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Research and Application of AI-Based Interactive Exhibits in Wuhan Museum of Science and Technology

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Abstract: This article aims to explore the development and application of AI-based interactive exhibits in Wuhan Museum of Science and Technology. By utilizing computer vision, natural language processing, and machine learning technologies, an innovative exhibit development and application system is proposed. This system employs deep learning algorithms and data analysis methods to achieve real-time perception of visitor behavior and adaptive interaction. The development process involves designing user interfaces and interaction methods to effectively enhance visitor engagement and learning outcomes. Through evaluation and comparison in practical applications, the potential of this system in enhancing exhibit interaction, increasing visitor engagement, improving educational effectiveness, and expanding avenues for scientific knowledge dissemination are validated.

Keywords: Artificial intelligence; Interactive exhibits; Computer vision; Natural language processing; Machine learning

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1. Introduction

Wuhan Museum of Science and Technology is a large science popularization venue that currently faces issues such as ineffective information communication and low visitor engagement. In order to enhance the interactivity and educational value of exhibits, the field of exhibit development and application is incorporating artificial intelligence technology. Wuhan Museum of Science and Technology is an important place for popular science and technology exchange, gathering a large number of scientific and technological talents. In order to further promote technological innovation at the Wuhan Museum of Science and Technology, AI-based interactive exhibit development and application will be conducted, creating a system platform driven by scientific research and technological innovation. This platform aims to improve the interactive experience of exhibits and the dissemination of scientific knowledge, provide a showcase for cutting-edge scientific achievements, and lead innovative development.

The development of an AI-based interactive exhibit development and application system requires the integration of technologies from fields such as computer vision, natural language processing, and machine learning [1]. Artificial intelligence is the ability of computer systems to simulate human intelligence, including speech recognition, image processing, and automated decision-making. Machine learning is a subfield of artificial intelligence that enables computer systems to learn and adapt by training algorithms to improve performance based on data. Deep learning is a specialized form of machine learning that simulates the structure and functionality of the human brain's neural network, enabling learning and analysis of complex data through training and optimization with large datasets. Visual system algorithms are a type of system based on computer vision technology, aimed at achieving interactive exhibit experiences through analysis and processing of behavioral and dynamic data. These algorithms have evolved from the general field of computer vision and incorporate specific requirements and challenges of the museum context.

We will utilize computer vision technology to achieve real-time perception of visitor behavior [2], employ natural language processing technology for real-time interaction with visitors, and utilize machine learning algorithms to analyze visitor behavior. To enhance the interactive experience and learning outcomes, we will design user interfaces and interaction methods that are well-suited to the context. The system design and implementation will include techniques for exhibit recognition and localization, principles and implementation methods for user interaction interfaces, algorithms and processes for data processing and analysis, as well as design concepts and implementation details for adaptive response and presentation modules.

By establishing an AI-based interactive exhibit development and application system at the Wuhan Museum of Science and Technology, the goals and background of this new research system will be defined, and AI and machine learning research will be conducted. We will explore new research directions in artificial intelligence, improve the research level and influence of the Wuhan Museum of Science and Technology in the field of artificial intelligence, promote innovation in science and technology experiences, enhance public understanding of artificial intelligence, and foster awareness of technological innovation. By combining artificial intelligence with exhibits, the system will provide services such as showcasing cutting-edge technology exhibitions, science education, technological innovation support, research and development services, technology transfer, and enterprise incubation. This will lead to the development of related industries, and promote the integration of scientific and technological innovation with the economy and society.

2. Technologies applied in AI-based interactive exhibit system

2.1. Main components of computer vision technology

Computer vision technology is the foundation for implementing key functionalities of AI-based interactive exhibit systems. It consists of several components.

(1) Feature extraction

It is a fundamental task in computer vision that converts image or video data into numerical representations that can be further analyzed and processed. Common methods for feature extraction include edge detection, corner detection, and texture feature extraction. These features capture information such as structure, boundaries, and textures in the image, providing a foundation for subsequent image recognition and analysis.

(2) Image classification and object recognition

The goal is to classify objects or scenes in images into predefined categories. Machine learning and deep learning techniques are used to train models to learn patterns for feature extraction and classification from images. Common algorithms include convolutional neural networks (CNN) and support vector machines (SVM).

(3) Object detection and tracking

Used to locate and identify specific objects in images or videos. Object detection algorithms detect and localize multiple objects in an image and assign category labels to each object. Tracking algorithms track the motion trajectory of objects in video sequences. Common algorithms include deep learning-based methods like region-based convolutional neural networks (R-CNN) and Kalman filters.

