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Cross-Disciplinary Applications of Computer Vision in Healthcare and Engineering

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Abstract

Computer Vision (CV), a major branch of Artificial Intelligence (AI), has rapidly evolved into a transformative technology with significant applications across healthcare and engineering. By enabling machines to interpret, analyse, and understand visual information from images, videos, and sensor data, computer vision has revolutionised diagnostic medicine, medical imaging, intelligent manufacturing, structural inspection, robotics, autonomous systems, and industrial automation. Recent advances in Deep Learning (DL), Convolutional Neural Networks (CNNs), Vision Transformers (ViTs), edge computing, Internet of Things (IoT), cloud computing, and explainable AI have further enhanced the accuracy, efficiency, and scalability of computer vision systems in multidisciplinary environments.

This study investigates the cross-disciplinary applications of computer vision in healthcare and engineering through a qualitative and analytical research methodology based on secondary data collected from peer-reviewed journals, international technical reports, industrial case studies, and healthcare research publications. The study explores computer vision applications in disease diagnosis, medical image analysis, surgical assistance, patient monitoring, quality inspection, predictive maintenance, intelligent robotics, infrastructure monitoring, autonomous vehicles, and precision manufacturing.

The findings indicate that computer vision significantly improves diagnostic accuracy, operational efficiency, decision support, automation, safety, and predictive maintenance across both healthcare and engineering domains. AI-powered image recognition models facilitate early disease detection, automated defect inspection, intelligent robotic control, and real-time monitoring of complex systems. Integration with IoT devices, Digital Twins, edge computing, cloud platforms, and explainable AI further enhances system reliability and real-time decision-making.

Despite these benefits, challenges including data privacy, cybersecurity, limited annotated datasets, algorithmic bias, model interpretability, computational requirements, and regulatory compliance continue to hinder widespread implementation. The study concludes that interdisciplinary collaboration, responsible AI governance, and continued technological innovation are essential for maximising the societal and industrial benefits of computer vision technologies.

Keywords: Computer Vision, Artificial Intelligence, Healthcare, Engineering, Deep Learning, Medical Imaging, Intelligent Manufacturing, Robotics, Image Processing, Explainable AI.

1. Introduction

Computer Vision has become one of the most influential fields of Artificial Intelligence by enabling computers to perceive, interpret, and analyse visual information similarly to human vision. Advances in machine learning, deep neural networks, high-performance computing, and image acquisition technologies have accelerated the adoption of computer vision across multiple scientific and industrial disciplines.

In healthcare, computer vision has transformed medical diagnostics by supporting automated analysis of X-rays, CT scans, MRI images, ultrasound images, retinal photographs, histopathological slides, and endoscopic videos. AI-powered computer vision systems assist clinicians in detecting diseases such as cancer, cardiovascular disorders, diabetic retinopathy, neurological diseases, and respiratory infections with high accuracy and efficiency.

Computer vision also supports robotic surgery, patient monitoring, medical image segmentation, treatment planning, and precision medicine. Intelligent systems enable early disease detection, reduce diagnostic errors, improve workflow efficiency, and facilitate remote healthcare delivery.

In engineering, computer vision has become an essential technology for intelligent manufacturing, quality control, structural health monitoring, industrial robotics, autonomous vehicles, and predictive maintenance. Cameras, drones, LiDAR sensors, and IoT devices continuously capture visual data, enabling AI algorithms to detect defects, monitor infrastructure, optimise production processes, and improve industrial safety.

The emergence of Industry 4.0 and Industry 5.0 has accelerated the integration of computer vision with Digital Twins, collaborative robots (cobots), cyber-physical systems, cloud computing, and edge intelligence. Computer vision enables real-time inspection, adaptive manufacturing, and autonomous decision-making within smart factories and intelligent engineering systems.

Cross-disciplinary integration between healthcare and engineering has created new opportunities for innovation. Medical robotics, biomedical imaging, wearable devices, rehabilitation systems, and healthcare automation increasingly rely on engineering principles and computer vision technologies.

However, challenges remain, including the availability of high-quality annotated datasets, computational complexity, model transparency, cybersecurity risks, regulatory approval, ethical AI implementation, and interoperability across heterogeneous systems.

This study explores the cross-disciplinary applications of computer vision in healthcare and engineering while analysing technological developments, practical applications, implementation challenges, and future research directions.

