GeoMAN: Multi-level Attention Networks for Geo-sensory Time Series Prediction

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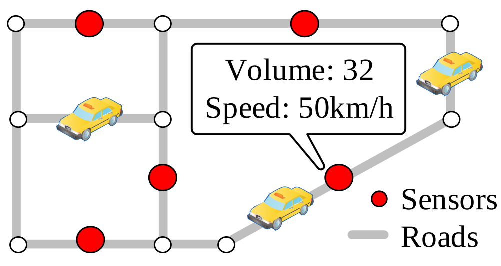
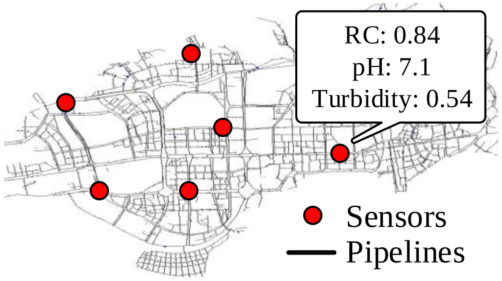
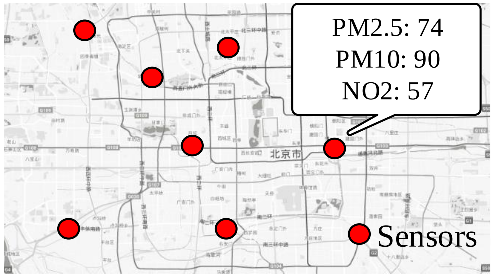
Geo-sensory Time Series

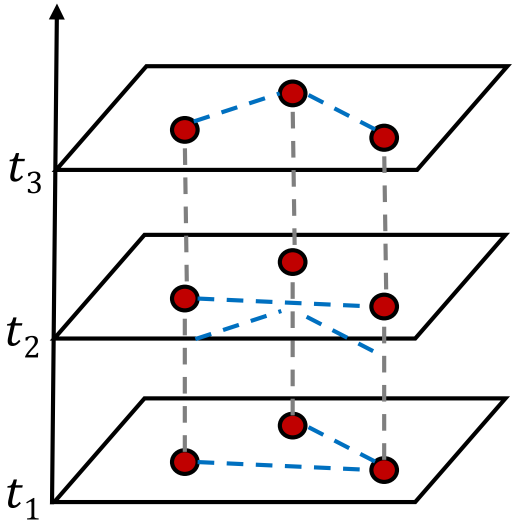
- Massive sensors deployed in physical world





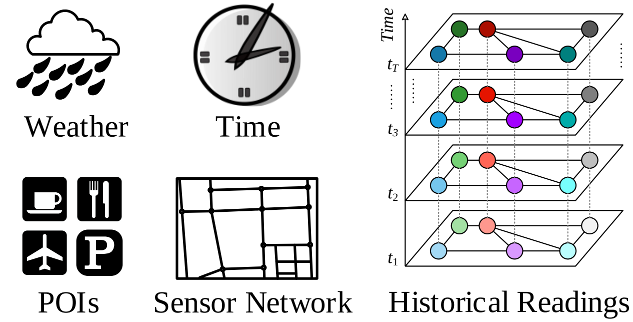


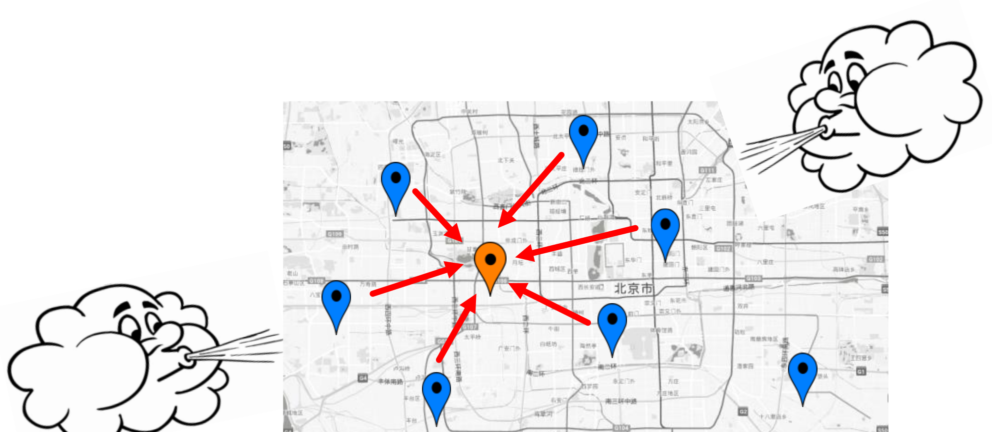
- Properties
  - Each sensor has a unique geospatial location
  - Constantly reporting time series readings
  - With geospatial correlation between readings
- **Prediction on geo-sensory time series**
  - Motivation: traffic control, air quality forecast…
  - Goal: predict target series at a sensor