(4) 3D reconstruction and depth perception

Used to infer the 3D structure and depth information of a scene from images or videos by extracting geometric and texture information from multiple views. Common algorithms include structured light, stereo matching, and dense optical flow.

(5) Pose estimation and motion analysis

Used to detect and estimate the pose and motion information of humans or objects, track dynamic changes in joints, estimate object trajectories, and for applications such as pose recognition, action recognition, and motion analysis. Common algorithms include deep learning-based pose estimation methods and optical flow analysis

(6) Behavior recognition and activity analysis

Identifies and understands human or object behavior and activities from video sequences, which is important in areas such as video surveillance, video understanding, and human-computer interaction. Common algorithms include deep learning-based methods (such as recurrent neural networks and 2D/3D convolutional neural networks), as well as optical flow analysis and trajectory analysis.

(7) Visual SLAM (Simultaneous Localization and Mapping)

A method that combines visual perception and localization techniques to dynamically build environment maps and simultaneously estimate the camera's position and orientation in real time. It is used in augmented reality, navigation, robotics, and virtual reality domains. Common algorithms include feature-based methods, direct methods, and semi-direct methods.

(8) Deep learning and transfer learning

Deep learning has powerful representation learning and pattern recognition capabilities in computer vision tasks. By using deep convolutional neural networks (CNN) and recurrent neural networks (RNN) models, excellent performance has been achieved in tasks such as image classification, object detection, image segmentation, and image generation. Transfer learning utilizes pre-trained deep learning models for fine-tuning new tasks to improve the model's generalization ability and effectiveness.

2.2. The development of an interactive exhibit system utilizing computer vision technology combined with natural language processing and machine learning techniques

In the development of interactive exhibition systems, computer vision can be combined with natural language processing (NLP) and machine learning techniques to achieve the following:

(1) Text recognition and understanding

Computer vision utilizes Optical Character Recognition (OCR) to convert text on exhibits into recognizable text, which is then processed using NLP techniques for natural language understanding and semantic analysis. This enables the exhibition system to understand the textual information on exhibits and provide relevant presentation content and explanations based on user queries or instructions.

(2) Voice interaction and speech recognition

By using speech recognition technology, the exhibition system converts user voice commands into text data. NLP techniques are then applied to this text data for speech understanding and semantic analysis, allowing users to interact with the exhibition system through voice, ask questions, obtain information, and control the displayed content.

(3) Intelligent question-answering and dialogue systems

By combining computer vision, NLP, and machine learning techniques, the exhibition system can implement dialogue functionality and intelligent question-answering. NLP techniques are used to understand user intentions from their questions and expressions and extract answers from relevant information about the exhibits. By training machine learning-based dialogue models, the exhibition system can engage in natural and fluent conversations with users.

(4) Sentiment analysis and personalized experiences

By combining computer vision and NLP techniques, the exhibition system can analyze user emotions and feedback. By recognizing user expressions, tone, and semantics, it can understand the user's emotional state and adjust the displayed content or interaction methods accordingly, providing a personalized exhibition experience.

(5) Knowledge graphs and recommendation systems

Knowledge graphs integrate relevant knowledge and information from exhibits, combining computer vision, NLP, and machine learning techniques. By analyzing the content of exhibits, extracting key information, and building a knowledge graph, the exhibition system can provide personalized recommendations, suggest related exhibits, or offer additional information based on the user's interests and preferences.

3. AI-based interactive exhibit development and application system

3.1. AI-based interactive exhibit development

The development of AI-based interactive exhibits involves several modules.

(1) Exhibit recognition and localization

Computer vision techniques are utilized to recognize and locate exhibits. By training deep learning models, the system can identify the features of exhibits from images captured by cameras or sensors and determine their position and orientation in the exhibition space. This exhibit recognition and localization can be achieved through algorithms such as object detection, image segmentation, and pose estimation.

(2) User interaction interface design

Intuitive and user-friendly interaction interfaces are designed for visitors to interact with exhibits. This includes touch screens, gesture recognition, and speech recognition. Visitors can interact with exhibits through touch, gestures, or voice commands and obtain related information, explanations, and educational content.

(3) Data processing and analysis module

The data collected from exhibit recognition and user interaction interfaces will be analyzed and processed. Additionally, this module can transmit real-time data to backend servers for further data analysis and mining to extract valuable information such as exhibition engagement, user preferences, and behavioral patterns.

