Analyzing Land Use Mixing Degree using a Vector Data Cube with Hierarchical Cell

: A Case Study of Seoul, the Republic of Korea

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Backgrounds

❖ Backgrounds and Goals of Study

- Rapid evolution of cities has created new challenges in urban planning and management
- Precise mapping of urban land use type can significantly aid urban planning and urban system understanding

  → Quantitatively calculate a land use mixing degree
- Accurate evaluation of the mixed use of urban area is critical, particularly at a fine scale

  → Extract and evaluate an optimal spatial unit for the land use mixing degree

❖ Previous Studies

- Used multiple heterogeneous sources to identify and evaluate the construction of urban functional areas
- Used different measurement methods to measure the urban function mixing degree
- Applied one-size spatial units (often inaccurate owing to spatial heterogeneity)

Scope & Approach

❖ Scope of Study

- Calculation of the land use mixing degree by applying an information entropy(IE) to point of interest(POI) time-series data in a grid cell
  - ✓ Grid: National Grid(1,000m), POI: National Address Navigation DB(2021.07, 2023.05)
- Partition of grid cells according to the land use mixing degree
- Visual comparison of changes in cells over time with real-life data provided by a map service portal

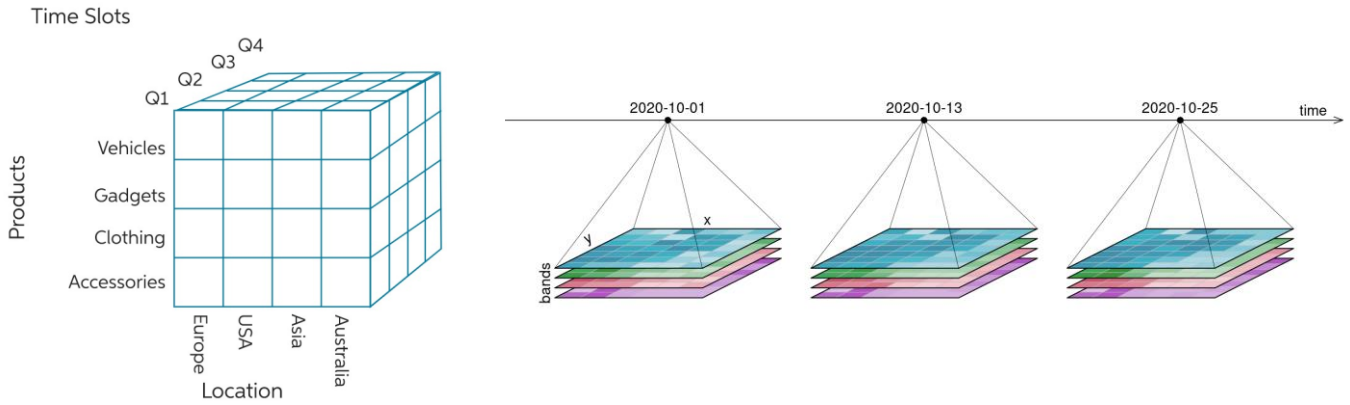
❖ Approaches of Study

- Re-classified the type of POI data into 10 refined categories
- Applied the information entropy(IE) method to analyze the mixing degree of each cell
- Each cell was hierarchically divided according to the land use mixing degree
- The partition of cells was performed iteratively based on the threshold value of IE
- The functional change of city was examined by analyzing the land use mixing degree in a fine-scale time series data, structured using data cubes for different spatial cell sizes in each time stamp

