era. *Library and Information, 5*, 1-8. (in Chinese)

Qi, Y. S. (2016). A comparative study on the evolution of topic popularity in domestic and international library and information science research based on DTM. *Library and Information Engineering*, *60*(16), 68-77.

So Advanced! Zhejiang Library Launches Robot Librarian [EB/OL]. (2025-01-01)[2025-01-01]. https://baijiahao.baidu.com/s?id=1832319039188913246&wfr=spider&for=pc.

Su, Y. T. (2024). An intelligent data service robot system based on NLP technology.

Wang, L. J. (2017). Location recognition based on convolutional neural networks. *Electronic Science and Technology*, *30*(1), 1-5.

Wang, T. T. (2018). A study on determining the optimal number of topics in topic models based on the confusion index. *Data Analysis and Knowledge Discovery*, *2*(5), 45-52.

Wang, X. X. (2024). Research and implementation of a dialogue system based on the Seq2Seq model. Doctoral dissertation, Nanjing University.

Xie, P. (2025). Research and practice of innovative library services through multi-modal intelligent robot collaboration: A case study of the Beijing city library. *Library Journal*, *44*(1), 1-10.

Yang, G. (2017). Image recognition for substation inspection robots based on convolutional neural networks. *Software*, *38*(12), 1-5.

Yang, Y. (2021). Research on the integration of robotics and library service innovation: Progress, issues, and prospects. *Journal of the National Library of China*, *30*(2), 1-10.

Yao, F., Ji, L., Zhang, C. Y. et al. (2011). A new approach to real-time virtual reference services: The Tsinghua University library intelligent chatbot. *Modern Library and Information Technology*, *4*, 77-81.

Zhou, L. (2019). Research on object pose recognition methods based on convolutional neural networks. Doctoral dissertation, Harbin Institute of Technology.

Zhu, C. L. (2021). Research on the optimization of book classification algorithms based on deep learning. Doctoral dissertation, Wuhan University.