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Online transfer learning with an MLP-assisted graph convolutional network for traffic flow prediction: a solution for edge intelligent devices

Key words: Online transfer learning; Traffic prediction; Intelligent edge devices

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Motivation

1. IoT devices have evolved from simple sensors to intelligent edge systems with integrated sensing, computing, and connectivity. These devices enable real-time monitoring and feedback but face resource limitations, especially in computation. They must balance processing with data transmission, while challenges like traffic flow collection in extreme weather remain.

2. Prediction accuracy is central to traffic flow research. Early models used micro- and macro-simulation, while data-driven and real-time methods grew in the 2010s. Today, deep learning dominates, excelling in spatiotemporal modeling. However, improved accuracy often brings higher algorithmic complexity and longer prediction time.

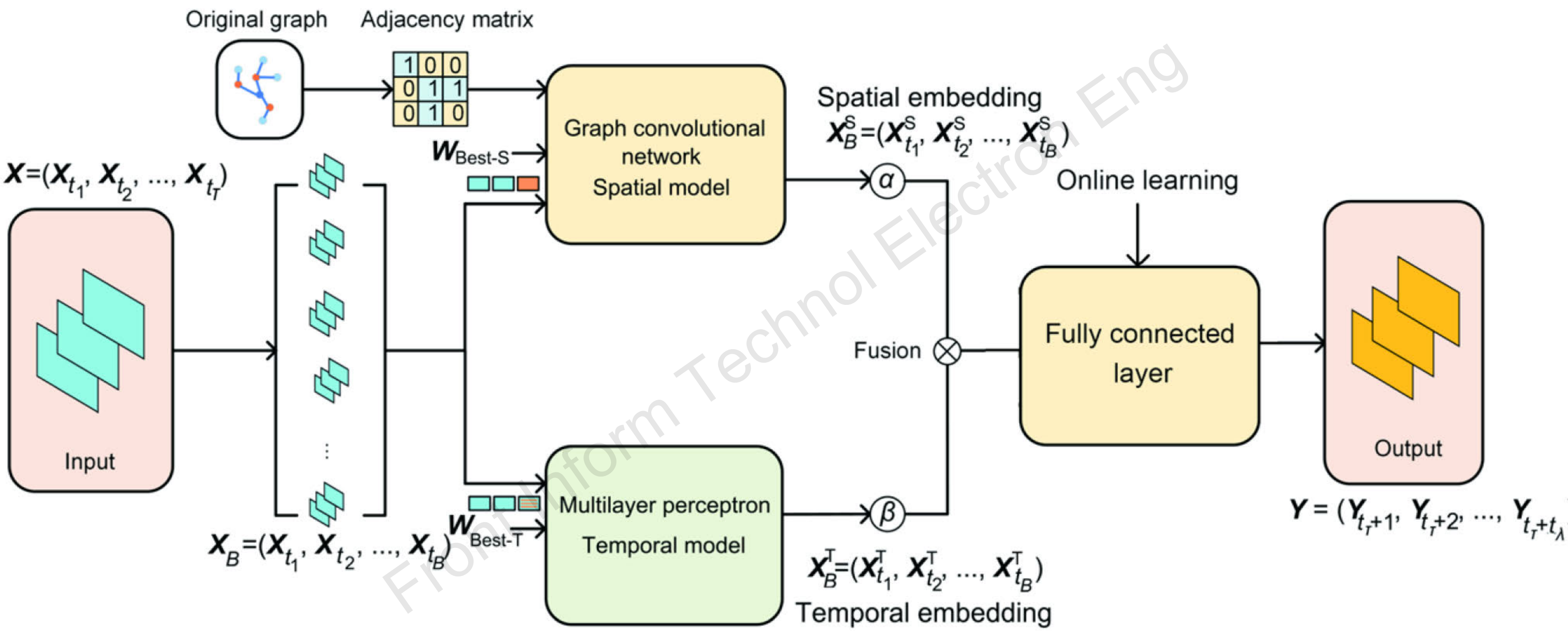
Main idea

1. We design a lightweight GM by combining multilayer perceptron (MLP) for temporal features with graph convolutional network (GCN) for spatial features, enabling efficient spatiotemporal modeling on edge devices.

2. We integrate GM with an online transfer learning (OTL) framework to ease resource use while keeping accuracy through compact models with small distances.

