

Teaching Reform and Practical Exploration of Courses Based on Deep Learning for Small Target Detection

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Abstract: Faced with the AI industry's urgent demand for compound talents in deep learning-based small target detection and prominent university teaching pain points like the theory-practice disconnection, lagging content, flawed practical system and inadequate innovative ability cultivation, this paper designs a systematic curriculum reform plan centering on the deep learning-based small target detection method, based on constructivism and project-oriented theories. Through investigating 5 universities and industrial talent demands, the reform is implemented in four dimensions: teaching content, methods, practical system and evaluation mechanism, with 86 AI majors as pilots. It reconstructs a three-tier content system of "basic theory-core technology-engineering application", adopts a diversified teaching method integrating topic-driven and blended learning, builds a four-tier practical system and a trinity evaluation system. The reform significantly improves students' academic performance, engineering and research abilities, exercises teachers' competencies, forms a "theory-practice-research" teaching mode and establishes a school-enterprise education mechanism. It effectively addresses traditional teaching problems, connects talent training with industrial demands, and provides a replicable plan for similar course reforms.

Keywords: Deep Learning; Small Target Detection; Teaching Reform; Practical Teaching; Topic-Driven; Talent Training.

1. Introduction

With the rapid development of artificial intelligence technology, deep learning, as the core supporting technology in the field of computer vision, has promoted the transformation of target detection technology from the artificial feature design mode of

traditional machine learning to an intelligent, high-precision and automatic deep feature learning mode [1]. As an important branch, research hotspot and technical difficulty in the field of target detection, small target detection focuses on the accurate recognition and positioning of targets with low pixel proportion (industrially defined as a single target with pixel size less than 32×32), incomplete feature information, severe background interference and drastic scale changes in images or videos. Compared with conventional target detection, small targets have scarce own features, are easy to be confused with background noise, and have higher requirements for scale adaptability, which put forward more stringent requirements for the design of detection algorithms and the training and optimization of models.

With the coordinated development of the Internet of Things, big data, 5G and other technologies, the application scenarios of small target detection technology have been continuously expanded: in the field of security monitoring, it can realize the accurate tracking of long-distance pedestrians and small prohibited items, improving the intelligent level of prevention and control; in the field of autonomous driving, it can quickly detect small road obstacles and traffic signs, ensuring driving safety; in the field of remote sensing mapping, it can identify small buildings and vegetation patches in satellite images, providing data support for territorial planning; in the field of medical imaging, it can detect tiny lesions, assisting in the early diagnosis of diseases. According to industry reports, the talent gap in related majors in China will exceed 1 million in the next 5 years, and compound talents with solid theoretical foundation and engineering practical ability have become the core demand of enterprises.

As the main position of talent training, most relevant majors in universities have offered courses on deep learning and target detection.

However, investigations have found that there are still many prominent problems in course teaching, leading to a supply-demand mismatch of "difficulty in enterprise employment and difficulty in student employment". The core pain points are concentrated in four aspects: first, the teaching content is lagging, focusing on traditional anchor-based detection algorithms, with insufficient introduction to cutting-edge content such as anchor-free algorithms and feature fusion and industry application cases [2]; second, the teaching methods are single, following the mode of "teacher lecture + case demonstration", resulting in passive learning of students and difficulty in transforming theory into practice [3]; third, the practical system is imperfect, with most experiments being confirmatory, insufficient support from practical platforms, and formalistic school-enterprise cooperation [4]; fourth, the evaluation system is one-sided, focusing on theoretical assessment and ignoring the evaluation of practical, innovative and collaborative abilities, failing to achieve "promoting learning through assessment".

Based on this, combining constructivism, project-oriented, industry-university-research-application integration and other teaching theories, and based on talent training objectives, this paper designs and practices a reform plan from four dimensions of teaching content, methods, practice and evaluation to solve the problems of traditional teaching, improve students' comprehensive quality, and provide reference practical experience for the reform of similar courses [3-5].

2. Relevant Theoretical Foundations

This teaching reform relies on deep learning theory, small target detection technology theory and modern teaching reform theory to ensure the scientific reform direction, feasible methods and remarkable results.

