Report of ISPRS Scientific Initiative 2021

ISPRS BENCHMARK DATASET ON OBJECT DETECTION IN HIGH-RESOLUTION SATELLITE IMAGES

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PROJECT GOALS

The ISPRS Benchmark Dataset on Object Detection in High-Resolution Satellite Images aims to stimulate and promote academic research on category-level object detection in high-resolution satellite images, including: (1) object detection and recognition in high-resolution optical satellite imagery; (2) object detection in high-resolution synthetic aperture radar (SAR) imagery; (3) semantic segmentation in high-resolution optical satellite imagery.

This benchmark provides a standard, large-scale and fine-grained dataset foundation for applying advanced deep learning technology to remote sensing, and will promote the development of the community of high-resolution satellite image understanding. It also provides a public access for the evaluation and comparison of the advanced algorithms on detection and segmentation tasks according to well-known evaluation metrics. Datasets will be available from the dedicated webpage on the ISPRS website (ISPRS scientific initiatives, 2021) and the mirror website (https://www.gaofen-challenge.com/benchmark), and interested participants will be invited to test their methods and submit their results for evaluation. The submitted models will be evaluated quantitatively, and the results will be published on the webpage.

BENCHMARK DATASETS

There are seven specific tasks on high-resolution satellite image understanding that have been addressed in the submitted benchmark proposal. To address these tasks, we constructed four high-quality datasets for our benchmark. The details are shown in Table 1.

Table 1 The datasets in the final benchmark

No.	Datasets	Corresponding Tasks in the Submitted Proposal
1	FAIR1M Dataset	Airplane Detection and Recognition in Optical Images
		Ship Detection and Recognition in Optical Images
		Automobile Detection and Recognition in Optical Images
		Road Extraction in Optical Images
2	AIR-SARShip Dataset	Ship Detection in SAR Images
3	AIR-SAR-ACD Dataset	Airplane Detection in SAR Images
4	AIR-SEG Dataset	Semantic Segmentation of Optical Images

1. FAIR1M Dataset

Available online: https://www.gaofen-challenge.com/benchmark

1.1 Image Collection

A novel benchmark dataset with more than 1 million instances and more than 40,000 images for Fine-grAined object recognItion in high-Resolution optical satellite imagery called FAIR1M was built. We collected satellite images with a resolution of 0.3 m to 0.8 m from Gaofen-2 satellite and Google Earth. The scenes cover more than 100 civil airports, harbors, cities and towns worldwide. The distribution of the FAIR1M dataset with respect to different continents can be seen in Fig. 1.

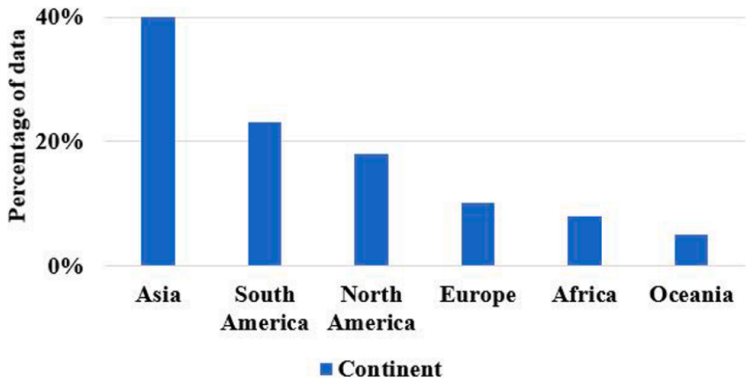

Fig. 1. The distribution of FAIR1M dataset across continents.

1.2 Category Design

Most existing datasets focus more on static objects, such as bridges, baseball fields, storage tanks and basketball courts. These datasets lack fine-grained information about objects, which plays an important role in real applications in the remote sensing field. In the FAIR1M dataset, all objects are annotated with respect to 5 categories and 37 fine-grained subcategories by oriented bounding boxes, as shown in Fig. 2. The 5 categories are airplanes, ships, vehicles, courts and roads. The selection of fine-grained types for each category in the FAIR1M dataset depends on practical application scenarios and the shapes of the observed objects.