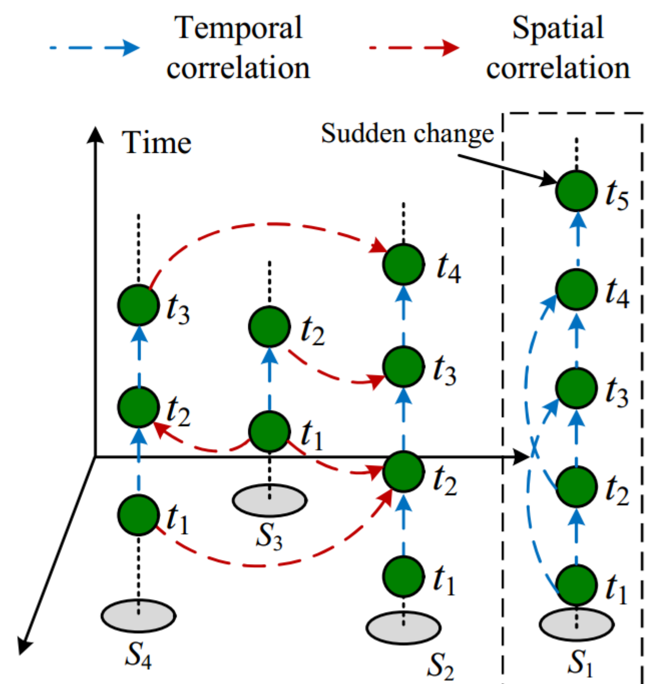
Challenges

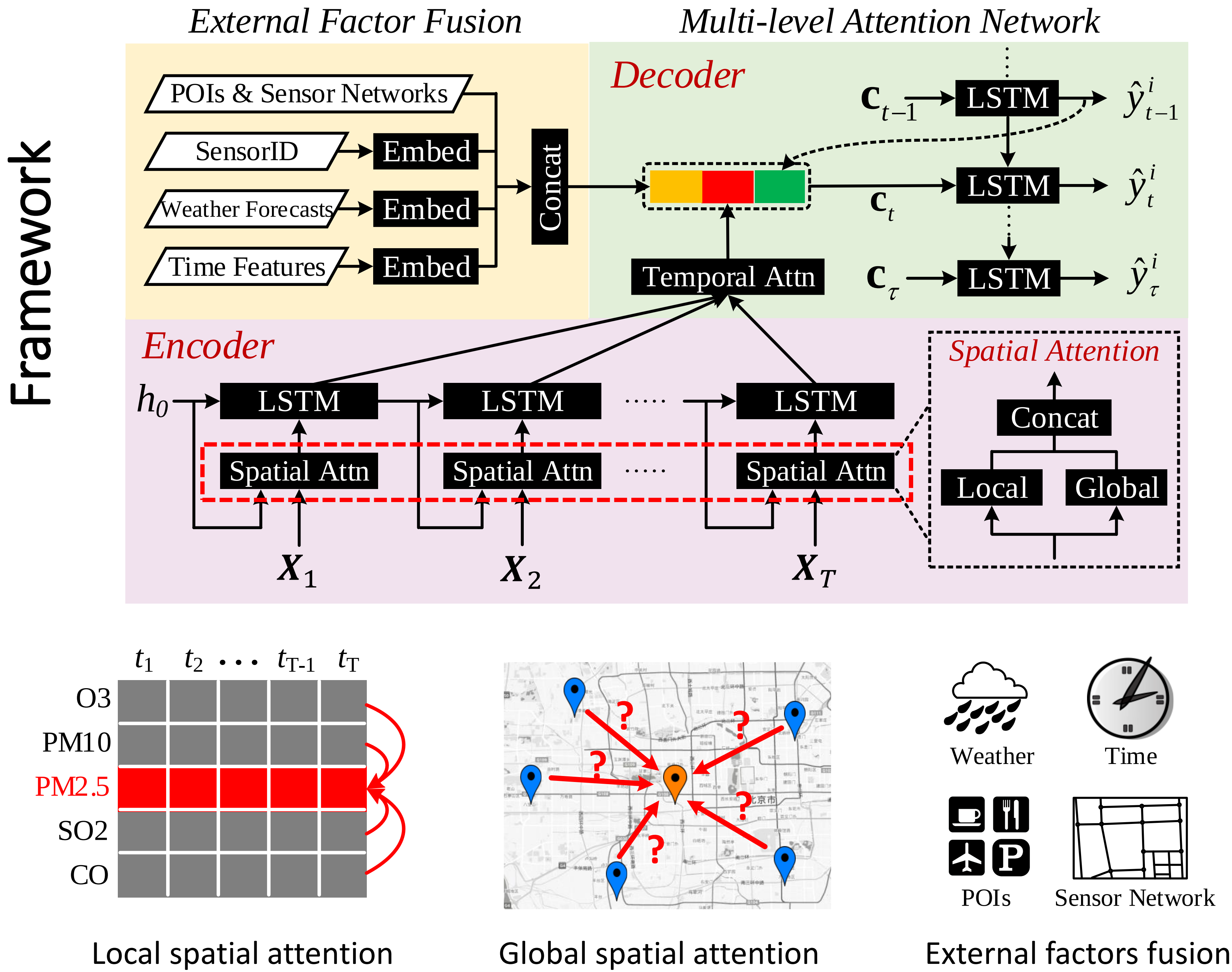
- Affected by many factors
  - Readings of previous time interval
  - Readings of other sensors in nearby regions
  - External factors: weather, time and land use
- Dynamic Inter-sensor correlations
- Dynamic temporal correlation