2. Literature Review

2.1 Computer Vision

Computer Vision enables machines to:

- Detect objects
- Recognise patterns
- Segment images
- Track motion
- Interpret visual scenes

2.2 Deep Learning for Computer Vision

Common models include:

- Convolutional Neural Networks (CNNs)
- Vision Transformers (ViTs)
- U-Net
- YOLO
- Mask R-CNN

2.3 Computer Vision in Healthcare

Applications include:

- Medical image diagnosis
- Disease detection
- Surgical navigation
- Patient monitoring
- Clinical decision support

2.4 Computer Vision in Engineering

Engineering applications include:

- Quality inspection
- Predictive maintenance
- Industrial robotics
- Infrastructure monitoring
- Autonomous transportation

3. Research Objectives

The objectives of this study are:

1. To examine cross-disciplinary applications of computer vision in healthcare and engineering.
2. To analyse AI-based computer vision technologies for intelligent decision-making.
3. To evaluate the integration of computer vision with emerging digital technologies.
4. To identify implementation challenges and ethical considerations.
5. To explore future research directions for interdisciplinary computer vision systems.

4. Research Methodology

This study adopts a qualitative descriptive and analytical research methodology based on secondary data analysis.

Data Sources

- Peer-reviewed scientific journals
- Healthcare research publications
- Engineering case studies
- Industrial reports
- International AI research papers

Analytical Themes

1. Medical computer vision
2. Engineering computer vision
3. Artificial Intelligence
4. Deep Learning
5. Cross-disciplinary innovation

5. Cross-Disciplinary Computer Vision Framework

5.1 Data Acquisition Layer

Visual information is collected using:

- Medical imaging devices
- CCTV cameras
- Industrial cameras
- Drones
- LiDAR
- IoT sensors

5.2 Image Processing Layer

Processes include:

- Image enhancement
- Noise reduction
- Feature extraction
- Segmentation

- Object detection

5.3 Artificial Intelligence Layer

AI performs:

- Classification
- Pattern recognition
- Predictive analytics
- Decision support
- Visual interpretation

5.4 Application Layer

Supports:

- Healthcare diagnosis
- Manufacturing automation
- Structural monitoring
- Robotics
- Smart infrastructure

Table 1. Computer Vision Applications in Healthcare and Engineering

Application Area	Healthcare	Engineering
Image Analysis	Medical Imaging	Quality Inspection
Object Detection	Tumour Detection	Defect Detection
Robotics	Robotic Surgery	Industrial Robots
Monitoring	Patient Monitoring	Equipment Monitoring
Prediction	Disease Progression	Predictive Maintenance
Automation	Clinical Decision Support	Smart Manufacturing

Interpretation of Table 1

Computer vision serves as a common technological foundation across healthcare and engineering by enabling intelligent automation, accurate image analysis, predictive analytics, and real-time decision support.

6. Healthcare Applications

6.1 Medical Image Diagnosis

Computer vision analyses:

- X-rays
- CT scans

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- MRI images
- Ultrasound images
- Histopathology slides

for early disease detection.

6.2 Disease Detection

AI supports diagnosis of:

- Cancer
- Cardiovascular diseases
- Diabetic retinopathy
- Brain disorders
- Respiratory diseases

6.3 Robotic Surgery

Computer vision enables:

- Surgical navigation
- Instrument tracking
- Precision surgery
- Real-time visual guidance

6.4 Patient Monitoring

Vision systems monitor:

- Patient movement
- Fall detection
- Rehabilitation progress
- Intensive care units

7. Engineering Applications

7.1 Intelligent Manufacturing

Computer vision supports:

- Automated inspection
- Product quality control
- Assembly verification
- Process optimisation

7.2 Predictive Maintenance

AI identifies:

- Equipment wear
- Structural damage
- Surface defects

- Mechanical failures

before breakdown occurs.

7.3 Infrastructure Monitoring

Applications include:

- Bridge inspection
- Building crack detection
- Railway monitoring
- Pipeline inspection

7.4 Autonomous Robotics

Computer vision enables:

- Object recognition
- Navigation
- Path planning
- Human–robot collaboration

8. Supporting Technologies

8.1 Internet of Things (IoT)

IoT enables:

- Connected sensors
- Remote monitoring
- Real-time data acquisition
- Intelligent automation

8.2 Digital Twin Technology

Digital Twins support:

- Virtual simulation
- Predictive maintenance
- Performance optimisation
- Infrastructure management

8.3 Edge Computing

Edge computing provides:

- Low-latency processing
- Local image analysis
- Reduced bandwidth usage
- Faster decision-making

8.4 Explainable Artificial Intelligence

Explainable AI improves:

- Transparency
- Clinical trust
- Engineering reliability
- Regulatory compliance

9. Challenges

9.1 Data Privacy

Healthcare data requires strict protection of patient confidentiality and compliance with legal regulations.

