

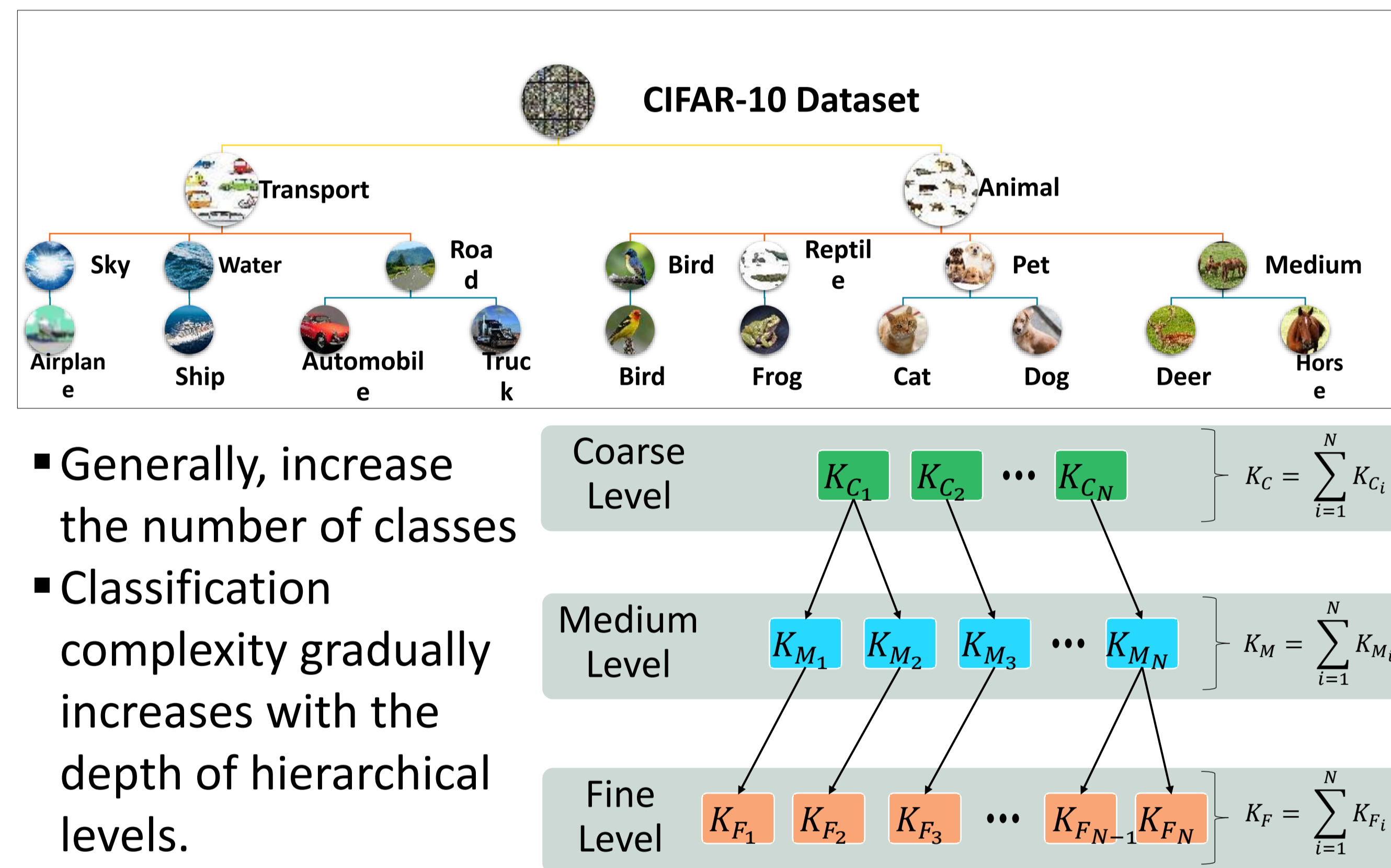


A Bottom-Up Capsule Network for Hierarchical Image Classification

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Hierarchical multi-label classification (HMC)