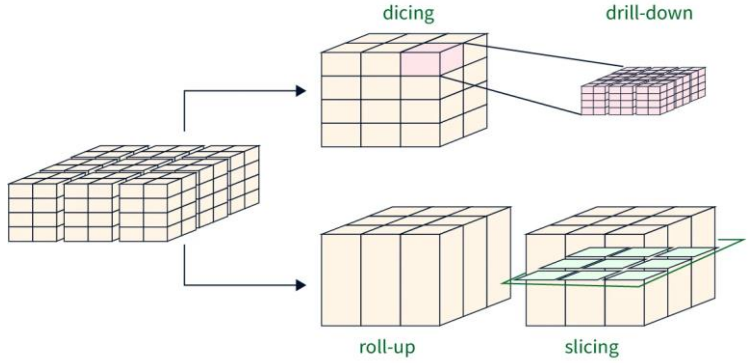
Scope & Approach

❖ Data Cube

- Data cube is multi-dimensional(n-D) array of values
- Originally used in BI(Business Intelligence) and OLAP(Online Analytical Processing) domain for data analysis
- Recently used in Earth Observation(EO) domain to manage spatially aligned time-series image/sensor data
- For spatio-temporal raster/vector data: geo data cubes(from OGC), vector data cubes
- Analysis-ready/flexible/extendable structure, easy to subset/slice/sample/aggregate, suitable for grid or raster type data



Samples of Data cube



Operations of Data cube

Method – IE Calculation

❖ Calculating Information Entropy (IE)

- IE is a physical concept to measure the disorder of a system and to measure the complexity and balance between systems
- Applied the types of POI data(10 categories) to calculate IE in each grid cell
- The complexity of the land use of the cell increases with an increase of IE
- Calculation process
  - ✓ The total number of POI of type k in cell m (k = 1, 2, …, 10)

$$A_k^m$$

  - ✓ The portion of POI type k in the grid cell m

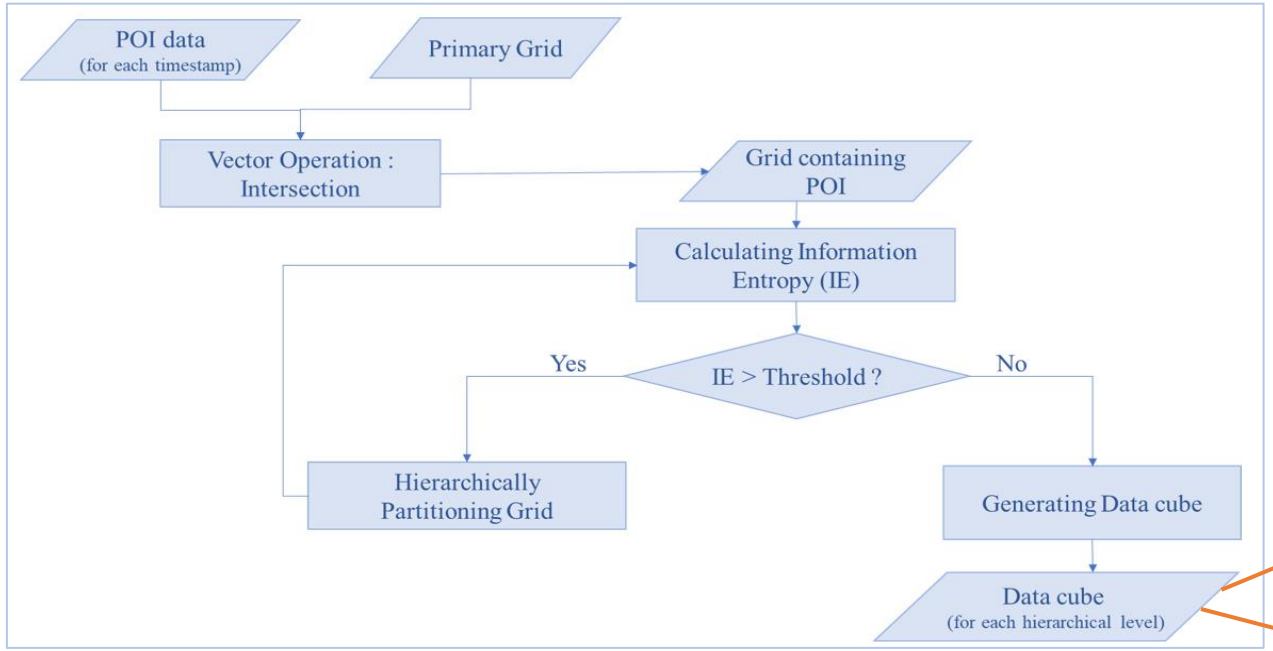
$$P_k^m = A_k^m / \sum_{k=1}^{10} A_k^m$$

