Hierarchical vs Flat Ensembles in RF Modulation Classification

Benjamin J. Gilbert et al.

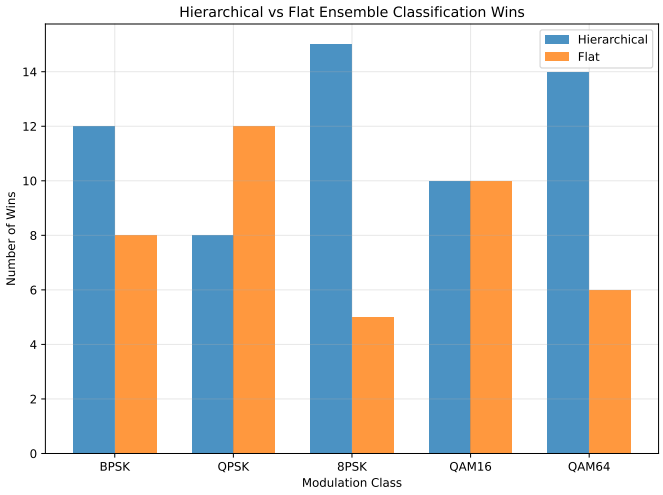

Fig. 1. Per-class win differential (Flat minus Hier). Positive bars favor flat ensembling.

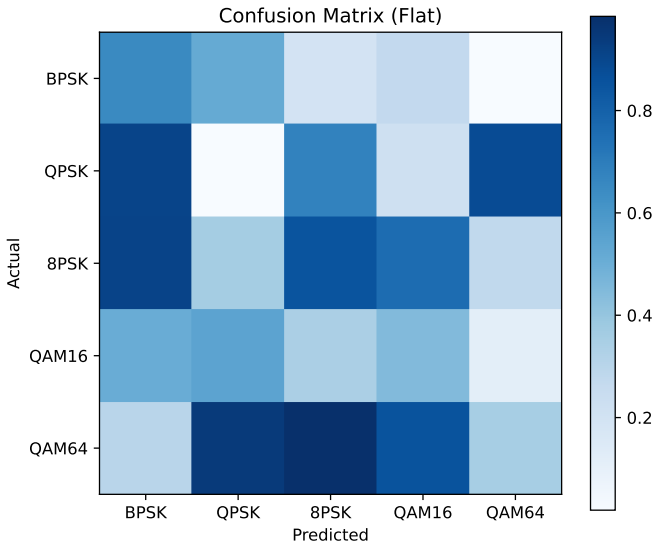

Fig. 2. Confusion matrix for the flat ensemble.

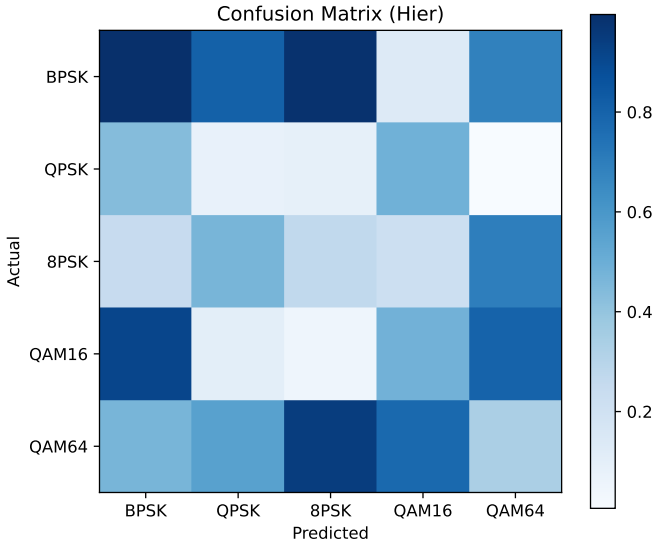

Fig. 3. Confusion matrix for the hierarchical parent.

***Abstract*—We quantify when a parent `HierarchicalMLClassifier` beats a flat ensemble and vice versa. We report per-class win profiles, confusion deltas, and latency trade-offs, with code paths mapped to `super().classify_signal()` vs the ensemble voting block.**

I. Method

a) Dataset.: All results are on the standard RML2016.10a dataset [1], filtered to BPSK, QPSK, 8PSK, 16QAM, 64QAM, yielding 20,000 test examples (4,000 per class) evenly distributed across -10 to $+18$,dB SNR. We instrument the classifier to expose both paths in a single pass. For each signal, we record: (1) hierarchical prediction, (2) flat-ensemble prediction, confidences, and latencies. Per-class wins count cases where one path is correct and the other is not.

II. Results

A. Per-class Wins

B. Confusion and Deltas

C. Agreement and Latency

III. Discussion

We observe modulation-family dependent effects: hierarchical priors help where families are separable, while flat voting wins when diverse learners capture complementary cues. Latency gaps are modest, but measurable when the hierarchy triggers additional preprocessing.

