

Image Processing Project

TEAM# : 9

Team Members:

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Data preparation process:

- **Includes functionalities for:**
 - Mapping RGB masks to class labels.
 - Data augmentation.
 - Get new images from the old images
 - Preprocessing training and validation datasets.
 - Resize images
 - Normalization for images
- **Modules Used:**
 - TensorFlow: For building models and data augmentation.
 - NumPy: For numerical computations.
 - PIL (Pillow): For image processing.
 - os: For file path manipulation.
- **Workflow:**
 - Define a color map for 8 classes.
 - Convert RGB masks to class labels.
 - Load and preprocess training and validation data.
 - Apply data augmentation to enhance the dataset.

Overview of implemented models and modifications:

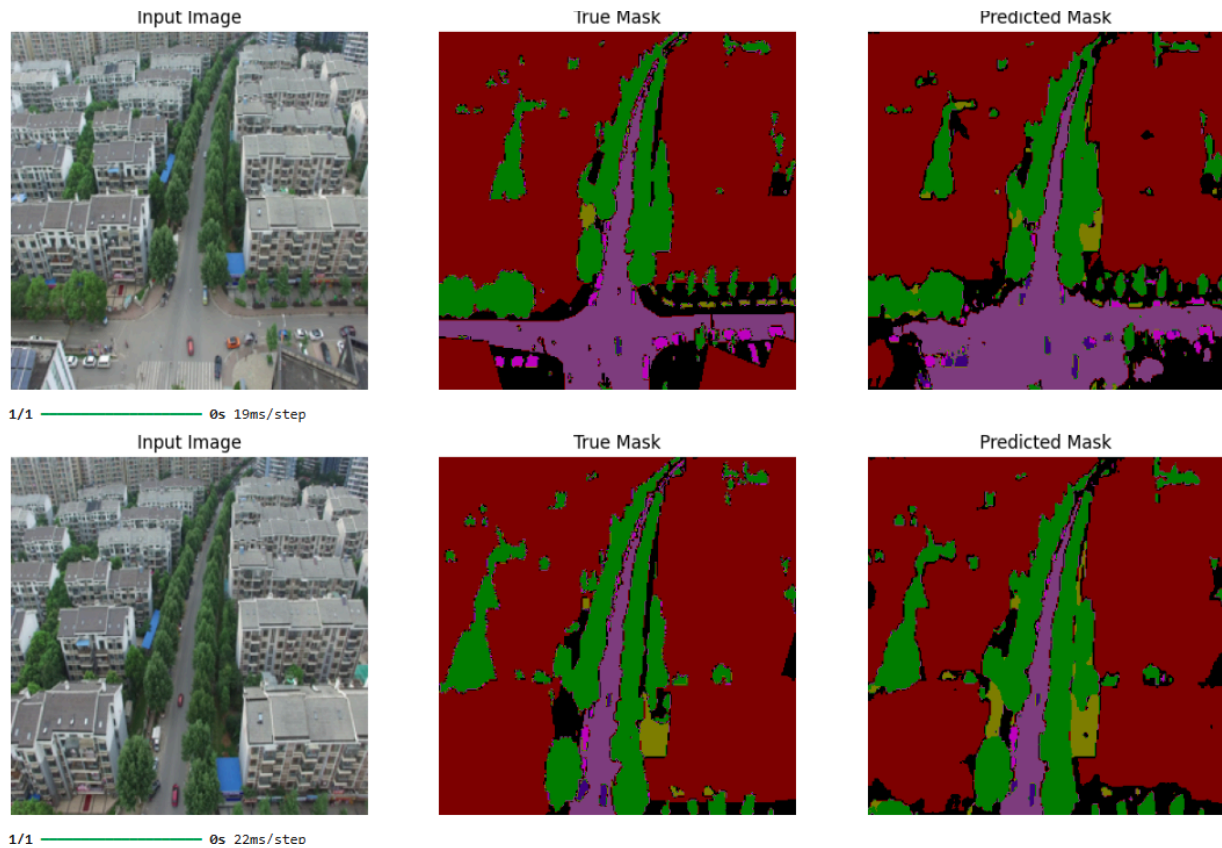
- **Includes functionalities for:**
 - Defining and building a (U-Net, Light U-Net, Attention U-Net)model for image segmentation.
 - Constructing encoder and decoder blocks with convolutional layers and skip connections.
 - Using a softmax activation for multi-class segmentation output.
- **Workflow:**
 - **Models**
 - **Model Architecture [U-net]:**
 - **Encoder Blocks:** Feature extraction using stacked convolutional and max-pooling layers.
 - **Bridge:** A bottleneck layer for connecting encoder and decoder paths.
 - **Decoder Blocks:** Upsampling layers with skip connections for reconstructing the segmentation map.
 - **Model Architecture [Light U-net]**
 - Added Dropout layer
 - Reduced number of filters
 - **Model Architecture [Attention U-net]**
 - **Added Attention Gates:** Applied to select important features only.
- **Output Layer:**
 - Use a **Conv2D** layer with 8 filters (for 8 classes) and softmax activation to produce the final segmentation mask.

