北京大学
PEKING UNIVERSITY

# A method to evaluate task-specific importance of spatio-temporal units based on explainable artificial intelligence

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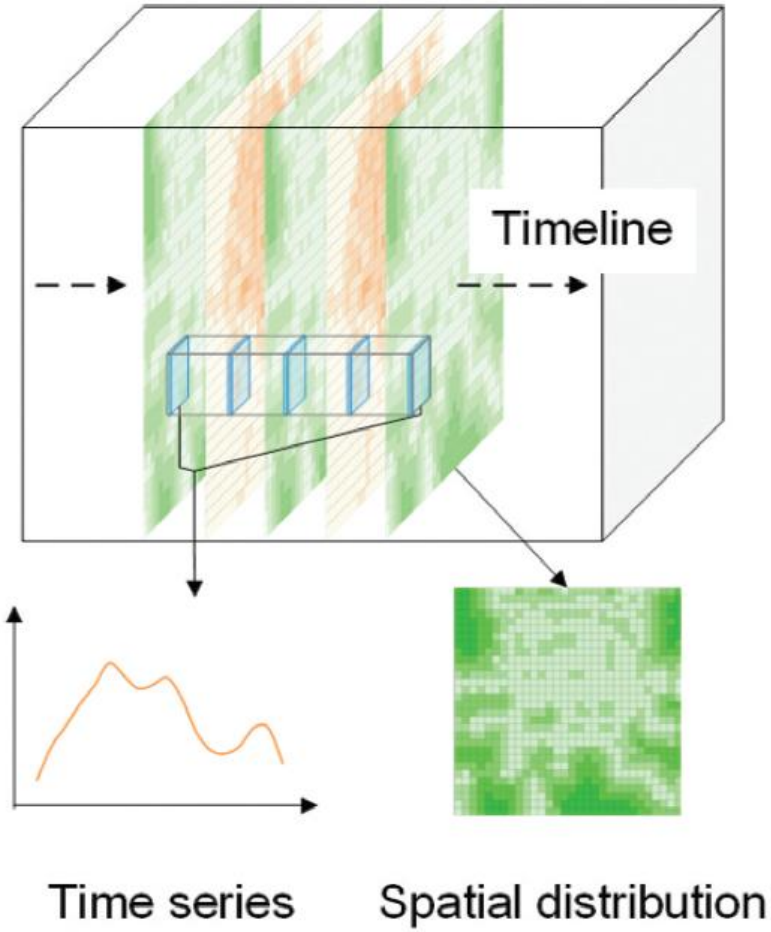
# Background

- Spatio-temporal data and data organization
  - Human activity data (e.g., social media check-ins) and earth observation data (e.g., remote sensing images)
  - Spatio-temporal units
  - Data organization in temporal dimension (i.e., time-series) and spatial dimension (i.e., spatial distributions)



# Background

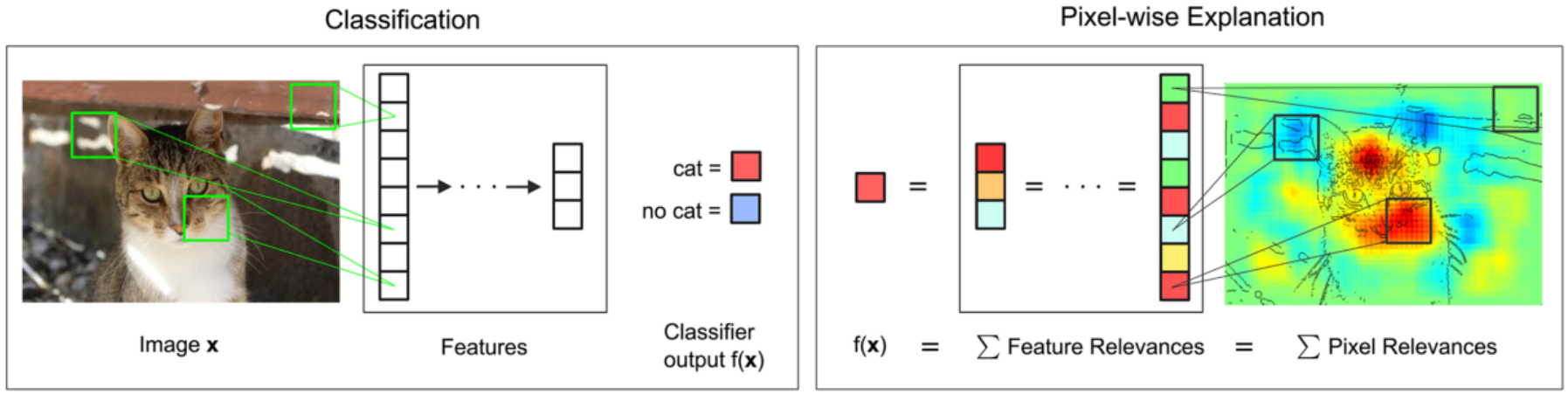
- Task-specific importance of spatio-temporal units
  - The contribution of the corresponding unit's characteristics to the task
  - The unit importance is different in a specific task (e.g., the study of rainfall's impact on traffic)
  - The unit importance will change with the task (e.g., nighttime is not as important as daytime in most studies but crucial in criminal research)