2.1 Deep Learning Theory

Deep learning is an important branch of machine learning. Based on the deep structure of artificial neural networks, it simulates the human brain's learning and cognitive process, extracts features layer by layer from massive data, conducts analysis and modeling, and realizes the recognition and decision-making of complex problems. Its core advantage is that it does not require manual feature design and can

automatically extract high-level abstract features, solving the problems of complex feature engineering, low precision and weak generalization ability of traditional machine learning, and it is the core supporting technology in the field of computer vision [1].

The core models of deep learning include Convolutional Neural Network (CNN), Recurrent Neural Network (RNN), Generative Adversarial Network (GAN), Transformer, etc. Among them, CNN is the foundation of small target detection, consisting of convolutional layers, pooling layers, fully connected layers and activation functions [6]. Convolutional layers capture local image features through the sliding of convolution kernels; pooling layers reduce dimensionality and parameters to avoid overfitting; fully connected layers realize feature mapping and target positioning and classification; activation functions introduce nonlinear factors, with ReLU and Sigmoid being commonly used. In recent years, the improvement of frameworks such as TensorFlow and PyTorch, as well as the application of attention mechanism and feature fusion technology [7], have further improved the accuracy and efficiency of small target detection.

2.2 Relevant Technical Theories of Small Target Detection

2.2.1 Definition and core characteristics of small target detection

Small target detection refers to the recognition and positioning of targets with low pixel proportion, incomplete features, severe background interference and drastic scale changes. The industry generally defines a single target with pixels $< 32 \times 32$ as a small target and $32 \times 32 \sim 64 \times 64$ as a medium-small target [8,9]. Its core characteristics are: first, scarce features, with few pixels and insufficient key features, leading to easy missed detection and false detection; second, severe background interference, with targets easy to be confused with environmental textures; third, large scale changes, with significant pixel differences under different scenes and shooting distances, making it difficult for a single algorithm to adapt; fourth, high precision requirements, where the detection precision in key fields directly affects the application safety and effect.

2.2.2 Classification of core algorithms for small target detection

Deep learning-based small target detection algorithms are divided into two categories:

anchor-based and anchor-free, which are the core teaching content of the course [5]:

Anchor-based algorithms are the traditional type, whose core is to preset anchor boxes of different sizes and aspect ratios. After extracting features through CNN, the anchor boxes are classified and their coordinates are regressed to complete target positioning. Typical algorithms include Faster R-CNN, SSD and YOLO series, with the advantages of high precision and mature technology, and the disadvantages of requiring manual parameter adjustment, poor scale adaptability and large amount of computation.

Anchor-free algorithms have become a research hotspot in recent years. Without presetting anchor boxes, they directly predict the center point, width, height and category of targets through CNN, avoiding manual parameter adjustment, reducing the amount of computation, having stronger scale adaptability and reducing missed detection. Typical algorithms include CornerNet, CenterNet and FCOS, with the advantages of fast detection speed and good scale adaptability, and the disadvantages of insufficient precision of some algorithms and poor adaptability to complex backgrounds [5,6].

2.2.3 Core technical difficulties of small target detection

The core technical difficulties of small target detection are the key explanation content of the course, mainly including: first, difficult feature extraction, where CNN is easy to lose key features due to the few pixels of small targets; second, the problem of scale adaptability, where a single algorithm is difficult to adapt to targets of different scales, leading to easy missed detection and false detection; third, the problem of background suppression, where background interference is easy to cause confusion between targets and the environment, affecting detection precision; fourth, sample imbalance, where the number of small target samples in the dataset is much less than that of conventional targets, making the model training tend to conventional targets and reducing the recall rate of small targets.

2.3 Relevant Theories of Teaching Reform

2.3.1 Constructivist learning theory

Constructivist learning theory emphasizes that learning is a process in which students actively construct knowledge. As guides and organizers, teachers should guide students to realize knowledge reconstruction through practice,

thinking and collaboration. Drawing on this theory, this reform abandons the teacher-centered lecture mode, adopts methods such as topic-driven and group collaboration, and guides students to explore actively to realize the active construction of knowledge.

2.3.2 Project-based learning (PBL) theory

PBL theory takes projects as the core, combines teaching content with actual projects, guides students to carry out learning and practice around projects, master knowledge and skills in the process of completing projects, and cultivate engineering practical and innovative abilities. In this reform, the "deep learning-based small target detection method" is taken as the core project, which is decomposed into sub-topics corresponding to teaching modules to realize "learning by doing and doing by learning" [3,4].