3. We validate OTL on PeMS04 with faster convergence, marking the first use of OTL in traffic prediction.

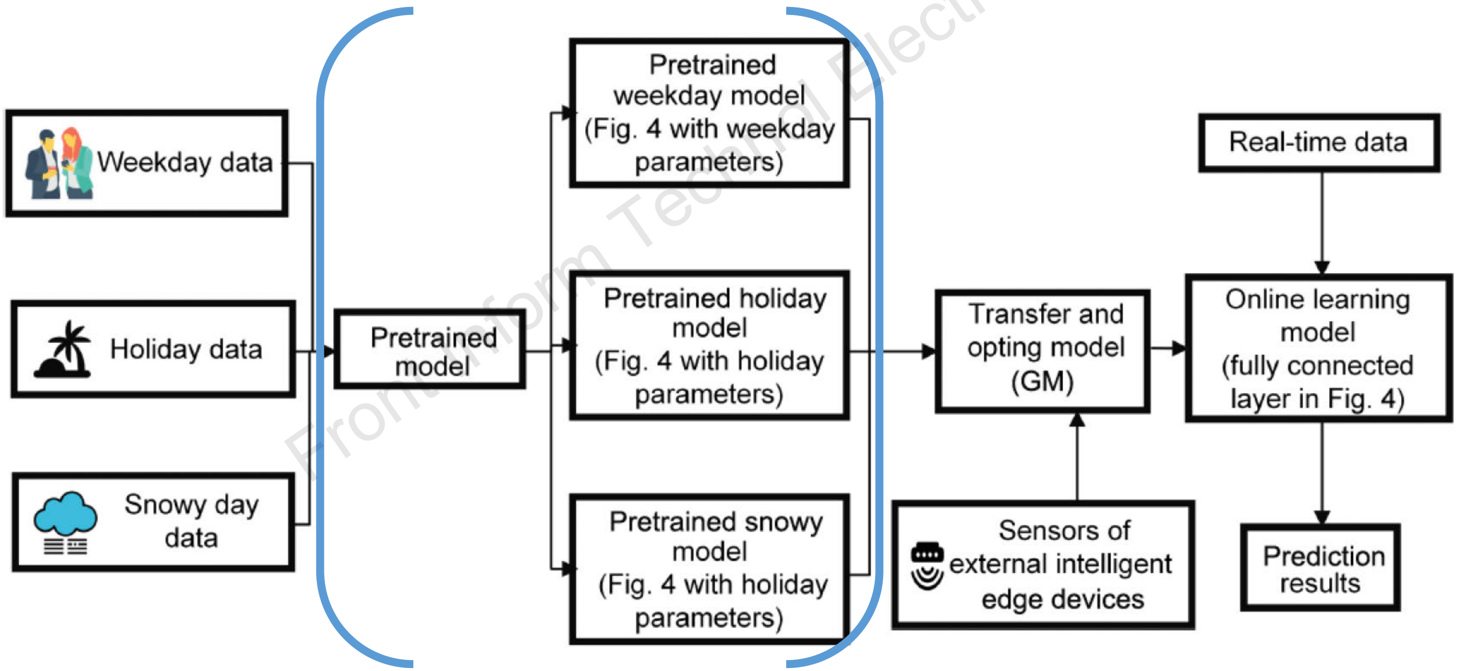
Framework



Overview of the MLP-assisted graph convolutional network (GM)