(1) For airplanes, we set 10 fine-grained subcategories covering 34 airports around the world. The types of airplanes include Boeing 737, Boeing 777, Boeing 747, Boeing 787, Airbus A320, Airbus A220, Airbus A330, Airbus A350, COMAC C919, and COMAC ARJ21, which are the most common types of airplanes in civil aviation.

(2) For ships, the subcategories are defined according to their functions. There are 8 specific subcategories including passenger ships, motorboats, fishing boats, tugboats, engineering ships, liquid cargo ships, dry cargo ships, and warships.

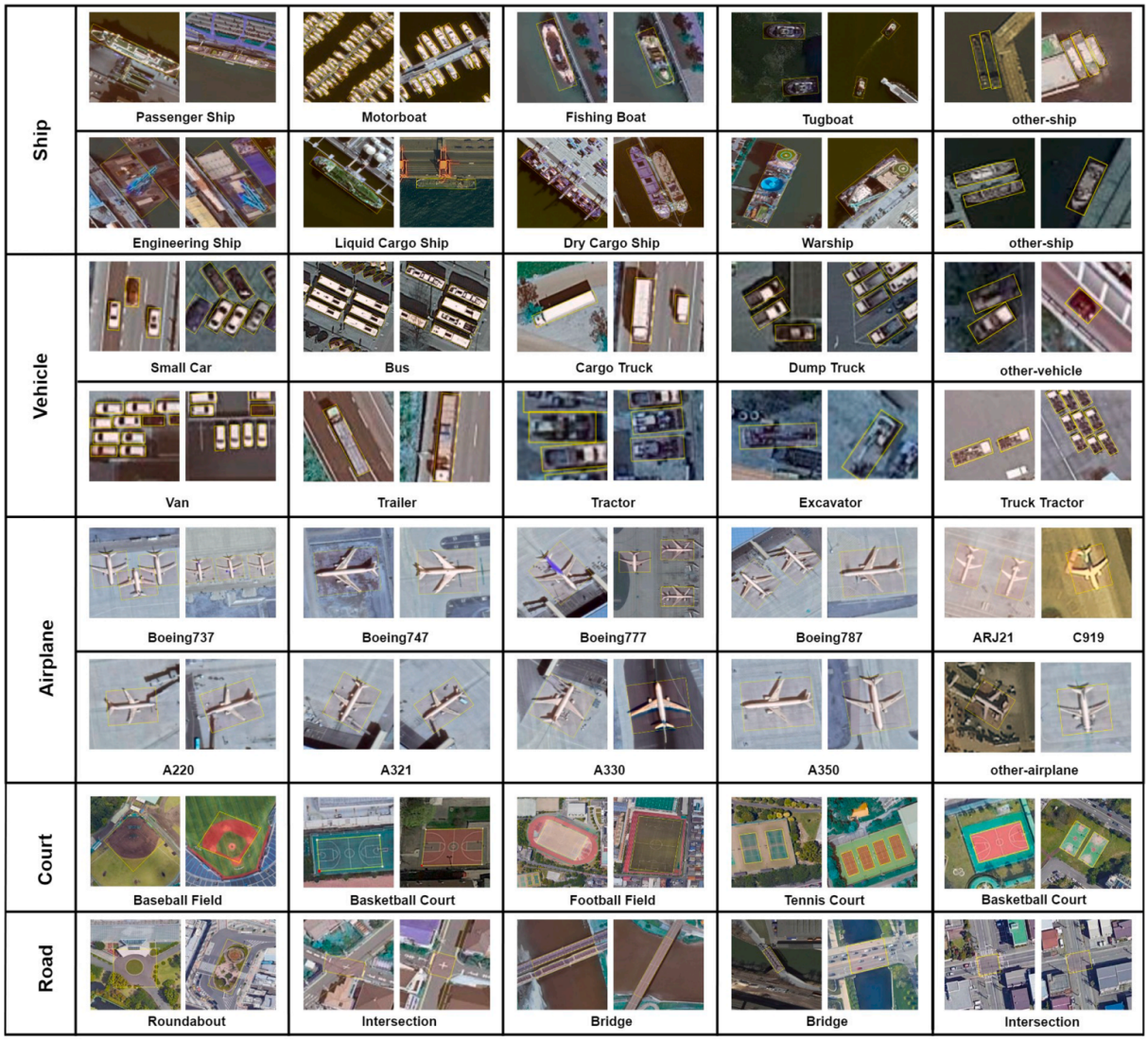

Fig. 2. Data samples of each category in the FAIR1M dataset.

(3) For vehicles, the subcategories are also defined according to their functions. There are 9 specific subcategories of vehicles, including small cars, buses, cargo trucks, dump trucks, vans, trailers, tractors, truck tractors, and excavators.

(4) For courts, we select the most 4 common subcategories including baseball fields, basketball courts, football fields and tennis courts.

(5) For roads, there are 3 key subcategories including roundabout, intersection and bridge.

In addition to these specific subcategories, we also assign the subcategories other-airplane, other-ship, and other-vehicle for objects that do not belong to the previously defined specific object types. As a result, 37 fine-grained subcategories are contained in the FAIR1M dataset. Some representative examples of images and their annotations are shown in Fig. 3.

