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Performance Evaluation of Lightweight Face Detection Models on Low-Resolution Images

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Extended Abstract

1. Objectives

This study evaluates the detection accuracy of lightweight face detection models on low-resolution images, focusing on their feasibility for edge devices with limited computational resources.

To understand the background of this research, it is essential to consider the growing demand for implementing machine learning functionalities, such as image recognition, on edge devices positioned at the network edge, like communication robots and surveillance cameras. Privacy is a critical concern for devices installed in domestic environments. For instance, when using the camera on a communication robot to estimate indoor conditions, low-resolution images, such as mosaics, are preferred for tasks like face detection that do not require identifying individuals. However, performing machine learning tasks such as object detection on images often relies on computationally intensive deep learning methods. Edge devices, with their limited computational resources, require simpler and more lightweight models.

This study evaluates the detection accuracy of lightweight face detection models for low-resolution images. Lightweight models are expected to have limitations in detection accuracy. However, this research compares the accuracy of these models to that of conventional advanced deep learning models run on cloud servers. Specifically, we investigate whether lightweight models can achieve detection accuracy comparable to conventional models.

2. Scope

This study highlights the potential of leveraging a simple 3-layer neural network (3-NN) and a relatively lightweight 4-layer convolutional neural network (4-CNN) as lightweight models. As a benchmark, we utilize Insightface[1], a face detection tool based on ResNet50[2], a 50-layer CNN. These models, trained on high-resolution images (256 × 256 pixels), are evaluated for their detection accuracy using low-resolution face images as test input.

As a foundational study, we focus on images where the face is roughly centered. Experimental data consists of 2,027 face images from the WIDER FACE dataset[3] and 2,003 non-face images from the Indoor Scene Recognition dataset[4]. These were divided into training (70%), validation (15%), and test (15%) datasets.

3. Results

The detection accuracies of the proposed lightweight models and the conventional model were compared across various low-resolution levels images. For the original resolution (256×256 pixels), detection accuracy followed the order: conventional model (99.83%), 4-CNN (97.34%), and 3-NN (90.70%). As resolution decreased, 4-CNN's accuracy dropped significantly, and at 32×32 pixels, the accuracies were 99.34%, 84.05%, and 91.86%, respectively. For extremely low resolutions below 15×15 pixels, the detection accuracy of the conventional model declined sharply, while the decline for 3-NN was more moderate. For instance, at 10×10 pixels, the detection accuracies were 62.13% for the conventional model, 83.72% for 4-CNN, and 93.19% for 3-NN. As demonstrated, lightweight models (4-CNN, 3-NN) outperformed the conventional model for low-resolution images. This indicates the feasibility of face detection using lightweight models with fewer parameters.

Additionally, when the detection task was extended to classify three classes—frontal face, profile face, and non-face images—a similar reversal in detection accuracy was observed. However, all models showed significantly reduced accuracy (41.98%, 61.62%, and 62.50%, respectively). More sophisticated approaches are required for advanced tasks.

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