(4) Adaptive response and presentation module

This module utilizes machine learning techniques to achieve adaptive response and presentation of exhibits based on visitor behavior and feedback. By analyzing visitor interaction and feedback, the system automatically adjusts exhibit demonstration content, presentation methods, or interaction modes to provide personalized exhibition experiences based on the needs and interests of different visitors.

(5) Multimodal interaction

In addition to traditional interaction methods such as touch screens, gestures, and speech, other multimodal interaction technologies can be introduced, such as virtual reality (VR) and augmented reality (AR). Through the use of VR headsets or AR glasses, visitors can have more immersive and realistic interactive experiences with exhibits, enhancing the attractiveness and educational effectiveness of the exhibition.

(6) Emotion recognition and feedback

Emotion recognition enables the system to perceive visitors' emotional states. By analyzing facial expressions, speech tones, and other physiological indicators, the system can understand visitors' emotional feedback and adjust exhibit presentation and content accordingly, providing a more personalized and emotionally engaging exhibition experience.

(7) Collaborative interaction

Collaborative interaction allows visitors to share exhibit-related information, opinions, and experiences with each other. Visitors can communicate with each other by connecting multiple user devices, creating a richer and more engaging exhibition interaction experience.

(8) Data analysis and optimization

In the data processing and analysis module, machine learning and data mining techniques are used to perform in-depth analysis of the collected data. By analyzing visitor behavior patterns, interests, and engagement metrics, the exhibition content, interaction methods, and exhibition design can be optimized to enhance the attractiveness and educational effectiveness of the exhibits.

(9) Intelligent recommendation and personalized services

Based on visitor interests and preferences, the system provides intelligent recommendation features, suggesting other exhibit materials and activities related to the exhibits. Through personalized exhibit recommendations and customized exhibition services, visitors can have a more enriching and personalized exhibition experience.

(10) Security and privacy protection

When designing the system, it is essential to ensure visitor data security and privacy protection. Adequate measures, such as data encryption and privacy protection, should be implemented to prevent the misuse or leakage of visitor's personal information and interaction data.

The development of such a system would involve various programming languages and tools, such as Python, deep learning frameworks (e.g., TensorFlow or PyTorch), computer vision libraries (e.g., OpenCV), and natural language processing toolkits (e.g., NLTK or spaCy).

3.2. AI-based interactive exhibit applications

AI-based interactive exhibit systems can be applied in various fields, including science education exhibitions, cultural heritage preservation displays, and social entertainment experiences. For different cases, the system will describe the goals, application scenarios, and actual effects of exhibit designs. For example, interactive and experiential innovative exhibitions are designed. By employing virtual reality (VR) and augmented reality (AR) technologies, immersive machine-learning experiences can be created. For example, using VR headsets to showcase the internal workings of machine learning algorithms to visitors, or projecting machine learning models into the real world for interaction using AR applications, demonstrating the principles, applications, and potential of machine learning to the public. The exhibition includes real-life cases, demonstrations, experiments, and gamified elements to engage visitors and facilitate learning.

Interactive displays using machine learning technologies will be created. Intelligent dialogue systems using natural language processing techniques will be built to allow visitors to interact with the displays to gain a deeper understanding of the workings and application of machine learning.

(1) Computer vision showcase

Demonstrate the applications of machine learning in image and visual processing using computer vision and image recognition technologies. Showcase applications such as facial recognition, object recognition, or emotion analysis to provide real-world examples of machine learning in action.

(2) Smart guiding system

An intelligent guiding system using machine learning and location recognition technologies will be created. Based on visitors' interests and requirements, the system provides personalized guidance and recommendations, enabling visitors to navigate the exhibition efficiently and explore exhibits that align with their preferences.

(3) Data visualization and exploration

AI techniques are utilized to analyze and visualize complex datasets. Interactive exhibits that allow visitors to explore and interact with the data visually are designed. Through interactive visualizations and data-driven storytelling, visitors can gain insights and a deeper understanding of complex information and phenomena.

3.3. Experimentation and evaluation of AI-based interactive exhibit system

To validate the performance and effectiveness of the system, experiments, and user research will be conducted in real exhibition settings. The experimental design includes experimental scenarios, settings, and data collection to gather feedback from the audience. The system will be evaluated in terms of interactivity, user experience, and educational outcomes to validate its practical effectiveness. The design and implementation of the actual system will vary depending on specific requirements and technological choices, and adjustments and expansions will be made accordingly based on research goals and available resources. The specific contents are as follows:

(1) Functionality testing

Functionality testing involves determining the accuracy of speech recognition exhibits in recognizing and answering audience questions and ensuring that the correspondence between virtual elements in virtual guides and AR exhibits and actual exhibits is correct.