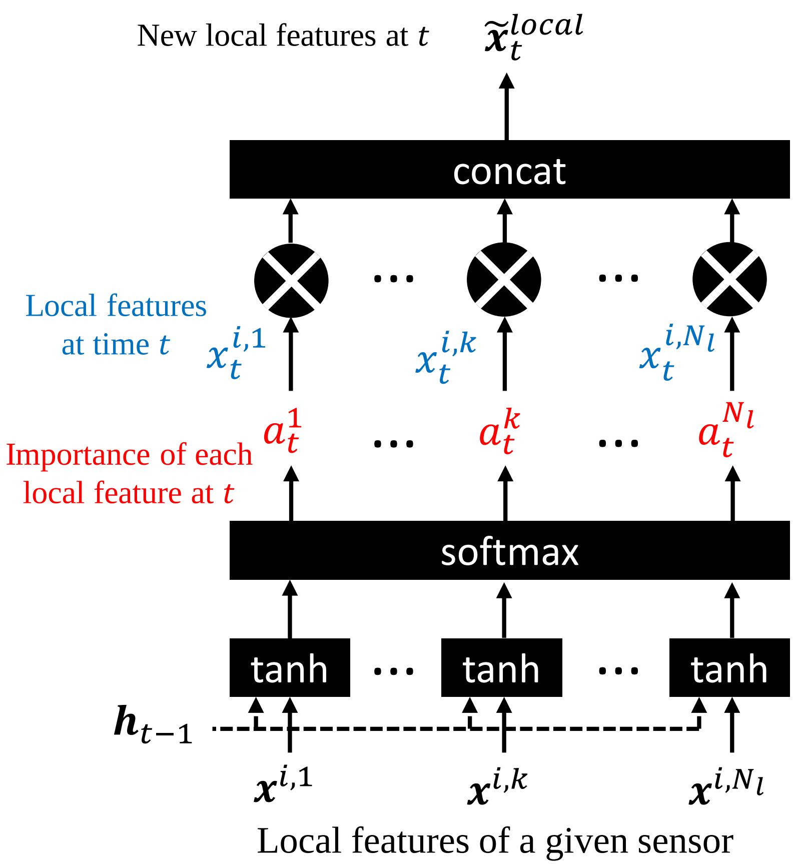
DAY 2

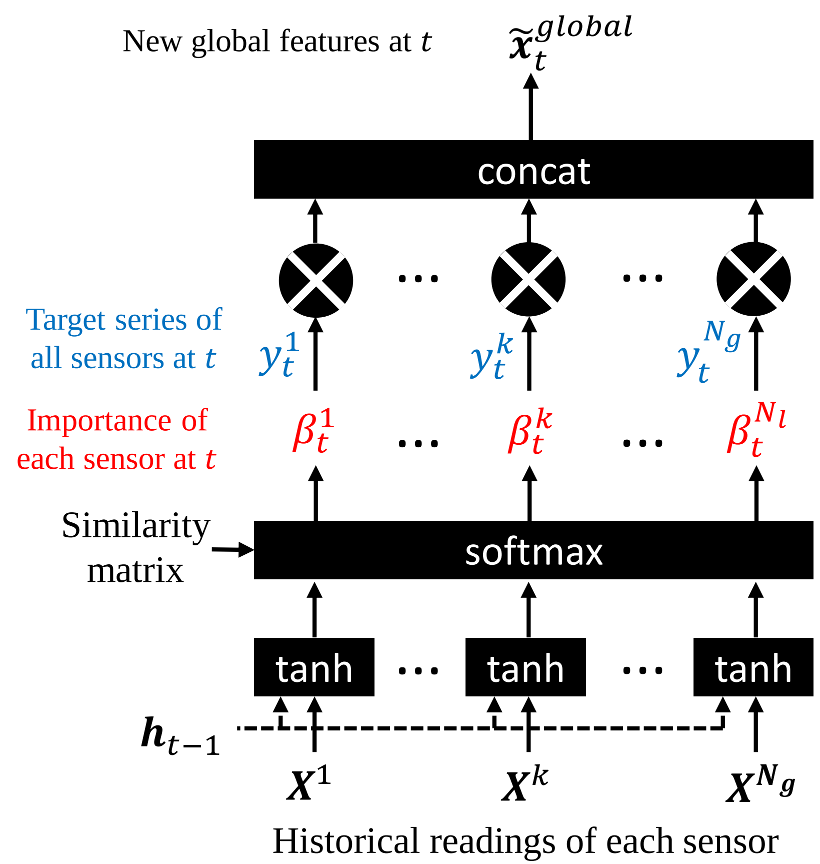



Framework
External Factor Fusion
Multi-level Attention Network
Decoder
POIs & Sensor Networks
SensorID
Embed
Weather Forecasts
Embed
Time Features
Embed
Concat
Temporal Attn
LSTM
LSTM
LSTM
Encoder
h_0
LSTM
LSTM
LSTM
Spatial Attn
Spatial Attn
Spatial Attn
X_1
X_2
X_T
Spatial Attention
Concat
Local
Global
t_1 t_2 ... t_{T-1} t_T
O3
PM10
PM2.5
SO2
CO
Weather
Time
POIs
Sensor Network
Local spatial attention
Global spatial attention
External factors fusion

