**Course Title**

**Computer Vision and Image Processing**

**Course Description**

This course covers the essential concepts and techniques for processing digital images and interpreting visual data. Students will explore both low-level image manipulation and higher-level tasks in computer vision such as object detection, segmentation, and scene understanding. Emphasis is placed on understanding the mathematical foundations, algorithm design, and practical implementations using contemporary programming tools.

**Prerequisites**

* **Programming:** Proficiency in Python (or MATLAB/C++).
* **Mathematics:** Basic knowledge of linear algebra, calculus, and probability.
* **Foundations:** Prior exposure to digital systems or introductory courses in signals and systems is beneficial.

**Learning Outcomes**

By the end of the course, students will be able to:

1. **Understand Image Fundamentals:** Explain the principles of image formation, acquisition, and representation.
2. **Implement Image Processing Algorithms:** Develop programs for basic image filtering, enhancement, noise reduction, and frequency analysis.
3. **Apply Computational Techniques:** Utilize transformations, edge detection, segmentation, and morphological operations.
4. **Extract and Match Features:** Identify key features in images and apply techniques to match and classify objects.
5. **Integrate Machine Learning:** Demonstrate an understanding of applying machine learning—and specifically deep learning—with CNNs—to tasks in object recognition and segmentation.
6. **Solve Complex Vision Problems:** Develop projects that integrate theory with real-world applications like video analysis, autonomous navigation, and augmented reality.

**Course Modules & Weekly Breakdown**

**Module 1: Introduction to Digital Images & Computer Vision**

*Weeks 1–2*

* **Topics:**
  + Overview of computer vision and image processing.
  + History and evolution of the field.
  + Understanding digital images: pixels, resolutions, and color models (RGB, grayscale).
  + Introduction to image acquisition and sensors.
* **Practical:**
  + Simple image I/O operations using Python libraries (OpenCV, PIL).
  + Visualization techniques and exploratory image analysis.

**Module 2: Fundamentals of Image Processing**

*Weeks 3–4*

* **Topics:**
  + Image representation and data structures.
  + Image transformations: scaling, rotation, and translation.
  + Spatial domain filtering: smoothing, sharpening, and noise reduction techniques.
  + Histograms, contrast stretching, and thresholding.
* **Practical:**
  + Implementing convolution filters and exploring effects of different kernels.
  + Lab sessions on histogram equalization and basic image enhancements.

**Module 3: Frequency Domain Analysis**

*Weeks 5–6*

* **Topics:**
  + Fourier Transform basics and their applications in image processing.
  + Frequency filtering: low-pass, high-pass, and band-pass filters.
  + Image reconstruction and compression basics.
* **Practical:**
  + Using FFT (Fast Fourier Transform) to analyze image frequency content.
  + Designing and applying frequency domain filters.

**Module 4: Edge Detection and Image Segmentation**

*Weeks 7–9*

* **Topics:**
  + Edge detection methods: Sobel, Canny, and Laplacian filters.
  + Gradient-based techniques and zero-crossing methods.
  + Image segmentation: thresholding, region growing, and clustering.
  + Morphological operations: erosion, dilation, opening, and closing.
* **Practical:**
  + Applying edge detectors to various images.
  + Developing segmentation algorithms and evaluating their performance.

**Module 5: Feature Extraction and Object Recognition**

*Weeks 10–11*

* **Topics:**
  + Keypoint detection and feature descriptors (SIFT, SURF, ORB).
  + Methods of feature matching and image alignment.
  + Overview of object detection and classification methods.
* **Practical:**
  + Implementing feature detection and matching between images.
  + Introduction to using libraries for object recognition tasks.

**Module 6: Machine Learning for Computer Vision**

*Weeks 12–13*

* **Topics:**
  + Fundamentals of machine learning as applied to image analysis.
  + Introduction to supervised and unsupervised learning techniques.
  + Evaluation metrics and dataset considerations for vision tasks.
* **Practical:**
  + Implementing classification tasks using traditional machine learning algorithms (e.g., k-NN, SVM).
  + Experimentation with feature-based classification.

