2023 IEEE Transactions on Intelligent Transportation Systems

HSTGCNT

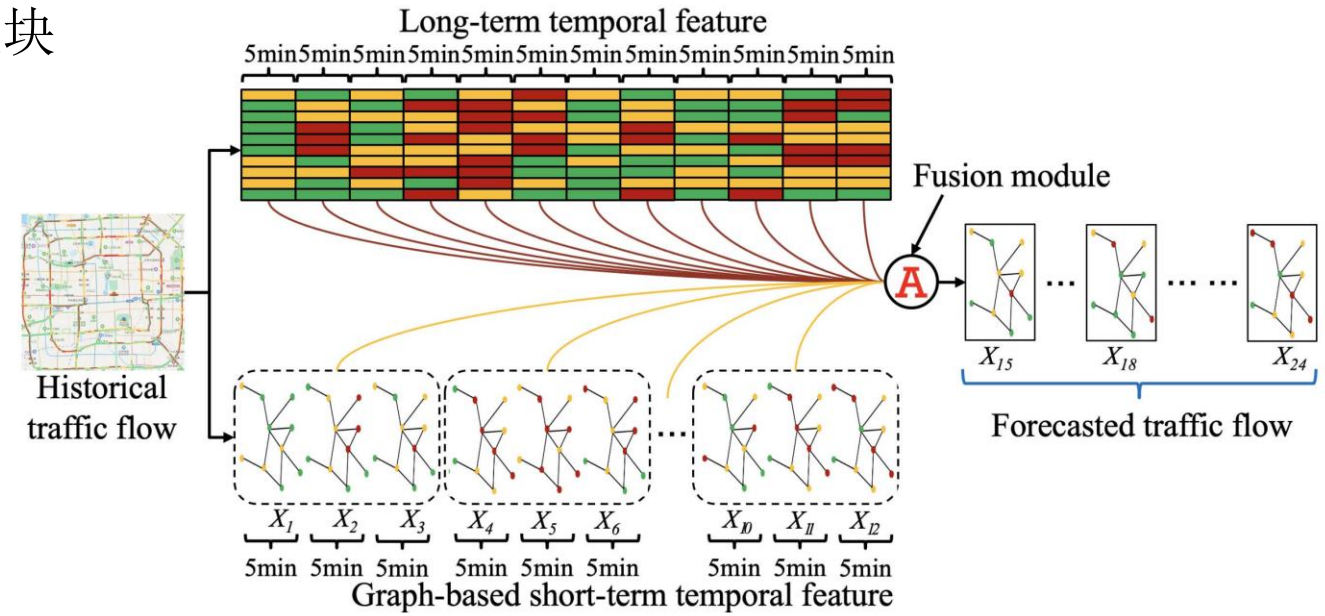
Hierarchical **S**patio–**T**emporal **G**raph **C**onvolutional **N**etworks and **T**ransformer Network for Traffic Flow Forecasting

