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Multi-scale detection and interpretation of spatio-temporal anomalies of human activities

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Brief self introduction

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  - Research Assistant of Institute of Remote Sensing and Geographical Information Systems, Peking University.
  - Research Interests: GIScience, spatio-temporal data mining, GeoAI, social sensing, urban studies, remote sensing, etc.
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Background

- Scale

Contents expressed at different scales

Background

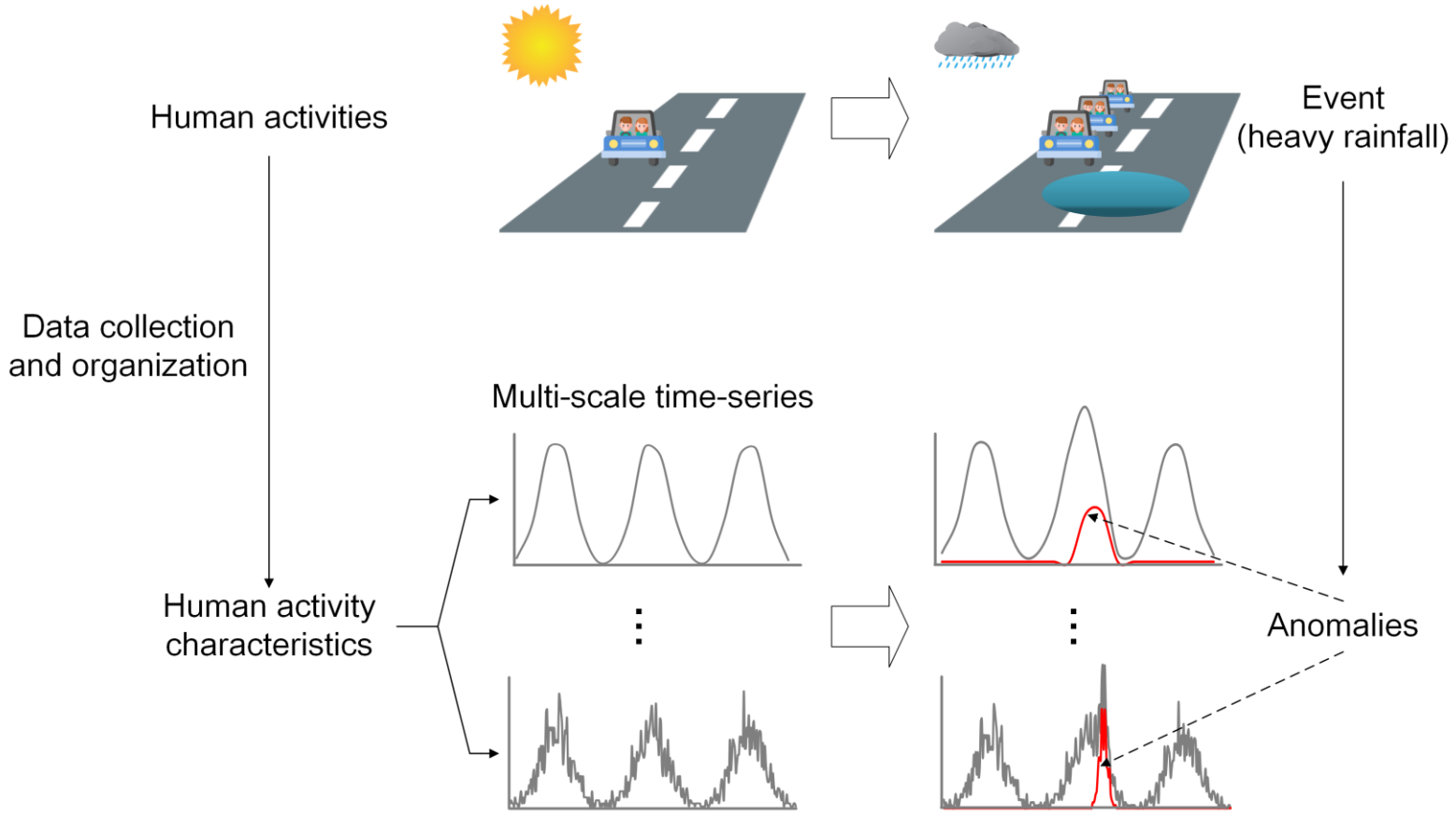
- Anomalies of human activities
  - Abnormal changes in activity characteristics caused by external events
  - Nature events: rainfall, air pollution, etc.
  - Social events: concerts, traffic accidents, etc.