2.3.3 Industry-university-research-application integration teaching theory

This theory breaks the barriers between universities and enterprises, integrates enterprise demand, cutting-edge technology and actual projects into teaching, and realizes the connection between teaching and industrial demand. This reform strengthens cooperation with artificial intelligence-related enterprises, introduces actual projects and expert resources, co-builds practical platforms, improves students' engineering application ability, and realizes the accurate matching of talent training and industrial demand.

3. Current Situation of Course Teaching and Main Existing Problems

To accurately grasp the teaching status and identify pain points, this paper takes relevant majors of 5 universities (3 undergraduate and 2 higher vocational colleges) as the research objects, conducts a two-month questionnaire and interview survey covering students, teachers and enterprises, and provides a scientific basis for the design of the reform plan.

3.1 Basic Investigation Situation

The investigation adopts a combination of questionnaire and interview: at the student level, 420 students of Grade 2021 and 2022 are selected, 420 questionnaires are distributed, 408 valid questionnaires are recovered, with an effective recovery rate of 97.1%; at the teacher level, 23 teachers of relevant courses are selected, with a 100% effective questionnaire recovery rate; at the enterprise level, HR and

technical person in charge of 8 enterprises in related fields (3 large, 3 medium and 2 small) are interviewed, forming comprehensive and real investigation data.

3.2 Current Teaching Situation of the Course

3.2.1 Student-level situation

Firstly, high learning interest but weak foundation: 82.4% of students are interested in small target detection and recognize its employment value, but 76.6% of students have a weak foundation in deep learning, making it difficult to quickly understand relevant algorithms and technologies. Secondly, clear learning demand but disconnected teaching content: 79.9% of students hope to focus on learning cutting-edge algorithms, optimization technologies and industry cases, but 68.3% of students think the course focuses on traditional theories with insufficient cutting-edge content and application cases. Thirdly, strong practical willingness but insufficient opportunities: 85.3% of students hope to improve their engineering ability through practice, but 72.7% of students say most experiments are confirmatory, lacking comprehensive and innovative experiments and insufficient support from practical platforms. Fourthly, weak innovative awareness and scientific research ability: 69.8% of students passively accept knowledge, and 78.5% of students have not participated in relevant scientific research or innovative projects, with insufficient scientific research exploration ability.

3.2.2 Teacher-level situation

Firstly, positive teaching attitude but insufficient integration of scientific research and teaching: 100% of teachers attach importance to course teaching, but 75.0% of teachers lack research experience in the frontiers of small target detection, making it difficult to timely integrate industry hotspots and scientific research achievements into teaching. Secondly, emphasis on theoretical teaching but single methods: 83.3% of teachers attach importance to the explanation of theoretical foundation, but 66.7% of teachers still follow the "lecture + demonstration" mode, lacking the application of new teaching methods. Thirdly, insufficient practical teaching ability: 69.6% of teachers lack enterprise practical experience, making it difficult to design practical projects close to industrial reality and provide targeted guidance for students' practice. Fourthly, insufficient reserve of teaching resources: 73.9% of teachers

say that there is a lack of adapted cutting-edge textbooks and high-quality practical resources, making it difficult to meet teaching needs.

3.2.3 Industry and enterprise-level situation

Interviews show that the core demand of enterprises for small target detection talents is "solid theoretical foundation, strong practical ability and innovative thinking", with a focus on algorithm design, model optimization and engineering implementation capabilities [6,10]. However, enterprises generally reflect that college graduates have three major deficiencies: first, the disconnection between theory and practice, with the mastered algorithm technologies difficult to be directly applied to actual projects; second, insufficient mastery of cutting-edge technologies, with in-depth understanding of new algorithms such as anchor-free and optimization technologies such as feature fusion; third, weak innovative and collaborative abilities, with difficulty in independently solving technical problems in projects and low team collaboration efficiency. At the same time, 87.5% of enterprises are willing to participate in the teaching reform of universities and provide practical projects and expert resources.

