EE641 Homework 1: Multi-Scale Detection and Spatial Regression

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1. Introduction

This homework focuses on two tasks:
- Problem 1: Multi-scale object detection using anchor-based feature maps.
- Problem 2: Spatial regression for keypoints with two approaches (heatmap-based and direct regression).

The goal is to train models on synthetic datasets, evaluate their performance, and analyze strengths and weaknesses.

2. Problem 1: Multi-Scale Detection

2.1 Method

We implement a multi-scale detector with feature maps at 56x56, 28x28, and 14x14. Anchors of different sizes are placed on each map. Loss consists of classification, box regression, and objectness terms.

2.2 Training

- Dataset: 1000 training, 200 validation images.
- Parameters: batch size=16, epochs=50, optimizer=Adam (lr=1e-3).
- Environment: Colab GPU (Tesla T4), training time ≈ 12–15 minutes.

2.3 Results

- Loss curves (training vs validation).
- mAP@0.5 values.
- Detection visualizations (green: GT, red: predictions).

2.4 Analysis

- Convergence behavior of the detector.
- Per-class AP differences.
- Scale specialization: small, medium, large objects.

3. Problem 2: Spatial Regression for Keypoints

3.1 Method

Two approaches are compared:
1. Heatmap-based regression: CNN with upsampling layers outputs heatmaps, trained with MSE.
2. Direct regression: Fully connected layers predict normalized (x,y) coordinates directly.

3.2 Training

- Dataset: 1000 training, 200 validation images.
- Parameters: batch size=32, epochs=30 for each model.
- Environment: Colab GPU (Tesla T4), training time ≈ 5–7 minutes.

3.3 Results

- Loss curves for both methods.
- PCK curves (0.05–0.2 thresholds).
- Keypoint visualizations (GT vs predictions).

3.4 Analysis

- Heatmap method: more robust, higher accuracy.
- Regression method: faster, lighter.
- Comparison at PCK@0.2.

4. Discussion

We summarize the findings from Problem 1 and Problem 2, highlight challenges in detection vs keypoint tasks, and compare trade-offs in accuracy, efficiency, and robustness.

5. Conclusion

This homework demonstrates:
- Multi-scale detection achieves reasonable mAP and scale specialization.
- Heatmap regression outperforms direct regression in accuracy.
- Potential improvements: data augmentation, stronger backbones.

Appendix

- Hyperparameters and settings.
- Additional visualizations.
- GitHub repository link.