Traffic accidents

Tourism Golden Week

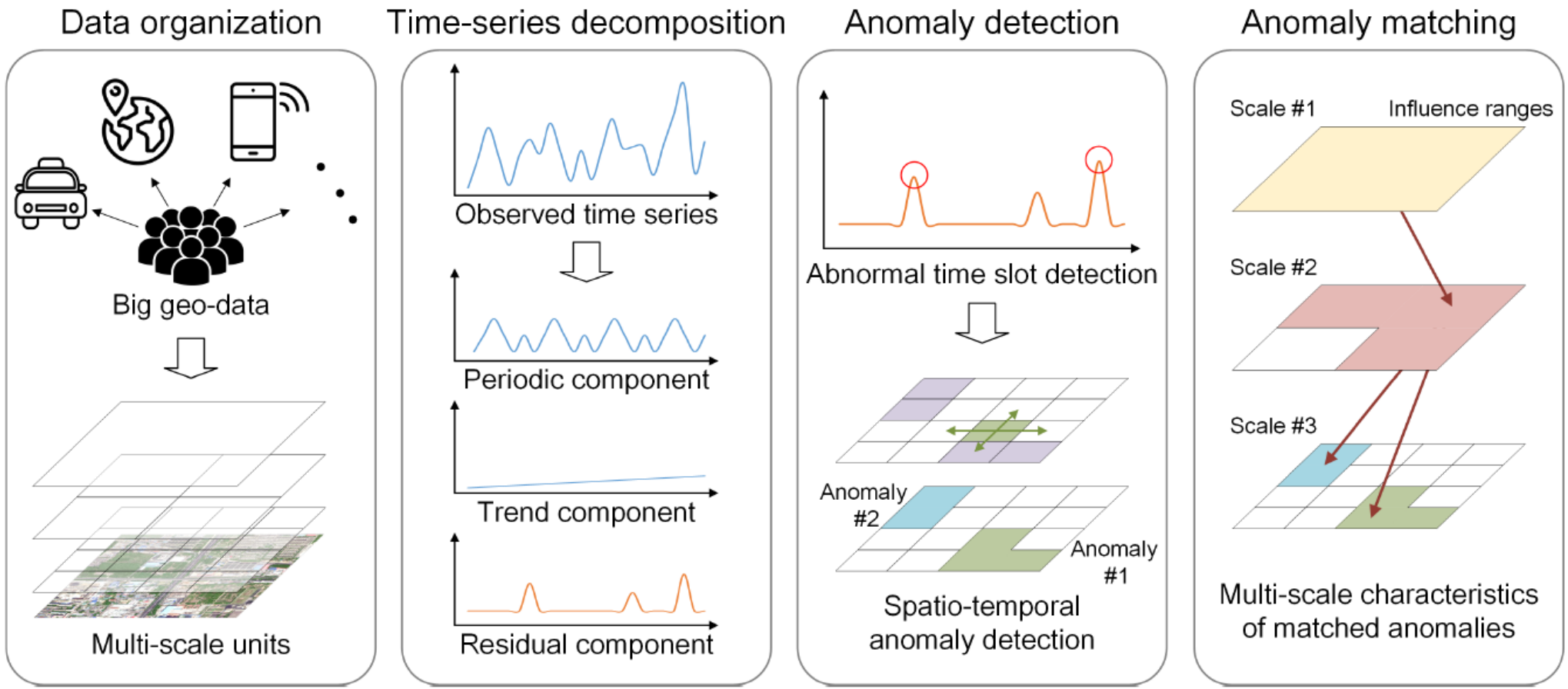
Background

- Scales affect the anomaly detection and interpretation
  - ➢ Scale affects the anomaly characteristics: influence intensity, time length, area, etc.
  - ➢ Considering multiple scales is good at detect anomalies with different characteristics