Spatial Attention

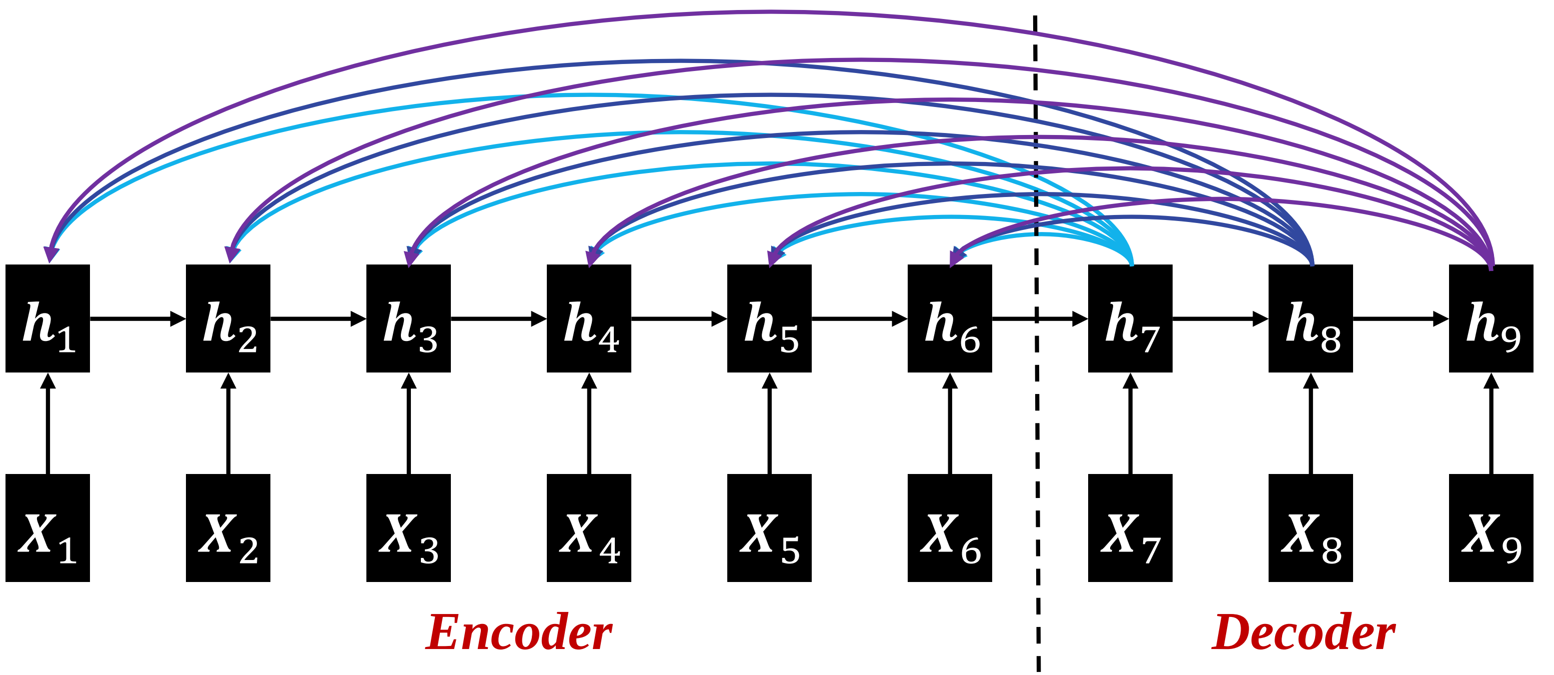
- Local spatial attention
  - Local features ⇔ target series
- Global spatial attention
  - Select relevant sensors





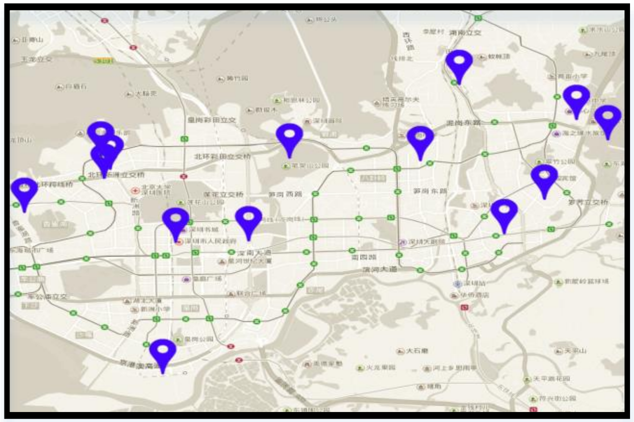
Temporal Attention

- Sequence-to-sequence architecture
- Select relevant previous time slots to make predictions

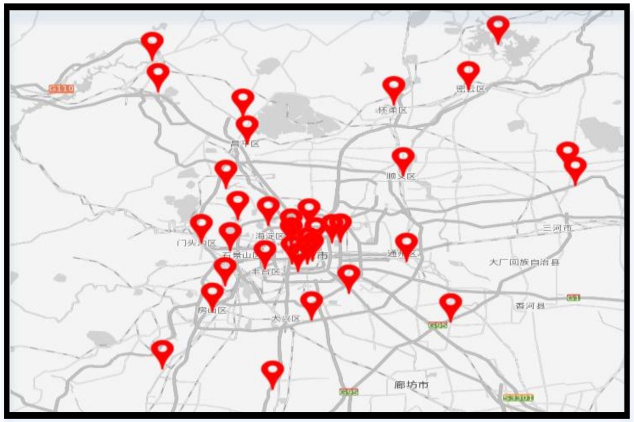


Evaluation

- Task 1 - water quality prediction
  - Water quality data
    - Residual chlorine
    - 10 kinds of time series
    - From 14 sensors in Shenzhen
    - Update each 5 minutes
  - Meteorology data
  - POIs data



