Research on the Dynamic Dissemination and Application of College Basketball Teaching Resources Empowered by Intelligent Display Watermarking

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ABSTRACT Open dissemination of basketball teaching resources is often constrained by insufficient copyright protection and limited traceability, which restrict the secure sharing and sustainable development of high-quality educational content. In modern multimedia communication environments, reliable digital content protection is increasingly important for maintaining signal integrity and supporting efficient information dissemination. This study proposes an intelligent display watermarking framework for the dynamic dissemination and application of college basketball teaching resources. A dynamic propagation model with an implicit front-end and explicit back-end architecture is constructed, incorporating four functional modules: resource preprocessing and feature extraction, adaptive watermark embedding, watermark extraction and verification, and resource tracking and aggregation. An adaptive watermark embedding strategy based on video attributes is developed by integrating Discrete Cosine Transform (DCT) and spread-spectrum techniques to improve robustness while preserving visual quality. Experimental results demonstrate that the proposed scheme maintains a watermark extraction rate exceeding 94% and a traceability accuracy of 95% under common processing operations such as transcoding and cropping. Furthermore, the framework promotes standardized resource dissemination and intelligent aggregation, increasing original resource collection by 36% and citation frequency by 42.4 %. The proposed approach provides an effective solution for secure multimedia resource management and digital content transmission in networked educational environments.

INDEX TERMS smart watermarking, basketball teaching resources, digital signal processing, multimedia communication, resource traceability

I. INTRODUCTION

WITH the deepening digital transformation of education , basketball instructional materials and spinning process simulations are increasingly becoming multimedia-based, utilizing dynamically edited animations to present complex body movements and intricate weaving structures. These high-value digital resources are driving educational innovation by providing precise, web-based demonstrations of sports techniques. However, when high-quality resources are disseminated in an open network environment, they often face problems such as easy copyright infringement, unclear dissemination channels, difficulties in resource traceability, and subsequent resource aggregation. This is detrimental to teachers' active development and sharing of resources, and also hinders the healthy development of the resource ecosystem. Existing research mostly focuses on resource construction and skills assessment within the teaching loop, lacking consideration for the open, dynamic allocation and ecological control of resources after creation. Aiming at the issues of copyright protection and controllable sharing in the open flow of resources, this paper systematically introduces intelligent digital watermark technology into the management of college basketball teaching materials This application ensures the traceability of dynamic sports videos, thereby protecting the intellectual property rights of teaching content. Namely, its main contributions are as follows: first, a framework based on smart watermarking is developed to support the dynamic distribution of basketball teaching materials through resource copyright protection levels, usage traces and intelligent aggregation; second, a proposal is made based on the specific situation of basketball teaching materials The adaptive strategy of watermark embedding significantly improves the robustness of watermarks to common video processing operations while ensuring visual quality. Third, a set of resource propagation path restoration and intelligent aggregation methods based

on watermark traceability information are designed and verified, providing new tools for the ecological operation and management of teaching resources.

The structure of this paper is as follows: Part II reviews relevant research; Part III elaborates on the proposed intelligent watermarking empowerment framework, adaptive embedding strategy, and source tracing aggregation method; Part IV presents the experimental design and results, and analyzes and discusses the technical performance, management efficiency, and ecological empowerment effects; Finally, the paper summarizes and looks forward to future research directions.

II. RELATED WORK

With the deepening of the digital education strategy, the basketball teaching paradigm is undergoing a profound transformation from traditional skills instruction to data-driven, personalized interactive intelligent teaching. Ding et al. [1] found that the blended teaching model in the era of smart education has optimized the allocation of basketball course teaching resources, met the personalized learning needs of students, and significantly improved the teaching quality of the course. Yu et al [2] explored the mechanism and practice path of digital technology in college basketball teaching. Liu et al. [3] proposed measures such as improving teachers' digital teaching ability, building a three-dimensional supervision and feedback mechanism, and enriching the construction of online teaching resources Xue and Li [4] built a shooting motion capture sub system and its micro-lesson teaching resource design and development module, combined with the system management module consisting of management database, user login management, teacher management, student management, class management, user personal management, etc., to improve the micro-lesson teaching auxiliary system architecture. Wen [5] relied on the "DingTalk" software, according to the three major sections of teaching environment, teaching activities, and student activities, and the three stages of pre-class, in-class, and post-class, to explore the construction of a blended teaching model for basketball courses in vocational and technical normal colleges.

