A TEMPLATE FOR THE *arxiv* STYLE

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ABSTRACT

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Keywords First keyword · Second keyword · More

1 Introduction

Fine-grained vehicle classification, which differentiates between various types, makes, and models of cars, presents significant challenges. This difficulty arises from the large number of visually similar vehicle categories, variations in lighting and weather conditions, occlusions, and the diverse viewpoints from which vehicles may be captured. As a result, building a robust vehicle classification system requires a model capable of recognizing subtle visual cues while generalizing across highly variable real-world conditions.

In this project, we aim to explore and compare different strategies for hierarchical image classification on the Stanford Cars Dataset (Krause et al., 2013). The dataset contains 16,185 high-resolution images labeled with three hierarchical attributes: vehicle make, vehicle type, and vehicle model. These labels naturally form a multi-level taxonomy, making the dataset well-suited for studying hierarchical classification approaches.

Our baseline approach uses a ResNet-50 model pretrained on ImageNet as the backbone architecture. Initially, we treat the problem as a flat classification task by predicting the complete car label (containing make, type, and model) as a single class among 196 possible categories. This serves as our starting point for evaluating how well a standard single-head classifier performs on fine-grained classification without explicit hierarchical structure.

Building on this baseline, the primary objective of this project is to investigate how different hierarchical output designs influence classification performance. Specifically, we focus on three classification strategies:

1. **Single-head (flat) classifier:** Predicts the entire label (make, type, and model) as one combined class. This ignores the hierarchical relationships.

2. **Two-head classifier:** One head predicts the vehicle make, while the second head predicts the combined type+model label.

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[*]Use footnote for providing further information about author (webpage, alternative address)—*not* for acknowledging funding agencies.

3. **Three-head classifier:** Predicts make, type, and model independently using three parallel classification heads.

After we evaluated these 3 variants, we will further enhance their performance using targeted regularization and optimization strategies. These include data augmentation, dropout, weight decay, and learning-rate adjustments, all of which can help reduce overfitting.

2 Headings: first level

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2.1 Headings: second level

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$$\xi_{ij}(t) = P(x_t = i, x_{t+1} = j | y, v, w; \theta) = \frac{\alpha_i(t) a_{ij}^{w_t} \beta_j(t+1) b_j^{v_{t+1}}(y_{t+1})}{\sum_{i=1}^{N} \sum_{j=1}^{N} \alpha_i(t) a_{ij}^{w_t} \beta_j(t+1) b_j^{v_{t+1}}(y_{t+1})} \tag{1}$$

2.1.1 Headings: third level

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3 Examples of citations, figures, tables, references

3.1 Citations

Citations use `natbib`. The documentation may be found at

> http://mirrors.ctan.org/macros/latex/contrib/natbib/natnotes.pdf

Here is an example usage of the two main commands (`citet` and `citep`): Some people thought a thing (**??**) but other people thought something else (**?**). Many people have speculated that if we knew exactly why **?** thought this...

3.2 Figures

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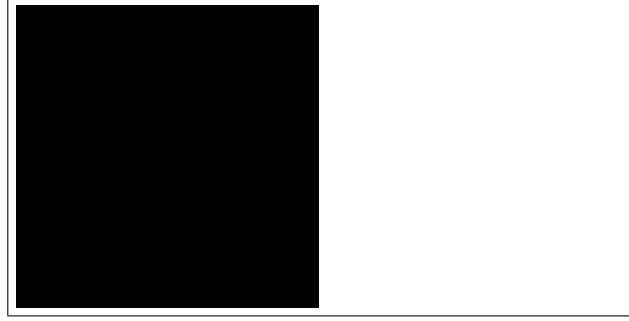
Figure 1: Sample figure caption.

Table 1: Sample table title

	Part	
Name	Description	Size (μm)
Dendrite	Input terminal	$\sim$100
Axon	Output terminal	$\sim$10
Soma	Cell body	up to 10^6

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3.3 Tables

See awesome Table **??**.

The documentation for `booktabs` ('Publication quality tables in LaTeX') is available from:

<div align="center">

`https://www.ctan.org/pkg/booktabs`

</div>

3.4 Lists

- Lorem ipsum dolor sit amet
- consectetur adipiscing elit.
- Aliquam dignissim blandit est, in dictum tortor gravida eget. In ac rutrum magna.

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[2]Sample of the first footnote.