  - ✓ IE of grid cell m

$$H^m = -\sum_{k=1}^{10} P_k^m \times \ln(P_k^m)$$

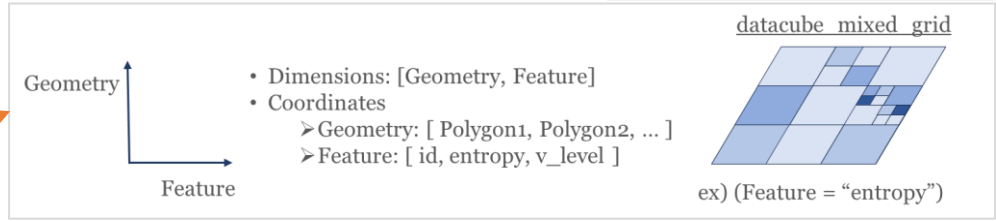
Method – Hierarchical Cells Partitioning

❖ Hierarchical Cells Partitioning

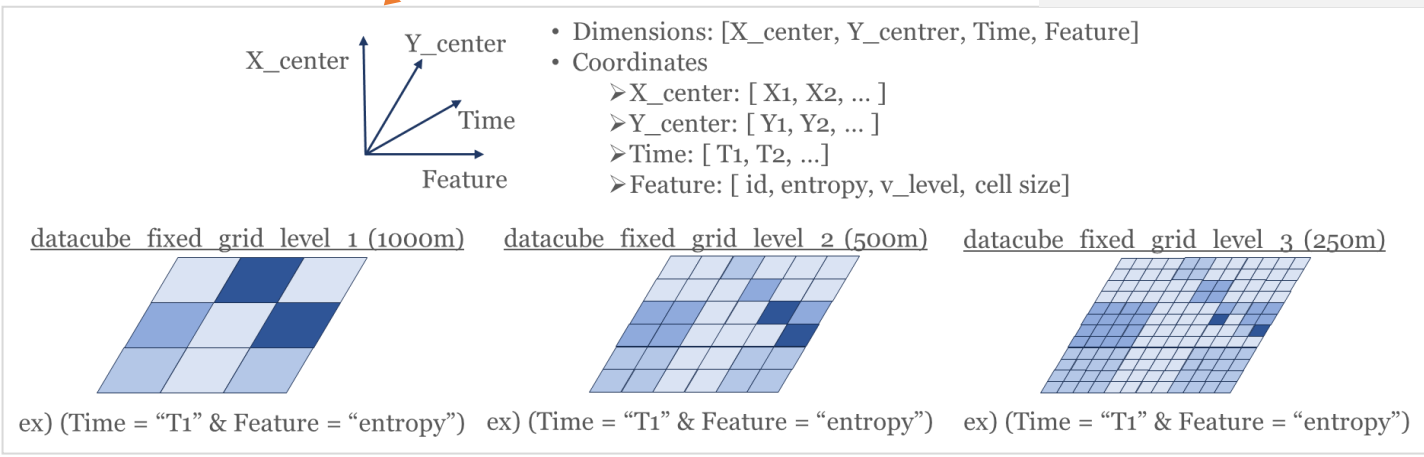


- A cell is partitioned iteratively if the IE of the cell is greater than the threshold value until it meets the maximum level
  - ✓ The threshold value is selected as the median value of the most occurrences range in the IE distribution graph
  - ✓ The maximum level is determined as 3 since a small granularity results in fragments, which might lead to lower identification accuracy