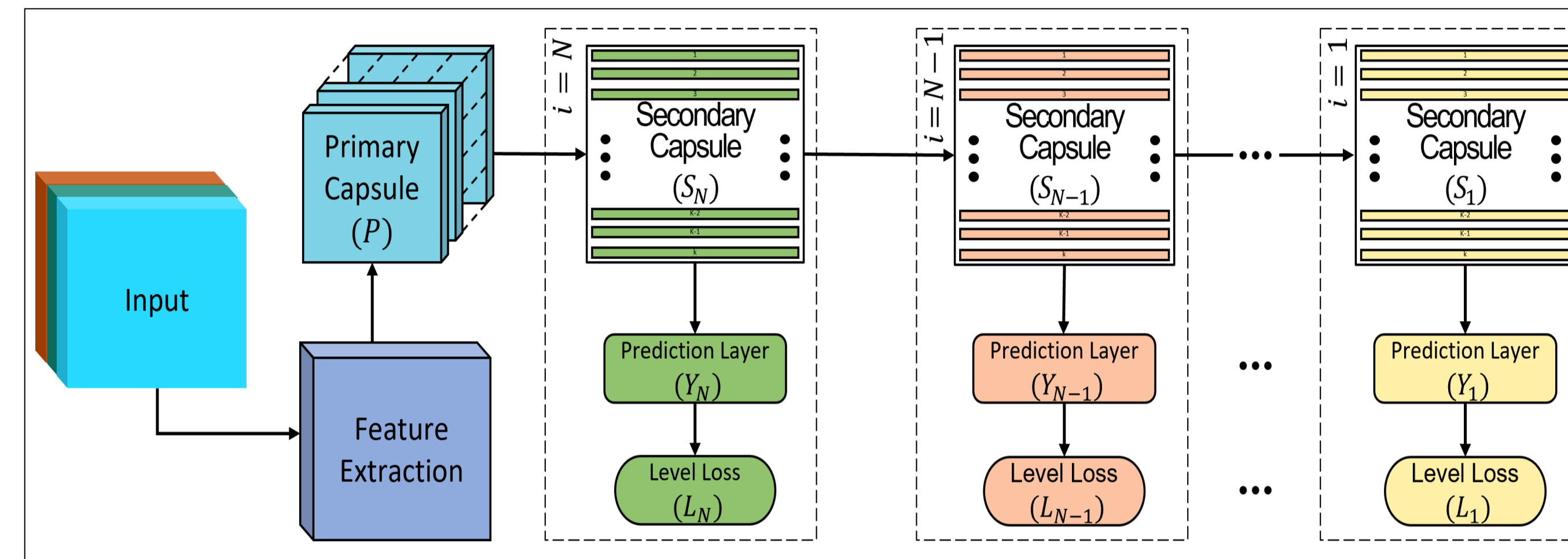
- Each instance may belong to multiple classes and these classes are organized in a hierarchical structure.
- In HMC, the model must not only predict the labels correctly but also respect the hierarchical relationship between the levels.
- One of the main challenges in HMC is ensuring hierarchical consistency.



