Ain Shams University
Faculty of Engineering

University of East London

CSE483 / CESS5004 – Computer Vision
Course Project Specification

Introduction.

This project is to be carried out in groups of **2–4 students**. It aims to cover several topics discussed in the Computer Vision course, as well as related advanced topics, to enrich your experience in designing practical solutions using classical computer vision techniques.

The main task is to automatically analyse jigsaw puzzle pieces from images, segment individual pieces, and suggest possible matches between puzzle edges based on their contour shapes. You are required to build a robust image processing pipeline to preprocess the input, extract contours, describe their shapes in a rotation-invariant manner, and compare edges to find potential matches, **all using classical computer vision, without machine or deep learning.**

Topics to be assessed.

1. Robust image preprocessing techniques.
2. Adaptive image enhancement and noise attenuation techniques.
3. Image preprocessing and segmentation of puzzle pieces.
4. Contour extraction and description using shape descriptors.
5. Edge matching using contour comparison and rotation invariance.
6. Robustness to noise, varying puzzle orientations, and irregular edges.

Detail of the task.

This project aims to incorporate the material discussed in the course in a practical application, encouraging students to explore said material in practice and how to apply it in an actual problem they are facing, such as that of analysing jigsaw puzzle pieces to automatically suggest matches between complementary edges, emulating the cognitive process humans use when solving puzzles. By preprocessing the captured puzzle piece images, clear contours can be extracted, edges can be classified and described, and potential matches can be identified based on shape similarity.

The edge matching portion of the project may not be fully explored in the course material, however; it aims to expand the knowledge of students, and how they can apply their obtained knowledge on basics of classical computer vision to implement a real-life problem through advanced geometric analysis; in this case that is to extract shape features from contours and compare them using appropriate distance metrics to identify complementary edge pairs. You should not attempt to use machine learning or deep learning techniques for any part of this project and should not use any external libraries other than those discussed in the course labs.

The project is divided into two milestones, and students are required to work in groups to produce working code, demo, documentation, as well as converse about their progress periodically and share their findings and conclusions with their instructors and discuss the final output. You can use this dataset for your project.

What you should hand in.

You will be handing in your work in the form of a well-documented git repository pushed and collaborated on through GitHub throughout the semester over two milestones, encompassing the following:

*Milestone 1 (due **by the end of Week 11**):*

The objective of this milestone is to develop a robust preprocessing and segmentation pipeline capable of isolating individual puzzle pieces from the input image, regardless of variations in lighting, orientation, noise, or background clutter. This step is crucial, as the quality of the subsequent contour extraction and edge matching depends heavily on obtaining clean, well-defined binary masks for each puzzle piece. The pipeline should address the following:

1. **Noise reduction and Image Cleanup:** Apply suitable filtering techniques to denoise the image while preserving the edges of puzzle pieces.
2. **Image Enhancement:** Apply all the needed filters to enhance the edges of the puzzle.
3. **Background Removal:** Apply any technique for background removal such as binarization and thresholding.
4. **Segmentation of individual puzzle piece:** Apply contour extraction for puzzle edges and crop (mask) each puzzle individually for subsequent processing.
5. **Descriptor storage:** store the contour and the edge points of each puzzle piece in a structured format with unique ID for later matching.

*Milestone 2 (due **by the end of Week 13**):*

In this milestone, you are required to make the system uses the edge descriptors computed earlier to identify likely matching pairs between puzzle pieces. The goal is to compare every edge against all other edges and compute a similarity score that reflects how well two edges fit together. Also, apply the system into a demo using any input stream. You are required to submit:

1. **Similarity computation:** For each edge descriptor, compute its similarity with all other edges in the dataset using an appropriate shape matching metric.
2. **Thresholding and Ranking:** Apply a similarity threshold to eliminate poor matches. Rank the remaining matches for each edge according to similarity score, producing a list of top candidate matches. The system should handle one-to-many and many-to-one comparisons, allowing for ambiguity in matches.
3. **Visualization of matches:** Display matching results visually by overlaying matched edges or connecting pieces with lines to indicate candidate matches.
4. **Documentation:** Provide a detailed READ.ME file describing the pipeline, techniques used, and justifications for each design decision. Include a clear explanation of how each step (preprocessing, contour extraction, edge representation, and matching) contributes to the overall goal. Cite any references, tutorials, or research papers you consulted.
5. **Demonstration:** Create a demo video or Jupyter notebook that showcases your system working on several puzzle images. The demo should include at least one clean case and one challenging case (such as: rotated pieces, noisy background). Demonstrate intermediate results, as well as final matching outputs.
6. **Discussion and Reflection**.

Regarding academic misconduct.

The University defines "*Academic Misconduct*" as: 'any case of deliberate, premeditated cheating, collusion, plagiarism or falsification of information, in an attempt to deceive and gain an unfair advantage in assessment'. This includes attempting to gain marks as part of a team without contributing. The department takes academic misconduct very seriously and any suspected cases will be investigated through the University's standard policy. If you are found guilty, you may be expelled from the University with no award. It is your responsibility to ensure that you understand what constitutes Academic Misconduct and to ensure that you do not break the rules. If you have any confusion regarding what is required, please ask (*via Teams*).

Also, make sure you've read the general guidelines for use of artificial intelligence in any coursework.

Exam ILOs according to UEL module specs

1. Demonstrate the basic definitions and aspects of computer vision concepts, primary steps, and advanced methods.
2. Demonstrate the foundations of digital signal processing in image transformation, enhancement, restoration, segmentation, feature extraction, and classification, and define the needed concepts from related sciences.
3. Define and be aware of the central role of computer vision in solving problems in several real-life environments and applications.
4. Design, analyze, and verify methods and algorithms for image acquisition, enhancement, restoration, segmentation, description, and classification.
5. Solve related mathematical and statistical problems based on the acquired knowledge.
6. Design efficient data structures and algorithms/solutions for different computer vision and image analysis problems that are optimized with respect to available resources.
7. Apply theoretical concepts and practical techniques from related fields (mathematics, statistics, signal processing …) to produce the required solution.
8. Work effectively as an individual and in teams, either as a leader or a member, and communicate ideas and solutions effectively by oral, written and visual means.

Course Assessment	1	2	3	4	5	6	7	8
Project	●	●	●	●	●	●	●	●

Exam LOs according to ASU course specs

Cognitive Domain	
1	Describe the basic definitions and aspects of computer vision concepts, primary steps, and advanced methods
2	Describe the foundations of digital signal processing in image transformation, enhancement, restoration, segmentation, feature extraction, and classification
Psychomotor Domaine	
3	Design, analyze, and verify techniques for computer vision problems.
Affective Domaine	
5	Discuss different computer vision systems methodologies.

Course Assessment	LO1	LO2	LO3	LO5
Project	•	•	•	•