Well-drained segments with lower activity

Poorly drained segments with higher activity

# Background

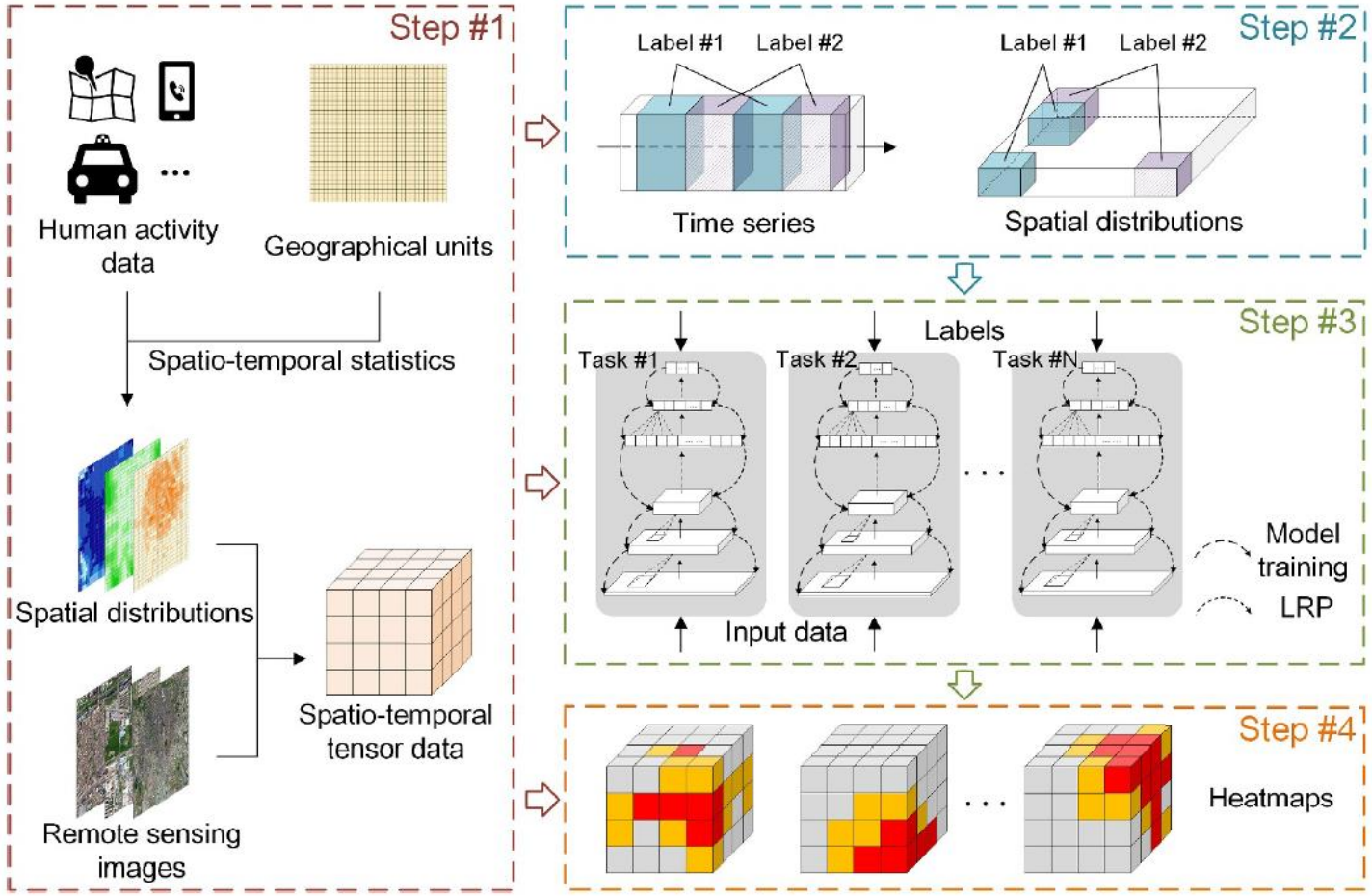
- Suitable methods to evaluate the task-specific importance of spatio-temporal units
  - The importance of units is task-specific
  - The method needs to consider the spatio-temporal dependence between units
  - The assessment results have physical meaning and can be extended to other applications
- Explainable artificial intelligence (XAI) methods
  - Layer-wise relevance propagation (LRP) algorithm (Bach et al., 2015)




Bach, S., et al., 2015. On pixel-wise explanations for non-linear classifier decisions by layer-wise relevance propagation. *PLoS ONE*, 10(7), e0130140.

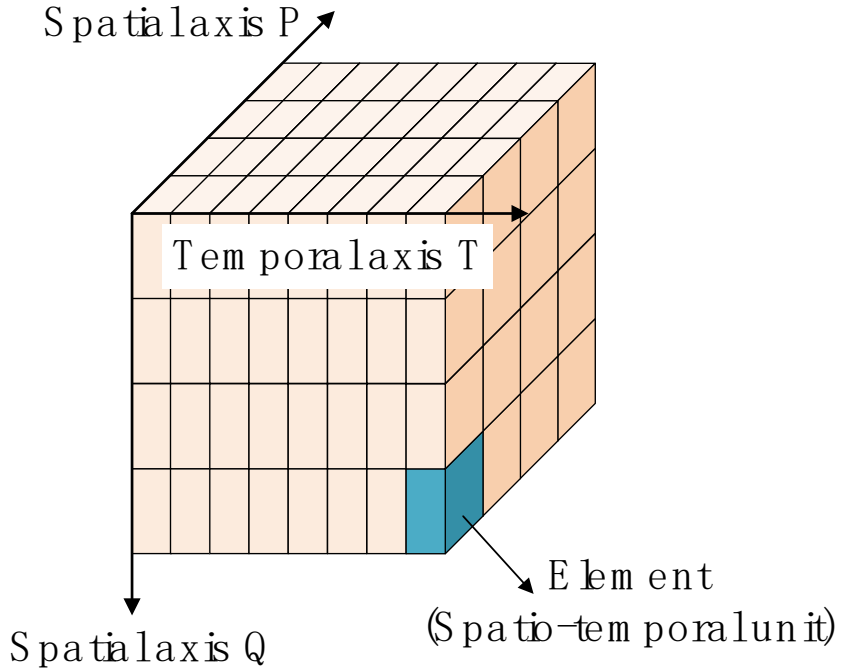
# Method

- Spatio-temporal layer-wise relevance propagation (ST-LRP) method
  - ➢ Four steps: data organization, data labeling, model training, unit assessment