Vector Data cube

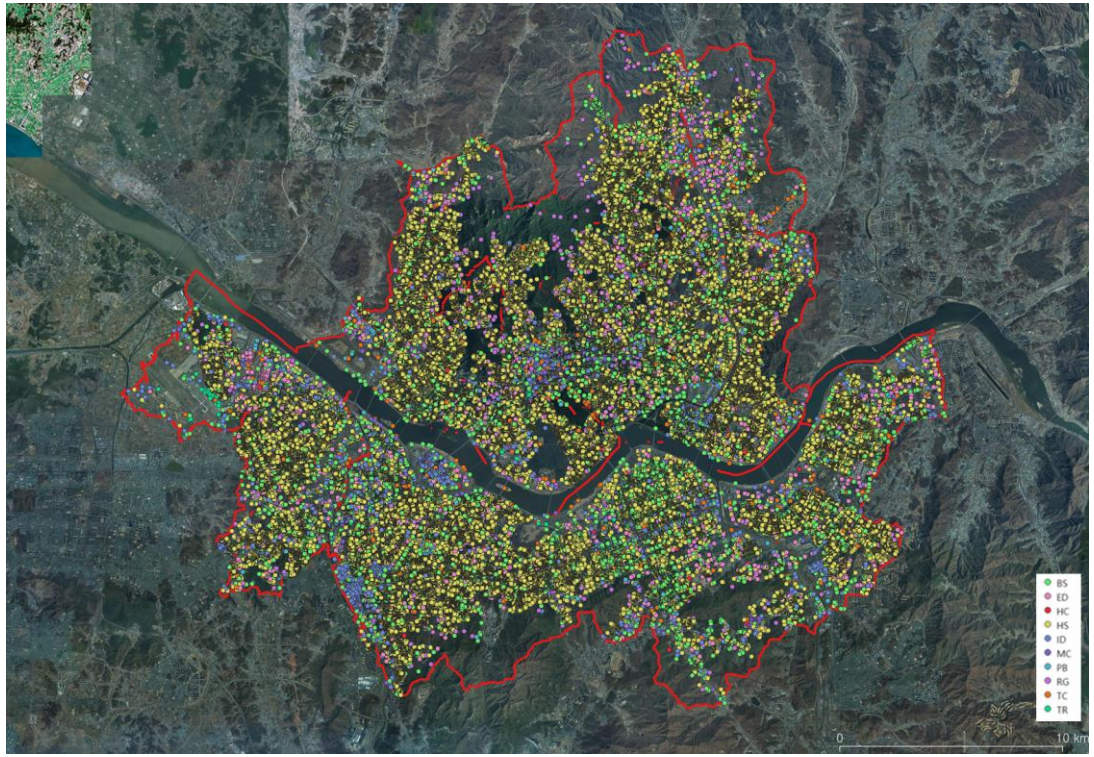


Hierarchical Data cubes



Test & Results

❖ Study area & Data sets



Study area (Seoul, ROK)

Data sets

	National grid (1,000 m)	POI (National Address Navigation DB)	
Date	2022.05	2021.07	2023.05
Number of features	710	608,325	597,599