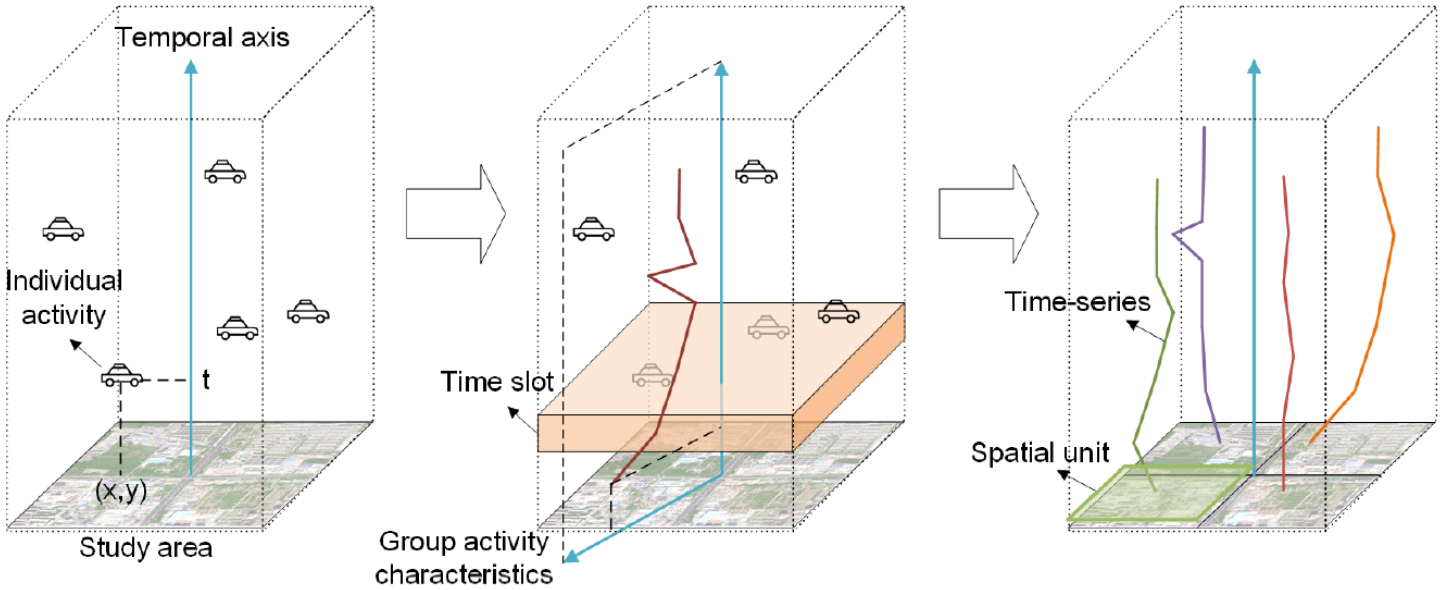
Method

- Multi-scale anomaly detection method
  - ➢ Four steps: data organization, time-series decomposition, anomaly detection, anomaly matching

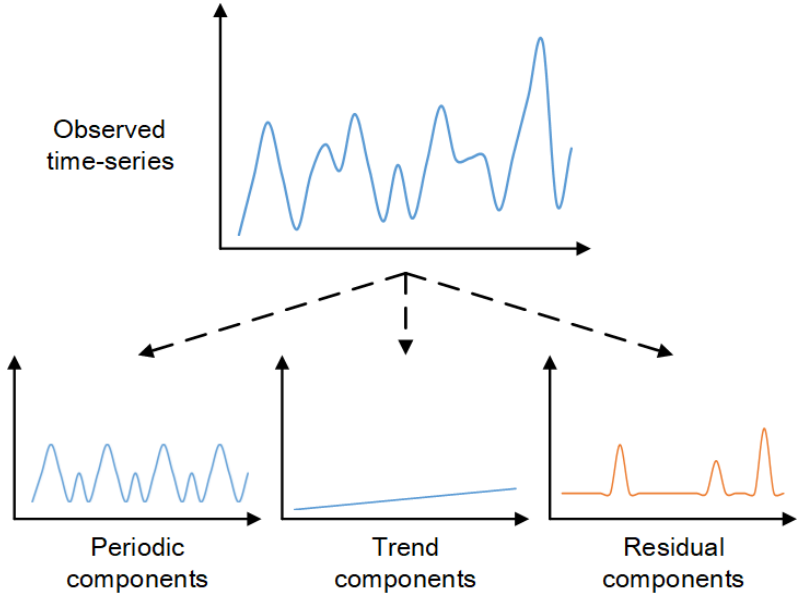


Method

- Multi-scale anomaly detection method
  - ➢ Data organization: Time-series at multiple spatio-temporal scales
  - ➢ Time-series decomposition: STL method (Cleveland et al., 1990)



Data organization



STL method

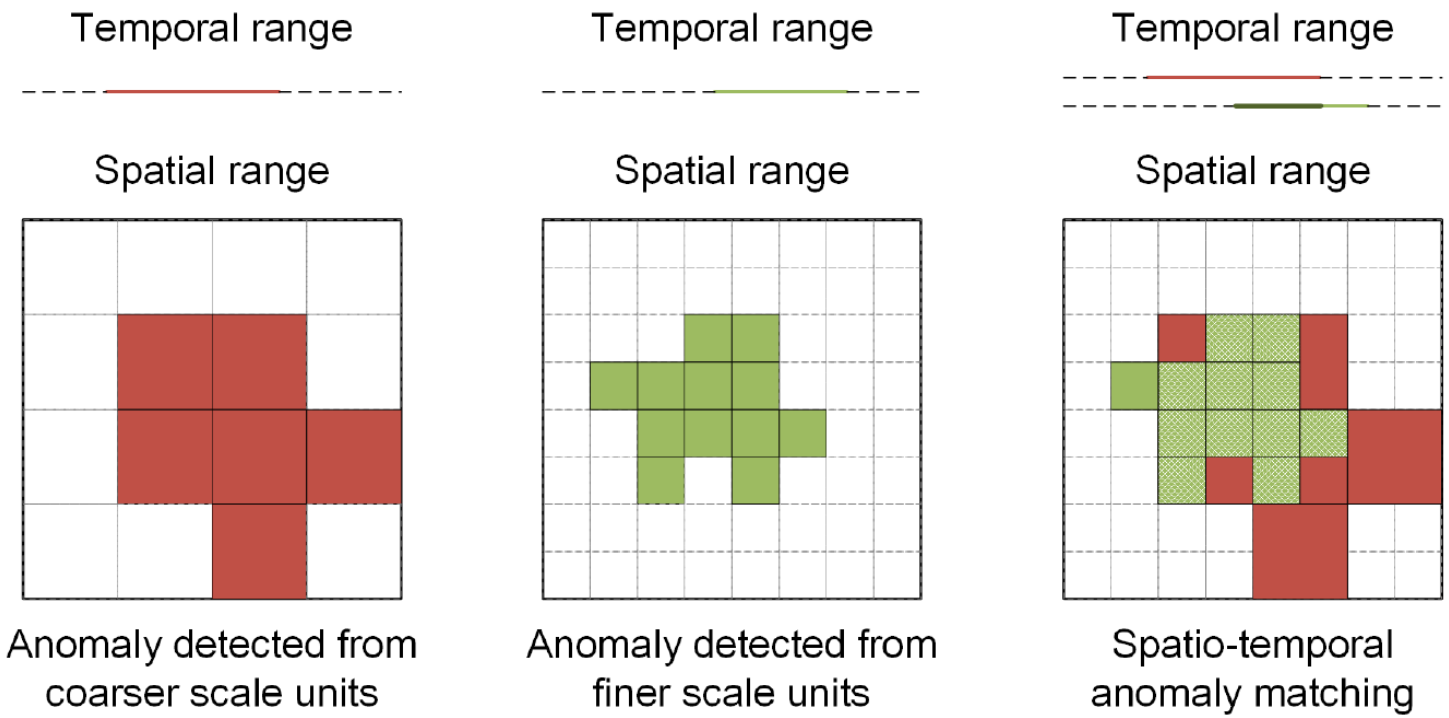
Cleveland, R. B., et al., 1990. STL: A seasonal-trend decomposition. *Journal of Official Statistics*, 6(1), 3-73.