Richards et al. [6] pointed out that structured basketball teaching with adaptive design can effectively promote the acquisition of basic basketball skills in children with ASD. Mubarak et al [7] found that students who used peer teaching to teach basketball free throws had significantly better learning outcomes than students who received traditional teaching methods. Wang [8] used Kinect to capture three-dimensional motion data of the body joints when students completed basketball technical movements. Abdullah [9] evaluated the effectiveness of basketball coaches using kinesthetic teaching styles in practical classes. Qiu and Cao [10] proposed a basketball-assisted teaching video system based on the mobile edge computing (MEC) architecture. Existing explorations are mostly focused on resource construction, skill assessment or instant feedback within the teaching loop, and have failed to effectively solve the problems of open dynamic dissemination, copyright confirmation and traceability aggregation after the generation of high-quality teaching resources. This paper introduces a new digital watermarking technology to explore how it can empower the traceable dissemination, intelligent aggregation and ecological co-construction of teaching resources while ensuring the copyright and integrity of resources, and promote the formation of an open, orderly and evolving new ecosystem of basketball teaching resources.

III. METHODS

A. DESIGN OF A FRAMEWORK FOR DYNAMIC DISSEMINATION OF TEACHING RESOURCES EMPOWERED BY INTELLIGENT WATERMARKING

The overall design of the framework follows the principle of "front-end invisibility and back-end visibility". The front-end is for teachers and students, and the watermark embedding and extraction process is automated and imperceptible, minimizing interference with normal teaching activities. The back-end builds a powerful watermark information management and analysis engine, responsible for watermark key management, embedding strategy formulation, extraction request processing, propagation path graph construction, and resource association calculation. The framework mainly includes four core modules:

(1) Resource preprocessing and feature extraction module: performs format unification, key frame extraction, and content feature analysis on uploaded basketball teaching resources (such as shooting action videos and tactical illustration animations) to select the best area for adaptive watermark embedding, ensuring the invisibility and robustness of the watermark.

(2) Intelligent watermark generation and embedding module: generates digital watermark information based on resource creator information, timestamp, resource unique identifier (UUID), and preset copyright statement. A hybrid watermarking algorithm based on discrete cosine transform (DCT) and spread spectrum technology is adopted to adaptively embed the watermark information into the visually unimportant frequency domain components of the resource carrier. Meanwhile, for scenarios requiring rapid visual verification, a semi-transparent visible dynamic watermark (such as text containing the creator's abbreviation and date) can be selectively superimposed to form double protection.

(3) Watermark extraction and verification module: When a resource is accessed or spread, the system or authorized user can use the corresponding extraction key to recover the watermark information from the resource. This module is responsible for verifying the integrity and authenticity of the resource and parsing out the embedded copyright and traceability information. This module is designed to support asynchronous processing. Extraction requests are queued and processed by background worker processes, thus avoiding blocking user interaction. This allows the system to handle large-scale, high-concurrency extraction

tasks without affecting the front-end user experience, providing a continuous data stream for the back-end intelligent aggregation engine.

(4) Resource dynamic tracking and intelligent aggregation engine: Based on the extracted watermark information (especially UUID), the system records every access and spread event of the resource and constructs a dynamic resource spread graph. The engine uses the graph data to analyze the resource's popularity, spread path, and associated resources (such as those based on the same technical actions or the same creator), thereby realizing intelligent resource recommendation, similar resource aggregation, and automatic discovery and alarm of copyright violations. This framework elevates watermarks from a simple copyright protection tool to an intelligent link connecting resources, creators, users, and management platforms [11] .

