Technical Architecture Documentation

DS 340W Data Science Capstone - Week 2

System Design and Implementation Specifications

September 28, 2025

# Introduction

This document provides comprehensive technical specifications for implementing the multi-task disaster detection system based on Weber et al.'s methodology. The architecture leverages state-of-the-art computer vision techniques to achieve robust performance in real-world emergency response scenarios.

# 1. System Overview

The disaster detection system employs a multi-task convolutional neural network architecture with shared feature extraction and specialized classification heads. The design optimizes both accuracy and computational efficiency for deployment in resource-constrained environments.

# 2. Core Architecture Components

## 2.1 Input Processing Layer

Input images undergo standardized preprocessing before feature extraction:

* Resize to 224x224x3 resolution
* Normalization using ImageNet statistics
* Data augmentation during training phase

## 2.2 Feature Extraction Backbone

ResNet-50 architecture serves as the shared backbone network:

* Convolutional Block 1: 64 filters, 7x7 kernel
* Convolutional Block 2: 128 filters, progressive downsampling
* Convolutional Block 3: 256 filters, spatial attention
* Global Average Pooling: Dimensional reduction to 2048 features

## 2.3 Multi-Task Classification Heads

Specialized classifiers for different prediction tasks:

* Incident Classifier: 43 classes with softmax activation
* Place Classifier: 49 classes for location context
* Confidence Estimation: Uncertainty quantification layer

# 3. Proposed Novel Enhancements

## 3.1 Multi-Scale Attention Mechanism

Enhanced feature extraction through attention-weighted multi-scale processing:

* Scale 1: High-resolution detail preservation (28x28 feature maps)
* Scale 2: Mid-level pattern recognition (14x14 feature maps)
* Scale 3: Global context modeling (7x7 feature maps)
* Attention Fusion: Weighted combination of multi-scale features

## 3.2 Advanced Data Augmentation

Domain-specific augmentation strategies for disaster imagery:

* Weather simulation: Fog, rain, snow effects
* Lighting variations: Day/night cycle simulation
* Perspective distortion: Aerial vs ground-level viewpoints

# 4. Training Specifications

## 4.1 Hyperparameters

* Learning rate: 0.001 with cosine annealing schedule
* Batch size: 32 images per GPU
* Optimizer: Adam with weight decay 1e-4
* Training epochs: 100 with early stopping

## 4.2 Loss Function Design

Multi-component loss function for optimal training:

* Incident Classification Loss: Class-negative enhanced cross-entropy
* Place Classification Loss: Standard cross-entropy
* Regularization Terms: L2 weight penalty and dropout

# 5. Performance Evaluation Framework

* Mean Average Precision (mAP) for multi-class evaluation
* False Positive Rate analysis by disaster category
* Inference latency measurements for real-time deployment
* Memory usage profiling for resource optimization

# 6. Deployment Architecture

Production deployment requires careful consideration of scalability and reliability:

* Containerized inference servers using Docker
* Load balancing for high-throughput processing
* Model versioning and A/B testing capabilities
* Monitoring and alerting for system health