Method

- Multi-scale anomaly detection method
  - Spatio-temporal anomaly detection: Tukey boxplot + seeded region growing (SGR)
  - Anomaly matching: Overlap ratio of spatio-temporal influence ranges

$$\frac{Overlap(IR_i, IR_j)}{IR_j} \geq K$$

$$\frac{f(TIR_i, TIR_j)}{TIR_j} \cdot \frac{g(SIR_i, SIR_j)}{SIR_j} \geq k^2$$



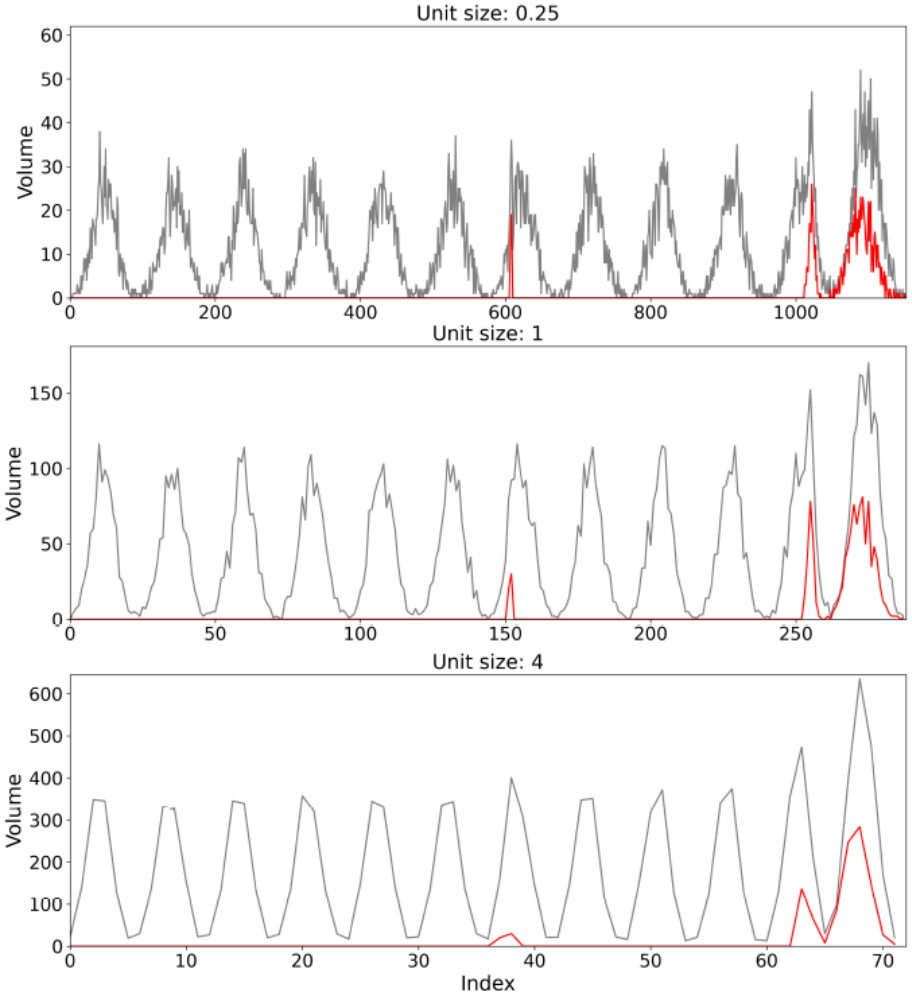
Anomaly matching at different spatial scales

Experiment

- Simulation of multi-temporal-scale anomaly detection
  - ➢ Data is generated according to known probability distributions
  - ➢ Multi-scale method vs Single-scale method

