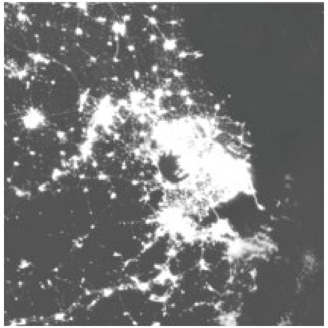
Detection, Accessibility, and Equity of Outdoor Sports Facilities in Shanghai



Xu Zhicheng

ECNU · School of Geographic Sciences

01

Introduction

01 Background

- Active physical exercise can effectively improve physical and mental health (Lee et al., 2021; Bourke et al., 2021)
- Physical inactivity contributes to 9% of premature deaths worldwide (Lee et al., 2012)
- Good stadium accessibility encourages people to participate in physical activity(Liu et al., 2020; Heath et al., 2012)
- Inadequate facility planning is an important reason why many people do not meet WHO recommendations for physical activity (Xiao et al, 2022)

01 Related works

Evaluate the accessibility and equity of different types of facilities

- Gaussian 2SFCA method with different population preferences was used to evaluate the accessibility of sports facilities in Dongguan City (Xiao et al.,2022)
- Using the Gini coefficient to evaluate the fairness of public sports facilities layout in Hangzhou (Chen et al., 2021)
- Evaluating the accessibility of sports facilities in Madrid and to explore its relevance to socio-economic conditions (Cereijo et al., 2019)
- Proposing a framework from data mining to accessibility and fairness evaluation and optimization, taking Shanghai as an example(Liu et al., 2024) *(My former work)*

01 Research gap

(1) Compared with hospitals, green spaces and other facilities, sports facilities have received relatively little attention.

(2) Facilities data is dependent on POI or census data, losing details.

(3) There are few applications of deep learning and other technologies in the object detection of outdoor sports Facilities.

01 The framework proposed in our previous work

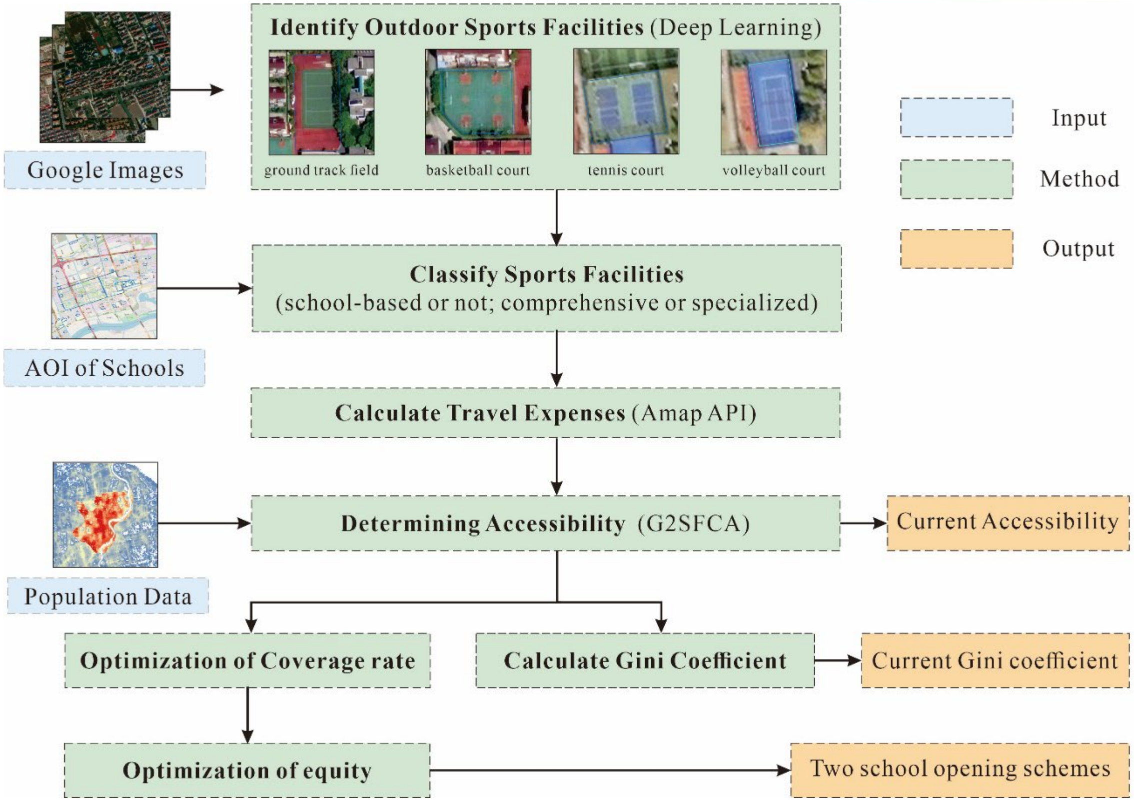
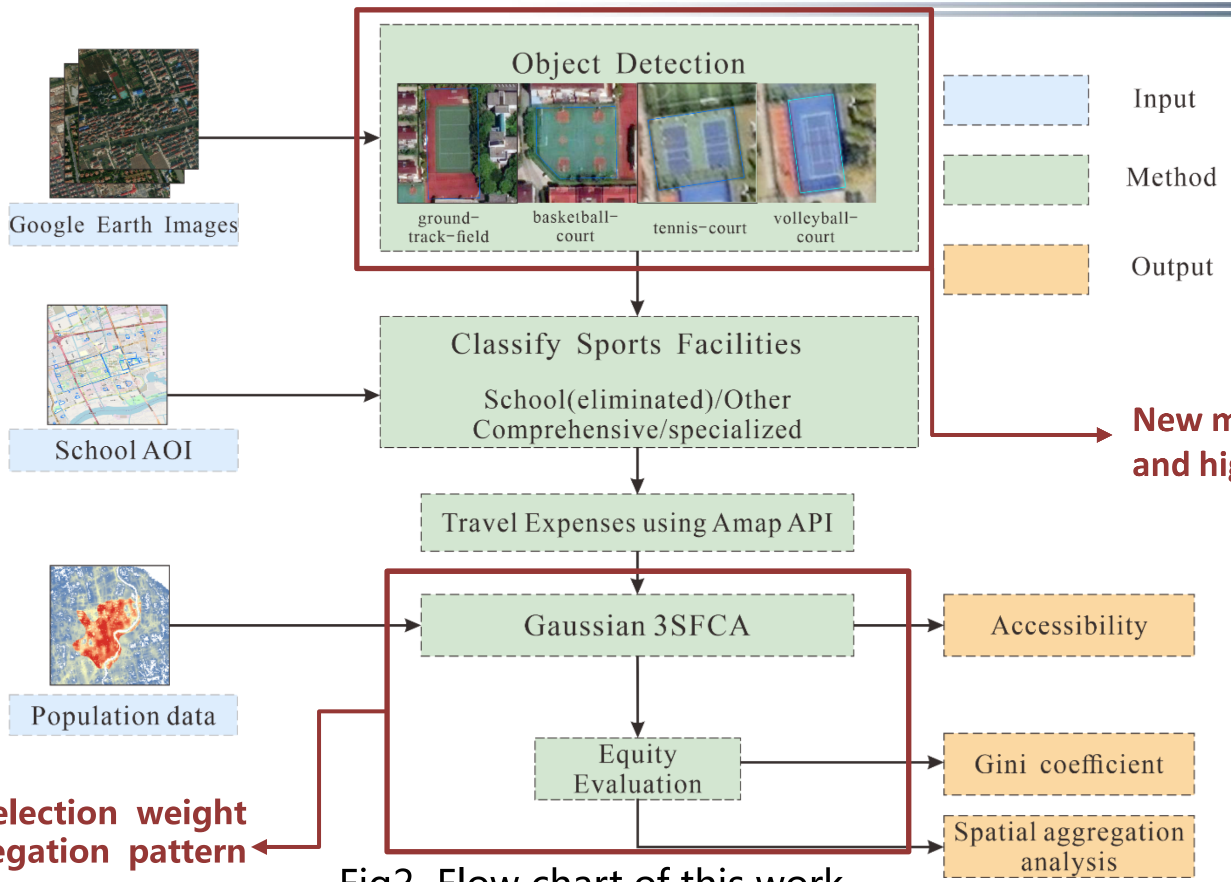


