Task-Related Feature Enhancement Network for Neuronal Morphology Classification

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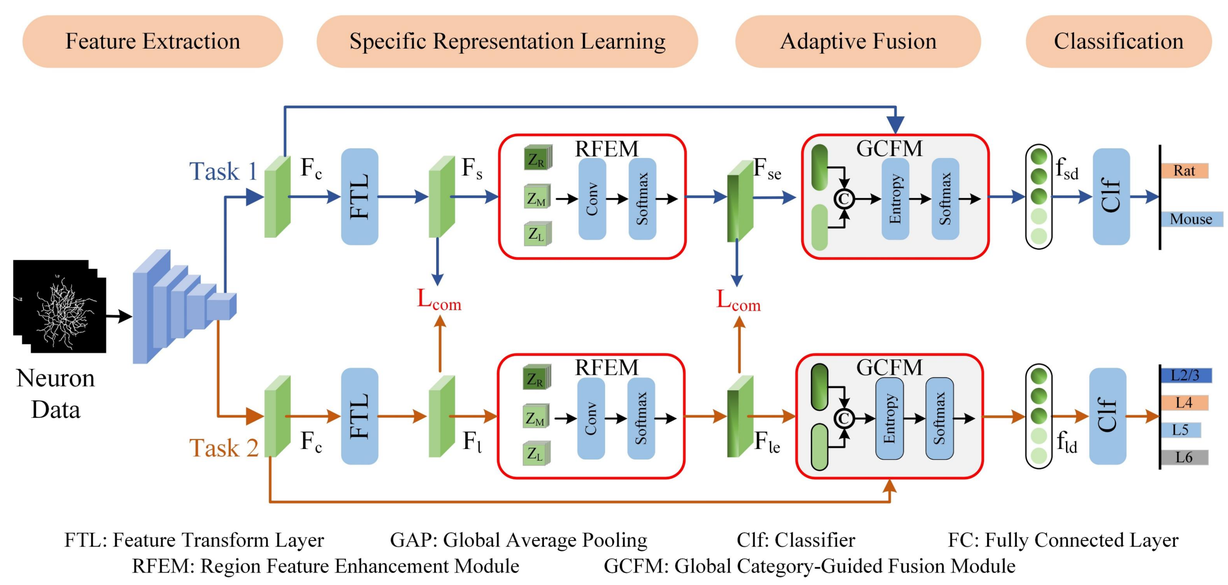
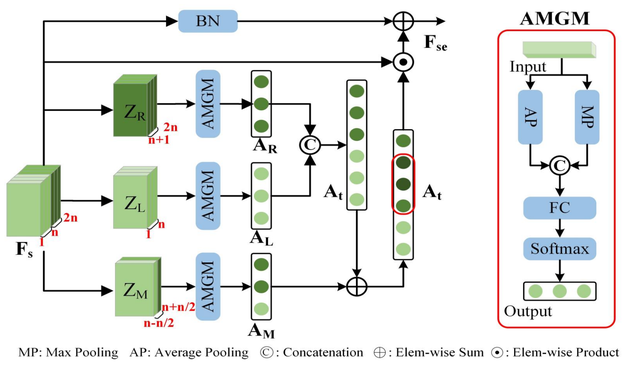
Introduction

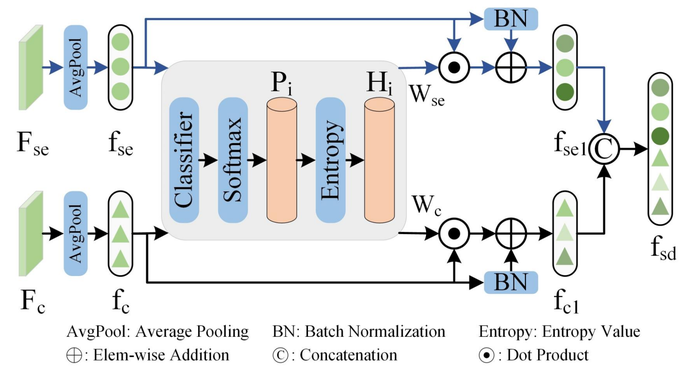
- Analyzing the morphology of pyramidal cells (PCs) is essential to understanding brain activity and disease mechanisms.
- Existing methods describe the morphology of PCs in a task-agnostic manner, leading to insufficient representations for various analysis tasks.
- We presents a Task-related Feature Enhancement Network (TFENet) extracts morphological features in a task-related manner and performs the analysis on the species and brain region to which the neuron belongs simultaneously.
- Our TFENet refines the task-specific features using a Region Feature Enhancement Module (RFEM) based on the morphology-aware regions.
- Our TFENet utilizes a Global Category-guided Fusion Module (GCFM) adaptively combines the task-specific and task-common features, yielding a distinctive morphology descriptor.