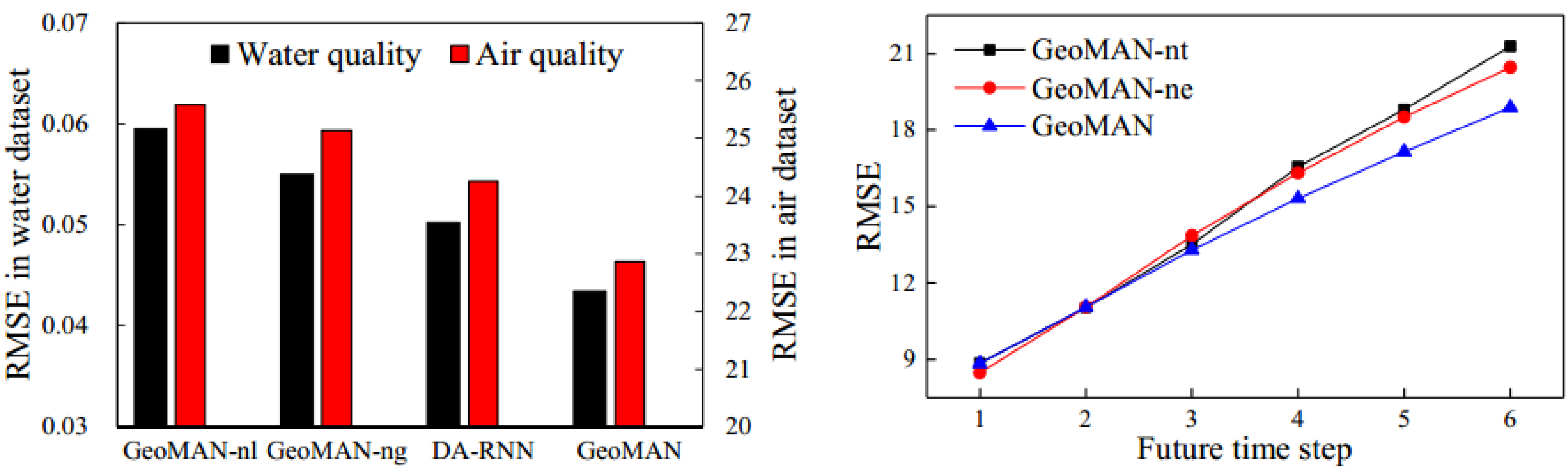
- Task 2 - air quality prediction
  - Air quality data
    - PM2.5
    - 19 kinds of time series
    - From 35 sensors in Beijing
    - Hourly updates
  - Meteorology data
  - POIs data



Results

Method	Water Quality		Air Quality	
	RMSE	**MAE**	**RMSE**	**MAE**
ARIMA	8.61E-02	7.97E-02	31.07	20.58
VAR	5.02E-02	4.42E-02	24.60	16.17
GBRT	5.17E-02	3.30E-02	24.00	15.03
FFA	6.04E-02	4.10E-02	23.83	15.75
stMTMVL	6.07E-02	4.16E-02	29.72	19.26
stDNN	5.77E-02	3.99E-02	25.64	16.49
LSTM	6.89E-02	5.04E-02	24.62	16.70
Seq2seq	5.80E-02	4.03E-02	24.55	15.09
DA-RNN	5.02E-02	3.52E-02	24.25	15.17
GeoMAN	**4.34E-02**	**3.02E-02**	**22.86**	**14.08**

