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The path and exploration of building the first-class course of machine vision

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Abstract: According to the development plan of "Made in China 2025" released by the State Council, intelligent manufacturing, as a new strategic pillar industry in China, is the main direction for advancing the strategy of building a strong manufacturing country. Accelerating the cultivation of professional technical talents needed for the development of the intelligent manufacturing industry is an urgent and significant task facing various universities in China. The course of machine vision, hailed as the "eyes" of intelligent manufacturing, is crucial for improving manufacturing efficiency and the level of intelligent automation. This paper, starting from the construction of the "Machine Vision" course at Xijing University, explores a path of course development focusing on the significant demands of the China intelligent manufacturing industry. It is based on the principles of "industry-education integration, study-education integration, science-education integration, and ideology-education integration." Through the reconstruction of course content, practical aspects, course projects, and ideological and political education, the organic integration of the course system with the demands of the intelligent manufacturing industry is achieved. This approach has yielded significant results and can be effectively extended and promoted to other engineering courses, facilitating the transformation and upgrading of traditional engineering courses.

1. Introduction

Manufacturing is the foundation, the tool for national prosperity, and the basis for national strength. Developed countries, to ensure their strong position in the world manufacturing sector, have vigorously developed intelligent manufacturing using technologies such as artificial intelligence, information technology, and network technology, ushering in a wave of "reindustrialization" [1]. In response to the challenges from developed countries and actively adapting to the development trends of the new global industrial technological revolution, the Chinese government has proposed the "Made in China 2025" development strategy [2]. It emphasizes the importance of considering talent as the fundamental element in building a strong manufacturing country. Accelerating the cultivation of professional technical talents urgently needed for the development of the manufacturing industry and building a high-quality and structurally reasonable talent team are essential steps on the path to development, following a talent-led development approach.[3]

Currently, intelligent manufacturing technology and industrial transformation are poised for explosive growth, posing new requirements for innovative talent education in higher education institutions. In the face of a new round of industrial revolution with intelligent manufacturing as the core technology, cultivating innovative talents in intelligent manufacturing that adapt to the development strategy of national industrialization, making them leaders who can guide social and technological development, is an important historical mission, responsibility, and challenge for higher education in China [4,5]. In August 2022, the Ministry of Education issued the "Opinions on Strengthening Organized Research in Colleges and Universities to Promote High-level Self-reliance." It pointed out that "colleges and universities are important components of the country's strategic scientific and technological strength. Organized research in colleges and universities is an important form of institutionalization and systematic service for national and regional strategic needs in scientific and technological innovation in colleges and universities," and "colleges and universities should take serving the strategic needs of the country as the highest pursuit."

The machine vision course is closely related to the development of intelligent manufacturing, serving as the "eyes" of intelligent manufacturing. As a crucial technology in the fields of quality control and industrial automation control in the intelligent manufacturing industry, it enables machines to "see" and "understand" the external world. It plays a vital role in achieving intelligent manufacturing. Machine vision implants the "wisdom eye" into machines, allowing them to replace manual labor and assist the intelligent manufacturing industry in achieving automation and intelligence. It is mainly applied in the field of industrial automation in intelligent manufacturing, where the inspected items have fast movement speeds, high precision requirements, and high repetitive work. It can replace human eyes in various scenarios to achieve recognition, positioning, measurement, and detection functions. It has significant advantages such as high degree of intelligence, fast detection speed, low defect rate, support for uninterrupted detection, and resistance to heavy workloads.

Xijing University, as a private undergraduate university, has maintained leading positions in various research indicators among national private universities, according to the "Research Competitiveness Evaluation Research Report of Chinese Private Undergraduate Colleges and Universities for the Year 2022." The university's research competitiveness has remained at the forefront of national private universities for five consecutive years, and in 2021, it was approved by the Ministry of Education to grant master's degree programs. The team's construction of the machine vision course is based on the national first-class undergraduate major in mechanical design, manufacturing, and automation, relying on Xijing University's commitment to innovative applied talent cultivation. It focuses on the significant demands of the national intelligent manufacturing industry and, based on the educational philosophy of "industry-education integration, study-education integration, science-education integration, and ideology-education integration," conducts first-class machine vision course construction.

2. Path and Plan for Building a First-Class Machine Vision Course

The machine vision course team at Xijing University originated from the research team of the Xi'an High-Precision Industrial Vision Intelligent Detection Key Laboratory. The team consists of seven Ph.D. teachers from different fields, including two professors, four associate professors, and one lecturer. Targeting the significant demands of the national intelligent manufacturing industry, the team actively integrates and contributes. They have undertaken two national-level research projects, three provincial-level key R&D projects, and five horizontal projects with large state-owned enterprises. Collaborations with companies such as AVIC Fujian Technology Co., Ltd., AVIC Xi'an Aircraft Industry Group, and AVIC 618 Institute have resulted in the development of industrial automation vision inspection equipment for tasks like defect detection in satellite electrical connectors, aircraft engine blade defect detection, and military chip defect detection, achieving positive outcomes and ensuring the completion of a series of national major model tasks.