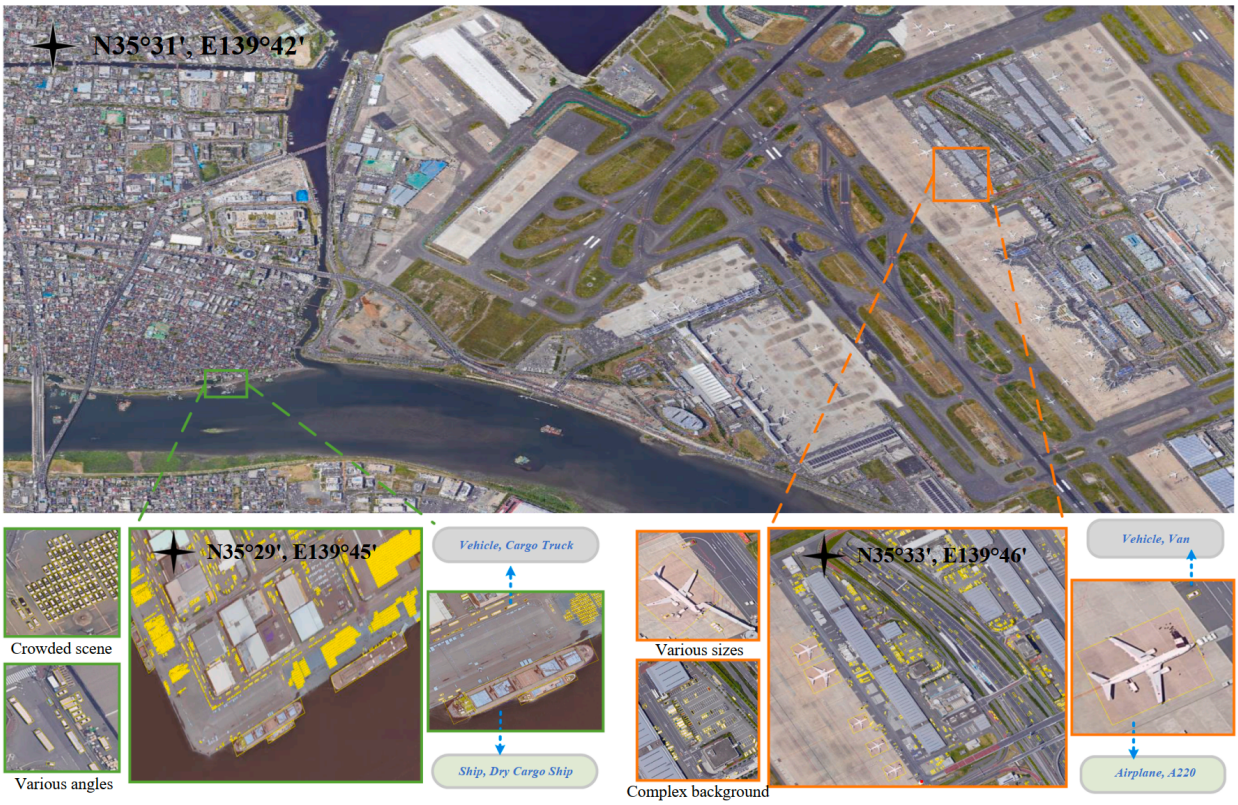

Fig. 3. Visualization of annotations in the FAIR1M dataset. In addition to the fine-grained object subcategories, the FAIR1M dataset contains crowded scenes, complex backgrounds, and various sizes and angles of objects. Yellow boxes are the bounding boxes we annotated.

It is well known that the number of items in each subcategory depends on the actual instance distribution in remote sensing scenarios. The distribution of instances can reflect the authenticity and challenge of the proposed dataset. All subcategories and the number of instances per subcategory can be seen in Fig. 4 and Fig. 5.

Compared with existing detection datasets, the FAIR1M dataset has 4 particular characteristics:

(1) It is much larger than other existing object detection datasets in remote sensing field both in terms of the number of instances and the number of images.

(2) It provides richer fine-grained subcategories information for objects in remote sensing images, which can promote the technical development of object detection to recognition.

(3) It contains geographic information such as latitude, longitude and resolution attributes.

(4) It provides better image quality due to the use of a careful data cleaning procedure.

We believe that the FAIR1M dataset will contribute to the earth observation community via fine-grained object detection in large-scale real-world scenes.

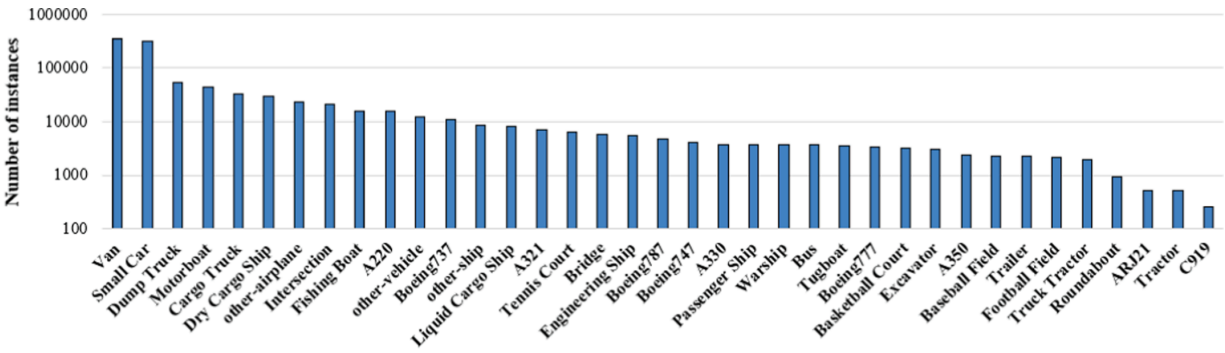

Fig. 4. The distribution of the number of instances across the fine-grained subcategories.

