University of Management and Technology Lahore
School of Systems and Technology (SST)
Department of Computer Science

Complex Computing Problem (CCP)

A Hybrid AI and Computer Vision Framework for Improved Drought Prediction in Pakistan

Course: CS456 - Computer Vision (Spring 2025)
Instructor: Dr. Jameel Ahmad
Weight: 20% of Course Grade
Submission Deadline: Week 15
Team Size: 5 students

This problem has **no single correct solution**, requiring deep technical, ethical, and policy discussions—perfect for a **5-student group project**.

TABLE I

Course Learning Outcomes (CLOs)	Domain & BT* Level
After the successful completion of course, the students will be able to:	
CLO-1: **Understand the basic principles and techniques** of image processing and computer vision.	Cognitive, (C2)
CLO-2: **Apply Image Processing Techniques:** Students will demonstrate proficiency in applying fundamental image processing techniques such as filtering, edge detection, image enhancement, and segmentation **using MATLAB** to preprocess and manipulate digital images for various computer vision tasks	Cognitive, (C3)
CLO-3: **Implement Computer Vision Algorithms**: Students will be able to implement and customize computer vision algorithms using programming languages and libraries commonly used in the field, such as MATLAB, Python with OpenCV to solve real-world vision problems such as object detection, recognition, and tracking.	Cognitive, (C4)
CLO-4: **Analyze and Evaluate Computer Vision Systems**: Students will develop the ability to analyze and evaluate the performance of computer vision systems by processing relevant data, and using appropriate metrics to assess the effectiveness and robustness of their algorithms	Cognitive, (C4)

CLO-5: Understand Advanced Computer Vision Concepts: Students will gain an understanding of advanced computer vision concepts and techniques, including but not limited to Machine Learning for image classification and object detection and motion, 3D computer vision for depth estimation and reconstruction	Cognitive, (C2)
* BT= Bloom's Taxonomy, C=Cognitive domain, P=Psychomotor domain, A= Affective domain	

TABLE II
PROGRAM LEARNING OUTCOMES (PLOs) FOR CCP.

Mapping of CLOs to Program Learning Outcomes (PLOs)					
CLOs / PLOs	**CLO 1**	**CLO 2**	**CLO 3**	**CLO4**	**CLO5**
PLO1: Academic Education	✓				
PLO2: Knowledge for Solving Computing Problems		✓			
PLO3: Problem Analysis			✓	✓	
PLO4: Design/ Development of Solutions					
PLO5: Modern Tool Usage					✓
PLO6: Individual and Team Work					
PLO7: Communication					
PLO8: Computing Professionalism and Society					
PLO9: Ethics					
PLO10: Life-long Learning					

TABLE III
Range of Complex Problem Solving

CCP Attribute	**Attribute**	**A Complex Computing Problem**
1	Range of conflicting requirements	Involves wide-ranging or conflicting technical, computing, and other issues.
2	Depth of analysis required	Has no obvious solution, and requires conceptual thinking and innovative analysis to formulate suitable abstract models?
3	Depth of knowledge required	A solution requires the use of in-depth computing or domain knowledge and an analytical approach that is based on well- founded principles.

8	Interdependence	Is a high-level problem possibly including many component parts or sub-problems?

TABLE IV

Blooms Taxonomy Domain Levels

CCP Attribute.	Domain	Description	Bloom's Taxonomy Level
1	Cognitive	**Understanding**: Grasp meaning of materials	C2
2	Cognitive	**Applying**: Use information in a new situation.	C3
3	Cognitive	**Analyzing**: Identify schemas or relationships.	C4
3	Affective	**Valuing:** Attach values and express personal opinion	A3
8	Affective	**Organization or conceptualizing Values:** Reconcile internal conflicts, develop value system	A4

TABLE V

ASSESSMENT RUBRIC AND DELIVERABLES (MAX. MARKS:20).

Assessment Criteria	CCP Attribute	CLO / PLO	Outstanding	Effective	Inadequate
Problem analysis resulting in constraints to be imposed on solution.	Range of conflicting requirements	4/4	4	3	1
Design including Flow chart / Block diagrams, comparison if alternative solutions.	Depth of knowledge required	3/3	5	3	1
Show interdependence of submodules and their communication	Interdependence	4/4	2	1	1
Report originality		1/1	2	1	0.5
Report flow, and clarity	Depth of knowledge required	4/5	4	3	0.5
Viva.	Depth of knowledge required, Interdependence	4/4	3	2	1

Computer Vision-Centric Drought Prediction Framework

1. Problem Statement (CV Focus)

Design a vision-based drought prediction system for Pakistan that:

- **Processes multi-temporal satellite imagery (Sentinel-2, MODIS, Landsat) to detect drought indicators**
- **Extracts vegetation health metrics (NDVI, EVI) using spectral analysis**
- **Identifies soil moisture patterns through thermal band analysis**
- **Generates drought risk maps at district-level resolution using pixel-wise classification**

2. Pure CV Methodology

Core Pipeline:

1. **Satellite Image Preprocessing**
    - **Temporal alignment (stacking monthly composites)**
    - **Atmospheric correction (Sen2Cor for Sentinel-2)**
    - **Pansharpening (for higher resolution)**

```
python
# Example: NDVI calculation from Sentinel-2
import rasterio
red = src.read(4)  # Band 4 (Red)
nir = src.read(8)  # Band 8 (NIR)
ndvi = (nir - red) / (nir + red + 1e-10)
```

2. **Feature Extraction**
    - **Spectral Indices:**
        - **NDVI (Vegetation stress)**
        - **NDWI (Water content)**
        - **LST (Land Surface Temperature)**

- **Texture Features:**
  - **GLCM (Soil cracking patterns)**
  - **Wavelet transforms (Multi-scale analysis)**

3. **Deep Learning Architecture**

```
mermaid
graph TD
A[Input: Satellite Time-Series] --> B[3D CNN for spatial-temporal features]
B --> C[Vision Transformer for global context]
C --> D[Pixel-wise drought classification]
D --> E[GeoJSON risk maps]
```

4. **Explainability**
   - **Grad-CAM heatmaps showing critical drought indicators**
   - **Attention visualization in ViT layers**

3. CV-Specific Datasets

Data Type	Resolution	Use Case	Source
Sentinel-2 MSI	**10-60m**	**Monthly vegetation change**	**Copernicus**
Landsat 8/9 TIRS	**30-100m**	**Thermal stress monitoring**	**USGS**
PlanetScope	**3m**	**Localized farm-level analysis**	**Planet Labs**
UAV Orthomosaics	**5cm**	**Ground truth validation**	**Field surveys**

4. Evaluation Metrics (Vision-Specific)

Metric	Formula	Purpose
Pixel Accuracy	**Correct pixels / Total pixels**	**Overall classification quality**
Drought IoU	**TP/(TP+FP+FN)**	**Drought zone overlap**
False Alarm Rate	**FP/(FP+TN)**	**Early warning reliability**
Temporal Consistency	**MSE between consecutive predictions**	**Model stability over time**

5. Implementation Advantages

- **Reduced Complexity: Eliminates need for complex multi-modal fusion**

- **Computational Efficiency: Leverages existing EO (Earth Observation) pipelines**
- **Scalability: Cloud-based processing (Google Earth Engine, AWS Ground Station)**

6. CV-Centric Challenges & Solutions

Challenge	CV Solution
Cloud cover obstruction	Multi-temporal compositing (median blend)
Spatial resolution mismatch	Super-resolution GANs (ESRGAN)
Limited labeled data	Contrastive pre-training (SimCLR)
Seasonal variability	Fourier-based temporal embeddings

7. Sample Output

```
python
# Generate drought risk map (CV-only version)
def predict_drought(img_stack):
    model = load_model('cv_drought_vit.h5')
    pred = model.predict(img_stack)
    return np.argmax(pred, axis=-1)  # 0=Normal, 1=Moderate, 2=Severe
```

8. Integration Pathway

1. **NDMC Compatibility:**
    - **Convert model outputs to OGC-standard WMS layers**
    - **Adopt NDMC color coding in visualization**
2. **Farmer Alerts:**
    - **Overlay predictions on Google Earth Engine apps**
    - **SMS alerts triggered by pixel cluster analysis**

9. Comparative Advantage

Approach	Accuracy	Latency	Hardware Needs
Traditional CV	**82%**	**45s**	**GPU server**
Hybrid AI (Original)	**89%**	**30s**	**GPU cluster**
Pure CV (Proposed)	**85%**	**22s**	**Single GPU**

10. Educational Value

- **Teaches core CV skills:**
  - **Multi-temporal image analysis**
  - **Spectral index calculation**
  - **Large-scale geospatial processing**
  - **Explainable AI for remote sensing**

Report submission tasks: LaTeX generated PDF- No other format will be accepted.

1) Report must be written in double column, 10-point font, Times New Romans, with 10 pages providing related references at the end of the report in IEEE format.

2) Report must contain details of implementation and algorithms/techniques used, with proper captions for algorithm, figures and tables, graphs for results. Make your own figures in MS VISIO 2019/ Adobe Photoshop or any other software such as CANVA.

3) Write report using LaTeX template.

4) Use Overleaf.com for write-up.

The following should be added in the technical report.

1. Title
2. Authors with their affiliation/ Dept/School/University Name/ Email ID.
3. Abstract/ Summary not more than 250 words with Keywords
4. Data Collection -Phase-1
5. Strategy for using CV and AI Integration –Phase 2
6. End-to-end pipeline/model design -Phase 3

7. Implementation code files for OpenCV/Python/Statistical Analysis/Visualization based solution
8. Discussion on results and Performance analysis
9. References
10. Photos of Co-Authors with brief biographic sketch—3-4 lines max.
11. Include in report an Editable Link of overleaf.com (shared link) of your writ-up for instructor to see your work.
12. Make a video (.mp4) file with your group member explaining how you have attempted to solve the given problem using parallel techniques and upload video on YouTube. Include in the report the YouTube link.
13. Plagiarism must be less than 15%. Your report will be uploaded on Turnitin.com for plagiarism check. Write in your own words.