B. ADAPTIVE WATERMARKING EMBEDDING STRATEGY BASED ON THE CHARACTERISTICS OF BASKETBALL TEACHING RESOURCES

The training tools used in basketball teaching are mainly videos, with many action scenes and complex backgrounds, and more attention is paid to the concealment and intensity of watermarks. These properties may not be suitable for general watermarking algorithms. Therefore, this paper introduces an adaptive embedding strategy for basketball instructional videos using watermarks. First, the video is segmented to identify key frames (shooting points, starting positions of defensive postures, and other relatively stable shots). In these keyframes, the image is detected based on a visual saliency model (employing a frequency-domain-based spectral residual model, which locates salient regions by calculating the amplitude spectrum residual after the Fourier transform of the image, thus avoiding areas of human visual interest) to extract background or texture regions. These locations are independent of the human visual system (HVS) and are the optimal locations for watermark embedding. Secondly, the final watermark embedding strength is dynamically adjusted based on the motion amplitude and spatial complexity of the video content. Specifically, the motion amplitude M is defined as the mean absolute difference (MAD) of pixel changes between adjacent frames, and the texture complexity T is the gray-level variance of local blocks. The watermark embedding strength α is adaptively determined using the following formula.The embedding strength can then be scaled up accordingly to higher levels for improved robustness when the teaching asset is low motion and predictable, or scaled down to focus more on image quality rather than the obvious blockiness and judder caused by watermarks in the case of fast action or game highlights or live demonstrations where images change rapidly. In the DCT domain, we select intermediate frequency coefficients for watermark embedding and use spread spectrum technology to modulate the watermark signal into a pseudo-random sequence to enhance its resistance to attacks. The spread spectrum factor is set to 15 to ensure that the watermark is robust while maintaining its invisibility. Even the watermark information is composed of fixed components (copyright owner ID, resource UUID) and variable components (anonymous identifier of the authorized user). In the case of authorized users to download or share resources, the system can dynamically update the watermark of the variable component in the embedding layer, thereby obtaining fine-grained control of the propagation path. This adaptive strategy ensures that the watermark will not have a negative impact on the core visual information of basketball teaching (such as player action details, ball trajectory) while resisting common attacks (such as H.264/265 compression, resolution scaling, brightness contrast adjustment, local cropping) [12,13].

C. A METHOD FOR RECONSTRUCTING AND AGGREGATING RESOURCE PROPAGATION PATHS BASED ON WATERMARKED SOURCE TRACING INFORMATION

Watermarks reconstruct the flow of resources conveying traceability information. This paper proposes a propagation path reconstruction scheme based on watermark UUID. Each original source is assigned a globally unique UUID, which is integrated as the core information of the watermark. In the case of a second dissemination (e.g. when student A downloads it to a teaching device and shares it with social group B), ideally the disseminator information (e.g. anonymous group ID or user hash) could always be stored as additional information or associated with the watermark in a specific way. The system can capture logs with resource UUID and propagation node data by using lightweight watermark extraction agents on various network nodes (such as official teaching platforms, cloud storage widely used by students, social media interfaces) or rendering watermark extraction devices to the client. These records are sent to a central node or stored in a distributed registry on the blockchain (thus providing tamper-proof records). The path reconstruction algorithm (server side) records all corresponding related logs with UUIDs, sorts them by time, and generates a directed graph, in which resources are nodes and the propagation relationships between them are the edges of the graph, that is, the resource propagation graph. According to this diagram, not only can the entire chain of the original creator's resources flow to the final consumer be monitored, but also key communication nodes can be examined to evaluate the impact of the resources. In addition, the intelligent aggregation engine performs multi-dimensional analysis through the propagation graph and metadata of the resource itself (which can be traced back to the original database through watermark UUID). With the help of like-minded topic tags or keywords in the watermark, these resources are automatically combined with each other to form a specialized resource package that is recommended to students or teachers who may be interested. This aggregation based on watermark traceability is more accurate and credible than retrieval based solely on file

names or tags, because it is based on dynamic data of actual resource usage and dissemination [14,15].

To verify the reliability of the adaptive watermark embedding strategy proposed in this study in a real-world distribution environment, we conducted robustness tests on common processing operations in basketball instructional videos. The results are shown in Table 1

