**Paper Template for COMP30027 Report**

**Anonymous**

1. **Introduction**

This is a report template, suitable for MS-Word, OpenOffice, and some other word-processing packages. Don’t use fonts smaller than this one (Times 11). Don’t include a title page, table of contents, abstract, or other similar front matter.

**Please don’t include your name and/or student ID in the title or header; your report should be anonymised for the reviewing process.**

1. **Section**

Your text should be aligned left, justified and styled in two columns format.

You can cite related papers or books like this (Bishop & Nasrabadi, 2006). You may use any formal citation styles if you prefer.

**2.1 Subsection**

Use **bold** for **emphasis**, but use sparingly.

Short quotations *“are included in the main text, in normal paragraph style, between double quotes and italicized.”* All quotes should be properly referenced.

**2.1.1 Subsubsection**

Figures should be placed in the text, not at the end. Figures must be captioned and explicitly mentioned in the text (Figure 1).

**Figure 1-** Figure captions should appear below the image (Times New Roman 9, Aligned Left, Single Line, 0 pt before, 12pt after, no indentation).

1. **Section**

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Tables also need to be captioned and explicitly mentioned in the text (see Table 1). If you don’t want the text in your tables to be counted in your word count, you can add your tables as pictures.

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| CCC | text |

**Table 1-** Table captions should appear below the image (Times New Roman 9, Aligned Left, Single Line, 0 pt before, 12pt after).

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1. **Section**

Please proofread your report (more than once) before submission. Many grammar and spelling error would impact the quality of your report (and your mark for this criteria).

1. **Conclusions**

Concluding text.

1. **References**

Christopher M Bishop and Nasser M Nasrabadi. 2006. *Pattern recognition and machine learning*, volume 4. Springer.

1. **Introduction**

Classifying traffic signs, automatically identifying traffic signs from images, is a task that’s growing rapidly in its usage in driver-assist and autonomous vehicle systems. In this project, I was tasked with tackling the German Traffic Sign Recognition Benchmark (GTSRB), a dataset that’s publicly available and has 43 variations of German traffic signs. My goal was to explore a variety of models, from classical machine learning on hand-crafted features, to convolutional neural networks (CNNs) and multi-input deep models, and then combine them through a stacking meta-learner to maximize sign classification accuracy.

This report is structured as follows. Section 2 (“Methodology”) describes the data, engineered features, and models I built conceptually. Section 3 (“Results”) summarizes the performance of each approach with tables and figures. Section 4 (“Discussion and Critical Analysis”) delves into why certain models succeeded or struggled, linking it with theory on feature representation, bias-variance, and ensemble learning. Finally, Section 5 (“Conclusion”) details my key findings and outlines future paths forward.

1. **Methodology**

My pipeline for this project evolved in multiple phases:

**2.1 Data & Feature Engineering**

* **Raw Images:** all images used were resized to 64 x 64 pixels.
* **Provided Features:** I merged the dataset’s CSV’s for colour histograms (24-dim), HOG-PCA (20 principal components), edge density, and mean RGB values, yielding 120 numeric features.
* **Additional Features:** I later extracted Local Binary Pattern (LBP) histograms at multiple scales (1, 2, 3) and methods (uniform & rotation-invariant), as well as per-channel LBP in the RGB space, and concatenated these with the original features for the enriched “hand-crafted” feature set.

**2.2 Baseline Models on Given Features**

* **k-Nearest Neighbours** (k = 5)
* **Random Forest** (100 trees, balanced class weights)

Each of these was wrapped in a StandardScaler -> Classifier pipeline and evaluated via stratified 5-fold CV on accuracy, precision macro, and recall macro, where the Random Forest classifier outperformed on all three metrics.

**2.3 Hyperparameter Tuning**

* A RandomizedSearchCV was run on the Random Forest classifier to search on hyperparameters, exploring number of trees, tree depth, maximum features, and leaf parameters. This totalled 250 fits.
* Using the best parameters provided by this search, I was able to boost the Random Forest accuracy from ~79.2% to ~81.2%.

**2.4 Deep Learning on Raw Images**

* **CNN From-scratch Trained on Images:** a small 3-conv-layer network (filters 32-128), trained with sparse categorical crossentropy and on-the-fly augmentations. This achieved a ~91.8% accuracy on a local 80/20 train/validation split. Further experimenting with different activation methods and layers led to a local validation set accuracy of ~97.7%.
* **MLP Model Trained on Features**: This was a three-layer MLP model trained exclusively on all the features provided in the dataset CSVs. This yielded a ~79.9% accuracy on a local validation split.

**2.5 LBP + Gradient Boosting**

* Extracted multi-scale and colour-aware LBP features.
* Trained a HistGradientBoostingClassifier on these. Using a RandomizedSearchCV on this to tune hyperparameters totalled 150 fits and gave the best parameters, which when used, led to an accuracy score of ~44.8% on a local validation split of the training dataset.
  1. **Stacking Meta Learner**

1. **Section**

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