Results

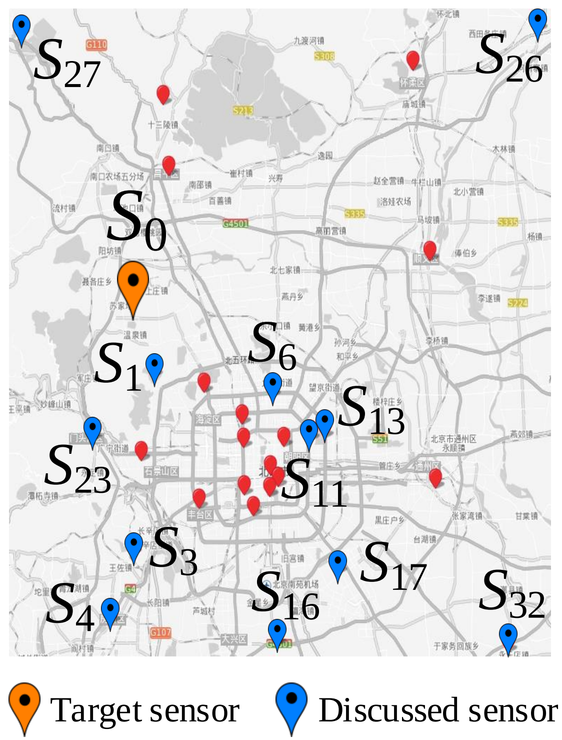


(a) Evaluation on spatial attention (b) Future time step vs. RMSE

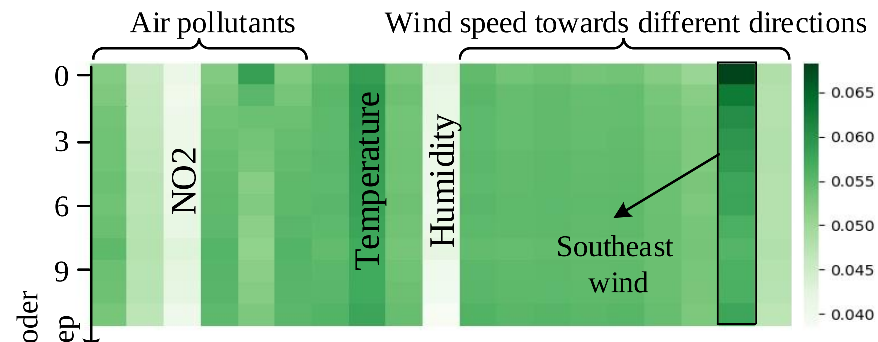
Figure 3: Performance comparison among different vairants.

Visualization: Dynamic Correlation

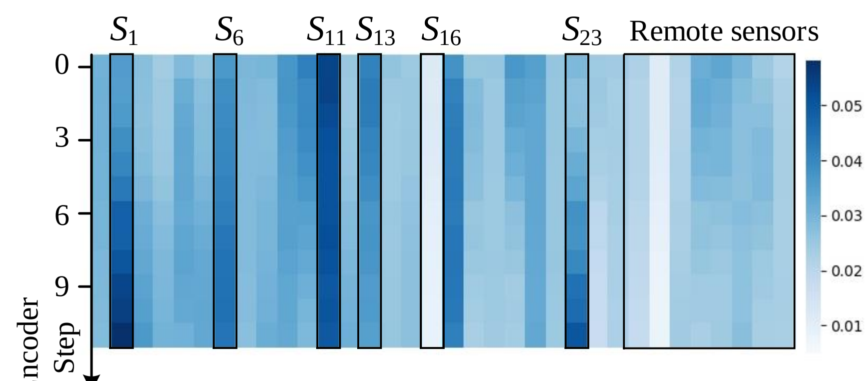
- Case study over air quality dataset
  - Discuss on sensor S_0
  - 4:00 to 16:00 on Feb. 28, 2017



(a) Air quality stations in Beijing



(b) Plot of local spatial attention weights



(c) Plot of global spatial attention weights

Conclusion

- A very fundamental but challenging task
  - Dynamic inter-sensor correlation
  - Dynamic temporal correlation
  - External factors
- Our method
  - Multi-level attention network
    - Spatial attention: captures the dynamic inter-sensor correlation
    - Temporal attention: captures the dynamic temporal correlation
  - External factor fusion
- Results
  - More accurate
  - Easily interpreted

Thanks!

We are Hiring!

Data & Code

Mail to: icity@jd.com

Liang, Yuxuan, et al. “GeoMAN: Multi-level Attention Networks for Geo-sensory Time Series Prediction." *IJCAI. 2018*.