Fig1 Flow chart of previous work

01 Updated framework



New model with lower cost and higher performance

Adds a facility selection weight and spatial aggregation pattern analysis

Fig2 Flow chart of this work

02

Data & Methodology

Population：WorldPop

- Data for 2020
- 100 m resolution

↓

1km fishnet

Raw Images：Google/Baidu

- 28549 2048px*2048px images
- 0.298 m resolution （level 19）

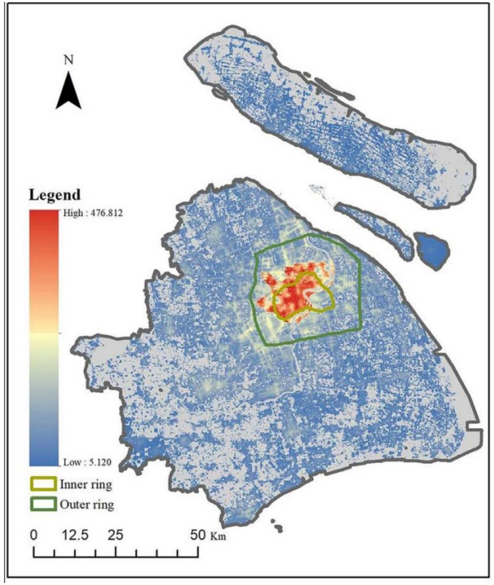


Fig3 Spatial distribution of population data and a sample of Google 19-level images

02 Methodology

Facilties detection：

- Ultralytics YOLO11-ob
- SAHI(Slicing Aided Hyper Inference)

Accessibility：

- G2SFCA->G3SFCA
- Calculate trip costs using the ride path planning API
- According to the 15-minute life cycle plan, the threshold is set at 15 minutes of cycling

Equity：

- Moran’ I & LISA Analysis
- Gini coefficient

Facility selection weight

$$w_i = \frac{\| area \|}{\| time \|} \qquad z_i = \frac{w_i - \mu}{\sigma} \qquad \boxed{w_f = \frac{z_f}{\sum_{f \in F} z_f}}$$

$$G(d_{pf}, d_0) = \begin{cases} \dfrac{e^{-\frac{1}{2}} \times (d_{pf}/d_0)^2 - e^{-\frac{1}{2}}}{1 - e^{-\frac{1}{2}}}, & if \quad d_{pf} \le d_0 \\ 0 & if \quad d_{pf} > d_0 \end{cases}$$

$$R_f = \frac{S_f}{\sum_{p \in \{d_{pf} \le d_0\}} G(d_{pf}, d_0) N_p}$$

$$A_p = \sum_{f \in \{d_{pf} \le d_0\}} R_f G(d_{pf}, d_0) \boxed{w_f}$$

G3SFCA

$$G = 1 - \sum_{i=1}^{n} (P_k - P_{k-1})(A_k + A_{k+1})$$

Gini coefficient

02 Base model fine-tuning

Model selection: Fine-tune the pre-trained model

- Using Ultralytics yolo11-obb model structure, it has been pre-trained on DOTAv1

- Base model link：
- https://github.com/ultralytics

- We only use YOLO11n and YOLO11s as the base and do not fine-tune the larger model.
- Model result:
- https://github.com/CatManJr/YOLOv11-Sports-Facilities

