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Interdisciplinary Case Design and Exploration for Machine Learning Course

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Abstract: Traditional machine learning teaching commonly suffers from repetitive experimental paradigms and narrow real-world application contexts, which leads students to rely on mechanical code replication and surface-level learning. This instructional pattern fails to cultivate interdisciplinary cognition and humanistic accomplishment. To improve the current teaching deficiencies, this study adopts digitized Dunhuang mural resources as an innovative teaching medium to develop interdisciplinary practice cases. Following the design concepts of staged ability progression, integration of technical and artistic perspectives, and authentic scenario orientation, this research constructs a three-tier teaching system including basic training, in-depth exploration and comprehensive innovation. The practical curriculum covers a full range of computer vision tasks: Dunhuang image preprocessing, stylistic discrimination, CNN visual recognition, artistic style migration, decorative pattern generation, and damaged mural inpainting. All experimental units combine algorithm engineering practice with Dunhuang art and cultural instruction. This study develops two-dimensional teaching support resources. It also constructs a tailored T-A-P evaluation system that integrates technical ability, artistic attainment and practical performance. The comprehensive student assessment covers coding skills, model error analysis and cultural aesthetic understanding. Classroom teaching practice has proven that the designed case system can significantly strengthen students' machine learning engineering capabilities and enrich their cultural accomplishment. This research offers a feasible and referable paradigm for interdisciplinary integration in artificial intelligence teaching.

Keywords: Machine Learning; Dunhuang Images; Interdisciplinarity; Case Design.

1. Introduction

Machine learning is a core required course for undergraduates. It covers computer science, artificial intelligence and digital media majors. Most traditional teaching uses well-known public datasets. Typical examples are MNIST and ImageNet. These datasets support general object classification and basic visual recognition tasks. Standard datasets are easy to obtain. They help models converge quickly for simple algorithm demonstrations. However, they cannot mirror real demands from practical scenarios. Simplified teaching environments cause shallow learning. Students simply call existing tool libraries and run fixed code pipelines. They fail to deeply understand complex real-world image features and data traits.

Modern machine learning teaching urgently needs to balance practical ability cultivation and interdisciplinary talent training quality [1]. Digitized Dunhuang cultural images contain complex texture details and diverse color layers, while naturally retaining real degradation characteristics including color fading, surface weathering and local structural defects. Introducing such authentic cultural heritage data into classroom teaching shifts the curriculum from rigid algorithm demonstration to practical digital heritage preservation applications.

Taking Dunhuang mural data as a unique interdisciplinary teaching medium, this study establishes a hierarchical machine learning teaching system with basic, advanced and innovative practical modules. Guided by progressive ability training, interdisciplinary integration and real-scenario-driven teaching concepts, this paper systematically elaborates the case design ideas, supporting resource construction and interdisciplinary integrated teaching implementation paths.

2. Related Work

Research communities have sustained keen interest in pedagogical reforms for machine learning courses. To tackle challenges including fading student motivation, unmet demands for personalized training, and inadequate professional competency development, Reference [2] puts forward a collaborative education framework for data mining and machine learning courses. This model adopts case-driven learning, blended instruction and value-oriented guidance. With tiered and diversified teaching materials, it establishes a personalized training scheme prioritizing hands-on practice. Addressing issues such as outdated course content, insufficient multi-dimensional teaching resources, limited interdisciplinary integration, weak practical orientation and barriers to collaborative teaching among cross-disciplinary instructors, Reference [3] follows a progressive logic of "basic cognition – comprehensive application – frontier exploration". It incorporates Kaggle competition tasks to build a sequential case library, aiming to boost learners' enthusiasm and strengthen their capacity for scientific innovation and practical work. To resolve pain points such as abstract theories, monotonous case formats and narrow practical training dimensions in machine learning classes, Reference [4] proposes a four-dimensional pedagogical reform framework named "Enlightening Intelligence": media innovation, technological empowerment, practice orientation and ideological guidance. It restructures courses by integrating diverse media, cutting-edge knowledge and interdisciplinary applications. Targeting low learner initiative, disconnect between teaching and learning, outdated examples and poor classroom engagement, Reference [5] conducts analyses from teaching methodologies, knowledge freshness and individualized instruction. It develops an integrated

teaching framework featuring one carefully selected case, two combined teaching approaches, three teaching phases and four assessment categories. From the perspective of industry-education integration, Reference [6] explores pathways to improve students' practical capabilities. It creates a case-centered comprehensive teaching method, builds a hybrid online-offline practical platform, and sets up a practice-centered multi-aspect evaluation system. Given the persistent gap between theory and practice in machine learning instruction and untapped potential for interdisciplinary integration, Reference [7] reviews mainstream teaching approaches and the development of industrial case repositories. It proposes an industry-oriented strategy for case library construction and validates case design and implementation with use cases in transportation.