Results and analysis from all experiments:

U-Net:

Evaluation Results:

Best Results:



- **200 Epoch, Adam:**

Pixel Accuracy: 0.7414

Mean IoU (Jaccard Index): 0.4934

Mean Dice Coefficient: 0.6255

Mean Precision: 0.6860

Mean Recall (Sensitivity): 0.6163

Adjusted Rand Index: 6000916.5919

Class 0: IoU: 0.4371, Dice: 0.6083, Precision: 0.5119, Recall: 0.7493

Class 1: IoU: 0.7137, Dice: 0.8329, Precision: 0.9534, Recall: 0.7395

Class 2: IoU: 0.6551, Dice: 0.7916, Precision: 0.8149, Recall: 0.7696

Class 3: IoU: 0.6503, Dice: 0.7881, Precision: 0.8093, Recall: 0.7680
Class 4: IoU: 0.5557, Dice: 0.7144, Precision: 0.6878, Recall: 0.7433
Class 5: IoU: 0.5444, Dice: 0.7050, Precision: 0.7557, Recall: 0.6607
Class 6: IoU: 0.3886, Dice: 0.5597, Precision: 0.6383, Recall: 0.4983
Class 7: IoU: 0.0021, Dice: 0.0041, Precision: 0.3163, Recall: 0.0021

- **100 Epoch, Adam:**

Pixel Accuracy: 0.7708
Mean IoU (Jaccard Index): 0.4904
Mean Dice Coefficient: 0.6195
Mean Precision: 0.6598
Mean Recall (Sensitivity): 0.6208
Adjusted Rand Index: 6449661.5667
Class 0: IoU: 0.4577, Dice: 0.6279, Precision: 0.6070, Recall: 0.6504
Class 1: IoU: 0.7951, Dice: 0.8858, Precision: 0.8828, Recall: 0.8889
Class 2: IoU: 0.6355, Dice: 0.7771, Precision: 0.8151, Recall: 0.7426
Class 3: IoU: 0.6441, Dice: 0.7835, Precision: 0.8218, Recall: 0.7486
Class 4: IoU: 0.5770, Dice: 0.7318, Precision: 0.6796, Recall: 0.7926
Class 5: IoU: 0.4821, Dice: 0.6506, Precision: 0.6043, Recall: 0.7045
Class 6: IoU: 0.3302, Dice: 0.4965, Precision: 0.5739, Recall: 0.4374
Class 7: IoU: 0.0012, Dice: 0.0025, Precision: 0.2941, Recall: 0.0012

Light U-Net:

Evaluation Results:

1. 150 Epoch, Adam, Dropout: 0.3:

Pixel Accuracy: 0.4771

Mean IoU (Jaccard Index): 0.2020

Mean Dice Coefficient: 0.3121

Mean Precision: 0.4128

Mean Recall (Sensitivity): 0.3052

Adjusted Rand Index: 4037679.9163

Class 0: IoU: 0.2506, Dice: 0.4007, Precision: 0.3143, Recall: 0.5527 Class 1:

IoU: 0.4587, Dice: 0.6289, Precision: 0.6449, Recall: 0.6137 Class 2: IoU:

0.2993, Dice: 0.4607, Precision: 0.4124, Recall: 0.5218 Class 3: IoU: 0.3241,

Dice: 0.4895, Precision: 0.5694, Recall: 0.4293 Class 4: IoU: 0.1138, Dice:

0.2044, Precision: 0.4029, Recall: 0.1369 Class 5: IoU: 0.0822, Dice: 0.1520,

Precision: 0.4156, Recall: 0.0930 Class 6: IoU: 0.0872, Dice: 0.1605, Precision:

0.5429, Recall: 0.0942 Class 7: IoU: 0.0000, Dice: 0.0000, Precision: 0.0000,

Recall: 0.0000

2. 150 Epoch, SGD, Dropout: 0.3:

Pixel Accuracy: 0.4541

Mean IoU (Jaccard Index): 0.1850

Mean Dice Coefficient: 0.3121

Mean Precision: 0.3528

Mean Recall (Sensitivity): 0.2652

Adjusted Rand Index: 4037679.9163

Class 0: IoU: 0.2506, Dice: 0.4007, Precision: 0.3143, Recall: 0.5527 Class 1:

IoU: 0.4587, Dice: 0.6289, Precision: 0.6449, Recall: 0.6137 Class 2: IoU:

0.2993, Dice: 0.4607, Precision: 0.4124, Recall: 0.5218 Class 3: IoU: 0.3241,

Dice: 0.4895, Precision: 0.5694, Recall: 0.4293 Class 4: IoU: 0.1138, Dice:

0.2044, Precision: 0.4029, Recall: 0.1369 Class 5: IoU: 0.0822, Dice: 0.1520,

Precision: 0.4156, Recall: 0.0930 Class 6: IoU: 0.0872, Dice: 0.1605, Precision:

0.5429, Recall: 0.0942 Class 7: IoU: 0.0000, Dice: 0.0000, Precision: 0.0000,

Recall: 0.0000

3. 200 Epoch, Adam, Dropout: 0.4:

Pixel Accuracy: 0.5143

Mean IoU (Jaccard Index): 0.2016

Mean Dice Coefficient: 0.3030

Mean Precision: 0.4524

Mean Recall (Sensitivity): 0.2978

Adjusted Rand Index: 4555177.9723

Class 0: IoU: 0.2625, Dice: 0.4159, Precision: 0.3876, Recall: 0.4485 Class 1: IoU: 0.4958, Dice: 0.6629, Precision: 0.6246, Recall: 0.7062 Class 2: IoU: 0.2623, Dice: 0.4156, Precision: 0.4587, Recall: 0.3799 Class 3: IoU: 0.3386, Dice: 0.5059, Precision: 0.4829, Recall: 0.5313 Class 4: IoU: 0.2251, Dice: 0.3675, Precision: 0.5095, Recall: 0.2874 Class 5: IoU: 0.0232, Dice: 0.0453, Precision: 0.8573, Recall: 0.0233 Class 6: IoU: 0.0055, Dice: 0.0109, Precision: 0.2983, Recall: 0.0055 Class 7: IoU: 0.0000, Dice: 0.0000, Precision: 0.0000, Recall: 0.0000

4. 400 Epoch, Adam, Dropout: 0.4:

Pixel Accuracy: 0.6025

Mean IoU (Jaccard Index): 0.2848

Mean Dice Coefficient: 0.4079

Mean Precision: 0.4949

Mean Recall (Sensitivity): 0.3973

Adjusted Rand Index: 5101354.4057

Class 0: IoU: 0.3253, Dice: 0.4909, Precision: 0.4505, Recall: 0.5394

Class 1: IoU: 0.6050, Dice: 0.7539, Precision: 0.7338, Recall: 0.7750

Class 2: IoU: 0.4218, Dice: 0.5933, Precision: 0.5338, Recall: 0.6679

Class 3: IoU: 0.3928, Dice: 0.5641, Precision: 0.6333, Recall: 0.5085

Class 4: IoU: 0.3357, Dice: 0.5026, Precision: 0.5420, Recall: 0.4686

Class 5: IoU: 0.1217, Dice: 0.2170, Precision: 0.5115, Recall: 0.1377

Class 6: IoU: 0.0760, Dice: 0.1413, Precision: 0.5546, Recall: 0.0809

Class 7: IoU: 0.0000, Dice: 0.0000, Precision: 0.0000, Recall: 0.0000

Attention U-Net:

Evaluation Results:

1. 50 Epochs

Pixel Accuracy: 0.6685

Mean IoU (Jaccard Index): 0.3609

Mean Dice Coefficient: 0.4832

Mean Precision: 0.6017

Mean Recall (Sensitivity): 0.4993

Adjusted Rand Index: 5314850.8046

Class 0: IoU: 0.3359, Dice: 0.5029, Precision: 0.4618, Recall: 0.5521

Class 1: IoU: 0.6153, Dice: 0.7618, Precision: 0.9270, Recall: 0.6466

Class 2: IoU: 0.5118, Dice: 0.6770, Precision: 0.5785, Recall: 0.8160

Class 3: IoU: 0.5817, Dice: 0.7355, Precision: 0.6735, Recall: 0.8101

Class 4: IoU: 0.5018, Dice: 0.6682, Precision: 0.6797, Recall: 0.6572

Class 5: IoU: 0.3276, Dice: 0.4935, Precision: 0.4886, Recall: 0.4986

Class 6: IoU: 0.0134, Dice: 0.0265, Precision: 0.8126, Recall: 0.0135

Class 7: IoU: 0.0001, Dice: 0.0002, Precision: 0.1923, Recall: 0.0001

2. 100 Epochs

Pixel Accuracy: 0.7423

Mean IoU (Jaccard Index): 0.4626

Mean Dice Coefficient: 0.5958

Mean Precision: 0.6463

Mean Recall (Sensitivity): 0.5851

Adjusted Rand Index: 6148320.1050

Class 0: IoU: 0.4334, Dice: 0.6048, Precision: 0.5730, Recall: 0.6402

Class 1: IoU: 0.7467, Dice: 0.8550, Precision: 0.9372, Recall: 0.7860

Class 2: IoU: 0.6263, Dice: 0.7702, Precision: 0.7726, Recall: 0.7678

Class 3: IoU: 0.6214, Dice: 0.7665, Precision: 0.6731, Recall: 0.8900

Class 4: IoU: 0.5089, Dice: 0.6746, Precision: 0.7625, Recall: 0.6048

Class 5: IoU: 0.4714, Dice: 0.6408, Precision: 0.6847, Recall: 0.6021

Class 6: IoU: 0.2914, Dice: 0.4513, Precision: 0.5394, Recall: 0.3879

Class 7: IoU: 0.0015, Dice: 0.0031, Precision: 0.2277, Recall: 0.0015

3. 200 Epochs

Evaluation Results:

Pixel Accuracy: 0.7790

Mean IoU (Jaccard Index): 0.5095

Mean Dice Coefficient: 0.6388

Mean Precision: 0.6884

Mean Recall (Sensitivity): 0.6293

Adjusted Rand Index: 6581519.1772

Class 0: IoU: 0.4548, Dice: 0.6253, Precision: 0.6381, Recall: 0.6130

Class 1: IoU: 0.8117, Dice: 0.8961, Precision: 0.8853, Recall: 0.9071

Class 2: IoU: 0.6528, Dice: 0.7899, Precision: 0.8144, Recall: 0.7669

Class 3: IoU: 0.6639, Dice: 0.7980, Precision: 0.7729, Recall: 0.8248

Class 4: IoU: 0.5528, Dice: 0.7120, Precision: 0.7071, Recall: 0.7170

Class 5: IoU: 0.5343, Dice: 0.6965, Precision: 0.6767, Recall: 0.7174

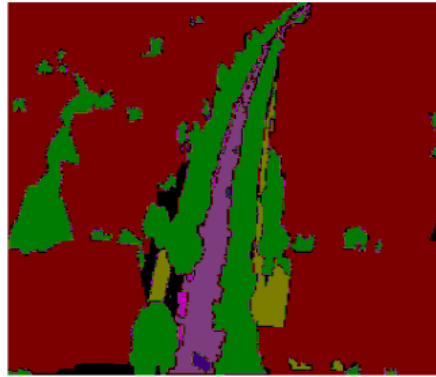
Class 6: IoU: 0.3884, Dice: 0.5594, Precision: 0.6894, Recall: 0.4707

Class 7: IoU: 0.0169, Dice: 0.0332, Precision: 0.3229, Recall: 0.0175

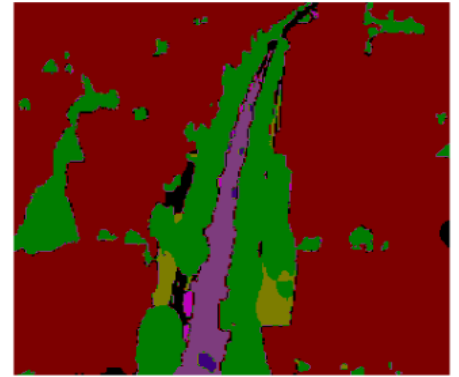
Input Image



True Mask



Predicted Mask



Conclusions and insights gained:

We found that the attention u-net with the 200 epochs gives the best results at a 77.9% and that's because the attention u-net select **relevant features** for each skip connection. This means only the most important features for the current task are passed forward , follows the U-net with accuracy 77% at 200 epochs and comes last the light-u-net (modified u-net archi that we made) as it use less number of parameters than u-net and attention unet It comes last with 60% accuracy at 400 epoch.

Code repository with clear documentation and instructions for reproducing the experiments:

[Repository link](#)

- The first code block is the data preprocessing block.(should be run regardless of what archi will be executed)
- The second one is for the light-U-net(run if testing the light-u-net)
- The third is for the U-net(run for the normal U-net)
- Forth is for the Attention-U-net
- Then the fifth is for the model training
- Sixth and seventh are the evaluation blocks
- The last block for visualizing the results and comparing it with the actual results