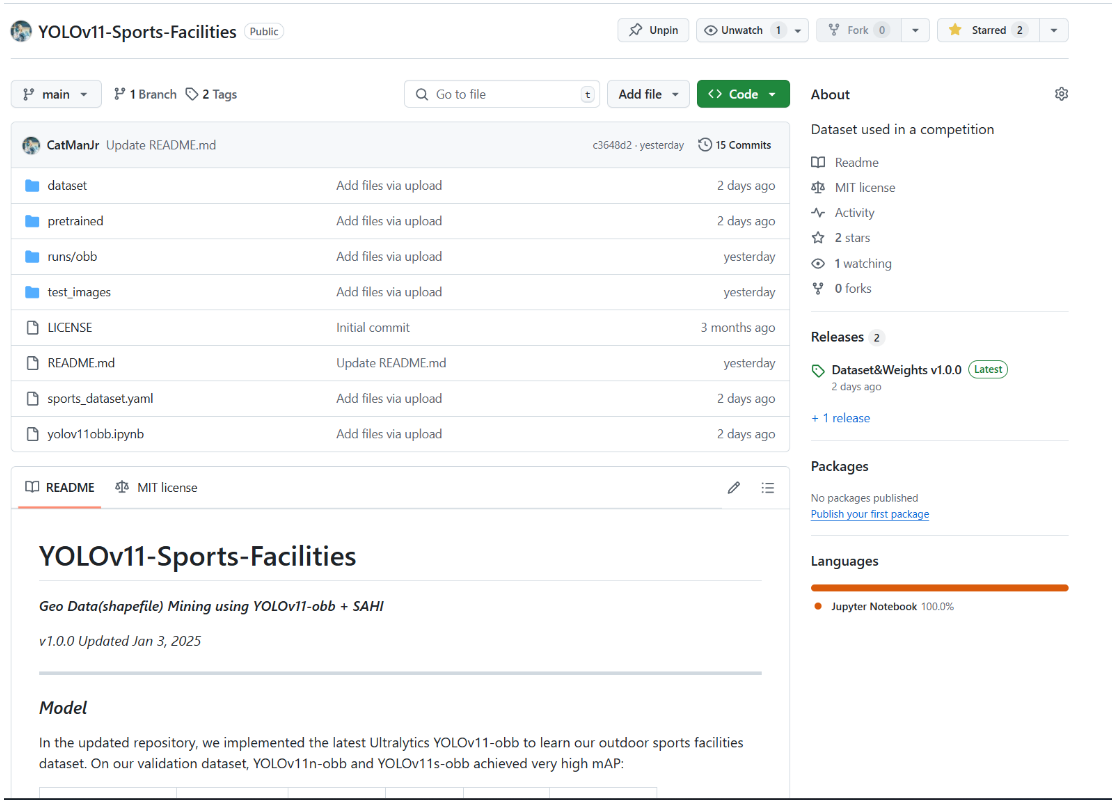


Fig4 our detection model and weights

02 Benchmark dataset

Use LocaSpace Viewer to download the latest 19-resolution remote sensing images

- Block in 16MB to obtain 2048×2048 resolution map tiles
- The benchmark dataset was constructed in Shanghai, and the sampling ratio was set according to the population and the number of schools in each district

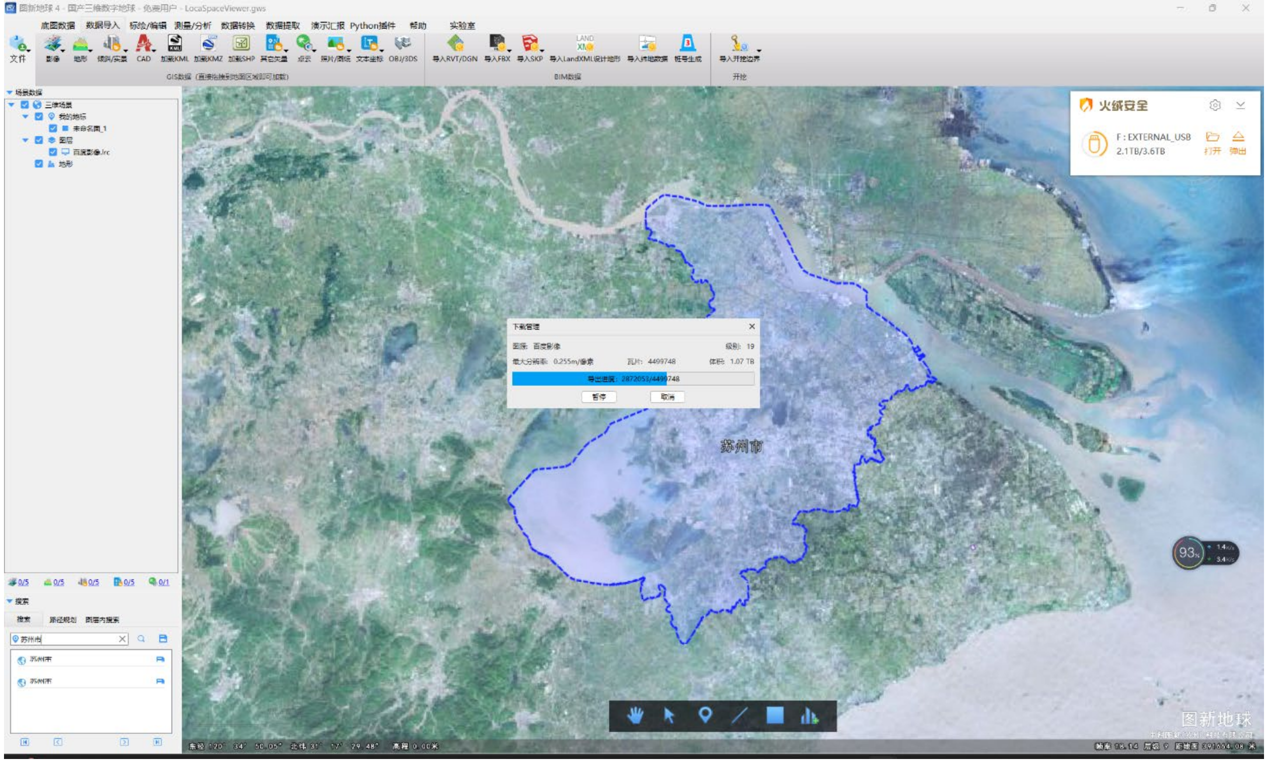


Fig5 download the latest 19-resolution remote sensing images

02 Benchmark dataset

Making Labels

- With the help of Clip and Prompt projects, tiles that may contain sports facilities are initially screened from remote-sensing images
- Code example: https://www.kaggle.com/code/catmanjr/zero-shot-potential-labels-finding-by-clip

