Literature Survey on Aircraft Classification

1. Introduction

Just as with the revolutionary effect of computer vision in the automotive industry, its application in the aerospace industry is a huge research field with great potential for companies like Collins Aerospace. Aircraft identification and classification are crucial to maintaining security, directing traffic control, and enabling maintenance automation. This research explores traditional machine vision approaches as well as deep learning methods, investigates hierarchical classification, and identifies current research gaps in the field.

2. Datasets for Aircraft Identification

Public datasets play a crucial role in training deep learning models:

- **FGVC-Aircraft** – Contains around 10,000 aircraft images across more than 100 variants.

3. Current Research on Aircraft Classification

3.1 Traditional Image Processing Approaches

Previous work focused on basic machine vision algorithms:

- (Triggs, 2005) proposed Histogram of Oriented Gradients (HOG) object detection that was a very popular method for image classification.
- (Lowe, 2004) introduced Scale-Invariant Feature Transform (SIFT) for object recognition, which demonstrated resilience to scale and rotation change.

3.2 Deep Learning Approaches

Ever since deep learning has come into existence, researchers have incorporated Convolutional Neural Networks (CNNs) for classifying aircrafts:

- (Krizhevsky, 2012) solves Computer Vision problems with Deep Learning using Alexnet seems to provide a good guideline to solve my projects problem statement. The paper discusses computer vision architecture along with recommended techniques and model tuning. In the meeting with Niall from Collins Aerospace and Mark they mentioned the importance of Qualitative Performance. This paper discusses a similar concept called Qualitative Evaluation

- (Kaiming, 2015) proposes ResNet would help increase classification performance through residual learning.
- (Kuo, 2021) This research presents a novel approach to aircraft classification based on still images rather than radar or radio frequency information. The approach entails image conversion to binary and classification using artificial neural networks.
- (Zhang, 2023) This study explores and addresses the issues of efficiency and precision in deep learning models used for the identification and classification of aircraft types, highlighting the ability of deep learning to handle large-scale classification tasks.
- (Starsman, 2023) Failure modes, such as misclassification due to low-quality images, occlusions, and similarities between aircraft, are discussed in the paper and suggest potential improvements with additional training data and model modifications.

3.3 Hierarchical Classification for Aircraft Classification

Hierarchical classification is useful for **multi-level recognition**:

- (Valmadre, 2022) considered hierarchical classification with **multiple operating points**. Instead of the model being uncertain of an annotation or class of an image, this paper discusses techniques to predict the parent class.
- (Babbar, 2013) This study contrasts flat and hierarchical classification methods in large taxonomies and provides an understanding of their relative performance. This paper is not very relevant to aircraft classification, understanding how flat classification is different from its hierarchical counterpart will act as a strong foundation.

4. Challenges and Research Gaps

- Class imbalance – Some aircraft types have limited training data.
- Environmental changes – Weather and lighting affect classification accuracy.
- Failure Modes – False positives and false negatives continue to be a problem. Strategies for handling uncertain classifications, such as rejection options or confidence thresholding, need further investigation.
- Comparative Model Analysis (HCL Tech.) – Different models, from early ML based models to modern deep networks, need to be compared against a uniform evaluation criterion.

5. Synopsis

Paper	**Method Used**	**Dataset**	**Key Findings**
Aircraft Classification Based on PCA and Feature Fusion Techniques in Convolutional Neural Network	HOG + SVM	MTARSI	Achieved high accuracy on simple backgrounds but struggled with complex scenes.

Intelligent Known and Novel Aircraft Recognition - A Shift from Classification to Similarity Learning for Combat Identification	Similarity Learning to address data scarcity; very architecture oriented	MTARSI	F1-score of 0.861 for aircraft type classification; F1-score of 0.936 for novel type identification.
Aircraft Classification Using Image Processing Techniques and Artificial Neural Networks	Feature-based image processing + Artificial Neural Networks (ANNs)	Unknown	Utilizes hand-crafted features and ANN for classification; demonstrates the feasibility of aircraft recognition using image processing instead of radar.
Prediction of Aircraft Using Deep Learning Techniques	Deep learning-based image classification	Unknown	Uses CNN-based deep learning models for aircraft recognition, emphasizing the role of data preprocessing and segmentation for better accuracy.

6. Conclusion & Future Directions

While recent research has been successful in improving aircraft classification using computer vision and deep learning, handling misclassified aircrafts, data expansion, real time processing and failure modes, are still open problems. Future work involves using generative AI techniques to increase synthetic training data especially for rare aircraft types thereby improving accuracy of predictions. Using best techniques and practices from the listed papers above could yield phenomenal results.

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