Tang Jing et al. [8] identify bottlenecks in machine learning courses and present a renewed "3M" teaching framework that balances mathematical theories, algorithmic mechanisms and hands-on operations. They also elaborate on implementation routes and outcomes of curriculum reform. Zeng Yuanyuan [9] analyzes prominent dilemmas of machine learning education under the Emerging Engineering Education initiative and constructs an innovative teaching system defined as "one integration, two convergences, three outputs", with detailed design of instructional modes. Ying Yi et al. [10] respond to teaching challenges arising from the interdisciplinary nature, rapid technical updates and heavy practical requirements of machine learning. Reform strategies are proposed across four dimensions: iterative updates to course content, blended learning, project-based labs and diversified assessment. Li Jie et al. [11] cater to the demand for cultivating compound engineering talents for big-data-related interdisciplinary fields. Following a progressive arrangement, they design lab cases and thoroughly introduce experimental content, teaching plans and evaluation mechanisms for machine learning courses with examples from intelligent manufacturing.

In the sphere of integrating traditional cultural heritage into higher education, Yang [12] introduced Dunhuang mural elements into graphic design courses, fostering a deep synergy between design craft and humanistic sensibility to sharpen students' professional versatility. Duan [13] investigated the formal artistic characteristics and contemporary relevance of Mogao Cave murals, uncovering how traditional aesthetic resources provide formal visual vocabularies and profound spiritual depth for modern creative expression.

Existing machine learning teaching reforms mostly center on industrial and intelligent manufacturing scenarios to enhance students' hands-on competencies. Nevertheless, few studies design interdisciplinary teaching cases targeting the digital protection of cultural heritage resources. Furthermore, current Dunhuang-related educational research is largely confined to art and design fields, with limited attempts to integrate Dunhuang visual materials into practical algorithm training for artificial intelligence courses. Addressing this research gap, this study integrates the strengths of engineering practice and cultural education. Guided by the application-oriented talent cultivation objectives of Beijing Union University, this paper develops a staged machine learning teaching system based on Dunhuang visual data, creating an innovative interdisciplinary teaching paradigm that unifies algorithmic technical practice with traditional cultural aesthetic education.

3. Interdisciplinary Case Design

All experimental cases in this curriculum adopt open-access digital Dunhuang mural data. Raw visual samples keep inherent imperfections. These imperfections include non-uniform lighting, surface smudges and structural deterioration. No manual modification or over-polishing is applied to the data. Such genuine data configurations support hands-on exercises for learners. Learners can practice under real cultural heritage research contexts. The overall case design principles are illustrated in Figure 1.

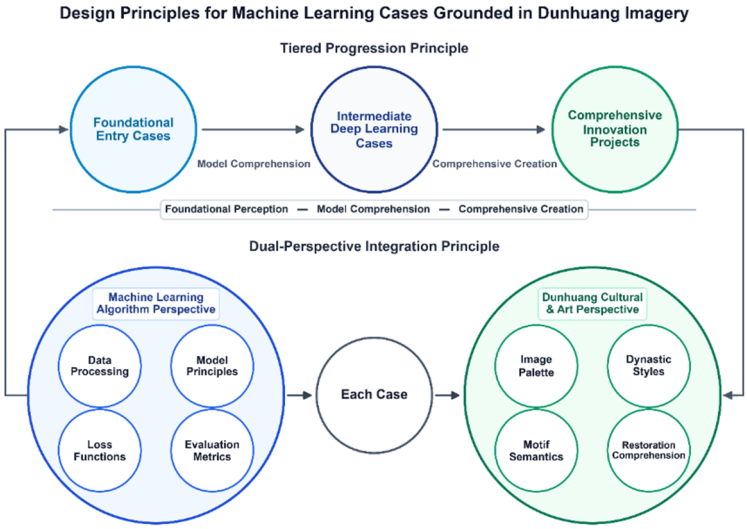


Figure 1. Interdisciplinary Case Design Principles

3.1. Design Principles

Progressive Hierarchical Design: The teaching content has a clear difficulty gradient. It matches the regular teaching rhythm of machine learning courses. The practical modules fall into three groups. They are basic traditional machine learning experiments, intermediate deep learning tasks, and advanced comprehensive innovation projects. This framework builds a complete training path. The path is "basic perceptual cognition — in-depth model comprehension — integrated innovative creation".