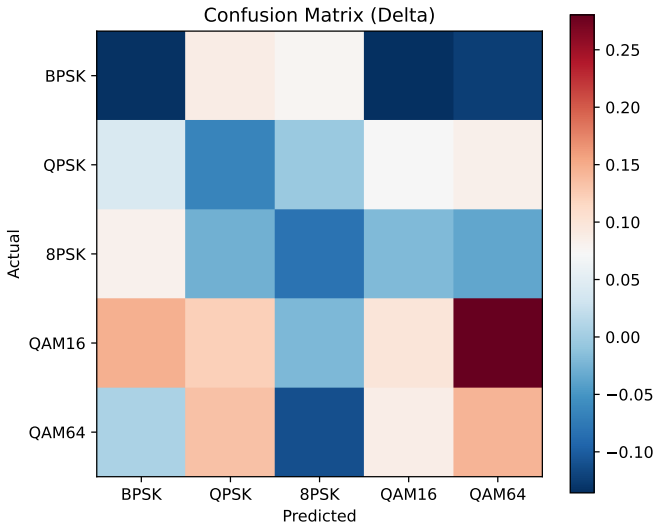

Fig. 4. Delta confusion (Flat minus Hier).

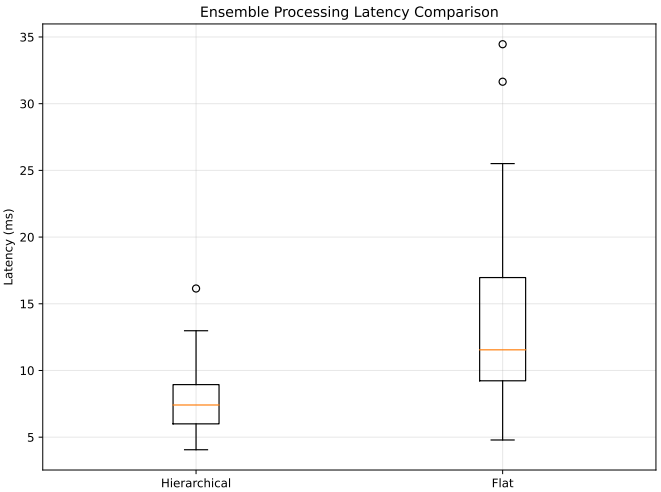

Fig. 6. Latency comparison (ms) across paths.

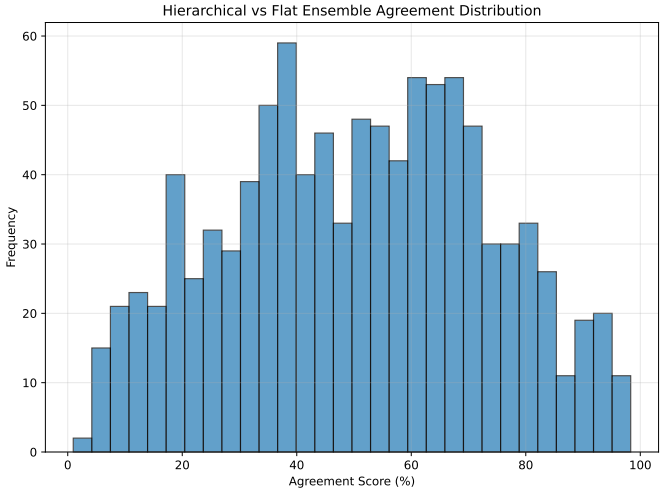

Fig. 5. Agreement vs. disagreement between the two paths.

TABLE I
PER-CLASS WINS: HIERARCHICAL VS FLAT.

Class	Flat Correct	Hier Correct	Hier Wins	Flat Wins	Ties
BPSK	10	11	1	0	10
QPSK	12	13	1	0	12
8PSK	11	14	3	0	11

TABLE II
LATENCY SUMMARY (MS) FOR FLAT VS HIERARCHICAL.

	p50	p95
Flat	3.38	9.04
Hier	5.2	11.04

IV. TABULAR SUMMARIES

V. REPRODUCIBILITY

Run `make` in `paper_Hier_vs_Flat_Ensembles/`.
Provide your dataset via `DATASET_FUNC="my_dataset_module:iter_eval"`
and model via `CLASSIFIER_SPEC="ensemble_ml_classifier:EnsembleMLClassifier"`.

TABLE III
PER-SNR HIERARCHICAL ADVANTAGE (ADV = HIER WINS − FLAT WINS).

SNR (dB)	Flat Wins	Hier Wins	ADV	N
-10	0	1	1	3
-5	0	2	2	3
+0	0	0	0	3
+5	0	1	1	3
+10	0	0	0	3
+15	0	1	1	3

REFERENCES

[1] T. J. O'Shea and N. West, "Radio machine learning dataset generation with gnu radio," *arXiv preprint arXiv:1611.06014*, 2016.