23.2.16

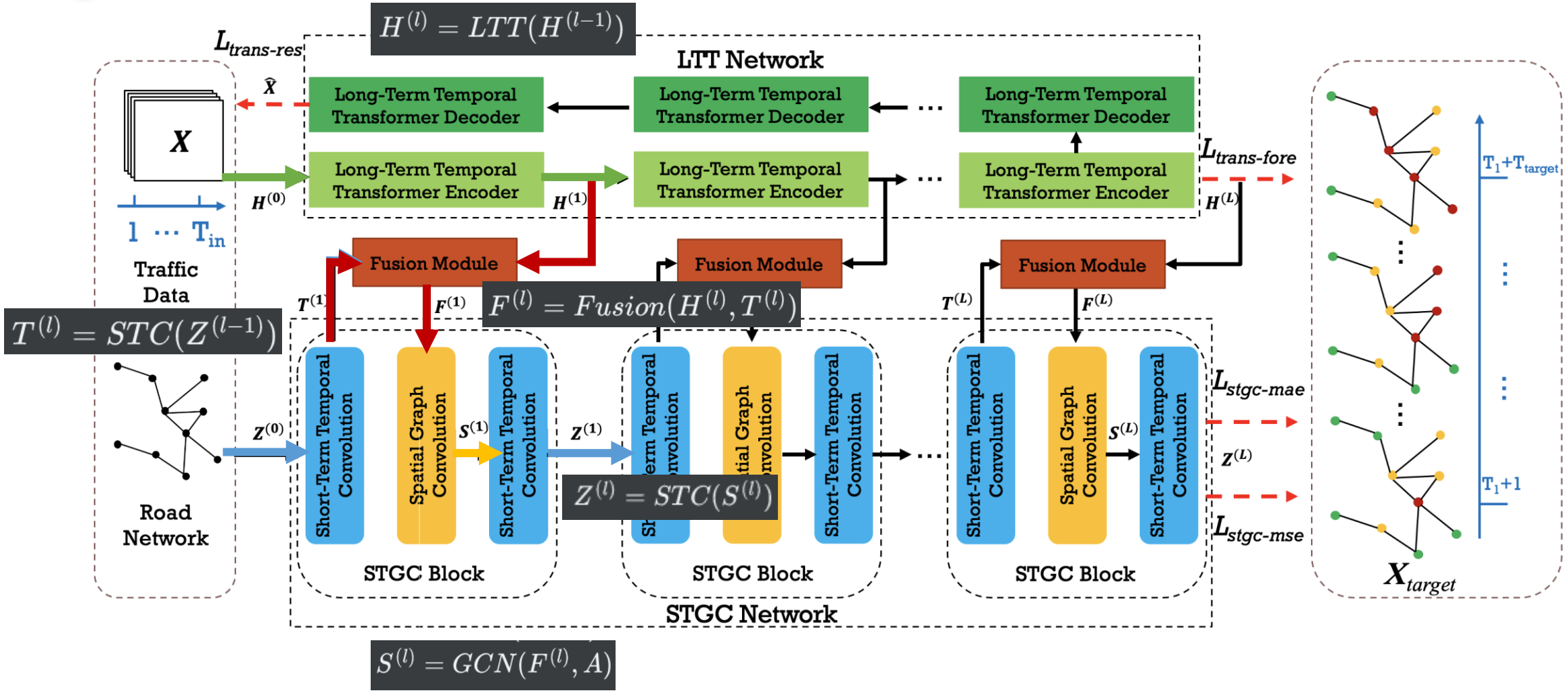
Presented by Yyyq

01 创新点

- **Hierarchical 分层结构：**两个并行网络——解决图卷积网络的过平滑问题
- LTT网络：长期时间关系
- STGC**网络：**短期时间关系、空间关系
- LSTIF模块：长短期时间信息融合模块



02 模型结构


$H^{(l)} = LTT(H^{(l-1)})$
$L_{trans\text{-}res}$
LTT Network
Long-Term Temporal Transformer Decoder
Long-Term Temporal Transformer Encoder
$\hat{X}$
X
$H^{(0)}$
$H^{(1)}$
$H^{(L)}$
$L_{trans\text{-}fore}$
1 ⋯ T_{in}
Traffic Data
Fusion Module
$T^{(1)}$
$F^{(1)}$
$T^{(L)}$
$F^{(L)}$
$F^{(l)} = Fusion(H^{(l)}, T^{(l)})$
$T^{(l)} = STC(Z^{(l-1)})$
Road Network
$Z^{(0)}$
Short-Term Temporal Convolution
Spatial Graph Convolution
$S^{(1)}$
$S^{(L)}$
$Z^{(1)}$
$Z^{(l)} = STC(S^{(l)})$
$Z^{(L)}$
$L_{stgc\text{-}mae}$
$L_{stgc\text{-}mse}$
STGC Block
STGC Network
$S^{(l)} = GCN(F^{(l)}, A)$
T_1+T_{target}
T_1+1
X_{target}