Dual-Dimensional Integration Design: All practical modules use two teaching perspectives. One perspective focuses on technical algorithms. The other focuses on cultural art appreciation. From the computational dimension, students focus on data preprocessing logic, model operational mechanisms, loss function optimization and quantitative evaluation methods. From the cultural dimension, learners analyze mural color features, dynastic stylistic characteristics and symbolic connotations of traditional patterns. This dual-track mechanism prevents monotonous algorithm-oriented training and realizes interdisciplinary integrated teaching.

3.2. Foundational Cases: Dunhuang Image Preprocessing and Traditional Machine Learning

Case 1: Preprocessing and Visualization of Dunhuang Mural Images

Task Description: Acquire digitized Dunhuang mural samples and implement a series of image operations, including region cropping, noise removal, color space transformation, edge feature extraction and image segmentation.

Algorithm Key Points: RGB/HSV color space conversion, edge detection, histogram equalization, etc.

Cultural Art Perspective: Observe image lines and color characteristics; understand noise caused by image weathering, and distinguish the texture of the cultural relic itself from later-stage contamination and damage.

Machine Learning Algorithm Perspective: Students will recognize how the quality of image data affects downstream visual analysis tasks. They will also master the basic technical methods for extracting valid image features.

Case 2: Stylistic Classification of Dunhuang Visual Works

Task Description: Researchers extract manually designed visual features from Dunhuang mural samples. They use classic machine learning models such as support vector machines and random forests, so the system can automatically sort these mural images.

Algorithm Key Points: This experiment includes several core steps. Researchers split datasets and standardize extracted features, then train classifiers and analyze confusion matrices. Accuracy and recall metrics are used to give quantitative assessment of model performance.

Cultural Art Perspective: Students need to identify morphological features and tonal variations of Dunhuang artworks. These stylistic traits vary from one historical period to another.

Machine Learning Algorithm Perspective: This section introduces the standard modeling workflow of conventional classification tasks. Students can discover both strengths and drawbacks of manual feature engineering, and they will learn how different feature selection choices change classification outputs. Such practice builds solid theoretical and hands-on groundwork for later deep learning modules that automatically learn image features.

3.3. Intermediate Cases: Deep Learning Applications on Dunhuang Imagery

Case 1: CNN-Driven Stylistic Classification of Dunhuang Images

Task Description: We build a lightweight convolutional neural network architecture. It can automatically classify Dunhuang murals according to their artistic styles.

Algorithm Key Points: Students explore how convolution and pooling layers extract image features. They run comparative experiments so that they can analyze classification performance under different network setups.

Cultural Art Perspective: As learners go through this module, they can observe how Dunhuang mural art changed across different dynasties. They will also notice that cultural artwork carries unique and complex visual features which differ from ordinary photos.

Machine Learning Algorithm Perspective: Students learn the core mechanism behind hierarchical feature learning in CNNs. When they compare results from handcrafted feature methods and automatic CNN feature extraction, they will deeply appreciate that deep learning fits complex cultural image recognition tasks much better.

Case 2: Dunhuang Image Style Transfer

Task Description: This experiment adopts the VGG19 network for visual feature extraction from target images. It calculates content loss and style loss separately, which ultimately realizes the stylistic migration of Dunhuang mural images.

Algorithm Key Points: Core learning contents include CNN-based feature extraction, Gram matrix calculation and targeted loss function design. Students also complete iterative parameter adjustment for generative tasks.

Cultural Art Perspective: Learners systematically recognize the unique composition rules, linear characteristics and color matching systems of Dunhuang artworks. They need to distinguish authentic Dunhuang artistic styles from superficial imitations that only copy simple colors and textures without absorbing core aesthetic connotations.