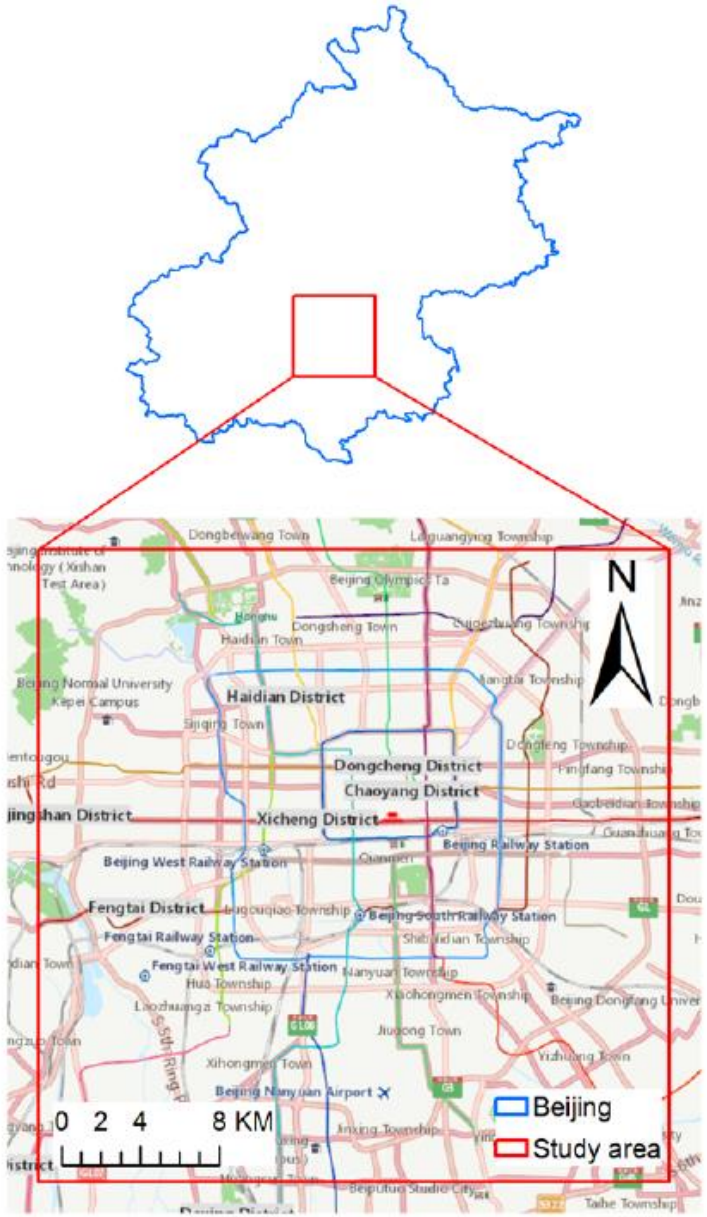
Anomaly detection accuracy

Scale	Anomaly #1	Anomaly #2	Anomaly #3	Total
Scale #1	**0.90**	0.89	0.67	0.82
Scale #2	0.83	**0.99**	0.91	0.91
Scale #3	0.24	0.90	**0.98**	0.71
Multi-scale	**0.95**	**0.99**	**0.98**	**0.98**