- Use Labelme to manually draw the target box as the Ground Truth

- Use DOTA_devkit to split it into 1024×1024 subgraphs

```
prompt = ['a ground track field or a sports facility is in the photo',
          'a photo of forest',
          'a photo of cropland',
          'a photo of buildings',
          'a photo of bare land',
          'a photo of a water body',
          'a photo of a rooftop',
          'a photo of agricultural land',
          'a photo of a road',
          'a photo of industrial land']
```

a photo of industrial land

Fig6 CLIP classification

02 Data Mining

YOLO11s-obb performs slice-assisted reasoning and converts to shapefile

- SAHI is used to deal with the inconsistency between the size of the predicted input image and the picture of the training set.
- The geometric properties of the mask object are extracted from the inference result. Carry out projection coordinate mapping according to the world file and draw it as a shapefile polygon element

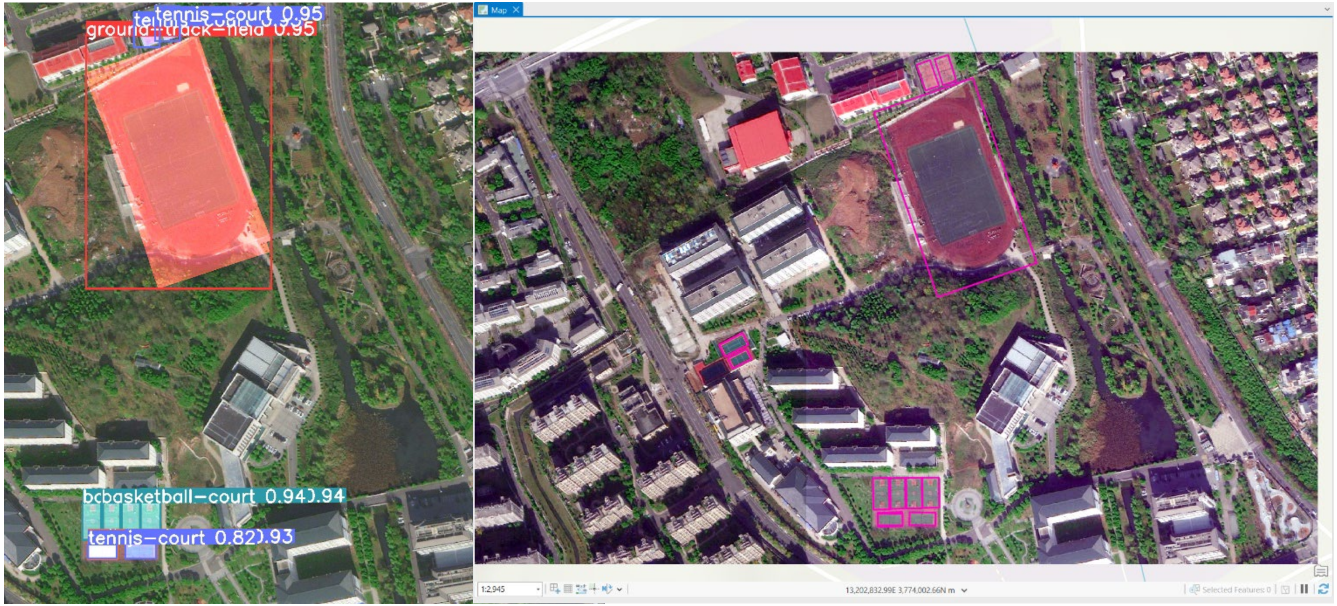


Fig7 SAHI inference sample and transform the resulting shapefile file

03

Case study

03

Research area

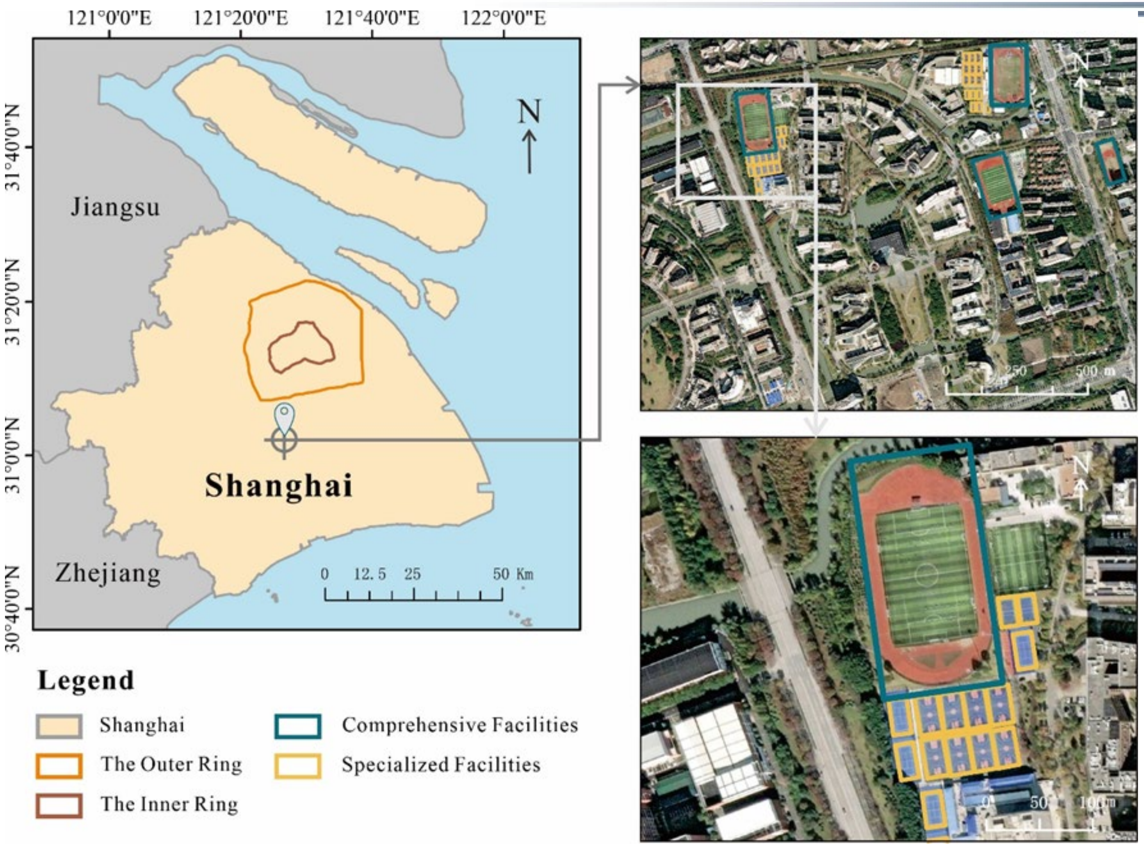
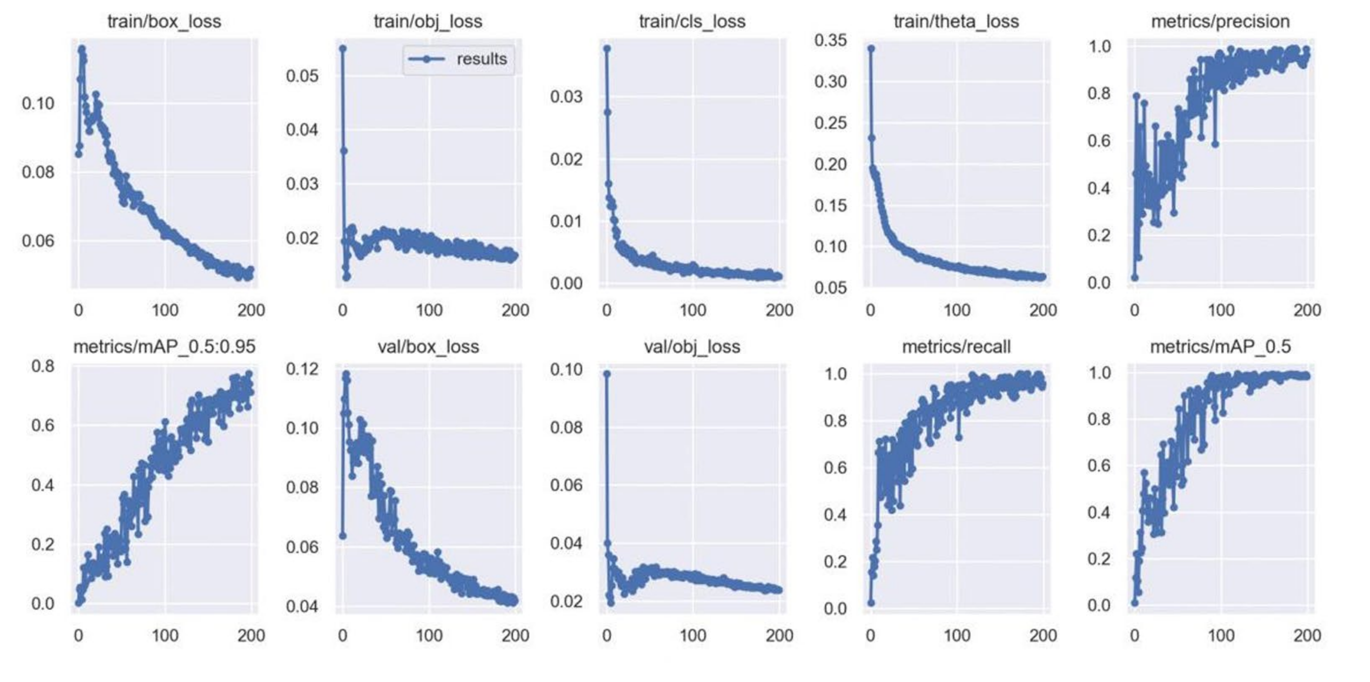