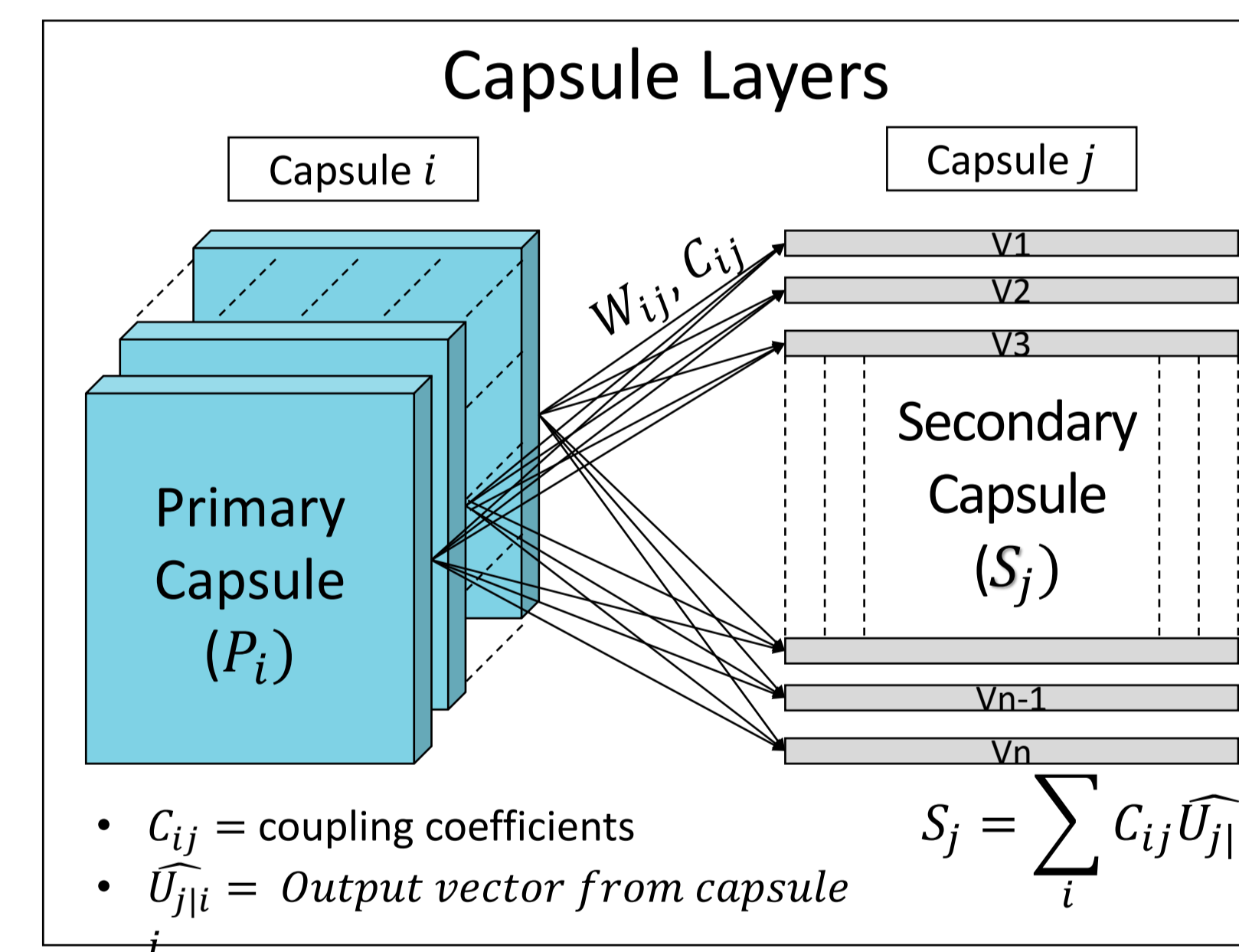
Flat, Top-Down and Bottom-Up Hierarchical Classification Approach

Feature	Bottom-Up	Top-Down	Flat
Granularity	Focuses on fine-grained, detailed classes first	Focuses on broad categories first	Treats all classes with equally
Error Propagation	Lower levels to upwards	Higher levels to downwards	Do not propagate
Hierarchical Consistency	Inherently maintained	More challenging	Not applicable
Model Complexity	Can be complex	Less complex	Varies, but often simpler

Neural Architecture of the BUH-CapsNet Model



- Designed to inherit the hierarchical structure of the dataset
- It takes the parent-child relationships between classes into account using the capsule network.
- Utilise the dedicated feature extraction block to form the primary capsule layer.
- Capsules are fully connected between each two layers
- Used iterative routing algorithm to update agreements.
- Employs the bottom-up strategy to update the agreement between the capsules.