Method

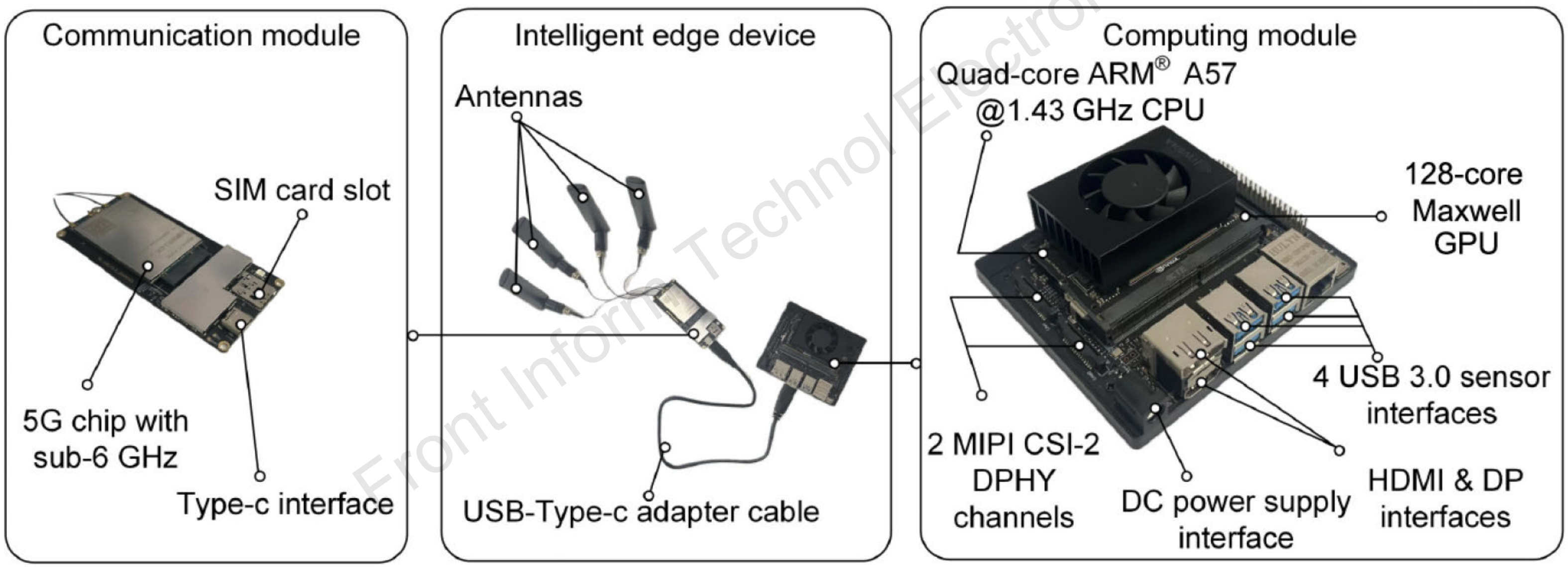
1. We train the model with classified datasets to evaluate convergence time and performance using MAE, MAPE, and RMSE.



OTL framework and data flow

Method

2. The edge device computes Euclidean distances with real-time data and selects the closest pretrained model.



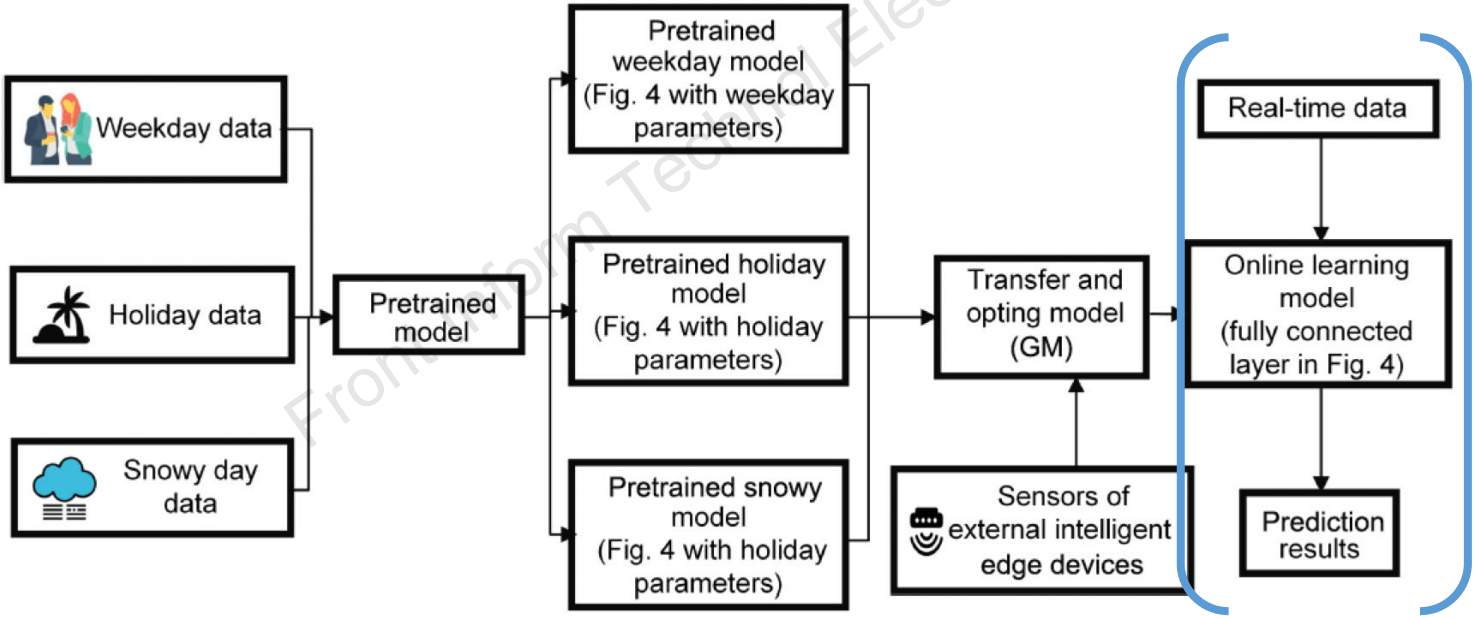
Edge device

$$d(x, y) = \sqrt{\sum_{i=1}^{n} (x_i - y_i)^2}$$

Euclidean distances

Method

3. After loading the transferred model, we freeze feature layers and perform online learning on the fully connected layer, adjusting its learning rate until convergence.