Machine Learning Algorithm Perspective: Understand the principle by which the Gram matrix quantifies image texture and style information through feature correlations; clarify the roles of content loss and style loss, and understand the image generation logic of joint optimization with dual losses; by tuning hyperparameters such as content weight, style weight, and iteration count, observe the impact of each parameter on generated image results, master hyperparameter tuning approaches in generation tasks, and understand the trade-off relationship between content fidelity and style transfer in models.

Case 3: Controllable Generation of Dunhuang Patterns Based on Conditional Generative Adversarial Networks

Task Description: Establish a labeled dataset of classic Dunhuang decorative motifs, including lotus patterns, flame textures and flying apsara ribbons. Relying on conditional generative adversarial networks, this experiment realizes targeted generation of designated Dunhuang decorative styles. The overall workflow covers model training, hyperparameter optimization and comprehensive evaluation of generative outcomes.

Algorithm Key Points: This practice focuses on the adversarial training logic between generators and discriminators, as well as the embedding strategies of conditional label information. It also involves loss function optimization, high-quality sample filtering and iterative model refinement procedures.

Cultural Art Perspective: Students are required to summarize the morphological features, linear rules and traditional aesthetic norms of typical Dunhuang patterns. It is essential to differentiate superficial texture simulation produced by artificial intelligence from authentic artistic creation that conforms to Dunhuang aesthetic standards. Students need to form objective artistic judgment criteria to

prevent stylistic distortion and morphological deviation in AI-generated results.

Machine Learning Algorithm Perspective: This module explains how conditional GANs utilize label constraints to implement targeted and controllable generation, and elaborates the basic logic of adversarial training. Students analyze how different loss weights affect pattern contour integrity, line fluency and overall modeling effects. With high-quality sample feedback for iterative optimization, learners master the interdisciplinary mode of guiding algorithm adjustment through artistic aesthetics, and comprehend the balance between random creativity and controllable constraint in generative neural networks.

3.4. Comprehensive Innovation Case: Inpainting of Damaged Dunhuang Imagery

Task Description: We select partially damaged Dunhuang mural samples. Advanced image restoration networks are used to reconstruct missing and worn regions, and we carry out systematic effect validation and performance analysis afterward.

Algorithm Key Points: This experiment investigates the internal structure of image restoration models. It includes mask generation for damaged regions and relevant data preprocessing pipelines. Students will get familiar with model inference mechanisms and texture filling strategies, and they can adopt mainstream quantitative metrics like PSNR and SSIM to objectively evaluate the quality of restored images.

Cultural Art Perspective: Students should put forward reasonable speculation on patterns, hues and composition within damaged areas. They need to form the ethical standards for digital restoration of cultural relics. It must be clarified that AI restoration merely serves as digital reference, and any alteration to the original historical information carried by murals is forbidden. Meanwhile, students can distinguish the boundary between digital creative restoration and the in-situ repair of physical cultural relics.

Machine Learning Algorithm Perspective: Students will grasp how image restoration models fill missing regions according to contextual semantics and texture cues. Mask information can constrain where the model performs restoration and what content it generates. When learners adopt multiple quantitative indicators to assess restoration precision, they may compare diverse models in terms of texture continuity, color transition and stylistic consistency. In this way, they can fully master model selection, experimental design and result analysis when handling complex damaged images.

4. Supporting Pedagogical Resource Development

To facilitate the effective implementation of interdisciplinary machine learning teaching cases and promote in-depth integration of technical training and cultural literacy education, this study develops discipline-specific datasets, dual-dimension teaching resources and a multi-angle evaluation system. All construction contents conform to the applied undergraduate talent training orientation of Beijing Union University. The above resources jointly form a complete, reusable and continuously updatable curriculum support system, as demonstrated in Figure 2.