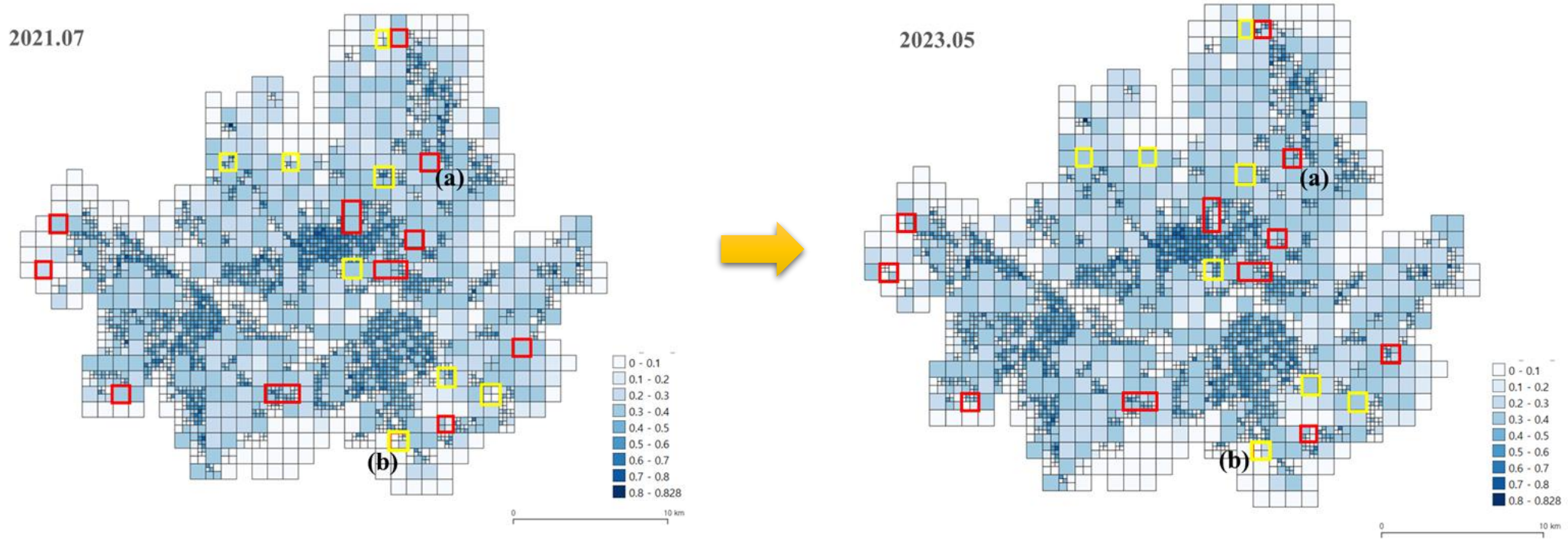
Categories of POI data

No.	Category	Details of the POI types
1	Business	Amusement facilities, livestock and fisheries facilities
2	Education	Educational and welfare facilities
3	Health	Hospital
4	Commercial	Catering, large shopping plaza, shopping
5	House	Residential region
6	Industrial	Factories or warehouse facilities
7	Public Service	Government, public library, senior citizen center
8	Religion	Religion
9	Tourism & Culture	Accommodation, Scenic spot, Cultural, tourism and leisure facilities
10	Transportation	Transportation facilities

Test & Results

❖ Partitioning results

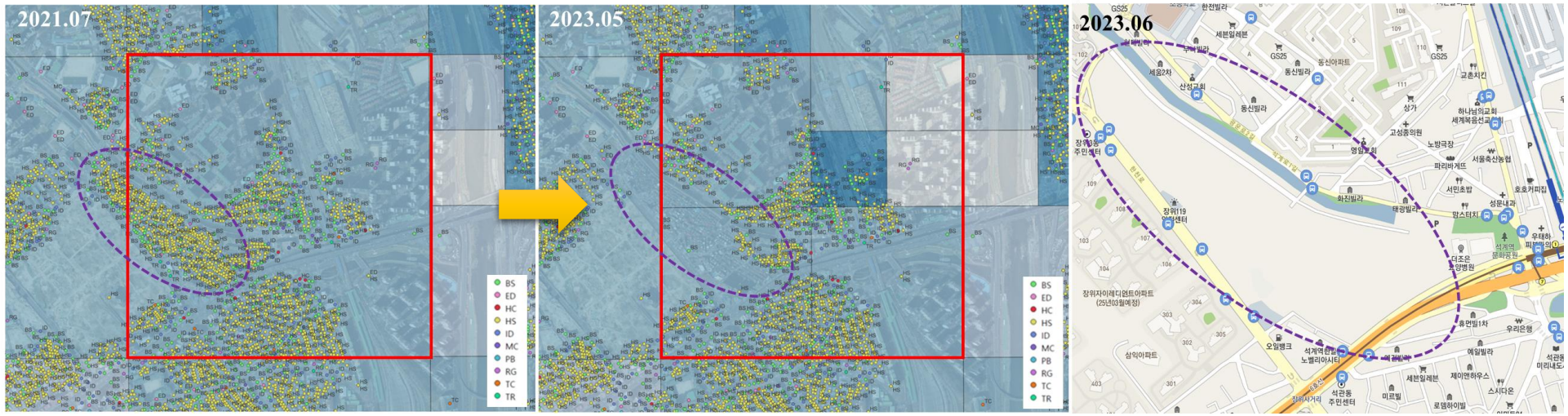
- Red box : Hierarchical level increases (smaller cells) → Land use mixing degree increases
- Yellow box : Hierarchical level decreases (bigger cells) → Land use mixing degree decreases