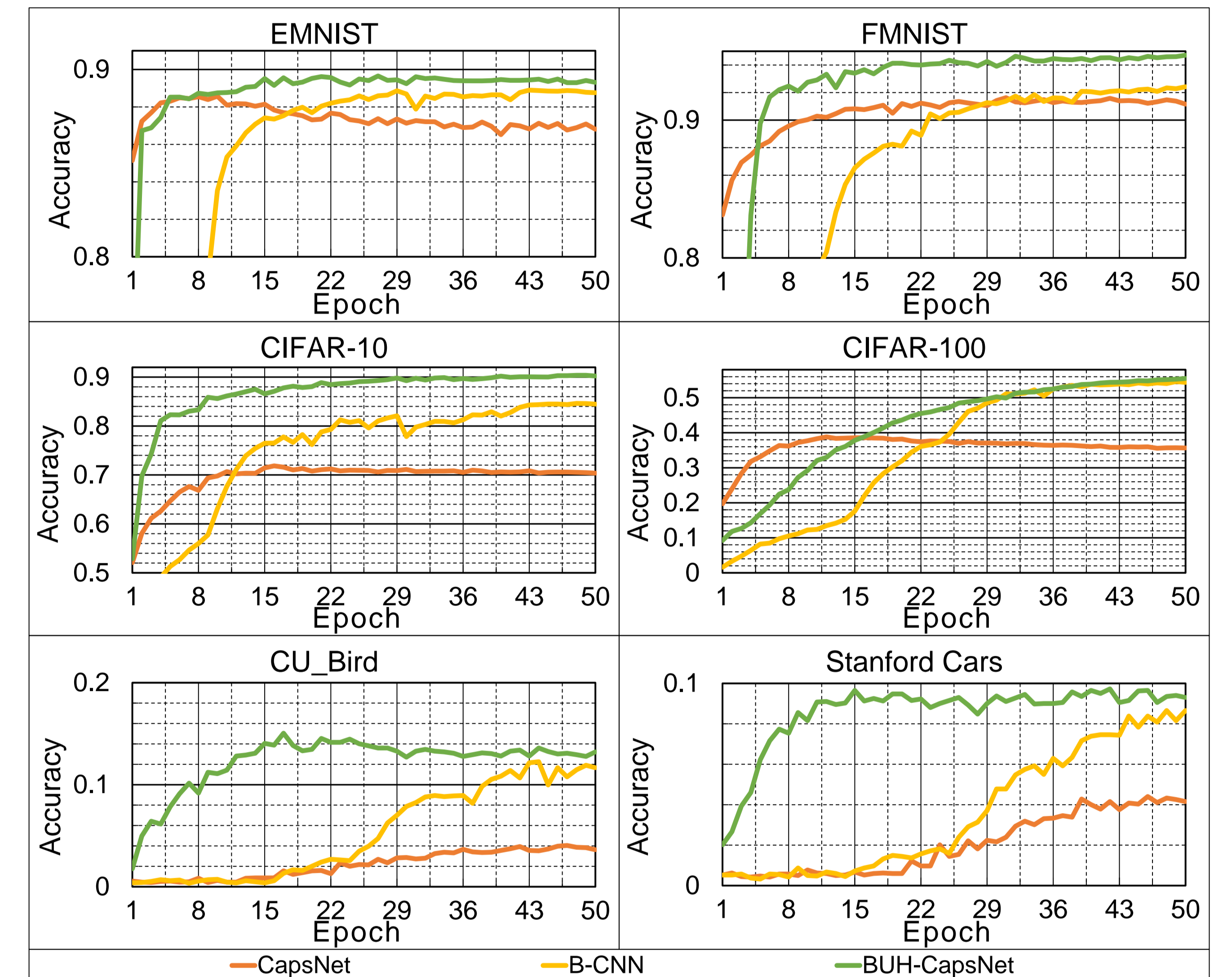
Experimental Setup Details

- Depending on the data complexity adjust the Feature Extraction and Capsule Layers

Dataset	Hierarchical Levels	Number of samples		Trainable Parameters (in Millions)		
		Training	Testing	CapsNet	B-CNN	BUH-CapsNet
EMNIST	2	112,800	18,800	13.97	1.87	5.10
FMNIST	3	60,000	10,000	8.22	9.41	4.79
CIFAR-10	3	50,000	10,000	17.39	12.38	5.04
CIFAR-100	3	50,000	10,000	44.66	12.48	8.52
CU_Bird	3	5,944	2,897	105.72	31.52	38.43
Stanford Cars	3	8,144	4,021	104.08	31.50	36.43

Accuracy plots and hierarchical performance metrics

- Accuracy of the fine level on the test datasets



- Overall performance of the BUH-CapsNet and the alternatives