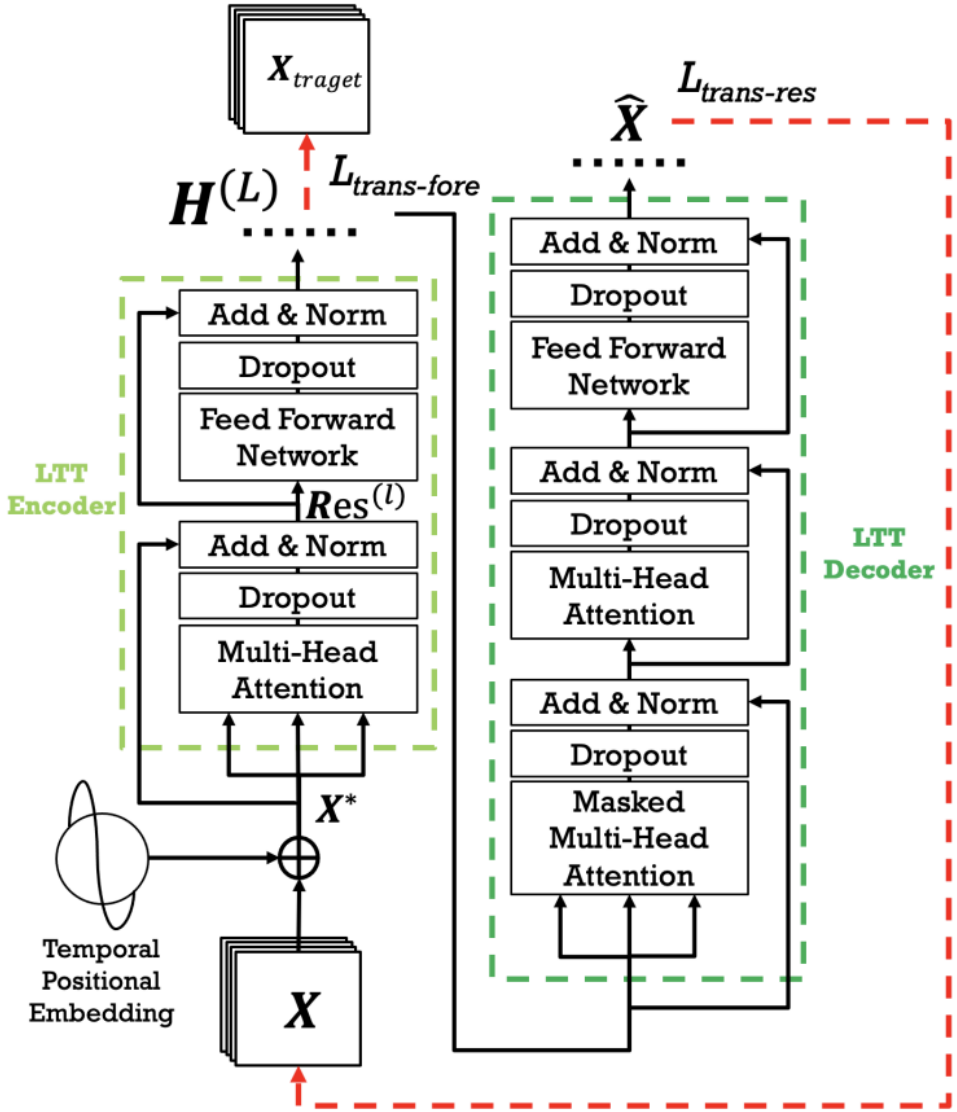
02 模型结构：LTT

- Temporal Positional Embedding：时间位置嵌入
- 让网络知道时间序列中各元素的次序关系

$$\mathrm{PE}(K) = \sin\left(\frac{2\pi K}{\mathrm{period}}\right)$$

$$\mathbf{X}^* = \mathrm{Concat}(\mathbf{X}, \mathbf{PE})$$

$$\mathbf{X}^* \in \mathbb{R}^{N \times T_{in} \times (D_p + D_r)}$$



*Ashish Vaswani et al. “Attention is All you Need” Neural Information Processing Systems(2017): n. pag.