**Module 7: Deep Learning and Advanced Topics**

*Weeks 14–15*

* **Topics:**
  + Convolutional Neural Networks (CNNs): architecture, convolution operations, pooling, and fully connected layers.
  + Training and fine-tuning deep networks for image recognition and segmentation.
  + Emerging trends: transfer learning, real-time object detection (e.g., YOLO, SSD), and 3D vision.
* **Practical:**
  + Building a CNN from scratch or using high-level libraries (e.g., TensorFlow or PyTorch).
  + Project work focusing on a real-world application (e.g., face recognition, autonomous drive scenarios).

**Module 8: Project Work and Case Studies**

*Weeks 16–18*

* **Topics:**
  + Integration of course concepts into a final project.
  + Case studies from research papers and industry applications.
  + Ethical considerations and future directions in computer vision.
* **Practical:**
  + Students work on a comprehensive project in teams or individually, applying all learned concepts.
  + Presentations and peer evaluations along with a written report.

**Assessment and Grading**

* **Homework Assignments and Labs (40%)** Regular programming assignments, lab exercises, and exploratory tasks to reinforce theory with practice.
* **Midterm Exam (20%)** A combined written and practical exam covering the fundamental topics of the course.
* **Final Project (30%)** A comprehensive project requiring students to design, develop, and present a vision-based application.
* **Class Participation and Quizzes (10%)** Regular in-class discussions, quizzes, and peer reviews to stimulate engagement and ensure consistent progress.

**Recommended Resources**

* **Textbooks:**
  + “Digital Image Processing” by Rafael C. Gonzalez and Richard E. Woods
  + “Computer Vision: Algorithms and Applications” by Richard Szeliski
* **Online Materials:**
  + OpenCV tutorials and documentation
  + Deep learning frameworks (TensorFlow, PyTorch) guides and community projects
* **Research Papers and Journals:**
  + IEEE Transactions on Pattern Analysis and Machine Intelligence (PAMI)
  + Conference papers from CVPR, ICCV, and ECCV

**Additional Tips & Further Exploration**

* **Project Ideas:** Consider exploring augmented reality, real-time surveillance, or medical image analysis for your project topics. Each of these areas presents unique challenges and learning opportunities.
* **Software Tools:** Familiarize yourself with integrated development environments (IDEs) like Jupyter Notebook or PyCharm, and version control systems like Git for project collaboration.
* **Guest Lectures & Workshops:** If possible, invite industry experts or researchers as guest lecturers to gain insights into the latest trends and real-world challenges in computer vision.
* **Continued Learning:** After the course, engaging in online competitions (like those on Kaggle) and exploring advanced topics such as reinforcement learning for vision can further sharpen your skills.

Before Mid

* What is DIP
* Image formation (How digital image form)
* Image Processing Steps
* Analogue and Digital Image
* Contrast, Brightness, Intensity, Sampling, Quantization, DPI, PPI
* Image Types (i) Binary (ii) Gray Scale (iii) RGB
* Histogram
* Applications of Digital Image Processing
* Image Processing vs Computer Vision
* Zooming Process
* ISO preference curves
* Dithering
* Increasing the Contrast of an Image with formula
* PMF and CDF
* Correlation, Convolution, Shearing
* Pixel Path Calculation N4, N8 and Nm distance measure in Units [Math]
* Image Size Calculation
* DPI, PPI Calculations
* Image Arithmetic Operations

After Mid

* Filtering
* Prewitt Operator Find out the Edge
* Edge Detection Connectivity
* Convolution Process
* Image Arithmetic Operations
* YOLO Operations

**Bonus Suggestions**

* **Mini Project (Optional):** Assign a small project in Week 7–8 like “Face Mask Detection,” “Lane Detection,” or “Real-time Object Counter.”
* **Tools:** Python, OpenCV, NumPy, Matplotlib, Jupyter Notebooks
* **Assessment Ideas:** Weekly quizzes, lab reports, and a final demo/presentation