Fig8 research area

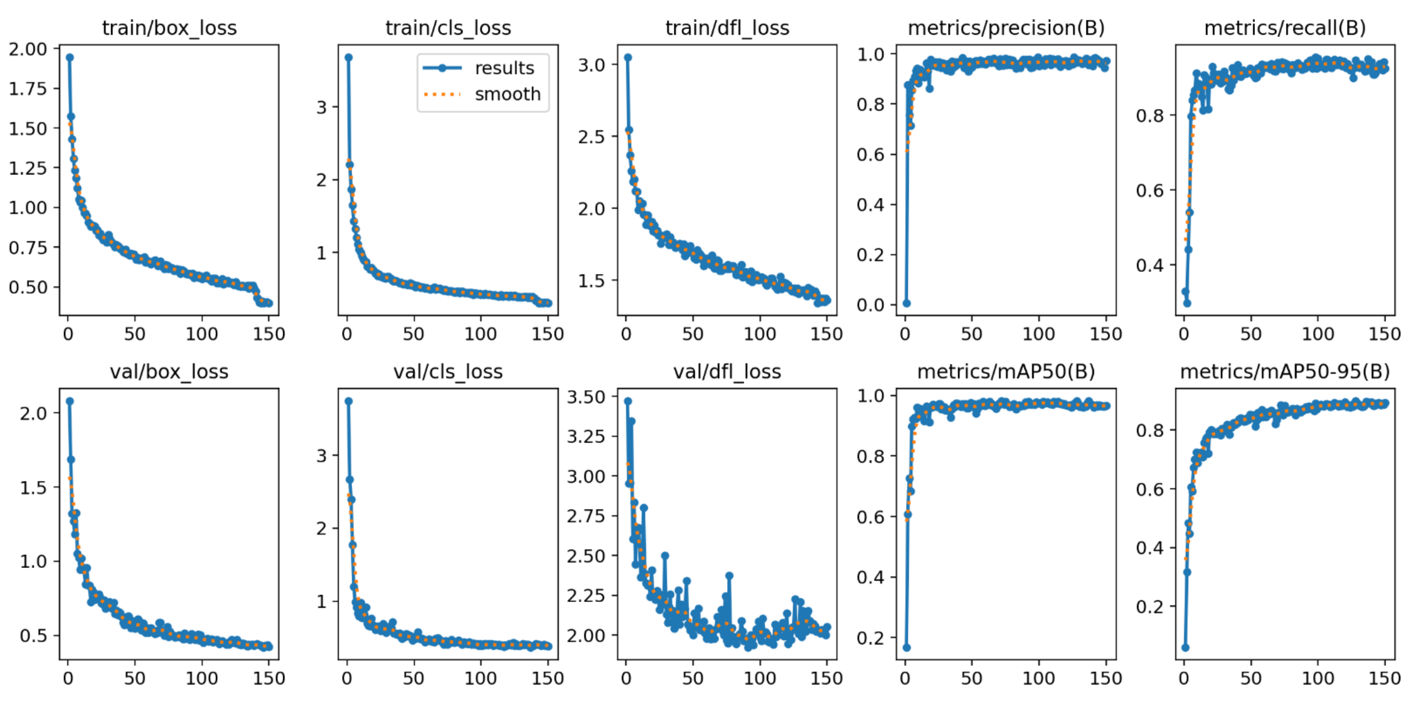
03 Facility detection result

Fig9 YOLOv5s-obb training results



03 Facility detection result

Fig10 YOLO11n-obb training results



03

Facility detection result

Fig11 YOLO11-obb test results

Model

In the updated repository, we implemented the latest Ultralytics YOLOv11-obb to learn our outdoor sports facilities dataset. On our validation dataset, YOLOv11n-obb and YOLOv11s-obb achieved very high mAP:

Model	Input Size	Precision(B)	Recall(B)	mAP50(B)	mAP50-95(B)
yolov11n-obb-100	1024 * 1024px	0.9647	0.93973	0.97289	0.87496
yolov11n-obb-150	1024 * 1024px	0.97194	0.92553	0.96654	0.89414
yolov11s-obb-200	1024 * 1024px	0.96612	0.95119	0.98045	0.93171

We found that although a larger model cannot get improvement in P & R, the detection boxes are much more satisfying.

Note that yolov11s-obb-200 may be over-fitted.

03 Accessibility and equity of city scale

Table1 the accessibility and equity result of G2SFCA the accessibility of Shanghai outdoor sports facilities

Region	Class	Population coverage(%)	Accessibility max	Accessibility min	Accessibility mean	Gini
The whole city	All facilities	97.9	15.9	0.0	0.29	0.58
	Comprehensive	77.8	7.18	0.0	0.17	0.69
	Specialized	97.69	15.9	0.0	0.13	0.52
Down-town	All facilities	100	0.25	0.0	0.08	0.39
	Comprehensive	92.5	0.19	0.0	0.05	0.45
	Specialized	100	0.18	0.0	0.03	0.44
Out-skirts	All facilities	99.98	1.06	0.0	0.16	0.41
	Comprehensive	91.88	0.83	0.0	0.12	0.51
	Specialized	99.8	0.26	0.0	0.06	0.35
Outer-suburbs	All facilities	96.08	15.9	0.0	0.31	0.6
	Comprehensive	65.26	7.18	0.0	0.17	0.72
	Specialized	95.68	15.9	0.0	0.14	0.51

The division of ‘Region’ is based on the ‘Inner ring’ and ‘Outer ring’ of Shanghai