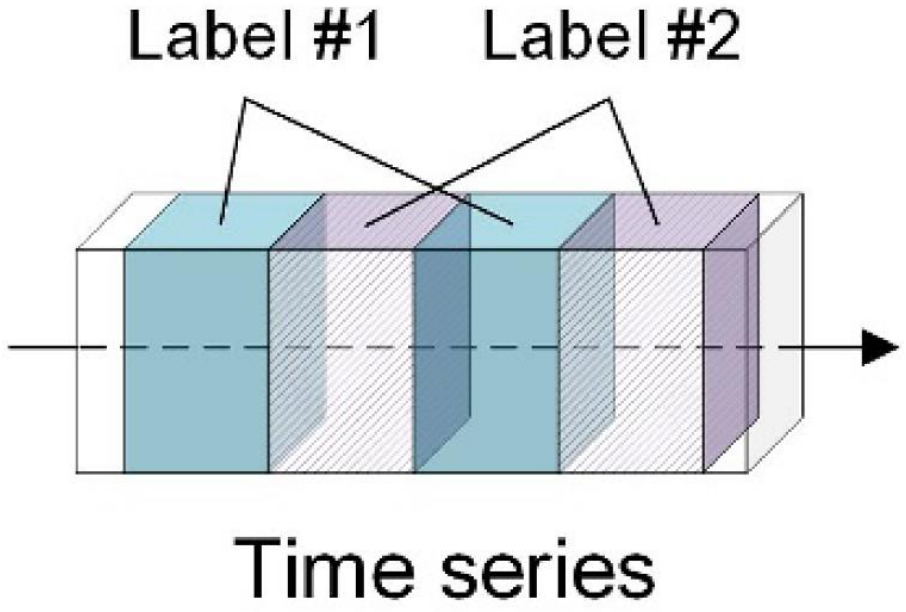


# Method

- Spatio-temporal layer-wise relevance propagation (ST-LRP) method
  - Data organization: Spatio-temporal tensor data (STTD)
  - Data labeling: Labeling the STTD according to its spatial or temporal information (e.g., season)




STTD structure




Data labeling according to temporal information

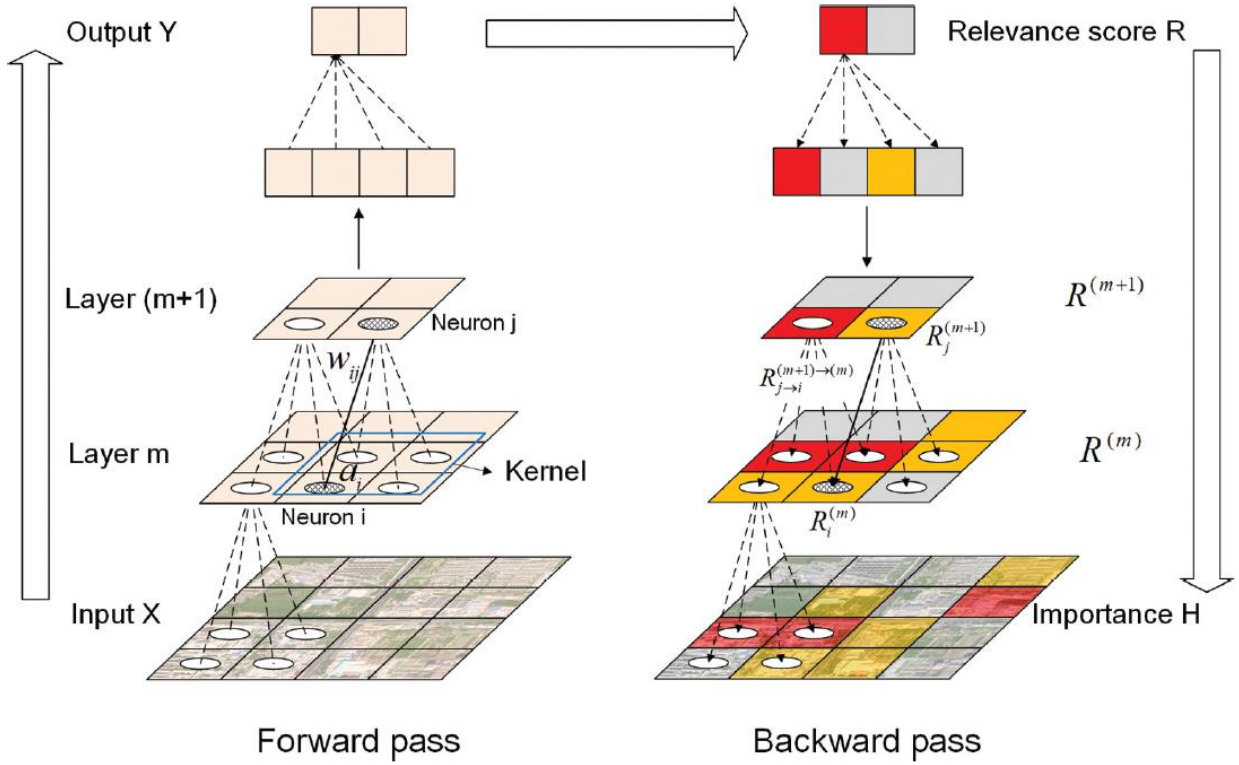
# Method

- Spatio-temporal layer-wise relevance propagation (ST-LRP) method
  - Model training: Labeled STTD as inputs and the training must be sufficient to extract knowledge
  - Unit assessment: LRP algorithm (Bach et al., 2015)

$$R = \cdots = R^{(m+1)} = R^{(m)} = \cdots R^{(1)}$$

$$R = \sum_{k=1}^{K} Y_k \ , R^{(m)} = \sum_{i \in l_m} R_i^{(m)}$$

$$R_{j \to i}^{(m+1) \to (m)} = R_j^{(m+1)} \frac{a_i w_{ij}}{\sum_{n \in l_m} a_n w_{nj}}$$