The results in Table 1 were analyzed to reveal that the adaptive watermark embedding strategy presented in this paper has a high level of robustness to most video processing attacks. With normal operations like transcoding, scaling, and changing of frame rate, the quality decrease of the watermarked image is negligible (PSNR is over 42dB) and the watermark-related data can be recovered nearly fully and free of error (bit error rate is less than half an percent). Signal enhancement attacks like noise of the signal, brightness/ contrast adjustment, etc. offer some errors in extracting the watermark, yet they are tolerable. Anyone can moderate the effect of bit errors with error correction coding techniques. The process of local cropping and screen recording is more challenging, as it can physically harm the carrier of the watermark. Nevertheless, test samples demonstrate that despite such attacks, over 94 percent of the samples are still able to extract the watermark. This can be explained by the fact that the adaptive strategy entails the ability to insert the watermark in a dispersive manner in a variety of keyframes and other visual parts that are not significant, which decreases the chances that the entire watermark will be lost because of the local position. However, the watermark extraction success rate drops significantly when facing advanced malicious attacks such as conspiracy attacks and deepfakes. Particularly in deepfake scenarios, the original watermark signal is severely damaged due to the partial or complete regeneration of video content, resulting in an extraction success rate of only 42%. This indicates that current solutions still have considerable room for improvement in combating intelligent malicious tampering, which is also a key area for our future research.On the whole, this watermarking plan is capable of fulfilling the needs of basketball instructional materials in the networked transmission setting to withstand an accidental or semi-malicious processing.

IV. RESULTS AND DISCUSSION

A. PERFORMANCE VERIFICATION AND ANALYSIS OF SMART WATERMARKING TECHNOLOGY

According to the data of the robustness test, presented in Table 1, the intelligent watermarking scheme used in the research described is proved to be not only technically valid but also efficient. The high PSNR value shows that there is insignificant effect of embedding the watermark process on the quality of the images of the original basketball teaching video; students and teachers will not notice any decline in the quality of the images as they watch the video that is teaching and acceptable. The error and success rate are also low and high respectively and this indicates that the information that is stored in the watermark stays the same even when it goes through all the common network propagation routines and this will give a good database to be further used against copyright checking and tracing of the source as well. It is interesting to note that unauthorized dissemination of resources through screen recording, as a typical mode of people without authorization dissemination, the watermark continues to succeed in watermark extraction at a 94% rate. This is because although the resource might be screen-recorded and subsequently reshared, the source information can in most instances be identified and this is a great discouraging factor on part of any would-be copyright infringement. In addition, the efficiency in computation of the process of embedding and extraction of the watermark has also been tested. Through server default settings, it only takes approximately 90 seconds to embed a watermark in a 5 minute 1080p basketball tutorial video and the average coverage is approximately 2-3 seconds to de-embed the watermark. All extraction requests (e.g., user-uploaded resources, system scanning of network nodes) are placed in a message queue and processed in the background by a distributed worker cluster. The processed results (such as UUIDs and timestamps) are stored in a database for offline, periodic data analysis by the intelligent aggregation engine.This can be tolerated with asynchronous background processing and it will not lead to delays to users in accessing resources. These are the technical performance indicators that pave the way to the implementation of watermarking technology in practical teaching systems.

To further verify the advancement of the proposed method, we conducted comparative experiments with two widely used modern robust watermarking algorithms—those based on Discrete Wavelet Transform (DWT) and those based on Singular Value Decomposition (SVD). The comparative experiments used the same basketball instructional video dataset (50 samples) and tested the average extraction success rate and average PSNR of the three algorithms under the same attack conditions (H.264 encoding, Gaussian noise, local cropping). The results are shown in Table 2.

As shown in Table 2, under three typical attacks, the proposed DCT+spreading adaptive watermarking method outperforms the DWT and SVD methods in both extraction success rate and PSNR. Especially when facing highly destructive attacks such as local cropping, the proposed method still achieves a 96% extraction success rate, while the DWT and SVD methods drop to 92.5% and 91.0%, respectively. This is attributed to the proposed method's ability to disperse and embed watermark information into non-salient regions of multiple keyframes, enhancing its resistance to local damage. Simultaneously, the proposed method maintains the highest visual quality (highest PSNR value), indicating that the adaptive embedding strategy achieves a better balance between robustness and invisibility. This comparative result strongly demonstrates the technical value of the proposed method in the context of protecting basketball teaching resources.