02 模型结构：LTT

- Encoder

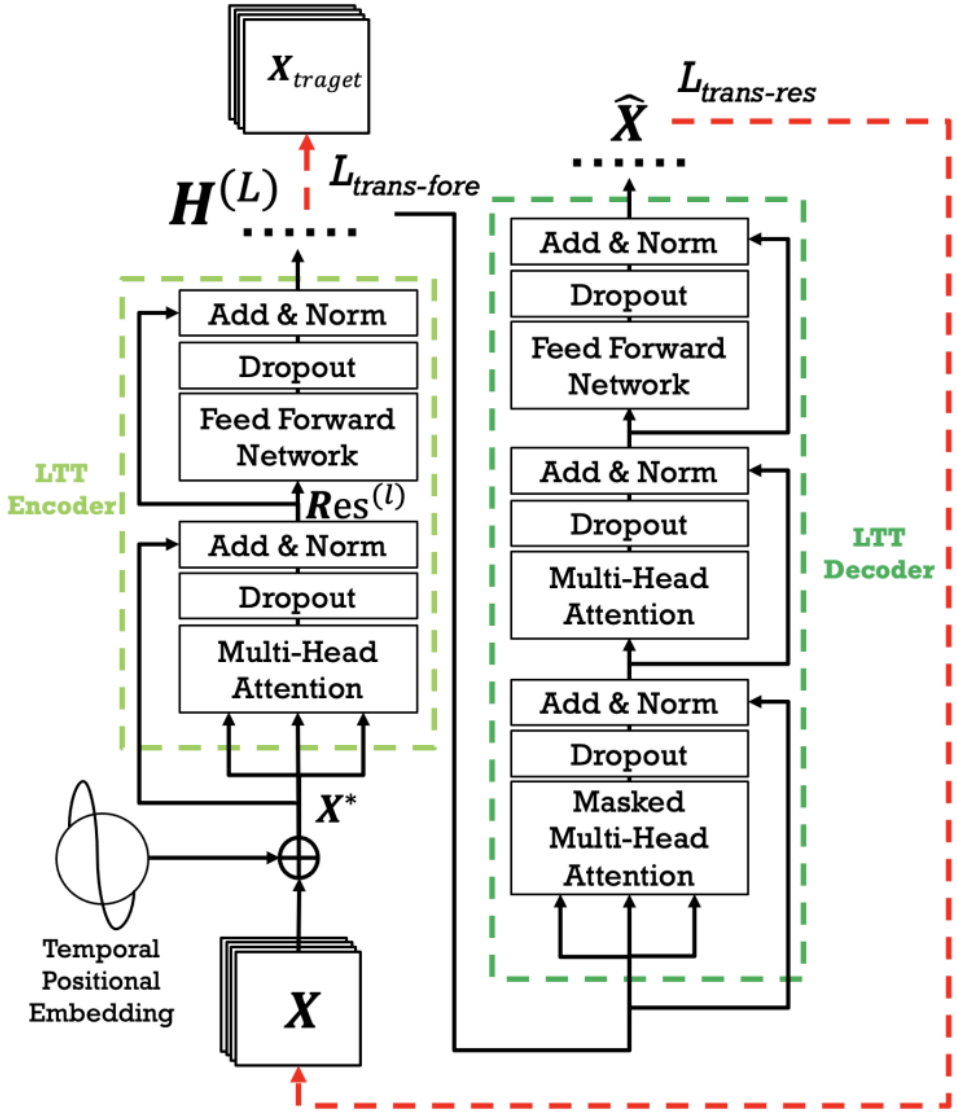
$$\mathbf{H}^{(0)} = \mathbf{X}^*$$

$$\text{MultiHead}\left(\mathbf{H}^{(l-1)}\right) = \text{Concat}\left(\text{head}_1, \ldots, \text{head}_M\right)\mathbf{W}^O$$