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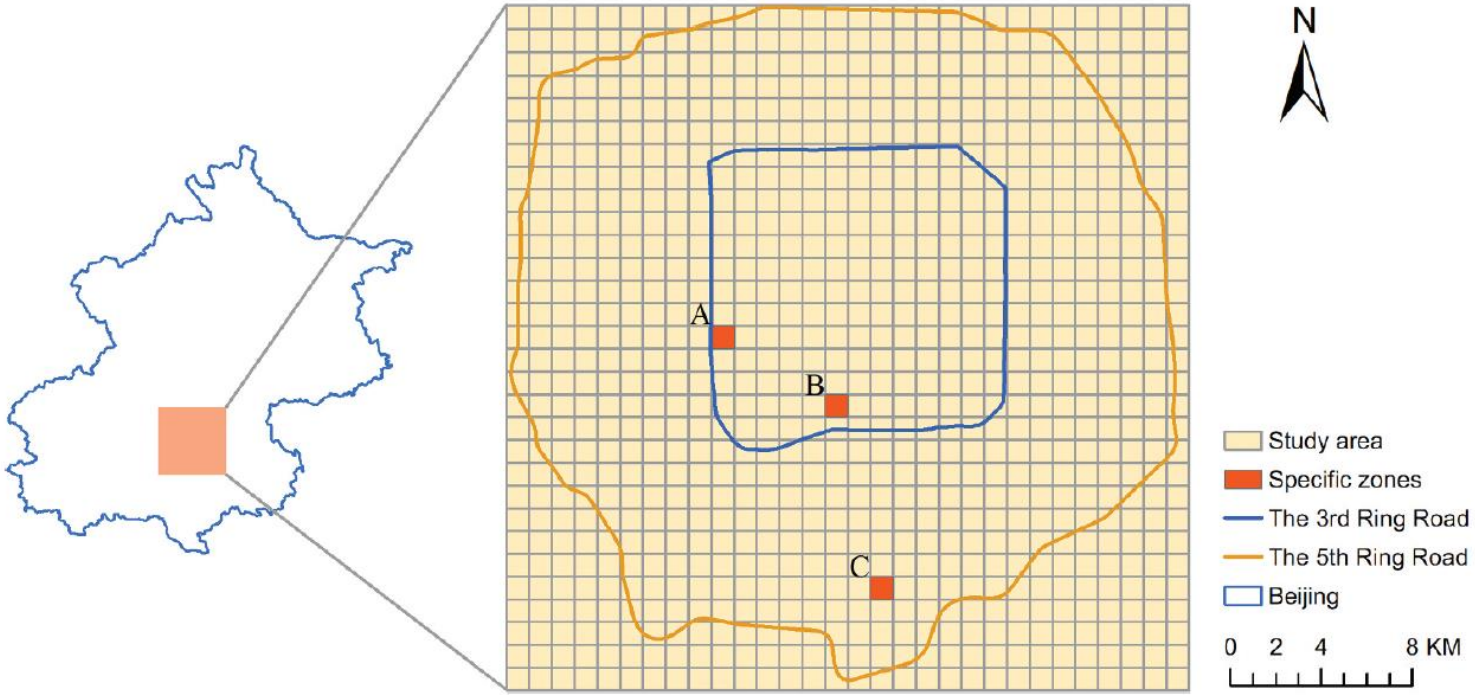
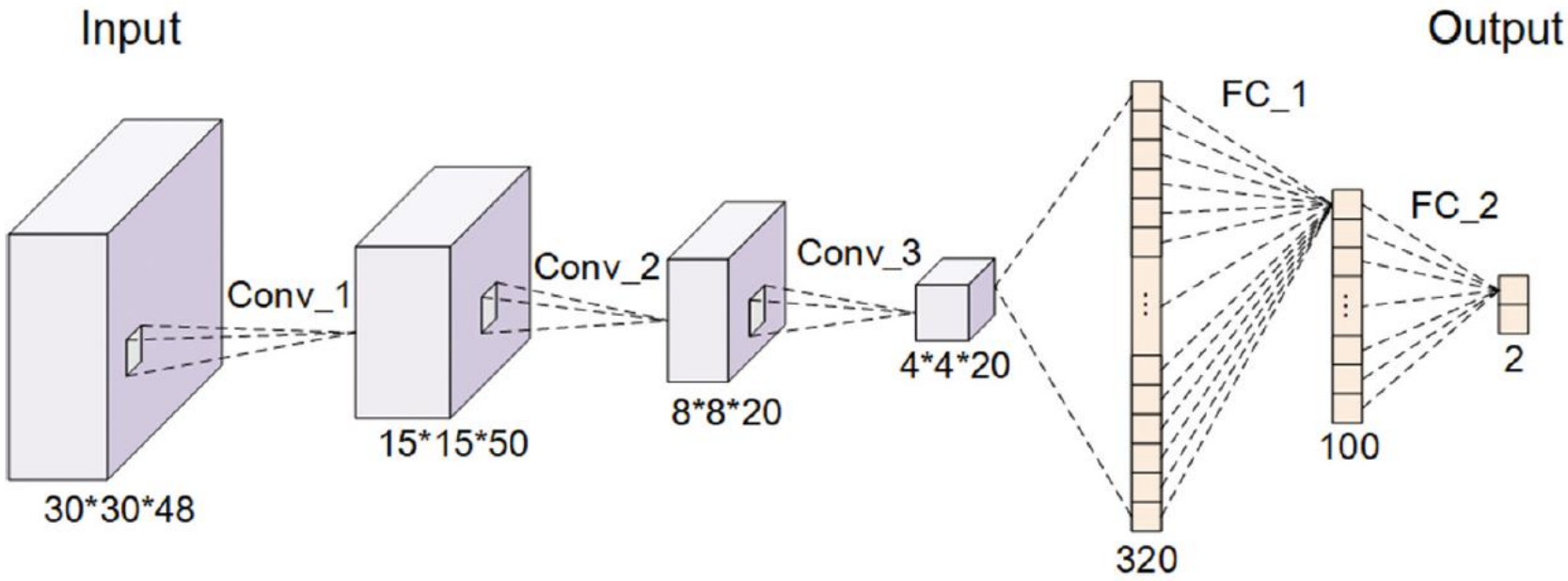
# Experiment