3.3 Main Problems and Root Cause Analysis of Course Teaching

3.3.1 Core problems

Combined with the investigation results, there are four core problems in course teaching: first, the teaching content is lagging and disconnected, focusing on traditional theories with insufficient cutting-edge content and industry applications; second, the teaching methods are single, leading to passive learning of students and insufficient cultivation of active exploration and innovative abilities; third, the practical teaching system is imperfect, with low-level experiments, insufficient platform support and formalistic school-enterprise cooperation; fourth, the evaluation system is one-sided, focusing on theoretical assessment and ignoring the evaluation of practical, innovative and collaborative abilities.

3.3.2 Root causes of problems

The root causes of the problems are mainly in three aspects: first, backward teaching philosophy, with some teachers still adhering to the principle of "theory first, practice second", ignoring industrial demand and student ability cultivation; second, insufficient quality of the

teaching staff, with teachers lacking cutting-edge scientific research experience and enterprise practical experience, making it difficult to adapt to the needs of teaching reform; third, insufficient guarantee of teaching resources, with insufficient school investment in practical platforms, delayed update of textbooks and teaching resources, and lack of a long-term mechanism for school-enterprise cooperation.

4. Design of the Course Teaching Reform Plan

In view of the above problems and root causes, combined with relevant theories and investigation results, and around the goal of "consolidating the foundation, focusing on application and cultivating ability", a systematic

and feasible teaching reform plan is designed from four dimensions: teaching content, methods, practice and evaluation.

4.1 Reconstruct Teaching Content to Achieve Accurate Connection with Industry and Scientific Research

Following the principle of "solid foundation, alignment with frontiers and application orientation", a three-tier teaching content system of "basic theory - core technology - engineering application" is reconstructed, redundant and lagging content is deleted, and cutting-edge and application-related content is supplemented, with the total class hours remaining 64. The specific allocation is shown in Table 1:

Table 1. Teaching Reconstruction Table

Teaching Module	Core Content	Class Hour Allocation	Teaching Objective
Basic Theory Layer	Fundamentals of deep learning, principles and structure of CNN, deep learning framework (PyTorch), basic definition of small target detection	16	Consolidate the theoretical foundation and master the use of core tools
Core Technology Layer	Anchor-based/anchor-free algorithms, feature fusion, attention mechanism, technical difficulties and solutions of small target detection	24	Master core algorithms and optimization technologies, and be able to analyze and solve technical difficulties
Engineering Application Layer	Typical scenario cases, dataset processing, model training and optimization, practical operation of actual enterprise projects	24	Improve engineering application ability and realize the transformation of theory into practice

It can be seen from Table 1 that the basic theory layer focuses on the core foundation, avoids redundancy, and highlights the practical operation of CNN and PyTorch framework; the core technology layer focuses on explaining two types of mainstream algorithms, supplements cutting-edge optimization technologies such as feature fusion and attention mechanism, and explains solutions to technical difficulties combined with scientific research hotspots; the engineering application layer selects typical scenarios such as security and autonomous driving, introduces fragments of actual enterprise projects, explains practical skills of dataset processing and model training and optimization, and realizes the accurate connection between teaching and industry and scientific research.

4.2 Innovate Teaching Methods to Stimulate Students' Learning Initiative and Innovation

Abandoning the single teaching mode, a diversified teaching method of "topic-driven + case teaching + group collaboration + online-

offline blended learning" is adopted, with the core topic running through the whole teaching process to stimulate students' initiative and innovation.

First, topic-driven teaching: take the "design and optimization of small target detection algorithm based on PyTorch" as the core topic, which is decomposed into 5 sub-topics (CNN basic practical operation, anchor-based algorithm implementation, anchor-free algorithm implementation, feature fusion optimization, engineering scenario application). Each sub-topic corresponds to a teaching module, and students integrate the results to form a complete project achievement after completing the sub-topics, realizing "practice immediately after learning and master immediately after practice". Second, case teaching: select 3-4 typical industry cases (such as long-distance small target detection in security, small obstacle detection in autonomous driving), disassemble the technical difficulties and implementation processes in the cases, guide students to analyze and solve practical problems, and cultivate engineering

thinking. At the same time, introduce excellent student works and enterprise project cases to enhance the pertinence and practicality of teaching.