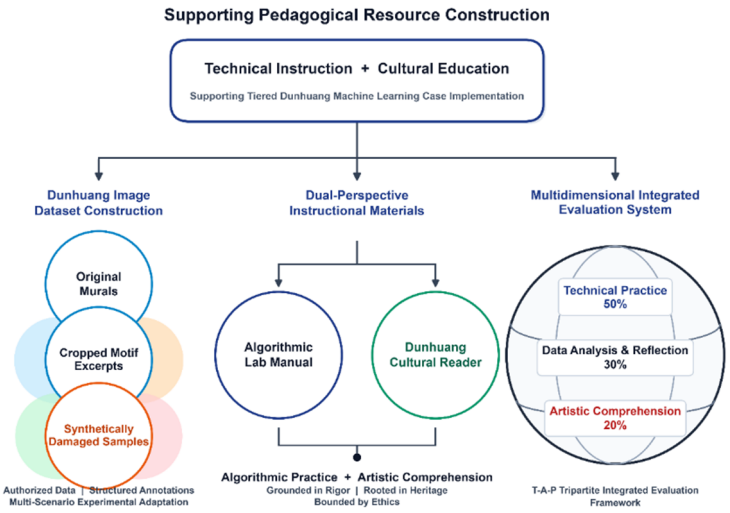


Figure 2. Supporting Pedagogical Resource Development

(1) Construction of Dunhuang Image Database

All digital Dunhuang visual resources applied in this teaching practice are sourced from publicly accessible and officially authorized repositories. In strict accordance with cultural heritage copyright specifications and digital preservation criteria, original image data are systematically sorted, screened and structurally annotated. Based on diverse experimental requirements, the established database is divided into three categories: complete mural images, locally cropped decorative pattern samples, and artificially constructed damaged murals. These sub-datasets correspond to multiple teaching scenarios, including image preprocessing, image classification, style migration and mural inpainting. Standardized dataset specification documents are also compiled to clarify data sources and applicable experimental scopes. They serve distinct experimental scenarios including image preprocessing, classification, style transfer and mural restoration. Complete dataset documentation is also provided to record image sources and intended usage.

(2) Construction of Dual-Perspective Teaching Handouts

To eliminate disciplinary barriers between computational technology and traditional art, all teaching units in this curriculum are supported by two complementary learning resources: algorithmic experimental manuals and Dunhuang

cultural reading materials. Technical guidebooks are designed by computer science instructors, detailing experimental fundamentals, program framework structures, standard operating procedures, parameter specifications and quantitative evaluation standards. These materials enable students to complete standardized algorithm practices and continuously optimize model performance. Meanwhile, art interpretation documents are jointly developed by teachers from the School of Art, Beijing Union University. They systematically introduce the aesthetic characteristics, symbolic connotations and classic color systems of Dunhuang murals and decorative patterns, guiding students to understand experimental tasks from a cultural and artistic perspective. The dual-system teaching materials achieve interdisciplinary teaching effects, enabling students to master standardized technologies, create works with cultural depth, and carry out innovative exploration within reasonable professional boundaries.

(3) Construction of Multi-Dimensional Comprehensive Evaluation System

Conventional evaluation methods for machine learning experiments overly focus on quantitative results while ignoring students' critical thinking and procedural growth. To optimize this imperfect evaluation mechanism, this study proposes a comprehensive T-A-P evaluation system covering technological practice, artistic cognition and practical application. Different from traditional single-dimensional assessment dominated by model accuracy and loss indicators, the new framework adopts diversified scoring standards, including code implementation and model training quality (50%), data analysis and reflection on model defects (30%), as well as artistic and cultural understanding (20%). This multi-dimensional evaluation mechanism realizes integrated cultivation of students' engineering practical abilities and humanistic artistic literacy.

5. Conclusion

Aiming at the common deficiencies of current machine learning teaching, such as repetitive teaching cases, single application scenarios, shallow practical training and inadequate humanistic cultivation, this study takes digital Dunhuang cultural resources as the innovative teaching carrier. Combined with the application-oriented talent training positioning of Beijing Union University and through interdisciplinary cooperation with art teachers, this research constructs a three-level progressive teaching system consisting of basic cognition, model mastery and comprehensive innovative practice. By building hierarchical experimental cases, establishing a dual-dimensional teaching mode integrating technology and culture, optimizing supporting datasets and teaching documents, and proposing the T-A-P multi-angle evaluation system, the curriculum reform effectively solves the existing teaching problem of emphasizing technical operation over practical application and attaching greater importance to numerical indicators than comprehensive literacy. This teaching innovation introduces authentic digital heritage protection scenarios into machine learning teaching practice. While completing hands-on tasks such as image preprocessing, style classification, style transfer, pattern generation and mural restoration, students can consolidate their engineering capabilities in machine learning modeling, parameter tuning and data analysis. Meanwhile, they deepen their understanding of Dunhuang artistic conventions, cultural connotations and ethics for relic restoration. The reform ultimately achieves synergistic cultivation of technical proficiency, innovative thinking and cultural literacy.

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