The red highlight shows a poor level

03 Accessibility and equity of city scale

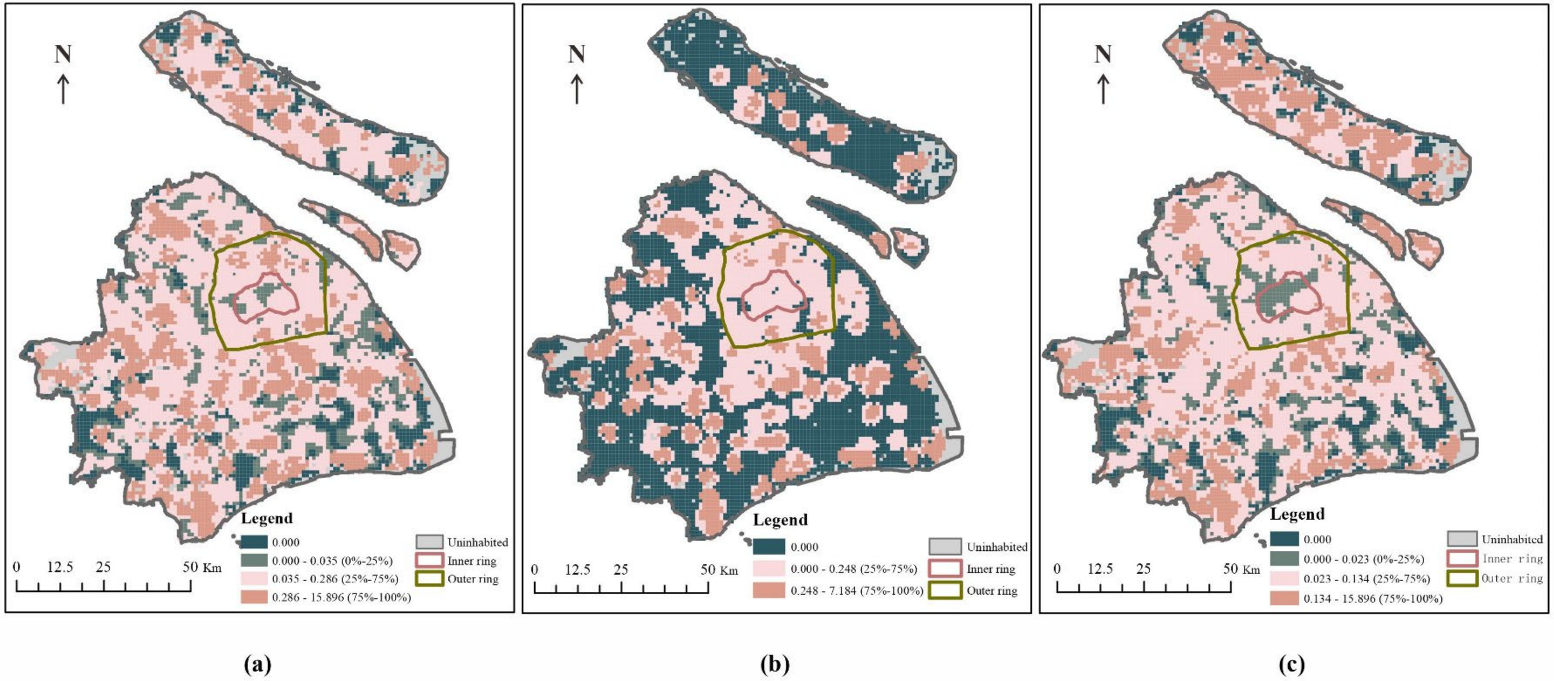


Fig12 the accessibility result of G2SFCA the accessibility of Shanghai outdoor sports facilities
a, b, and c correspond to all facilities, comprehensive facilities, and specialized facilities respectively

03 Accessibility and equity of city scale

Table2 the accessibility and equity result of G3SFCA the accessibility of Shanghai outdoor sports facilities

Region	Class	Population coverage(%)	Accessibility			Gini
			max	min	mean	
The-whole-City	All facilities	97.9	15.9	0.0	6.78e-2	0.68
	Comprehensive	77.8	7.18	0.0	0.11	0.73
	Specialized	97.69	15.9	0.0	0.035	0.69