TABLE 1. Robustness test results of the intelligent watermarking algorithm (for 1080p basketball instructional video samples)

Attack type	Parameter settings	Sample size	Average PSNR (dB)	Watermark extraction bit error rate (%)	Success rate (%)
H.264 encoding	CRF=23	50	45.2	0.12	100
H.265 transcoding	CRF=25	50	44.8	0.21	100
Resolution scaling	720->480	50	42.5	0.48	100
Gaussian noise	SNR=30dB	50	41.3	1.05	98
Frame rate halved	30fps ->15fps	50	43.9	0.33	100
Brightness/contrast adjustment	±20%	50	44.1	0.27	100
Partial cropping	Trim 10% of the edge	50	40.2	2.15	96
Screen recording re-encoding	1080p screen recording encoded in H.264	50	39.8	3.40	94
Collusion Attack	Average of 3 differently watermarked versions	30 groups	N/A	8.75	67
Deepfake / AI Manipulation	FaceSwap-based local replacement	50	37.1	15.30	42

TABLE 2. Performance Comparison of Different Watermarking Algorithms

Attack Type	Algorithm	Average Extraction Success Rate (%)	Average PSNR (dB)
H.264 Encoding (CRF=23)	Proposed DCT+Spread Spectrum	100	45.2
	DWT	98.5	43.8
	SVD	97.2	44.1
Gaussian Noise (SNR=30dB)	Proposed DCT+Spread Spectrum	98	41.3
	DWT	95.6	40.2
	SVD	94.3	39.8
Partial Cropping (10%)	Proposed DCT+Spread Spectrum	96	40.2
	DWT	92.5	38.7
	SVD	91.0	37.9

B. EVALUATION OF THE EFFECTIVENESS OF WATERMARK-BASED RESOURCE PROPAGATION PATH MANAGEMENT AND TRACEABILITY

To examine the practical effectiveness of watermarking in the dynamic dissemination and management of resources, this study simulated a resource dissemination chain comprising four levels: original teacher, internal school platform, student community, and external network. In the simulation, 100 basketball teaching resources embedded with smart watermarks were fed into this chain, and their dissemination events were recorded. Simultaneously, a control group was set up, using a traditional method of tracing the source solely based on file metadata (such as creator and modification time). The results are shown in Figure 1.

Tracing using watermark has a mean accuracy of 95, which is much higher compared to the 54.7 of metadata methods. The accuracy of the two techniques diminishes as the propagation level becomes even deeper (between the original creator and the student population), although the reduction in accuracy of the watermarking technique is much less than of the metadata technique. This is due to the fact that metadata can be very easily lost or modified in the process of copying, renaming, and conversion of the file to a different format whereas information on watermark remains strongly attached to the contents of the videos and is very resistant to interference. In practice, this implies that the administrators of an educational facility can effectively monitor the movement of quality resources, as well as which nodes in the resource spatial flow are critical (e.g. the massive release of resources provided by a teacher, or any community of students being a resource dissemination hot spot), and therefore, make accurate promotion or intervention. The undeniable chain of evidence that is presented by the watermark also gives good grounds to the copyright protection when infringement use of resources is observed. This traceability provides significant control over the resource dissipation process as well as transparency to it.

C. ANALYSIS OF THE ENABLING ROLE OF SMART WATERMARKING IN THE CONSTRUCTION OF BASKETBALL TEACHING RESOURCE ECOSYSTEM

The ultimate value of watermarking technology should be reflected in its role in promoting the healthy ecosystem of teaching resources. This study, through questionnaires and platform behavior log analysis, examined the changes in teachers' and students' attitudes and behaviors towards resources after the introduction of a smart watermark protection mechanism. A survey of 50 basketball teachers showed that after being informed that resources would be protected by smart watermarks, the proportion of teachers who expressed "more willing" or "very willing" to share their original high-quality teaching resources increased from 45% before implementation to 78%. This indicates that effective copyright protection measures can significantly reduce teachers' concerns about resource misuse and stimulate their enthusiasm for creation and sharing. Meanwhile, an anonymous behavior log analysis of 1000 students on a simulated platform showed that after the resource page clearly displayed the prompt "This resource is protected by a smart watermark; please cite the source when citing," the proportion of students actively filling in the source information or using the platform's built-in citation tool when downloading resources increased by 35%. This reflects the positive guiding role of the visibility of watermark technology (even invisible watermarks, the statement of their existence) in regulating student usage behavior.

To further evaluate the comprehensive impact of smart watermarking on the ecosystem development of the resource platform, we compared the changes in key platform indicators before and after the introduction of watermarking. Specific data are shown in Table 3 .