$$\text{head}_m = softmax\left(\frac{QK^T}{\sqrt{d_k}}\right)V$$

- Decoder

Masked MultiHead



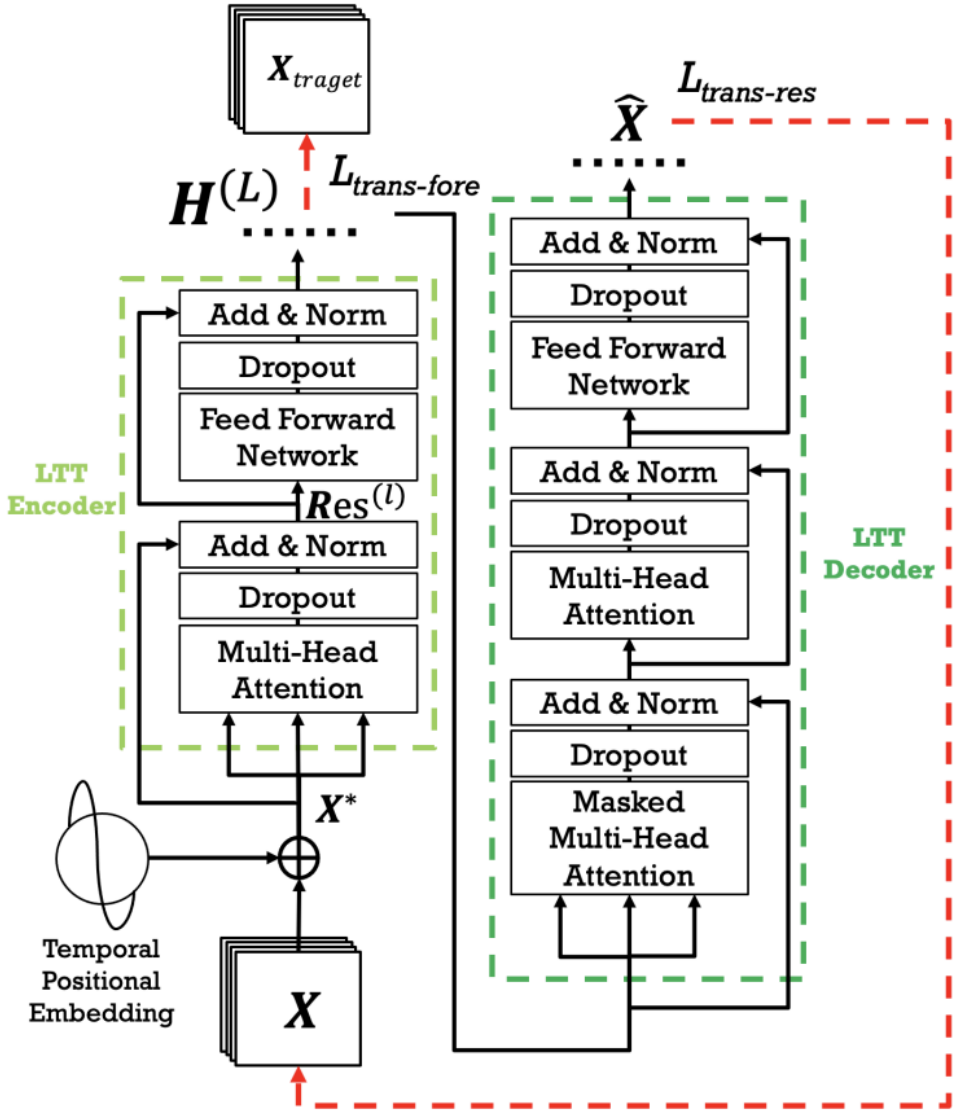
*Ashish Vaswani et al. “Attention is All you Need” Neural Information Processing Systems(2017): n. pag.

02 模型结构：LTT

- Loss

$$\mathcal{L}_{\text{trans-fore}} = ||\mathrm{H}^{(\mathrm{L})} - \mathrm{X}_{\text{target}}||$$

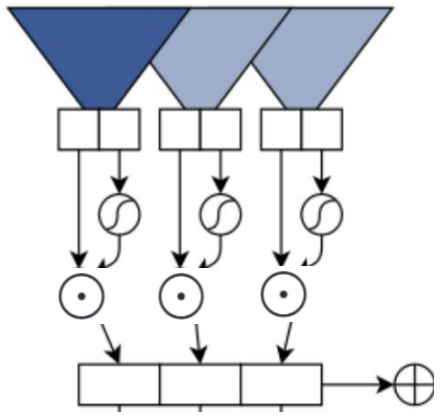
$$\mathcal{L}_{\text{trans-res}} = ||\hat{\mathrm{X}} - \mathrm{X}||$$