The team proposed a strategy to build a first-class machine vision course focusing on the significant demands of the national intelligent manufacturing industry. Throughout the course development process, they actively invited and engaged enterprise technical personnel for discussions to ensure seamless alignment between course content and industry requirements.

2.1. Construction of Course Content System Based on "Study-Education Integration"

The machine vision course content system consists of pilot courses, core courses, extension courses, and disciplinary frontiers, as shown in Figure 1. The pilot courses, comprising six compulsory courses, serve as prerequisite courses for studying the machine vision course. The combination of "Machine Vision + Extension Courses" achieves interdisciplinary integration, giving rise to various application directions in the field of intelligent manufacturing. Students can choose different directions based on their interests, highlighting the "personalization" of education. Table 1 provides application directions in different areas of intelligent manufacturing corresponding to the integration of machine vision courses with different extension courses. Core courses cover fundamental concepts, development history, basic theories, practical applications of machine vision, and incorporate the dynamic development of disciplinary frontiers into the core course system. The aim is to cultivate first-class talents with innovative, practical, and internationally oriented capabilities for the construction and development of the intelligent manufacturing field.

When designing teaching content, industry demand serves as the starting point. The course content knowledge system is connected through industry practical applications, progressing from basic to advanced. The teaching method integrates theory with application by introducing students to the most basic and latest machine vision technologies and application scenarios, creating a teaching loop of "demand—algorithm—application."

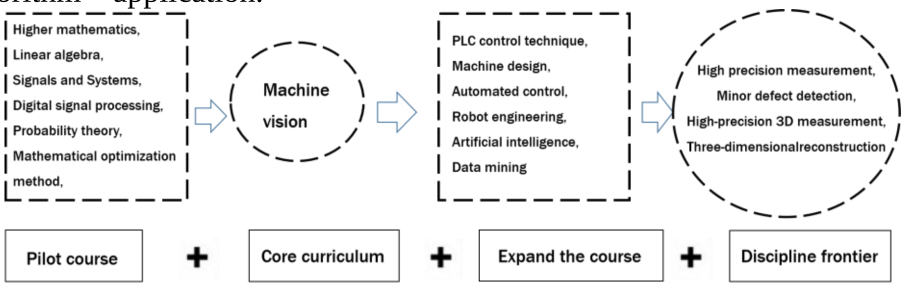

Figure 1: Content architecture of the machine vision course

Table 1: Areas corresponding to the integration of machine vision and extended courses

Core curriculum	Expand the course	Intelligent manufacturing field
Machine vision	Robot engineering	Robot sorting, robot automatic assembly, etc
Machine vision	Artificial intelligence	Semiconductor chip defect detection, solar panel defect detection and other defect detection
Machine vision	PLC control	Automatic assembly line, automatic visual detection equipment, automatic sorting and assembly, etc
Machine vision	Data mining	Quality traceability, warehousing registration, information management, etc
Machine vision	Mechanical design, automatic control	Automatic production line design, assembly line design, automatic loading and unloading system design, etc

2.2. Construction of the "Industry-Education Integration" Course Practice System

To apply machine vision in the field of intelligent manufacturing, it involves various interdisciplinary areas such as optical imaging technology, light source illumination technology, computer image processing, pattern recognition, artificial intelligence, electrical automation, robotics, and mechanical engineering. Therefore, the practical content of the machine vision course includes experiments in image acquisition (image capture and optical illumination), image processing algorithm experiments, automation control experiments, robot control experiments, artificial intelligence algorithm experiments, robot vision experiments, and comprehensive application experiments. The comprehensive application experiments are derived from the team's accumulated enterprise project cases over many years, totaling 85 project cases covering various aspects of the intelligent manufacturing domain, including visual positioning, visual defect detection, visual dimension measurement, robot grasping and assembly, visual sorting of workpieces, quality traceability, and other comprehensive projects.

In terms of practical teaching approaches, a collaborative education model is established, combining industry and education, integrating industry and academia, and fostering cooperation between the university and enterprises. The team, in collaboration with multiple companies, has created an Industry 4.0 smart factory experimental platform. This platform employs big data technology for analysis and optimization management. In a computer virtual environment, the entire production process is simulated, evaluated, and optimized to achieve intelligent manufacturing that is automated, intelligent, and interconnected. The platform includes servo control systems, pneumatic systems, variable frequency conveyor systems, industrial 6-axis robots, stepper motor control systems, intelligent machine vision inspection systems, sensors and execution systems, PLC control systems, etc. All experimental projects of the course can be incorporated into this platform, as shown in Figure 2. All course practice projects can be completed in a simulated environment.