(2) User experience survey

Audience feedback on exhibit experiences will be collected through questionnaires or interviews to improve the design and functionality of the exhibit system.

(3) User behavior observation

The audience's behaviors and reactions when interacting with exhibits will be observed. Data such as interaction methods, frequency of use, and duration, will be recorded to evaluate the attractiveness and engagement of the exhibit system.

(4) Emotion recognition accuracy testing

Audience samples with known emotional states will be used to test the accuracy of the exhibit system in recognizing audience emotions. The audience's emotional states will be observed through their facial expressions, voice, and other indicators.

(5) Data accuracy and visualization evaluation

The accuracy and readability of data presented by the data visualization system will be evaluated. The information presented by the exhibit system will be compared with professional domain data to verify its accuracy, ease of understanding, and effectiveness in communication.

(6) Interaction performance testing

The interaction between the exhibit system and the audience will be evaluated, including response time, accuracy, and fluency. Various usage scenarios and user loads will be simulated to verify the exhibit system's interaction performance under different conditions.

(7) Safety and privacy testing

The security and privacy testing for exhibits involves ensuring that the exhibit system's data protection and privacy measures comply with relevant regulations and standards.

(8) Sustainability assessment

The sustainability and environmental impact of the exhibit system will be assessed. This involves the consumption of energy, materials, and renewable resources, as well as their potential environmental effects. Improvement measures will be proposed based on the assessment results.

4. Discussion and prospects of AI-based interactive exhibit system development and application

An in-depth analysis of research results will be conducted to discuss the advantages, potentials, and limitations of the AI-based interactive exhibit system. Improvement measures will be proposed based on the results of experiments and application cases. The potential applications of artificial intelligence in exhibit design will be explored. Further research will focus on utilizing deep learning algorithms to fuse and analyze multimodal data to enhance the personalized interactive effects of exhibits [3].

(1) Data-driven exhibit design

AI technology can help exhibit designers better understand audience needs and behavioral patterns. By collecting and analyzing a large amount of data, exhibits can be optimized and improved based on audience interests, feedback, and interaction data. This data-driven design approach will enhance the attractiveness and engagement of exhibits.

(2) Affective intelligence

Affective intelligence is an emerging field in the field of artificial intelligence that aims to enable machines to understand and respond to human emotions. In interactive exhibits, affective intelligence can help exhibits perceive the audience's emotional states and adjust interactions and feedback accordingly to create more personalized and emotional experiences.

(3) Multimodal interaction

AI technology enables multimodal interactions, including voice, gestures, images, and touch. Exhibits can integrate various interaction modes, allowing audiences to interact with exhibits in their preferred ways, providing a more comprehensive and rich experience.

(4) Group interaction and collaboration

AI-based interactive exhibits can facilitate group interaction and collaboration among audiences. Audiences can participate in exhibit interactions together, solve problems, and collaborate to complete tasks, enhancing teamwork and collaboration skills.

(5) Integration with social media

Integrating social media with interactive exhibits provides audiences with broader engagement and sharing experiences. Audiences can communicate with other attendees, share their interactive experiences through social media platforms, and further interact with exhibits.

(6) Continuous updates and upgrades

The rapid development of AI technology means that exhibits need to be continuously updated and upgraded to keep up with the latest technological and algorithmic advancements. The design and development of exhibits should consider scalability and flexibility for future updates and enhancements.

(7) Education and social impact

AI-based interactive exhibits have great potential in education and social impact[4]. Exhibits can be used to educate and inspire audiences, fostering interest and skills in science, technology, engineering, and mathematics (STEM) fields. Additionally, exhibits will stimulate reflections and discussions on important issues related to AI, such as ethics, privacy, and fairness.

5. Conclusion

The AI-based interactive exhibit development and application system at the Wuhan Museum of Science and Technology will provide innovative display methods for large-scale science education venues. Through application experiments in actual exhibition settings, the effectiveness of the system in enhancing audience engagement and learning outcomes will be validated. By interacting with the audience through speech recognition, augmented reality, and data visualization, the exhibit system aims to create immersive and personalized experiences for visitors, highlighting its importance and potential in the fields of science education and exhibition design, and effectively expanding avenues for scientific knowledge dissemination.

Disclosure statement

The author declares no conflict of interest.

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