Down-town	All facilities	100	1.1e-2	0.04e-2	0.38e-2	0.34
	Comprehensive	92.5	6.27e-2	0.0	1.52e-2	0.42
	Specialized	100	0.18	0.0	0.09e-2	0.27
Out-skirt	All facilities	99.98	6.36e-2	0.06e-2	0.92e-2	0.41
	Comprehensive	91.88	0.55	0.0	3.51e-2	0.5
	Specialized	99.8	1.90e-2	0.03e-2	0.23e-2	0.36
Outer-suburbs	All facilities	96.08	15.9	0.0	6.7e-2	0.63
	Comprehensive	65.26	7.18	0.0	0.11	0.72
	Specialized	95.68	15.9	0.0	3.79e-2	0.62

The division of ‘Region’ is based on the ‘Inner ring’ and ‘Outer ring’ of Shanghai

The red highlight shows a uprise and green highlight shows a drop

03 Accessibility and equity of city scale

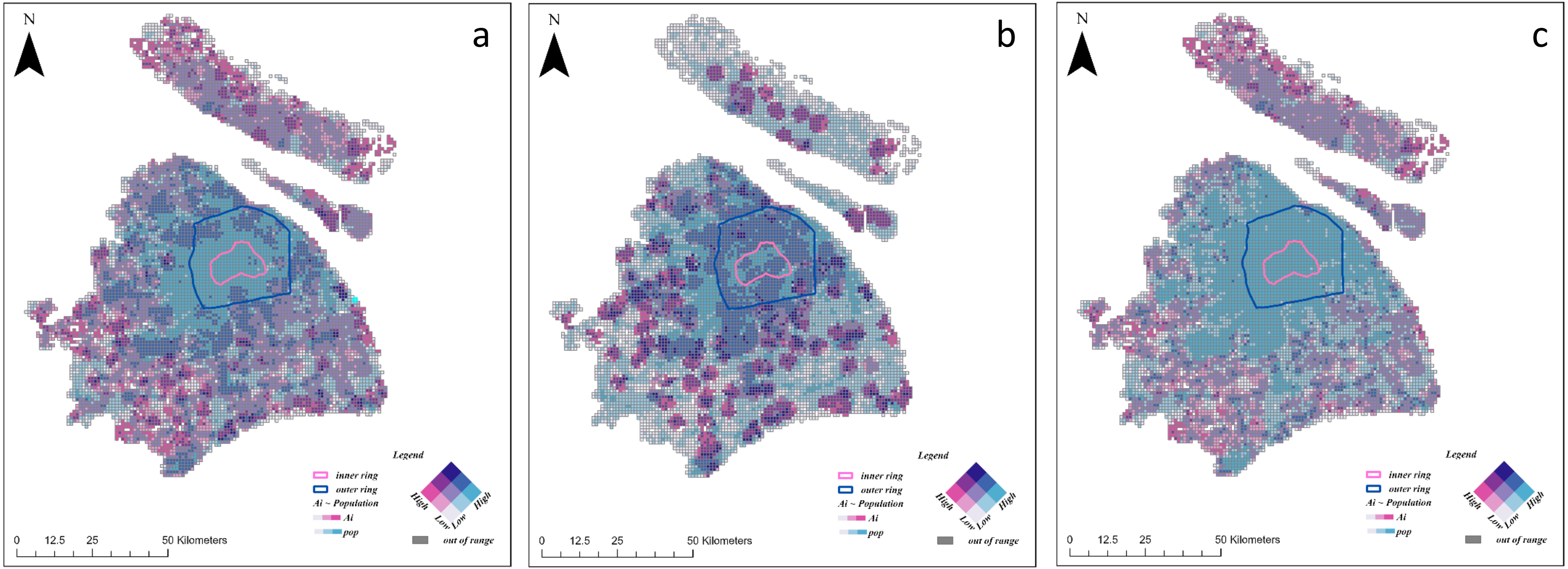
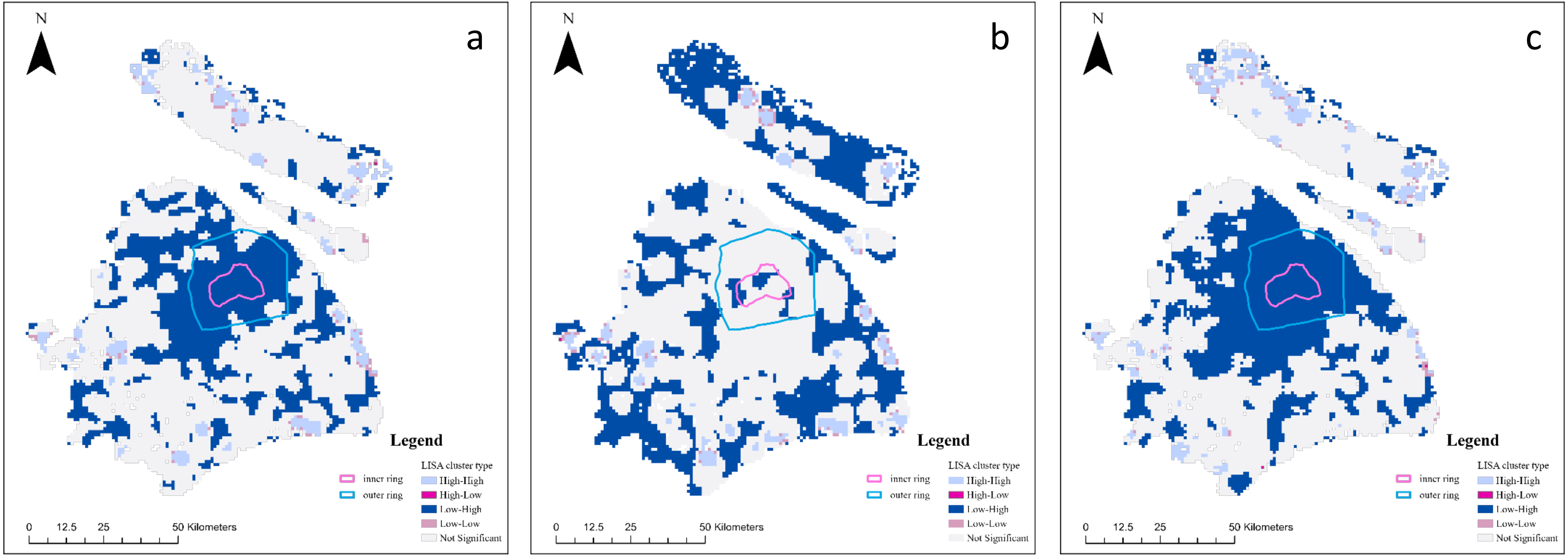