Methods



- The proposed Task-related Feature Enhancement Network (TFENet) first extracts task-common features via a shared backbone across tasks and then generates task-specific features for each task individually.





- We introduce a Region Feature Enhancement Module (RFEM) to mine the salient features from the key morphology-aware regions to capture the distinctive task-specific features.
- We introduce the Global Category-guided Fusion Module (GCFM) to determine the importance of the task-common and task-specific features for the final decision and adaptively fuse them to generate a distinguishing morphology descriptor.

Data

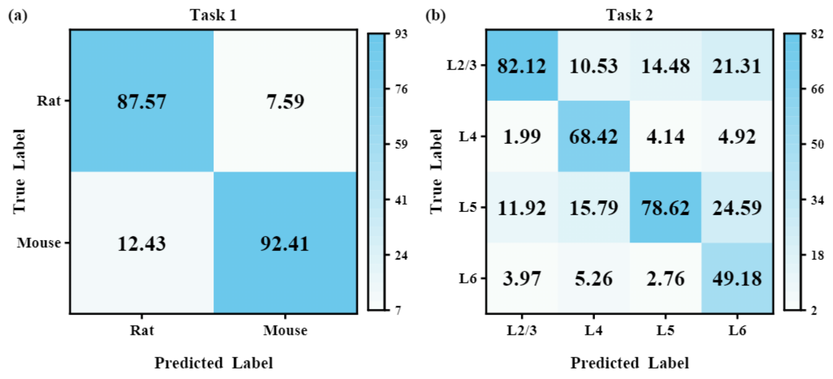
- The species analysis of PCs (denoted as Task 1).
  (1) Number of classes: 2
  (2) There are 2,630 rat pyramidal cells and 3,321 mouse pyramidal cells.
- The brain region analysis of PCs (denoted as Task 2).
  (1) Number of classes: 4
  (2) There are 2,350, 723, 2261, and 617 pyramidal cells in Layer 2/3, Layer 4, Layer 5, and Layer 6, respectively.

Results

- Our method outperforms other methods. The performance of each task is significantly improved.

Method	Feature	Task 1			Task 2		
		F_1	OA	AA	F_1	OA	AA
LCCDNN [16]	Task-agnostic	86.14 ± 0.68	86.57 ± 0.44	84.27 ± 1.70	67.62 ± 1.43	67.06 ± 0.79	62.60 ± 2.69
DRNN [17]	Task-agnostic	71.94 ± 5.07	74.12 ± 3.27	69.78 ± 4.74	63.05 ± 7.32	63.33 ± 9.72	58.12 ± 1.59
TreeMoCo [4]	Task-agnostic	85.28 ± 3.10	85.58 ± 2.90	82.27 ± 4.17	70.56 ± 2.49	71.88 ± 2.22	61.72 ± 2.88
Baseline	Task-agnostic	85.24 ± 0.46	85.22 ± 0.48	85.13 ± 0.29	67.85 ± 0.43	68.60 ± 0.12	58.78 ± 0.79
Sun *et al.* [25]	Task-related	87.48 ± 0.49	87.44 ± 0.48	87.60 ± 0.52	72.28 ± 0.59	72.46 ± 0.60	**69.81 ± 0.23**
TFENet (Ours)	Task-related	**90.32 ± 0.79**	**90.34 ± 0.81**	**89.99 ± 0.72**	**73.69 ± 0.52**	**74.15 ± 0.57**	69.59 ± 0.69

- Our method achieves superior results for each type of two tasks.



- RFEM and GCFM both improve the performance of our method.

RFEM	GCFM	Task 1		Task 2	
		F_1	OA	F_1	OA
✘	✘	86.52	86.47	69.41	69.32
✔	✘	88.64	88.65	72.17	72.46
✘	✔	88.43	88.41	70.97	71.38
✔	✔	90.32	90.34	73.69	74.15

Conclusions

- Our TFENet effectively describes the subtle morphological differences of pyramidal cells in a task-related manner.
- Our TFENet captures the salient task-specific features via mining and enhancing the key morphology region features through the RFEM and generates distinguishing morphological descriptors by adaptively fusing the task-specific and task-common features based on the guidance of global features through GCFM.
- Our TFENet achieves accuracies of 90.34% and 74.15% on the species and brain region analysis tasks, respectively.