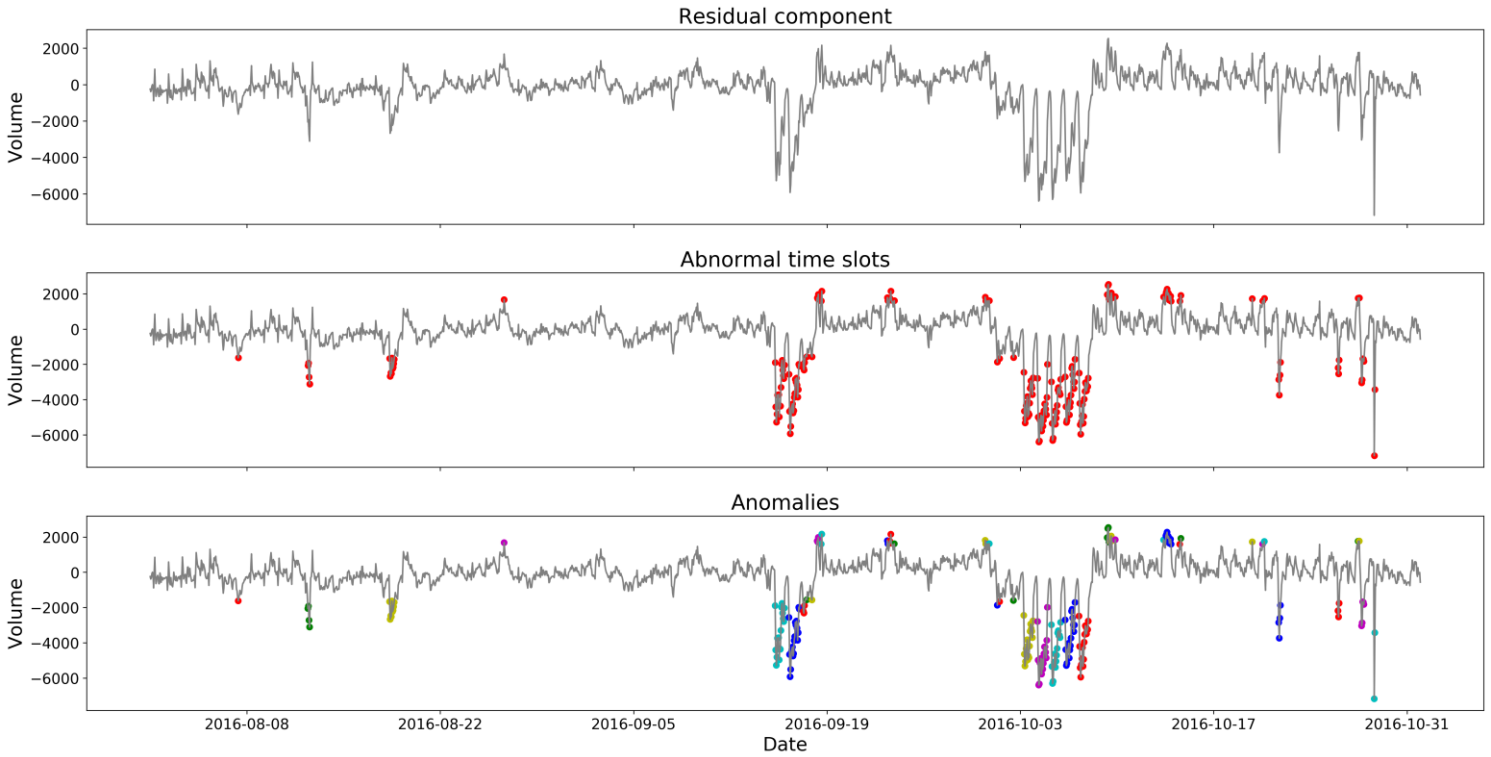
Experiment

- Case study of multi-spatial-scale anomaly detection
  - Data: Taxi origin and destination points (OD)
  - Study area: Center of Beijing, $32 \times 32\ km^2$ square area
  - Collected time: 01/08/2016 to 31/10/2016
  - Spatial unit form: Regular grids
  - Spatial unit size: From $1 \times 1\ km^2$ to $32 \times 32\ km^2$ (six scales)
  - Temporal unit size : one hour
  - Time-series length: 2208

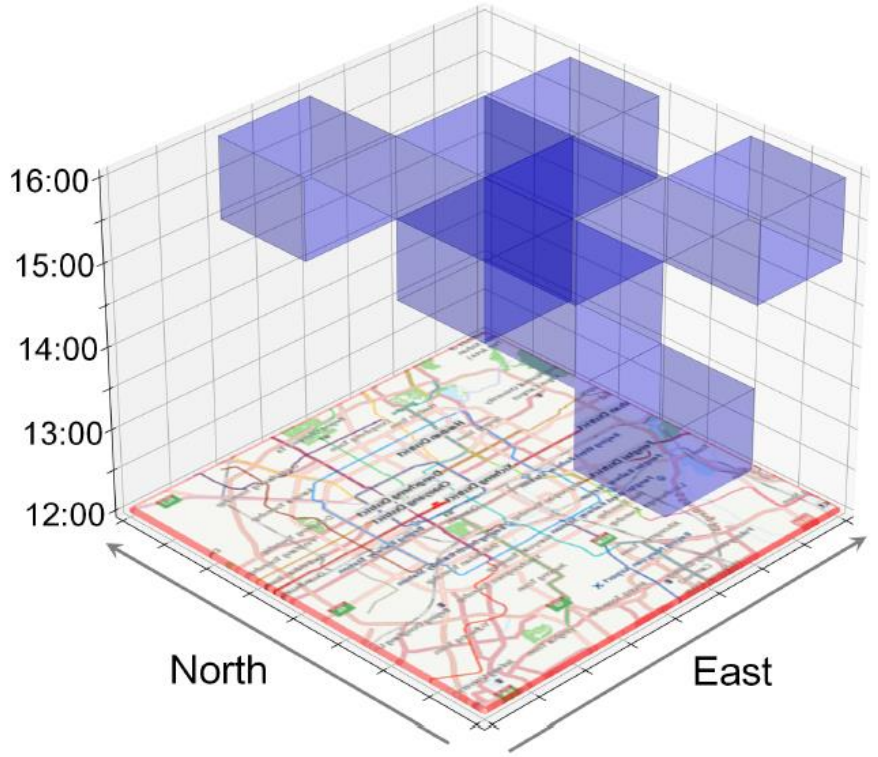


Experiment

- Case study of multi-spatial-scale anomaly detection
  - ➢ Spatio-temporal anomaly detection