- Case study of spatio-temporal unit assessment
  - Data: Taxi origin and destination points (OD) collected in 2016
  - Study area: Center of Beijing, $30 \times 30\ km^2$ square area
  - Spatio-temporal unit: $1 \times 1\ km^2$ grid in spatial dimension and half-hour in temporal dimension



# Experiment

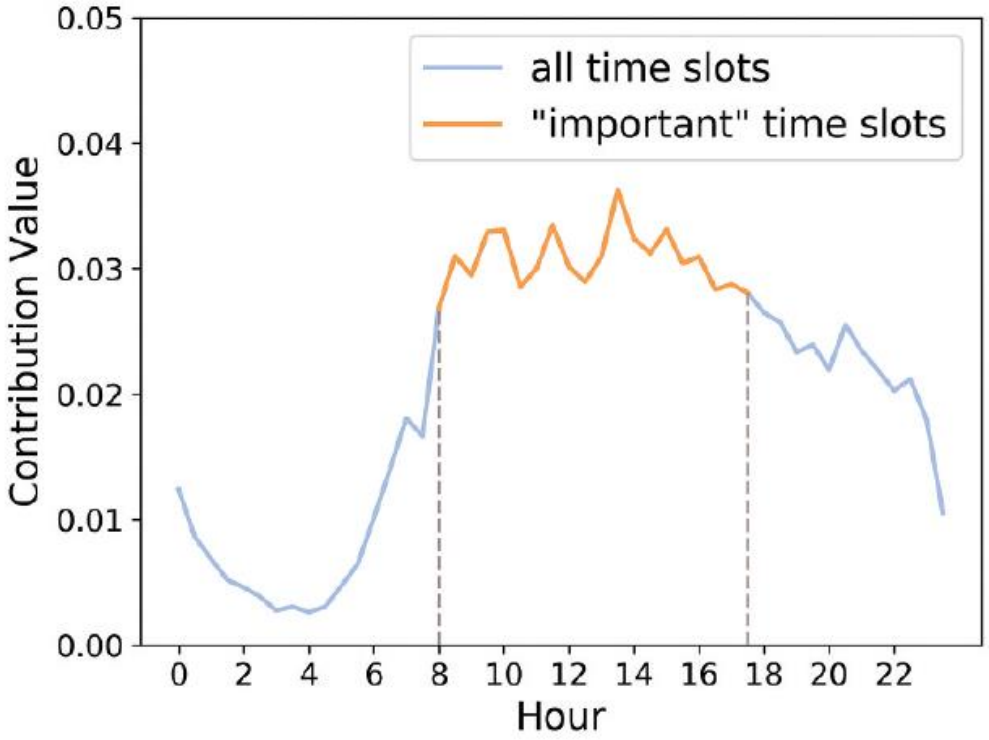
- Case study of spatio-temporal unit assessment
  - Input data: Spatio-temporal distributions of taxi origin point volume
  - Classification task: Distinguishing between distributions for weekdays and weekends/holidays



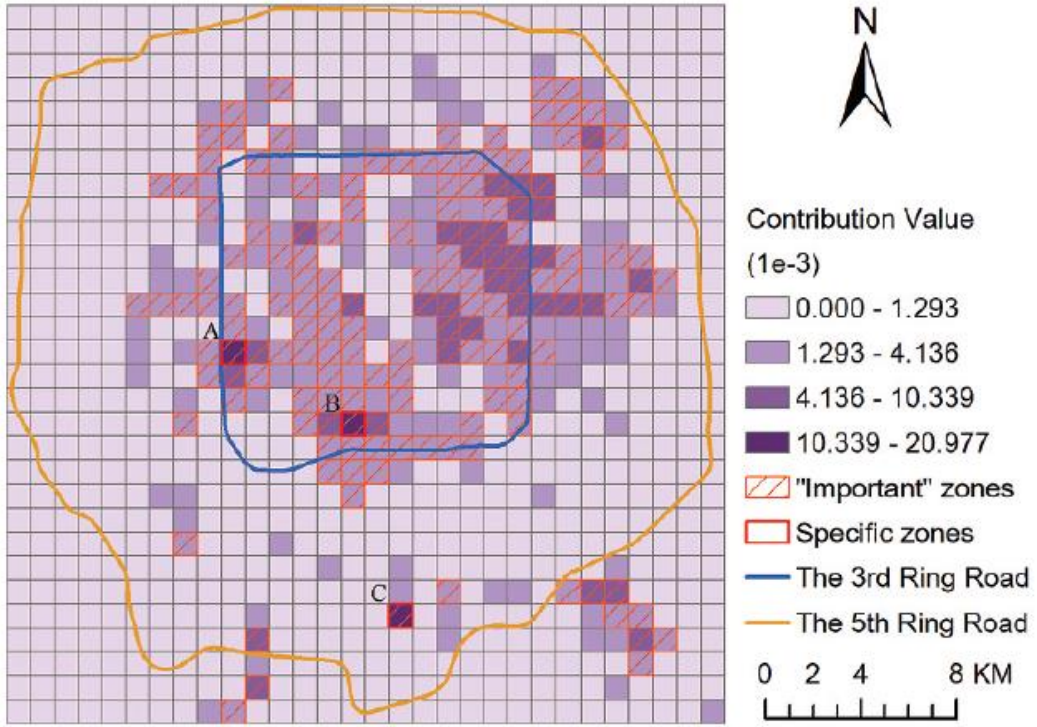

Neural network structure

# Experiment

- Case study of spatio-temporal unit assessment
  - ➢ Task-specific importance of spatio-temporal units