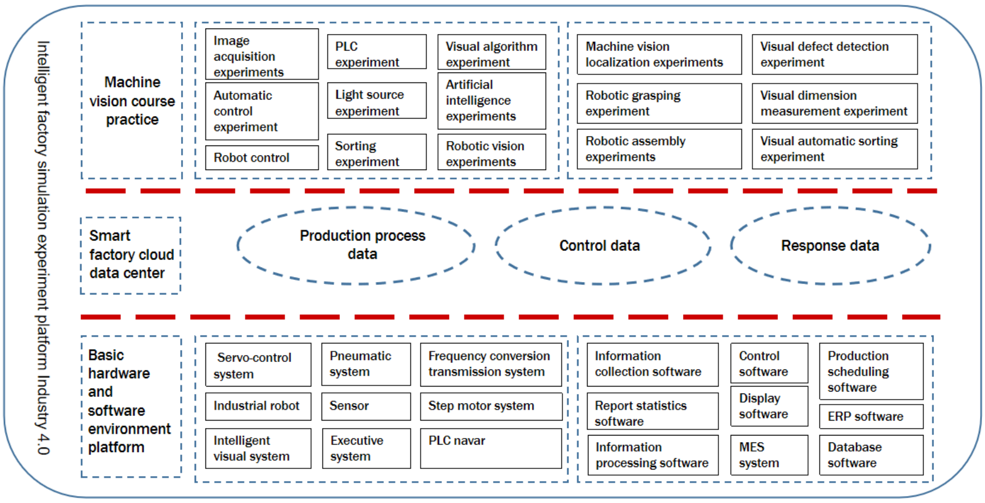

Figure 2: Architecture of machine vision curriculum practice

The reform of machine vision course experimental teaching adheres to the guiding ideology of "student-centered, coordinated development of knowledge, literacy, and abilities, mutual promotion of learning, practice, and innovation." It emphasizes the cultivation of students' awareness, thinking, and ability in practical innovation. Specific measures include: (1) Establishing a strong teaching team combining experts from academia and industry, meeting students' learning needs at multiple levels and dimensions; (2) Combining industrial scenes, engineering projects, cutting-edge technology, and advanced equipment to create a realistic production and teaching experimental environment for students, constructing a cognition-practice-innovation industry-education integrated practice system, achieving the integration of engineering training with cutting-edge technology, software with hardware, and comprehensive practice with innovative activities to cultivate first-class talents; (3) Developing rich machine vision experimental electronic textbooks, video materials, and online resources to meet students' learning needs anytime and anywhere, without spatial and temporal constraints, to some extent, satisfying students' "personalized" learning needs.

2.3. Construction of Course Projects Based on "Integration of Science and Education"

Course projects originate from preliminary research projects and enterprise collaborative projects undertaken by the course team teachers. These projects, after certain improvements and upgrades, become course projects that align with cutting-edge technology while meeting industry demands. Compared to practical course projects, course projects are more interdisciplinary and comprehensive, demonstrating theoretical foresight, technological innovation, and methodological breakthroughs. The course projects primarily focus on the machine vision frontiers in the field of intelligent manufacturing, such as large-field high-precision measurement, high-precision 3D measurement, small-sample workpiece surface defect detection based on semantic segmentation, unsupervised deep learning for tiny defect detection, high-precision 3D reconstruction, and non-uniform surface reconstruction. These topics are closely related to the significant demands of the national intelligent manufacturing industry and can be widely applied in aerospace, automotive, rail transportation, electronic semiconductors, and other production and manufacturing sectors.

The implementation of course project practices aims to further enhance students' research capabilities and innovative spirit, providing opportunities and space for students to think and innovate. It nurtures a pragmatic spirit in students to address national and social needs, solve practical problems, and overcome core challenges. By introducing interdisciplinary research projects and achievements, conducting course projects centered around research projects, and establishing a standardized collaborative mechanism for science and education using cutting-edge practical projects as carriers, it cultivates students' research skills, research confidence, professional interests, critical thinking, and ethical awareness.

2.4. Course Ideological and Political Education Design Based on "Integration of Thought and Education"

University curriculum reforms must consistently embody the deep integration of ideology and education, implementing the fundamental task of fostering virtue and nurturing talents, by combining values shaping, knowledge imparting, and ability cultivation.