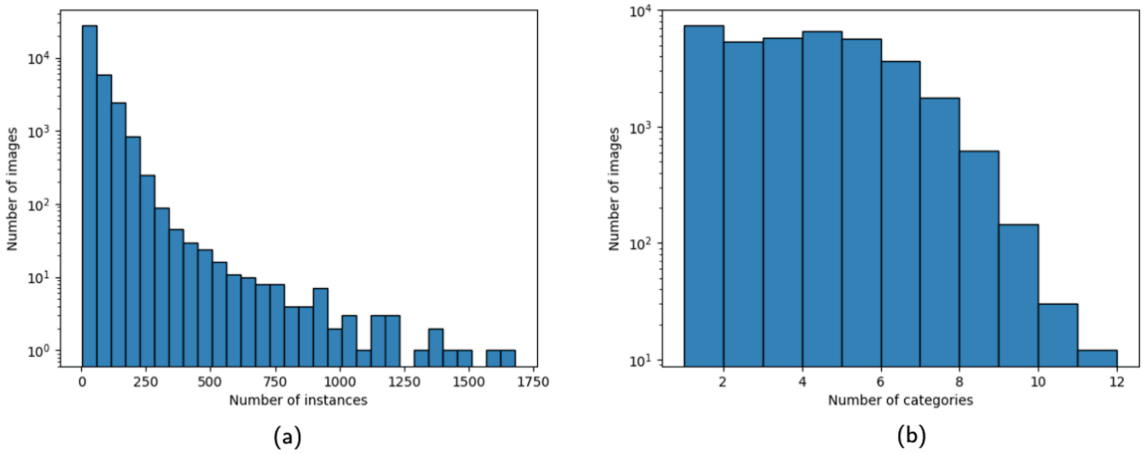

Fig. 5. (a) The distribution of the number of instances per image. (b) The distribution of the number of categories per image.

2. AIR-SARShip Dataset

Available online: https://radars.ac.cn/web/data/getData?newsColumnId=abd5c1b2-fe65-47f7-8ebf-990273a91a48

2.1 Image Collection

We provide a SAR ship detection dataset with a high resolution and large-scale images. It comprises 31 images from Gaofen-3 satellite SAR images, including harbors, islands, reefs, and the sea surface in different conditions. The backgrounds include various scenarios such as the near shore and open sea. The resolution of SAR images includes 1 m and 3 m. The imaging mode has both spotlight and strip modes. All images are in single polarization mode with a size of about 3000 × 3000 pixels and all saved in TIF format.

Details of each image, including image number, pixel size, resolution, sea state, scene type, and the number of ships, are presented in Table 2.

Table 2 AIR-SARShip dataset information in detail

Image No.	Size	Sea condition	Scenario	Resolution (m)	Number of Ships
1	3000×3000	Level 2	nearshore	3	5
2	3000×3000	Level 0	nearshore	1	7
3	3000×3000	Level 3	offshore	3	10
4	3000×3000	Level 2	offshore	3	8
5	3000×3000	Level 1	nearshore	3	15
6	3000×3000	Level 4	offshore	3	3
7	3000×3000	Level 4	offshore	3	5
8	3000×3000	Level 1	nearshore	1	2
9	3000×3000	Level 2	nearshore	1	7
10	3000×3000	Level 1	offshore	1	50
11	3000×3000	Level 1	nearshore	1	80
12	3000×3000	Level 2	nearshore	1	18
13	4140×4140	Level 1	nearshore	1	21
14	3000×3000	Level 1	nearshore	1	15
15	3000×3000	Level 1	nearshore	1	77
16	3000×3000	Level 3	nearshore	3	13
17	3000×3000	Level 3	nearshore	3	3
18	3000×3000	Level 3	nearshore	3	2
19	3000×3000	Level 3	nearshore	3	1
20	3000×3000	Level 2	nearshore	3	7
21	3000×3000	Level 2	nearshore	3	9
22	3000×3000	Level 1	nearshore	3	14
23	3000×3000	Level 1	offshore	3	4
24	3000×3000	Level 4	offshore	3	6
25	3000×3000	Level 4	offshore	1	20
26	3000×3000	Level 2	nearshore	3	15
27	3000×3000	Level 2	nearshore	3	19
28	3000×3000	Level 1	nearshore	3	8
29	3000×3000	Level 3	offshore	3	6
30	3000×3000	Level 2	offshore	3	8
31	3000×3000	Level 1	nearshore	3	3

2.2 Category Design

Since it is difficult to distinguish the categories of ships in SAR images, we just focus on extracting ships from the background in this dataset. Examples are shown in Fig. 6.