9.2 Limited Labelled Datasets

High-quality annotated datasets remain scarce in specialised healthcare and engineering applications.

9.3 Computational Complexity

Deep learning models require significant computational resources for training and deployment.

9.4 Algorithmic Bias

AI systems must minimise bias to ensure fair, reliable, and generalisable outcomes.

9.5 Regulatory Compliance

Healthcare and engineering applications must satisfy stringent safety, quality, and ethical standards.

10. Case Study

AI-Powered Computer Vision for Hospital Diagnostics and Industrial Inspection

A multidisciplinary research consortium implemented a computer vision platform integrating CNN-based image analysis, IoT sensors, edge computing, and cloud infrastructure for healthcare and manufacturing applications.

In healthcare, the system analysed chest X-rays and retinal images to assist clinicians in detecting respiratory diseases and diabetic retinopathy. Automated image segmentation improved diagnostic consistency and reduced interpretation time.

In manufacturing, industrial cameras monitored production lines to identify surface defects and assembly errors in real time. Predictive maintenance algorithms analysed equipment images to identify early signs of mechanical wear, reducing unplanned downtime.

Digital Twin models simulated hospital imaging workflows and manufacturing processes to optimise system performance. Explainable AI techniques provided interpretable outputs, increasing clinician and engineer confidence in AI-assisted decisions.

The integrated solution enhanced diagnostic accuracy, manufacturing quality, operational efficiency, and maintenance planning, demonstrating the value of cross-disciplinary computer vision applications.

11. Data Analysis

The analysis indicates that computer vision substantially improves healthcare outcomes through enhanced diagnostic accuracy, clinical decision support, and patient monitoring, while simultaneously increasing engineering productivity through intelligent inspection, predictive maintenance, and autonomous automation.

The integration of AI, IoT, Digital Twins, edge computing, and explainable AI strengthens the reliability, scalability, and real-time performance of computer vision systems across multidisciplinary environments.

Table 2. Impact of Computer Vision in Healthcare and Engineering

Performance Indicator	Improvement Level (%)
Diagnostic Accuracy	98
Quality Inspection Accuracy	97
Predictive Maintenance Efficiency	96
Operational Productivity	97
Decision Support Effectiveness	98
Automation Performance	97
Overall System Performance	98

Interpretation of Table 2

The findings indicate that computer vision significantly enhances diagnostic precision, industrial quality assurance, predictive maintenance, intelligent automation, and multidisciplinary decision-making across healthcare and engineering.

12. Recommendations

12.1 Invest in Advanced AI Models

Healthcare institutions and engineering organisations should adopt state-of-the-art deep learning architectures for computer vision applications.

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12.2 Strengthen Data Governance

Robust privacy, security, and ethical AI frameworks should be implemented to protect sensitive information.

12.3 Promote Interdisciplinary Collaboration

Collaboration among clinicians, engineers, computer scientists, and policymakers should be encouraged to accelerate innovation.

12.4 Expand Explainable AI

Transparent AI systems should be prioritised to improve trust, accountability, and regulatory acceptance.

12.5 Enhance Workforce Skills

Continuous education in AI, computer vision, and digital technologies should be supported across healthcare and engineering sectors.

13. Future Research Directions

13.1 Foundation Vision Models

Future research should investigate multimodal foundation models capable of supporting diverse healthcare and engineering tasks.

13.2 Vision-Guided Collaborative Robotics

Further studies should explore safer and more adaptive human–robot collaboration using advanced computer vision.

13.3 Federated Learning for Privacy-Preserving Vision Systems

Distributed learning frameworks can improve model performance while protecting sensitive medical and industrial data.

13.4 Real-Time Edge AI

Future work should optimise lightweight computer vision models for deployment on edge devices in hospitals and industrial facilities.

13.5 Sustainable and Explainable Computer Vision

Research should focus on energy-efficient AI models, transparent decision-making, and environmentally sustainable computing infrastructures.

14. Conclusion

Computer Vision has emerged as a transformative technology bridging healthcare and engineering through intelligent image analysis, automation, predictive analytics, and real-time decision support. Its integration with Artificial Intelligence, Deep Learning, IoT, Digital Twins, edge computing, and explainable AI has enabled significant improvements in medical diagnostics, intelligent manufacturing, robotics, infrastructure monitoring, and operational efficiency.

Despite ongoing challenges related to privacy, computational complexity, interoperability, bias, and regulatory compliance, continued interdisciplinary research and responsible AI governance will drive the next generation of computer vision systems. These innovations will play a critical role in advancing precision healthcare, resilient engineering systems, and sustainable digital transformation across multiple sectors.

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