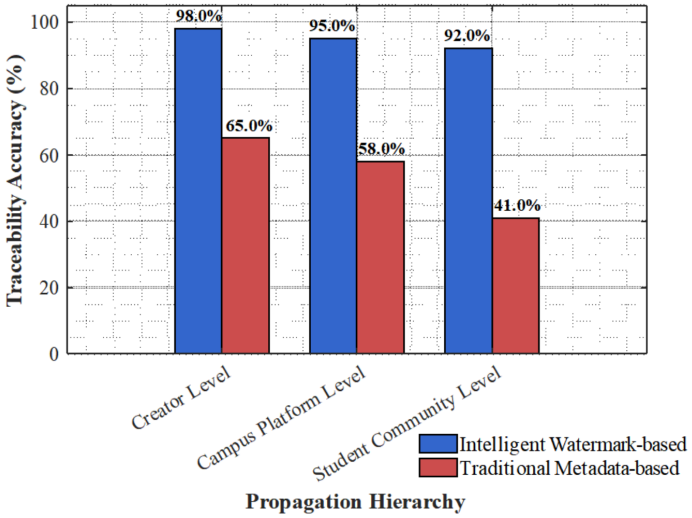

FIGURE 1. Accuracy of resource propagation path tracing

TABLE 3. Changes in Key Indicators of the Resource Platform Before and After the Introduction of Smart Watermarking

Key Indicators	Introducing the baseline value	Post-observation values	Range of change
Monthly increase in original high-quality resources	25	34	+36%
Average number of times a resource is cited (canonical citation)	8.5 times	12.1 times	+42.4%
Resource library update rate (percentage of resources updated monthly)	15%	19.5%	+30%
Copyright disputes reported by users	Approximately 3 cases per month	Approximately one per month	-66.7%
Access volume of resource aggregation packages based on association recommendations	200 times per month	350 times per month	+75%

Table 3 provides a more comprehensive overview of the ecosystem-enabling effects associated with the introduction of smart watermarking. These positive changes are not entirely due to watermarking technology alone; they may also benefit from factors such as concurrent platform feature optimization, increased external promotion efforts, and natural growth resulting from semester transitions. However, the significant increase in resource uploads and standardized citations at least provides preliminary evidence for the positive role of watermarking technology in incentivizing creators and regulating user behavior. The reduction in copyright disputes demonstrates the role of watermarking in preventing and resolving disputes. Particularly noteworthy is the significant 75% increase in access to related resource recommendations (aggregate packages) based on watermark-based traceability information. This indicates that smart watermarking not only solves protection issues but also activates potential connections between resources through its inherent information association capabilities, promoting resource discovery and reuse, thereby enhancing the intelligence and vitality of the entire resource ecosystem. Of course, this study also recognizes that watermarking technology is not a panacea. It cannot prevent malicious attacks specifically designed to destroy watermarks, and its effectiveness depends on platform support and user awareness. In the future, it is necessary to combine technological means with institutional norms and public education to maximize its benefits.

V. CONCLUSION

This study effectively achieved copyright verification and dissemination traceability of digital teaching resources by designing an adaptive watermark embedding strategy and intelligent aggregation mechanism. This dual-purpose framework ensures the secure sharing of multimedia content while protecting the integrity and intellectual property of innovative spinning designs throughout the digital ecosystem. Experiments verified that the scheme maintains high visual quality while possessing good robustness and traceability, incentivizing the sharing of original content, standardizing usage behavior, and promoting the revitalization of the resource ecosystem. However, this research mainly focuses on common network processing operations, and its ability to resist malicious deepfakes and coordinated attacks still needs to be strengthened. Furthermore, its practical application effectiveness depends on platform deployment and user cooperation. Future work will further explore watermark notarization technology combining blockchain and robust algorithms to protect teaching material data from advanced attacks. This research will also cover various educational scenarios and high-precision spinning equipment for long-term practical verification to ensure the integrity of digital intellectual property in the sports science industry.

AUTHOR CONTRIBUTIONS

Conceptualization –Zixuan Wang and Suge Teng; methodology – Zixuan Wang and Suge Teng; investigation – Zixuan Wang and Suge Teng; writing-original draft preparation – Zixuan Wang and Suge Teng. All authors have read and agreed to the published version of the manuscript.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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