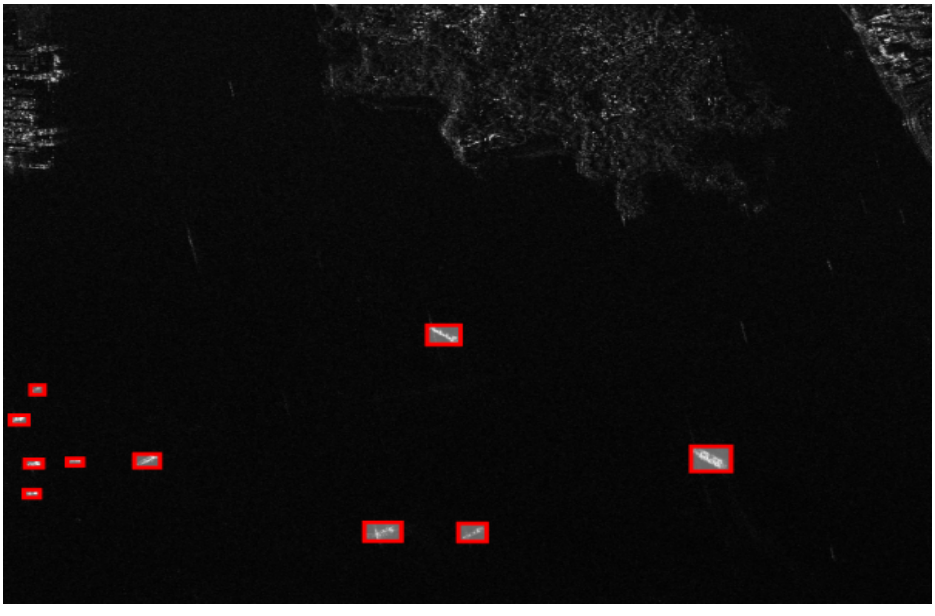

Fig. 6. Examples of ship detection in the AIR-SARShip dataset.

3. AIR-SAR-ACD Dataset

Available online: https://www.gaofen-challenge.com/challenge/dataset/4

3.1 Image Collection

A total of 11 Gaofen-3 C-band images with 1m resolution working in the Spotlight mode are used for our SAR Airplane Categories Detection (AIR-SAR-ACD). These images cover the Shanghai Hongqiao Airport area, Beijing Capital International Airport area, and another airport in different time phases with HH polarization. A total of 4322 airplane clips are contained in AIR-SAR-ACD. It should be emphasized that AIR-SAR-ACD contains complex scenes at different airports. Meanwhile, the targets in AIR-SAR-ACD are rich in categories and have large differences in size. These factors lead to a very challenging classification task. Examples are shown in Fig. 7.