Major results

Table 7 Metrics of all methods on PeMS04 (weekday), PeMS04 (holiday), and PeMS04 (weather)

Method	PeMS04 (weekday)				PeMS04 (holiday)				PeMS04 (weather)			
	MAE	MAPE (%)	RMSE	Time (s)	MAE	MAPE (%)	RMSE	Time (s)	MAE	MAPE (%)	RMSE	Time (s)
HA	48.42	38.55	65.43	90.35	33.57	27.99	53.11	48.85	40.52	48.23	60.23	26.16
GCN	46.92	36.75	62.69	96.90	29.63	32.40	42.29	32.33	35.09	27.73	49.77	19.17
VAR	25.62	21.58	38.02	89.26	20.46	17.25	31.18	48.37	26.32	27.47	39.22	20.63
MLP	24.77	18.36	36.28	69.38	25.52	18.60	38.29	21.48	29.62	36.57	39.03	12.14
DCRNN	23.56	16.28	35.62	68.58	23.43	17.43	37.24	42.24	28.42	32.46	36.12	18.33
STGCN	22.64	15.08	36.64	70.58	24.38	16.42	38.25	40.25	27.56	31.45	36.14	19.58
AGCRN	21.88	13.43	35.21	72.33	22.34	15.52	34.26	50.25	26.28	29.43	32.48	20.69
Cy2Mixer	21.74	13.08	33.44	123.56	21.85	15.18	33.18	80.33	25.98	30.14	38.23	25.48
STAEformer	21.78	12.96	34.02	111.35	21.98	15.27	34.01	76.48	26.03	29.00	38.88	23.19
GM	22.27	15.69	33.28	75.91	23.27	18.97	33.07	39.25	34.60	35.93	49.74	19.37
OTL-HA	34.52	34.23	47.44	14.02	32.54	27.93	50.85	5.56	37.49	45.72	55.42	14.02
OTL-GCN	32.12	26.27	45.96	13.00	29.25	32.21	41.73	4.12	33.28	26.01	47.42	13.28
OTL-VAR	24.52	17.43	30.02	15.52	20.12	17.02	30.25	5.02	23.98	26.17	37.85	15.52
OTL-MLP	24.55	16.58	35.86	16.01	25.23	18.45	34.74	5.93	26.77	31.08	36.23	2.79
OTL-DCRNN	22.98	14.18	31.52	9.65	23.01	17.21	35.98	3.58	26.47	32.18	34.12	8.32
OTL-STGCN	22.53	14.02	32.28	7.56	23.95	15.89	37.52	3.99	25.74	27.93	34.38	6.78
OTL-AGCRN	19.24	12.44	29.51	5.43	19.25	15.03	29.21	2.35	23.58	21.49	**31.51**	4.3
OTL-Cy2Mixer	**19.10**	12.28	30.18	28.12	**18.14**	14.33	28.20	13.34	**23.33**	22.65	37.78	18.63
OTL-STAEformer	19.19	**12.01**	29.41	20.55	18.23	**14.02**	29.01	10.56	23.46	**20.38**	37.62	17.32
ST-GFSL	19.23	13.89	29.34	113.35	18.41	16.56	29.13	57.43	23.38	24.51	36.47	68.43
ST-DAAN	19.14	13.31	29.28	98.72	18.33	15.15	**28.00**	65.43	23.35	23.31	34.58	80.72
OTL-GM	19.25	14.09	**29.04**	**4.93**	18.38	15.14	28.18	**2.20**	25.54	26.09	36.26	**1.10**

The best results are in bold

Conclusions

1. This paper addresses two major challenges in real-world traffic flow prediction within the IoT context: limited computational resources on intelligent edge devices and data sparsity caused by extreme weather conditions.

2. Extensive experiments and ablation studies on the PeMS04 dataset confirmed that OTL-GM effectively addresses both computational resource constraints and data sparsity on edge devices.

3. The proposed approach enhances the practical value of traffic flow prediction and offers a feasible solution for edge computing environments.

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