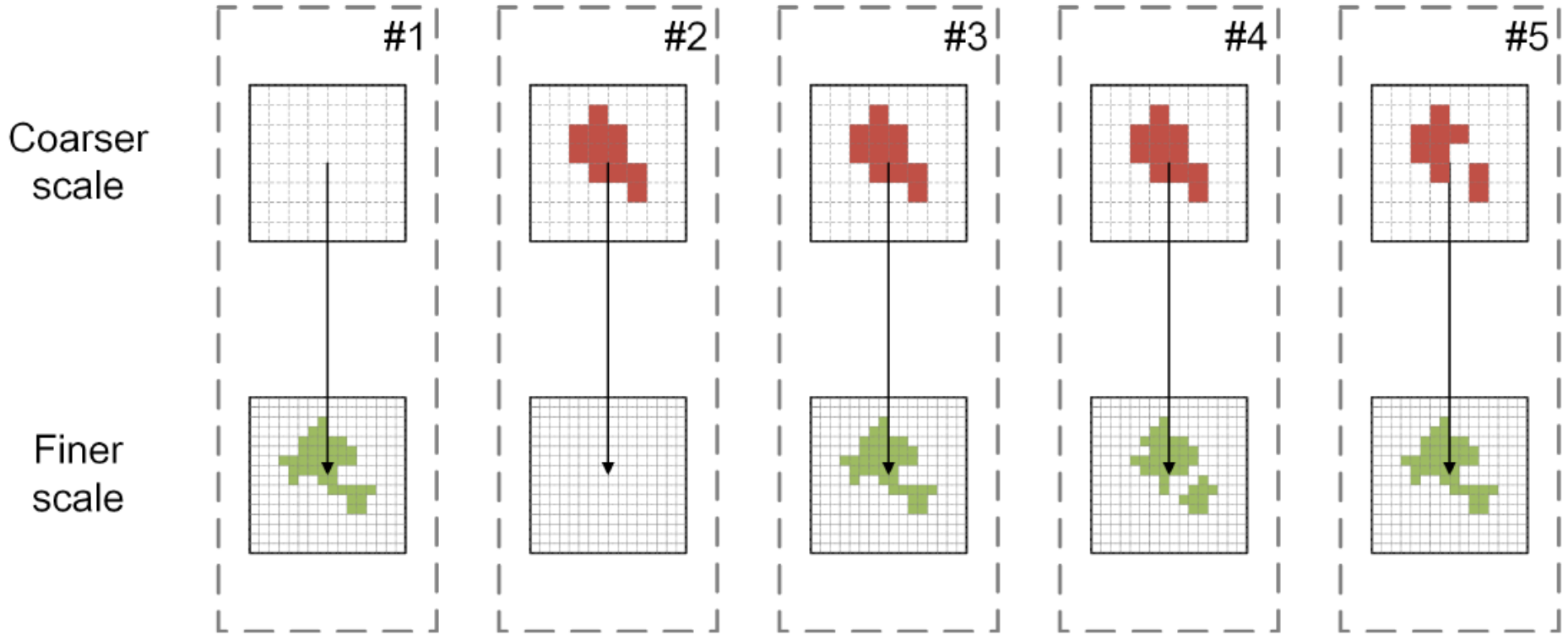
Anomaly detection at the coarsest scale



Visualization of influence range example

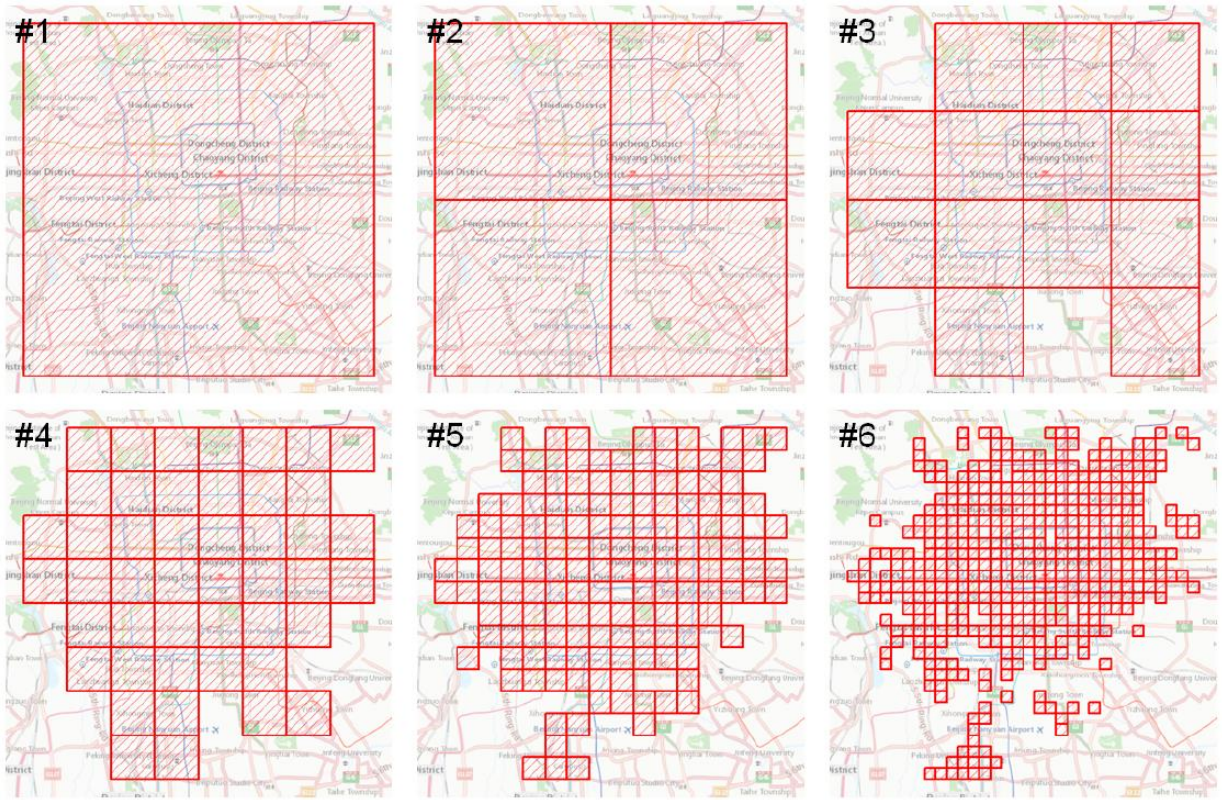
Experiment

- Case study of multi-spatial-scale anomaly detection
  - Anomaly matching at different spatial scales
  - Matching relationships: Creation, loss, continuation, splitting, and merging