Fig13 Visualization of accessibility and bidirectional population aggregation distribution of Shanghai outdoor stadium obtained by G3SFCA. a, b, and c correspond to all facilities, complex facilities, and specialized facilities respectively

03 Spatial aggregation pattern of the whole city



Moran's I: 0.43,
p-value: 0.001

Moran's I: 0.73,
p-value: 0.001

Moran's I: 0.30,
p-value: 0.001

Fig14 Spatial Autocorrelation (LISA) visualization of accessibility of Shanghai Outdoor Stadium obtained by G3SFCA. a, b, and c correspond to all facilities, complex facilities, and specialized facilities respectively

04

Conclusion

04 Conclusion

(1) By introducing facility selection weights, G3SFCA can better characterize the accessibility of developed areas.

(2) In most areas of Shanghai, the population is large and the accessibility of sports facilities is low,

(3) The equity is further deteriorated after the introduction of selection weight

(4) There is a spatial autocorrelation aggregation of accessibility, which also explains why the Gini coefficient is so high

04 Policy suggestion

(1) Improve fairness. It is targeted at the street towns and districts with low fairness, especially the outer suburbs and downtown.

(2) Urban updating and transformation

(3) Policy making and investment

(4) Open up outdoor sports facilities in schools to the public (this is actually on the government agenda)

References

Bourke, M., Hilland, T. A. & Craike, M. (2021). 'A systematic review of the within-person association between physical activity and affect in children's and adolescents' daily lives', Psychology of Sport and Exercise, 52, 101825.

Cereijo, L., Gullón, P., Cebrecos, A., Bilal, U., Santacruz, J.A., Badland, H. & Franco, M. 2019, 'Access to and availability of exercise facilities in Madrid: an equity perspective', International journal of health geographics, 18, 1, 15-15.

Chen Y, Lin N, Wu Y, Ding L, Pang J&Lv T. (2021). 'Spatial equity in the layout of urban public sports facilities in Hangzhou', PLoS ONE, 16, e0256174

Heath, G. W., Parra, D. C., Sarmiento, O. L., Andersen, L. B., Owen, N., Goenka, S., Montes, F., Brownson, R. C. & Lancet Phys Activity Series, W. (2012). 'Evidence-based intervention in physical activity: lessons from around the world', Lancet, 380, 272-281.

Lee, H. H., Emerson, J. A., Bohlen, L. C. & Williams, D. M. (2021). 'Affective response to physical activity as an intermediate phenotype', *Social Science & Medicine,* 271**,** 112038.

Lee, I. M., E. J. Shiroma, F. Lobelo, P. Puska, S. N. Blair, P. T. Katzmarzyk, and W. Lancet Phys Activity Series. 2012. "Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy." Lancet 380 (9838):219-229. https://doi.org/10.1016/s0140-6736(12)61031-9.

Liu, L., Xu, Z., Yao, S., Lv, M. & Liu, C. (2024). 'Optimizing the Spatial Accessibility of Outdoor Sports Facilities: A Greedy Heuristic Algorithm Based on Remote Sensing Images.' International Journal of Digital Earth 17 (1). doi:10.1080/17538947.2024.2390427.

Liu, Y., Wang, X., Zhou, S. & Wu, W. (2020). 'The association between spatial access to physical activity facilities within home and workplace neighborhoods and time spent on physical activities: evidence from Guangzhou, China', International Journal of Health Geographics, 19, 22.

Xiao, T., Ding, T. F., Zhang, X. K., Tao, Z. L. & Liu, Y. (2022). 'Spatial Accessibility to Sports Facilities in Dongguan, China: a Multi-Preference Gaussian Two-Step Floating Catchment Area Method', Applied Spatial Analysis and Policy, 15, 1093-1114.

THANKS

敬请批评指正！