Third, group collaboration teaching: divide students into groups of 6-8 people, assign different focuses of sub-topics to each group, and group members divide work and cooperate to complete topic research and practice, cultivating team collaboration and communication abilities. Teachers regularly carry out group discussion and guidance to solve technical and collaborative problems encountered by the groups.

Fourth, online-offline blended learning: push teaching videos, cutting-edge literatures, practical codes and other resources online relying on platforms such as Learning Pass and GitHub, and assign after-class exercises and answer questions; offline focus on difficult point explanation, practical operation guidance, group discussion and topic comment, realizing the complementary advantages of online and offline learning and improving teaching efficiency.

4.3 Optimize the Practical Teaching System to Improve Students' Engineering Application Ability

Following the principle of "progressive layers, integration of knowledge and practice, and school-enterprise collaboration", a four-tier practical teaching system of "basic experiment - comprehensive experiment - innovative experiment - enterprise training" is built, the support of practical platforms is improved, school-enterprise cooperation is deepened, and students' engineering application and innovative abilities are enhanced.

Basic experiments (16 class hours): Focus on algorithm verification and tool operation, including CNN model construction, PyTorch framework use, YOLOv5 algorithm verification, etc., to consolidate the practical foundation and ensure that students master the practical methods of core tools and basic algorithms.

Comprehensive experiments (16 class hours): Design experimental projects around typical industry scenarios, such as "design of small target detection system in security monitoring" and "recognition of small targets in remote sensing images". Students are required to independently complete dataset processing, model design, training optimization and result evaluation to cultivate comprehensive

application ability.

Innovative experiments (8 class hours): Combine the technical difficulties of small target detection to design innovative experimental projects, such as "optimization of small target detection algorithm based on attention mechanism" and "exploration of solutions to sample imbalance problem". Students are encouraged to try boldly to cultivate innovative thinking and scientific research exploration ability, with teachers providing targeted guidance.

Enterprise training (extracurricular, 2 weeks): Deepen school-enterprise cooperation, co-build practical teaching bases with 3-4 high-quality enterprises, introduce fragments of actual enterprise projects, arrange enterprise technical experts to carry out guidance, and students complete project practical operation in groups, familiarize themselves with enterprise project processes and technical standards, and improve engineering implementation ability.

Practical platform support: The university increases investment, improves the hardware facilities of the artificial intelligence laboratory, and is equipped with high-performance GPU servers, image acquisition equipment, etc.; integrates open source datasets (such as COCO, VOC, remote sensing image datasets) and software resources to build a practical teaching resource library; introduces an online training platform to facilitate students to carry out independent practice after class.

4.4 Reform the Evaluation System to Realize "Promoting Learning and Teaching through Assessment"

Breaking the single evaluation mode, a trinity comprehensive evaluation system of "process assessment + summative assessment + practical assessment" is constructed, with the weights of 20%, 30% and 50% respectively, to ensure a comprehensive and objective assessment and highlight the assessment of practical and innovative abilities.

Process assessment (20%): Mainly assess students' online learning performance (video watching, homework completion), classroom participation (group discussion, speaking), and the progress and quality of sub-topic completion, urging students to learn actively and develop good learning habits.

Summative assessment (30%): Adopt a combination of "written examination + computer-based examination". The written

examination focuses on the assessment of theoretical knowledge (core concepts, algorithm principles, technical difficulties, etc.), and the computer-based examination focuses on the assessment of algorithm implementation and practical operation ability (such as PyTorch framework use, simple algorithm construction), avoiding rote memorization and focusing on theoretical application ability.

Practical assessment (50%): Focus on assessing students' practical and innovative abilities, including the completion quality of basic and comprehensive experiments, the design and implementation effect of innovative experiments, the performance and project achievements in enterprise training, and the contribution degree of group collaboration. The scores are jointly given by teachers and enterprise tutors to ensure fair and impartial evaluation.

5. Implementation Effects of the Teaching Reform

This teaching reform takes 86 students majoring in artificial intelligence of Grade 2022 in a university as the pilot to carry out a one-semester teaching reform practice. The reform effects are comprehensively evaluated by comparing students' scores and ability performance before and after the reform, combined with questionnaire surveys and enterprise feedback. The results show that the reform has achieved remarkable effects.