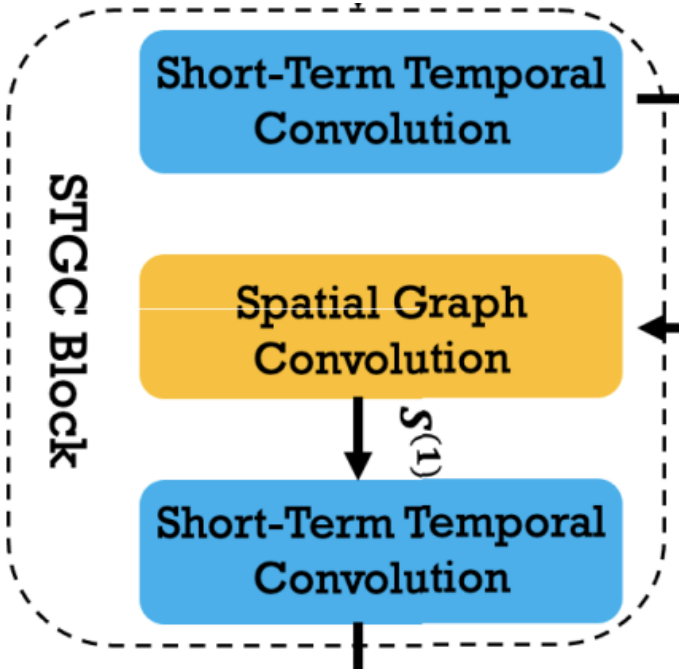


02 模型结构：STGC

- STC

$$\mathrm{Conv}_{1\mathrm{d}} + \mathrm{GLU}$$





- SGC

$$\mathbf{S}^{(l)} = \mathrm{GCN}\left(\mathbf{F}^{(l)}, \mathbf{A}\right)$$
$$= \sigma\left(\hat{\mathbf{D}}^{-\frac{1}{2}}\hat{\mathbf{A}}\hat{\mathbf{D}}^{-\frac{1}{2}}\mathbf{F}^{(l)}\mathbf{W}^{(l)}\right)$$

- Loss

$$\mathcal{L}_{\text{stgc-mae}} = \left\| \mathbf{Z}^{(L)} - \mathbf{X}_{\text{target}} \right\|$$
$$\mathcal{L}_{\text{stgc-mse}} = \left\| \mathbf{Z}^{(L)} - \mathbf{X}_{\text{target}} \right\|$$

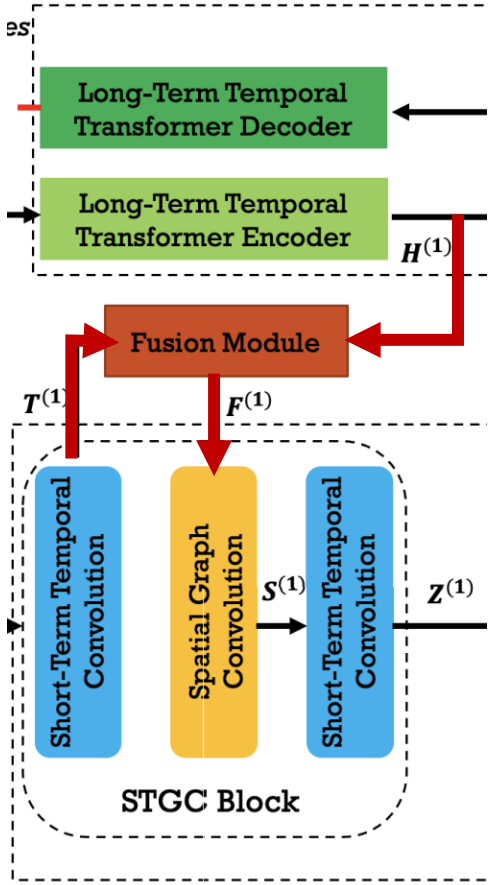
02 模型结构：Fusion Module

- Attention

$$\mathrm{F}^{\mathrm{l}} = \mathrm{Fusion}(\mathrm{H}^{(\mathrm{l})}, \mathrm{T}^{(\mathrm{l})})$$

$$= \mathrm{Attention}((\mathrm{H}^{(\mathrm{l})}, \mathrm{T}^{(\mathrm{l})}) \cdot \mathrm{Y}^{(\mathrm{l})})$$

$$\mathrm{Y}^{(\mathrm{l})} = \mathrm{Concat}(\mathrm{T}^{(\mathrm{l})}, \mathrm{H}^{(\mathrm{l})})$$



03 数据集和评价指标

- PeMS-BAY：驾驶速度数据
- PeMSD7：加州高速公路
- Beijing Metro：北京地铁（仅使用入口流量）

- 平均绝对误差(MAE)
- 平均绝对百分比误差(MAPE)
- 均方根误差(RMSE)