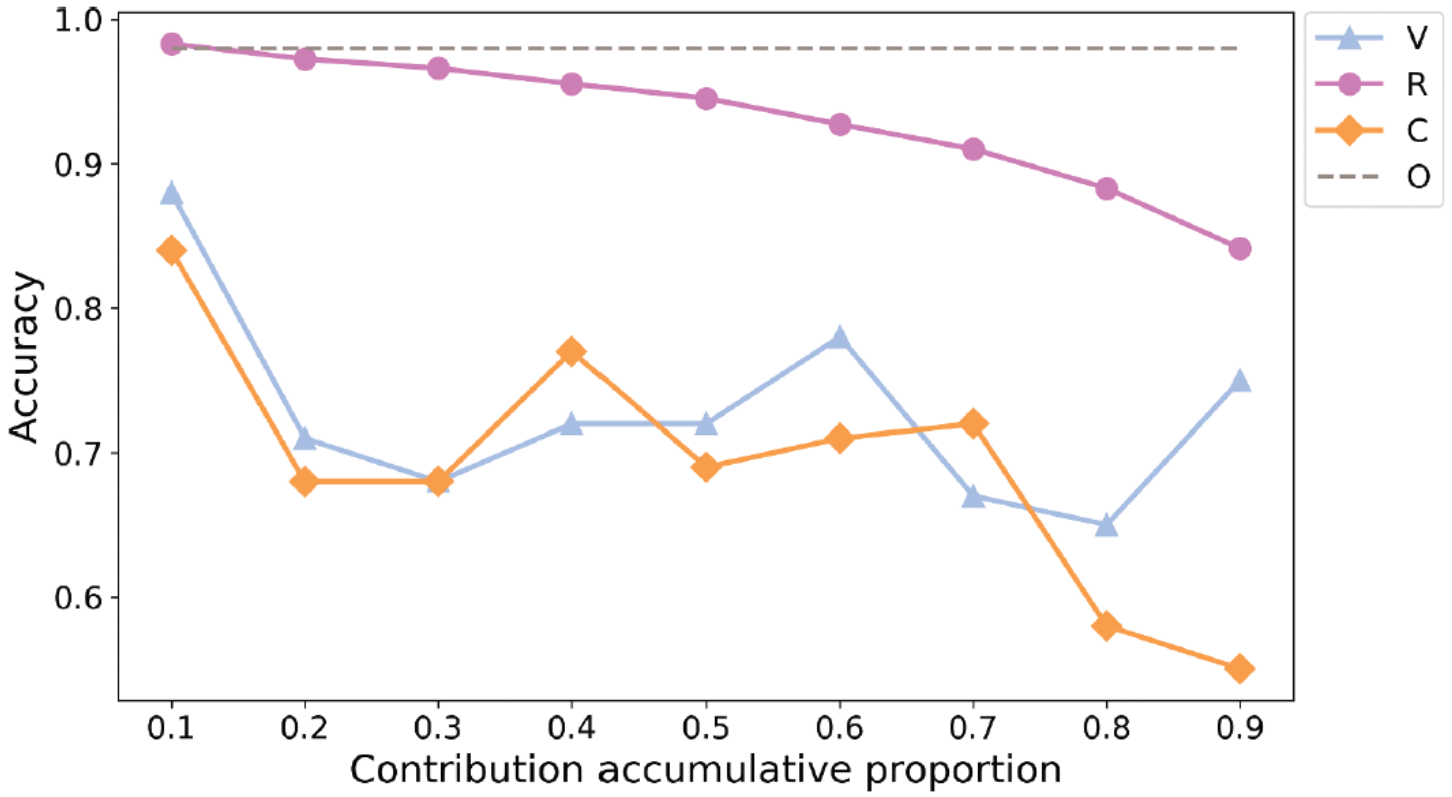

Unit importance in temporal dimension




Unit importance in spatial dimension

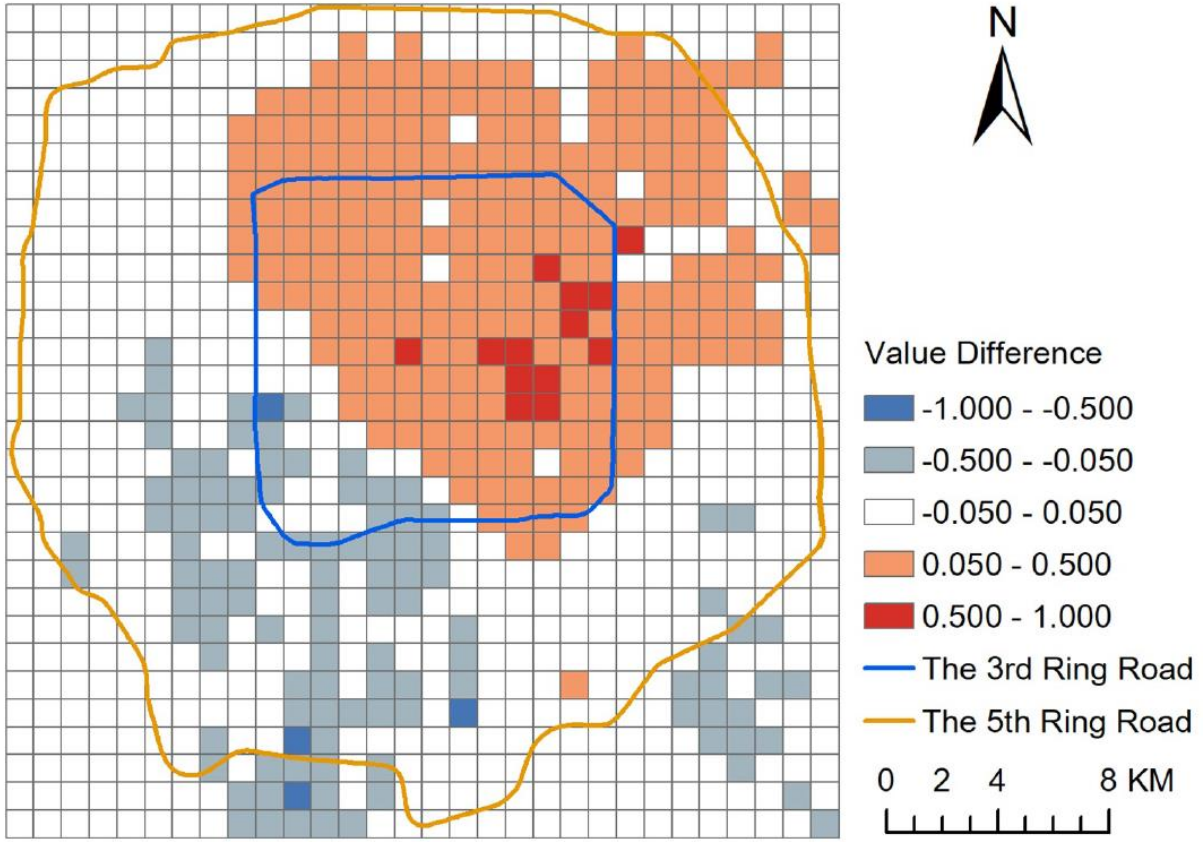
# Validation

- Validation of unit assessment results
  - Replacing the units' values of input data and to evaluate the variation of model accuracy
  - The more the accuracy decreases, the more the units are crucial for the classification task