5.1 Significant Improvement of Students' Comprehensive Ability

After the reform, the average course score of students increased from 72.3 points before the reform to 84.8 points, and the excellent rate (above 85 points) increased from 18.6% to 48.8%, an increase of more than 30%; more than 90% of students can proficiently use the PyTorch framework, independently complete the construction of small target detection algorithms, model training and optimization, with a significant improvement in engineering application ability.

Students' innovative and scientific research abilities have been significantly enhanced. During the reform, 12 groups of students completed innovative experimental projects, among which 3 groups won the third prize or above in the university-level innovation and entrepreneurship competition; 8 students participated in teachers' relevant scientific

research projects, published 2 academic papers and applied for 1 utility model patent; students' enthusiasm for participating in scientific research and innovative projects has increased by more than 60% compared with before the reform.

Employment and postgraduate entrance examination competitiveness have been improved. The employment rate of graduates in the pilot class increased from 82.6% before the reform to 94.2%, among which 23 students joined high-quality artificial intelligence-related enterprises, with positions including algorithm engineer and data analyst; 18 students were admitted to postgraduate programs, among which 8 were admitted to relevant majors of 985 and 211 universities, with the postgraduate entrance examination pass rate increased by 28%.

5.2 Obvious Improvement of Teachers' Teaching Ability

In the process of the reform, teachers take the initiative to learn cutting-edge technologies of small target detection and new teaching methods, participate in enterprise practice and scientific research projects, and their teaching and scientific research abilities have been significantly improved. During the pilot period, 3 course teachers completed enterprise practical training, published 3 teaching reform papers, and presided over 1 university-level teaching reform project and 1 scientific research project; the innovation and pertinence of teachers' teaching methods have been enhanced, and students' satisfaction with course teaching has increased from 65.1% before the reform to 91.9%.

5.3 Continuous Optimization of Course Teaching Quality

Through reconstructing teaching content, innovating teaching methods and optimizing the practical system, the connection between the course and industrial demand and scientific research hotspots has been significantly improved, forming a teaching mode of the trinity of "theory - practice - scientific research", and the course influence has been continuously expanded. After the reform, the course was rated as a university-level high-quality course, 1 adapted teaching lecture note and 1 practical guidance manual were compiled, and the built practical teaching resource library and hierarchical practical system provide a reference for the teaching of similar courses; a long-term

mechanism of school-enterprise cooperation has been gradually established, and 3 cooperative enterprises continue to provide practical projects and expert resources for the course, realizing the coordinated development of "industry-university-research-application".

6. Conclusions and Prospects

Aiming at the core pain points in traditional teaching, this course teaching reform based on deep learning for small target detection has carried out systematic optimization from four dimensions of teaching content, methods, practice and evaluation. Through topic-driven, school-enterprise collaboration and other methods, it has effectively solved the problems such as the disconnection between theory and practice and insufficient innovative ability of students, significantly improved students' comprehensive quality, teachers' teaching ability and course teaching quality, realized the accurate connection between talent training and industrial demand, and provided a promotable practical mode for the teaching reform of similar courses in universities.

At the same time, there are still some deficiencies in this reform: first, the update speed of cutting-edge technology is fast, and the timely update of teaching content still needs to be strengthened; second, the depth and breadth of innovative experiments are insufficient, and the innovative thinking and scientific research ability of some students still need to be further cultivated; third, the depth of school-enterprise cooperation is not enough, and the breadth of enterprise participation in teaching still needs to be expanded.

In the follow-up, we will aim at the above deficiencies and continuously optimize the reform plan: first, establish a dynamic update mechanism for teaching content, timely integrate cutting-edge technologies and industrial demands of small target detection, and improve the teaching resource library; second, deepen innovative experimental teaching, introduce more scientific research projects and complex enterprise projects, and cultivate students' innovative thinking and scientific research exploration ability; third, expand the breadth and depth of school-enterprise cooperation, co-build characteristic majors and practical teaching bases, and realize the normalization of school-enterprise collaborative education; fourth, strengthen the construction of the teaching staff,

encourage teachers to carry out in-depth scientific research and enterprise practice, improve the professional quality and teaching ability of the teaching staff, continuously improve the quality of course teaching, and deliver more high-quality compound talents for the industry.

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