Experiment

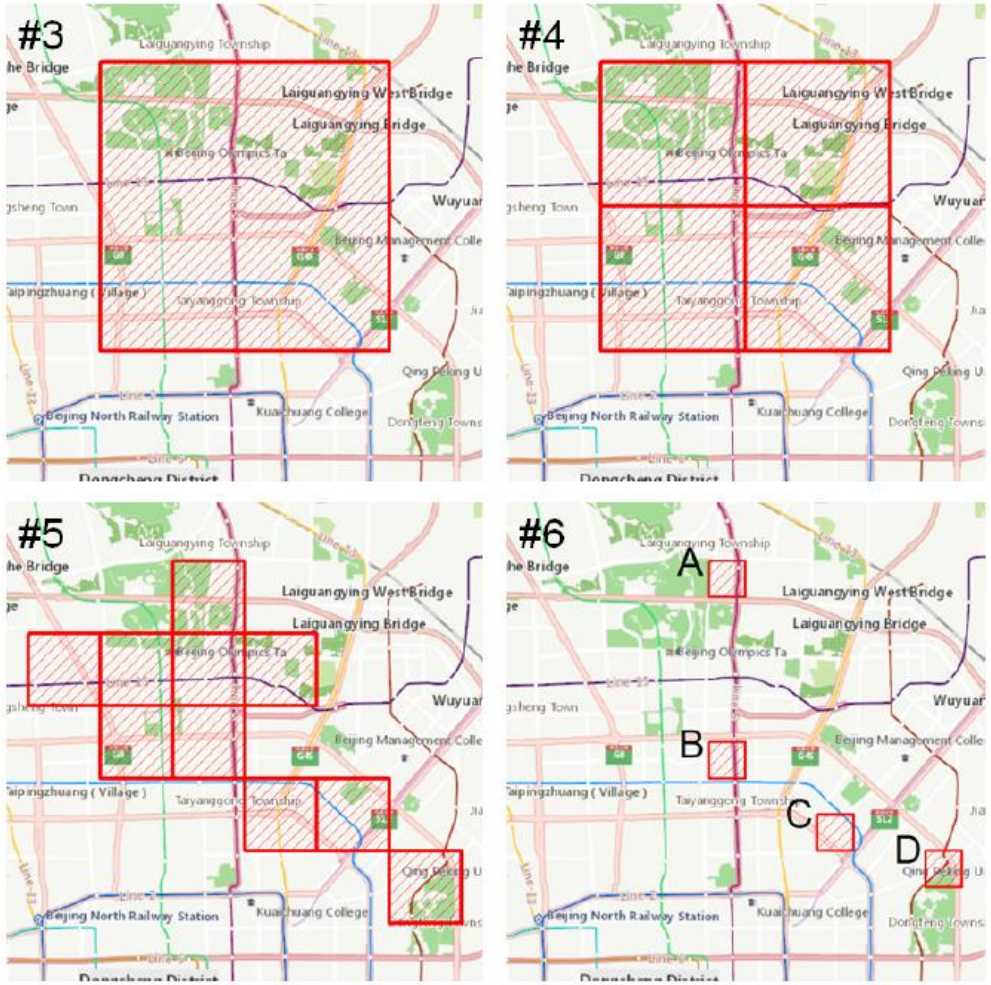
- Anomaly interpretation from a multi-scale perspective
  - ➢ Sample #1: Occurred on 15 Sep 2016
  - ➢ Coarse holiday arrangement data: the Mid-Autumn Festival (a traditional Chinese festival)
  - ➢ Fine points of interest (POI) data: Units with many transport POIs are more affected



Expressed spatial influence ranges at six scales

Experiment

- Anomaly interpretation from a multi-scale perspective
  - ➢ Sample #2: Occurred on 26 Aug 2016
  - ➢ Coarse mega-event data: the National Stadium, a Mayday (Chinese band) concert
  - ➢ Fine subway station data: Four non-adjacent zones are all close to subway stations



Expressed spatial influence ranges at four scales

Conclusions

- Conclusions
  - Scales are important in spatio-temporal anomaly detection of human activities
  - The proposed multi-scale method has good anomaly detection performance
  - Multi-scale characteristics of anomalies help the anomaly interpretation
- Other
  - Cheng, X., et al., 2021. Multi-scale detection and interpretation of spatio-temporal anomalies of human activities represented by time-series. *Computers, Environment and Urban Systems*, 88, 101627. https://doi.org/10.1016/j.compenvurbsys.2021.101627
  - Data and codes: https://github.com/GISCheng/multi-scale-anomaly

Thanks!

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