04 实验结果1

Model	PeMS-BAY(15min/30min/60min)			PeMSD7(M)(15min/30min/60min)		
	MAE	MAPE(%)	RMSE	MAE	MAPE(%)	RMSE
HA	2.94	6.61	6.69	4.82	11.78	9.17
LSVR	1.85/2.48/3.28	3.80/5.50/8.00	3.59/5.18/7.08	2.49/3.46/4.94	5.91/8.42/12.41	4.55/6.44/9.08
FNN	2.20/2.30/2.46	5.19/5.43/5.89	4.42/4.63/4.89	2.53/3.73/5.28	6.05/9.48/13.73	4.46/6.46/8.75
FC-LSTM	2.95/3.97/4.74	4.81/5.25/5.79	4.19/4.55/4.96	3.57/3.92/4.16	8.60/9.55/10.10	6.20/7.03/7.51
STGCN	1.39/1.84/2.42	3.00/4.22/5.58	2.92/4.12/5.33	2.25/3.05/4.04	5.26/7.33/9.77	4.04/5.70/7.55
DCRNN	1.38/1.74/2.07	2.90/3.90/4.92	2.95/3.97/4.74	2.37/3.31/4.01	5.54/8.06/9.99	4.21/5.96/7.19
GWN	1.36/1.85/1.98	2.84/3.79/4.59	2.93/3.86/4.63	2.17/**2.80**/3.44	5.13/6.89/8.68	4.01/5.48/6.71
STSGCN	1.57/1.98/2.53	4.34/4.64/6.13	4.42/4.51/5.97	2.59/3.34/4.62	6.19/8.18/11.71	4.91/6.59/8.75
STFGNN	1.47/1.91/2.44	3.14/4.32/6.07	3.04/4.28/5.54	2.47/3.23/4.21	5.86/8.10/10.35	4.54/6.27/8.07
HSTGCNT	**1.29/1.62/1.91**	**2.68/3.70/4.57**	**2.67/3.79/4.51**	**2.14/2.80/3.40**	**5.02/6.88/8.55**	**4.00/5.38/6.44**

04 实验结果2

Model	Beijing Metro(15min/30min/45min)	
	MAE	RMSE
HA	20.52	52.72
LSVR	14.71/16.55/17.75	25.12/31.33/32.93
FNN	11.01/14.46/18.78	23.61/31.22/40.75
FC-LSTM	10.76/12.27/12.86	21.22/22.33/23.74
STGCN	7.83/9.56/10.16	16.81/17.92/20.29
DCRNN	8.37/9.64/11.63	19.13/23.38/25.87
GWN	7.39/7.45/8.49	15.85/16.00/18.14
STSGCN	10.65/12.24/16.22	20.71/24.03/33.23
STFGNN	9.13/9.60/11.72	17.47/18.50/22.39
HSTGCNT	**6.72/7.15/7.69**	**14.91/15.65/17.06**

05 消融实验

Model	PeMS-BAY(15min/30min/60min)			PeMSD7(M)(15min/30min/60min)		
	MAE	MAPE(%)	RMSE	MAE	MAPE(%)	RMSE
HSTGCNT-wLTT	1.35/1.68/2.06	2.85/3.79/5.19	2.78/**3.79**/5.31	2.16/2.95/3.40	5.20/7.59/8.98	4.11/5.54/6.65
HSTGCNT-Linear	1.34/1.72/2.11	2.89/3.84/5.07	2.71/3.97/5.15	2.22/2.89/3.57	5.45/7.42/8.91	4.29/5.58/6.82
HSTGCNT-wFUSE	1.31/1.66/2.02	2.69/3.75/4.86	2.73/3.92/4.95	2.17/2.82/3.50	5.33/7.20/8.72	4.11/5.51/6.76
HSTGCNT	**1.29/1.62/1.91**	**2.68/3.70/4.57**	**2.67/3.79/4.51**	**2.14/2.80/3.40**	**5.02/6.88/8.55**	**4.00/5.38/6.44**

Model	Beijing Metro(15min/30min/45min)	
	MAE	RMSE
HSTGCNT-wLTT	7.31/7.98/8.24	15.28/16.44/17.55
HSTGCNT-Linear	7.25/7.74/8.10	15.39/15.90/17.71
HSTGCNT-wFUSE	7.16/7.46/7.85	15.42/15.76/17.93
HSTGCNT	**6.72/7.15/7.69**	**14.91/15.65/17.06**

谢谢观看

MANY THANKS !

23.1.10