# Validation

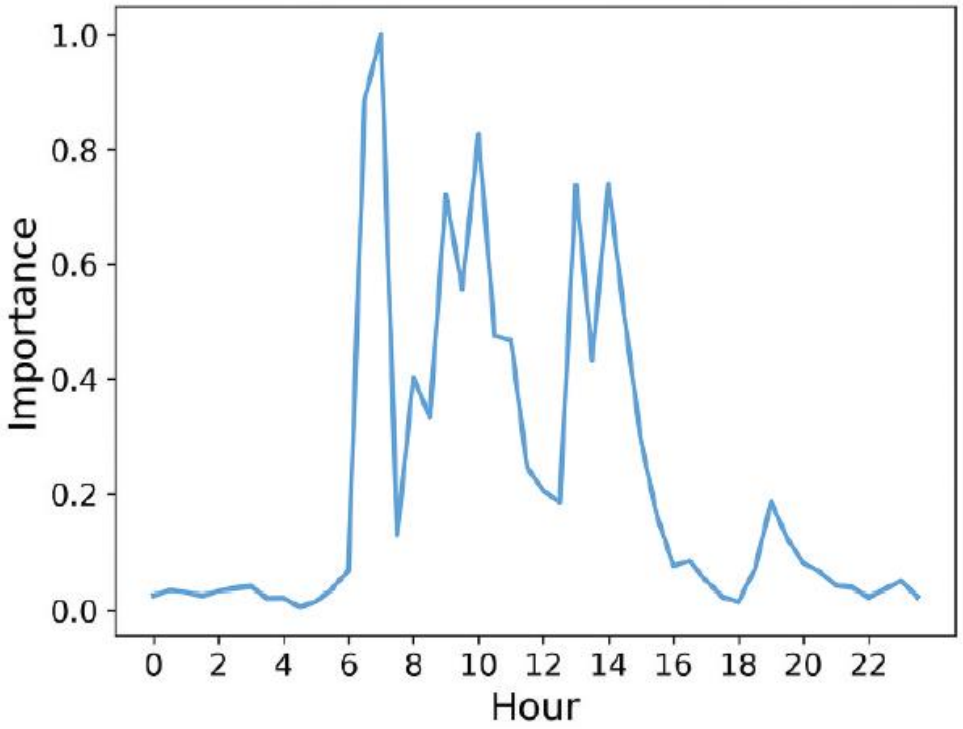
- Task-specific assessment results
  - Samples can have characteristics of both the two categories (e.g., weekends but working day)
  - Weekday: *Government* POIs
  - Weekend/holiday: *Entertainment*, *life services*, and *transportation* POIs



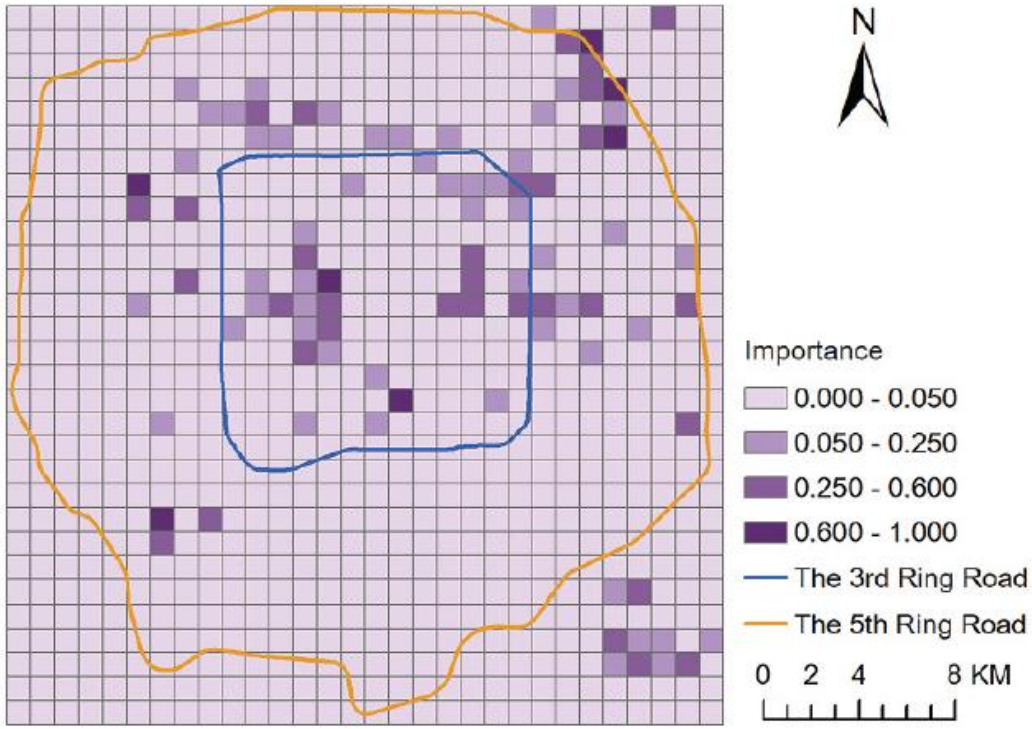

Contribution value differences based on the same input with different labels

# Validation

- Spatio-temporal dependence between units
  - ➢ Comparison method: Random forest algorithm