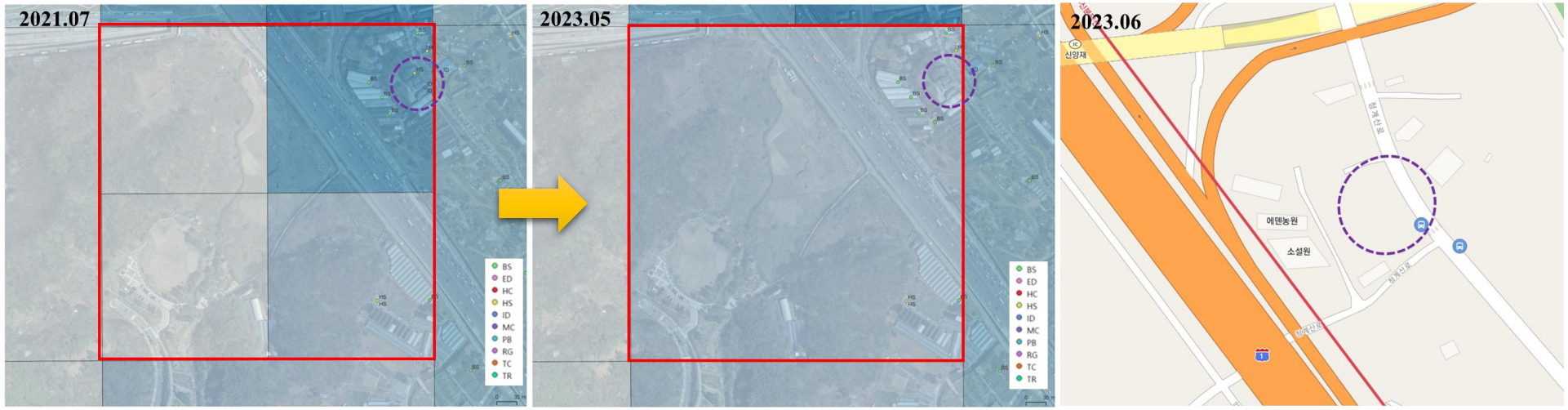
Vector data cube model for the time-series land-use mixing degree

Test & Results

❖ Visual evaluation with map service portal



- Red box : Increase in the land use mixing degree in the cell



- Yellow box : Decrease in the land use mixing degree in the cell

Conclusion

❖ Conclusion

- The time-series analysis of the land use mixing degree was performed using IE of POIs for each cell of grid
- Cells were partitioned to form hierarchical structures(as data cubes) according to IE
- Visual evaluations confirmed the significance of the proposed method

❖ Future Studies

- *As an ongoing study of a national funded project... developing and extending phases are ahead...*
- Should analyze the land use mixing degree using other real-life POI or multi-source data
- Should develop technologies for storing, indexing and managing vector data cubes
- Should improve method for determining IE threshold value and hierarchy level limit
- Should devise automated and quantitative methods for evaluations and verifications
- Should extend spatial dimension to 3D (Quadtree → Octree)
- Ultimate application targets
  - ✓ ex) urban and transportation planning by combining data of urban space features or transportation behaviors with the land use mixing degree

End of Document

Thank you!!!

Please, send us email for questions or opinions

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