In the construction of the machine vision course, the team integrates ideological and political elements throughout the course by thoroughly reviewing and exploring the ideological elements of the course. The course's ideological and political objectives include "love for the country, adherence to principles, innovation, perseverance, dedication to work," and these elements are seamlessly integrated into various aspects of the course, completing the fundamental task of fostering virtue and nurturing talents in a subtle manner. Specific practices include:

In the construction of course content, ideological elements related to breakthroughs achieved by outstanding Chinese companies such as Huawei and Hikvision in core machine vision devices and algorithms are explored. Students learn about the growth history and struggles of these companies, understanding the pioneering and innovative spirit of Chinese national enterprises and the tenacity and dedication spirit of the Chinese people, fostering students' patriotism and enthusiasm for learning. Ideological elements related to the world-class achievements of outstanding Chinese scholars such as Zhang Zhengyou, Sun Jian, and He Kaiming in the field of machine vision research are also integrated, incorporating the spirit of scientists into the main ideological and political courses, making scientists idols for young people and inspiring students' enthusiasm for scientific research.

In practical aspects of the course, by jointly constructing a collaborative education platform with enterprises, students are immersed in the aerospace-related industry, experiencing the spirit of space exploration held by generations of aerospace personnel, characterized by "hard work, selfless dedication, strong collaboration, and courage to climb." This helps students integrate lofty ideals with the realistic needs of the country, enhances students' awareness of the importance of independent and controllable aerospace technology, further nurtures patriotic sentiments, and reinforces the belief in serving the country through science and technology. Actively guiding students' ideals, beliefs, and value pursuits in the course of project practice, the cultivation of craftsmanship spirit and national pride is internalized and externalized, treating the cultivation of "qualified and soulful" talents as a sacred mission.

In the course project case aspect, by analyzing the major technical gaps between domestic and foreign research in the field of machine vision for intelligent manufacturing applications, students understand the industry position of China and recognize that core technologies are not easily obtainable. This further stimulates students' sense of mission and honor. By involving students in the research and development of cutting-edge topics, talent cultivation is combined with the significant demands of the country, continuously inheriting the research culture and beliefs of "dedication to learning, proactive and enterprising; dedication to work, striving for innovation."

3. Results of Course Development and Next Steps for Development

3.1. Achievements in Development

The course team, relying on the construction of the machine vision course in the Key Laboratory for High-Precision Industrial Vision Intelligent Detection in Xi'an, has provided strong support for the construction of the national first-class undergraduate program in mechanical design, manufacturing, and automation. Leveraging the course system and the open practice platform developed, the quality of student training has achieved favorable outcomes.

Enhanced Innovation and Entrepreneurship Skills: Over the past five years, the course team has trained over 200 students, with more than 500 students participating in various discipline competitions, innovation and entrepreneurship training projects for undergraduates, and collaborative education projects. The achievements include 10 national awards and 32 provincial awards in competitions, 2 national-level and 5 provincial-level approved innovation and entrepreneurship training projects, and 5 projects funded by the Ministry of Education's collaborative education initiative. Notably, in 2020, 2021, and 2022, the team secured one national silver award, two national bronze awards, and three gold awards in the Shaanxi division of the China International "Internet+" Innovation and Entrepreneurship Competition. This marked a breakthrough for private colleges in Shaanxi, with student representative Li Zhiguo delivering a keynote speech at the closing ceremony, drawing widespread attention from attendees and the media.

Continuous Improvement in Graduates' Quality: Over the past five years, more than 80 graduates who were trained by our course team and laboratory achieved a 100% employment rate, with over half of them securing high-quality employment opportunities, earning a monthly salary 20% higher than the average for their contemporaries. According to the "Graduate Employment Quality Tracking Report" from 2019 to 2022, published by Michael Page, the overall satisfaction of information, communication, and machinery industries with students reached 95%, the highest among all industries. Employers expressed 90% satisfaction with graduates' practical skills and 95% satisfaction with their problem-solving abilities.

3.2. Next Steps for Development

In July 2017, the State Council released the "New Generation Artificial Intelligence Development Plan," which clearly states the need to accelerate the reform of talent training modes and teaching methods using intelligent technology, constructing a new education system that includes intelligent learning and interactive learning.[6] In recent years, with the rapid development of artificial intelligence technology, the deep integration and empowerment of artificial intelligence in education have become a trend in future educational development.

The construction of the machine vision course is an ongoing journey. In the next steps, the construction of the machine vision course should integrate with artificial intelligence technology, continually enrich and improve digital online course resources and virtual simulation platforms. Artificial intelligence should be considered as an endogenous variable for the overall transformation of machine vision education. This transformation aims to shift from "industrial education" to "intelligent education," promoting innovations in teaching methods, changes in learning methods, and the reconstruction of evaluation systems. The goal is to establish an education service system that is more selective, personalized, and precise, striving to meet the developmental needs of each student.

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