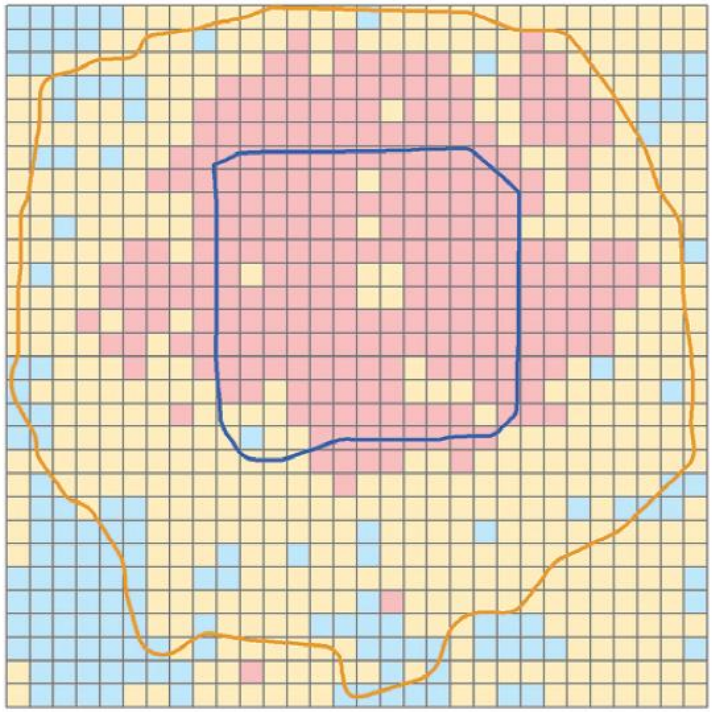

Unit importance in temporal dimension



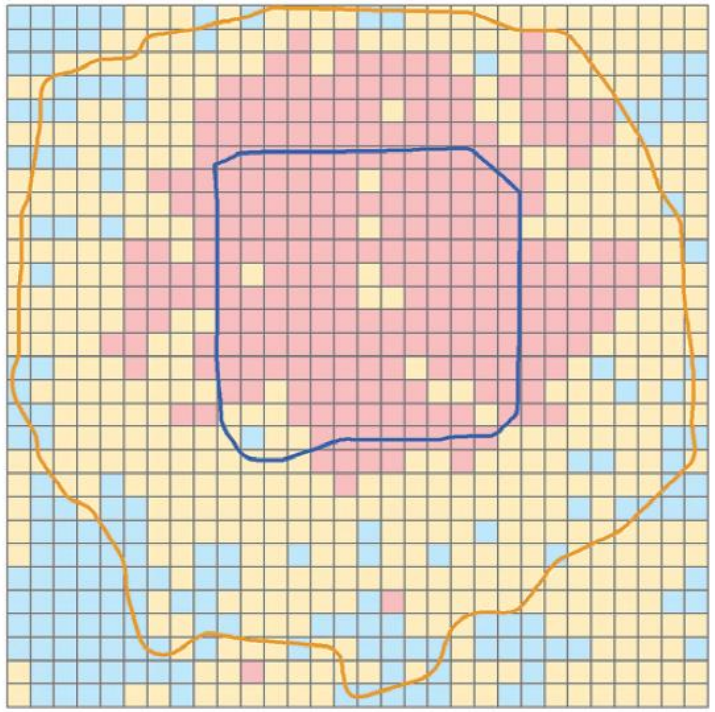

Unit importance in spatial dimension

# Validation

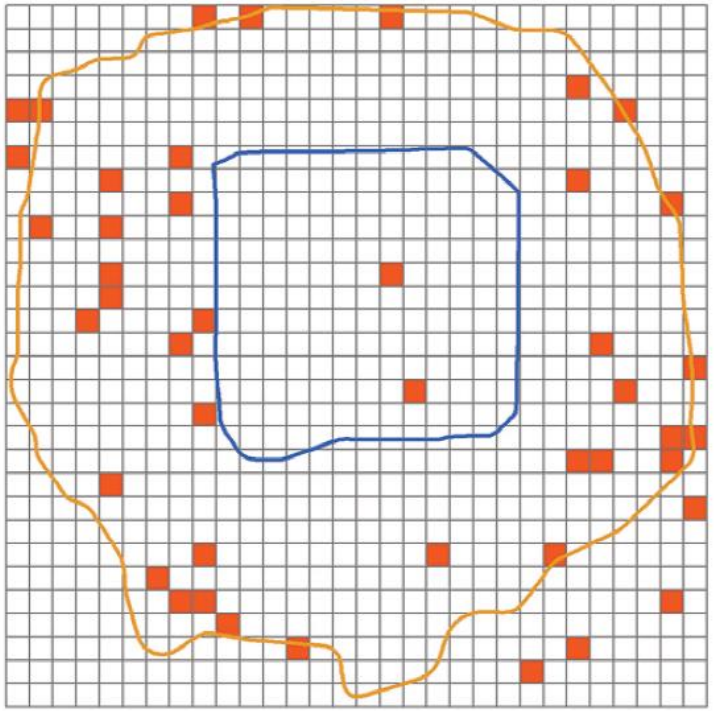
- Data compression application
  - Reducing the element number from 48 to 20 according to unit importance
  - Spectral clustering (only 4.89% units have different labels after data compression)



Clustering result based on data with 48 elements



Clustering result based on data with 20 elements



Differences between the two clustering results

# Conclusions

- Conclusions
  - The result of unit assessment is rational, task-specific, and valuable for data compression applications
  - The spatio-temporal dependence between units has been considered
  - The ST-LRP method based on XAI can be used to acquire knowledge in geographical studies
- Other
  - Cheng, X., et al., 2020. A method to evaluate task-specific importance of spatio-temporal units based on explainable artificial intelligence. *International Journal of Geographical Information Science*, in press. https://doi.org/10.1080/13658816.2020.1805116
  - Data and codes: https://github.com/GISCheng/ST-LRP


# Thanks!

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