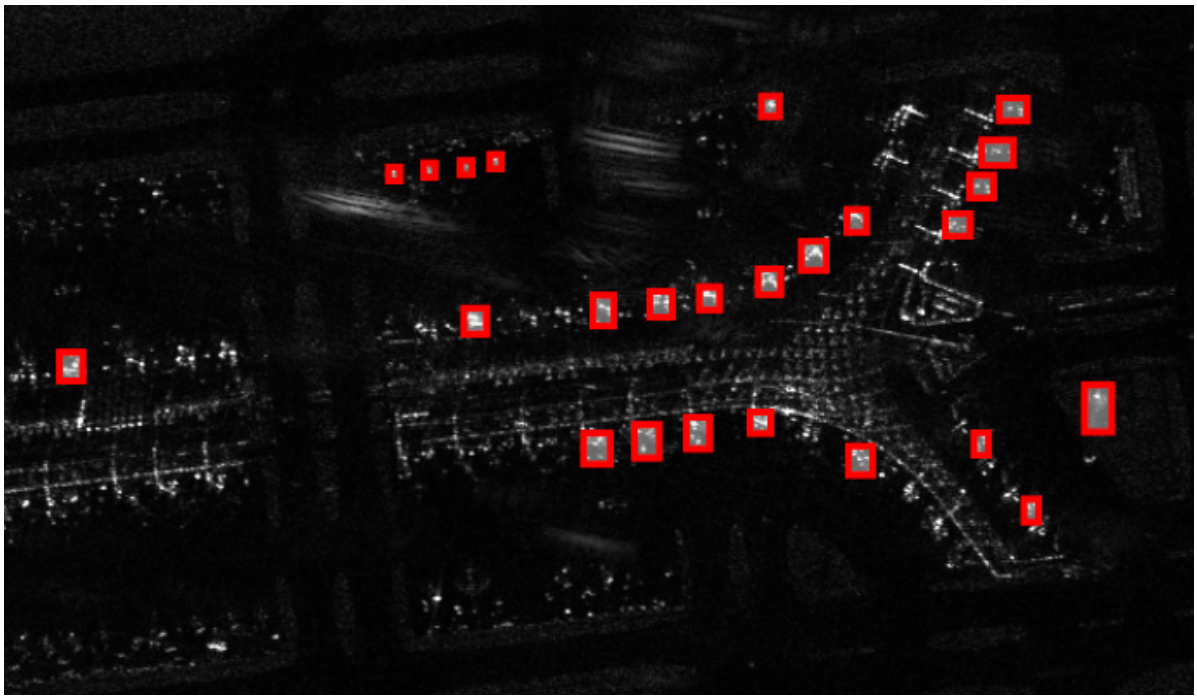

Fig. 7. Examples of airplane detection in AIR-SAR-ACD dataset.

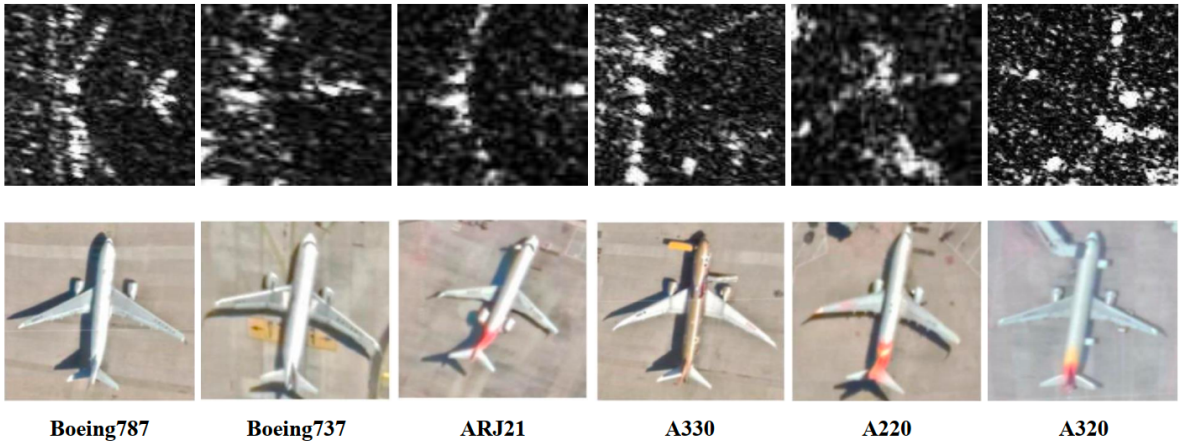

Fig. 8. Civil airplanes in AIR-SAR-ACD and their corresponding optical images.

3.2 Category Design

There are 6 civil airplane categories in the dataset, including Boeing 787, Boeing 737, ARJ21, A330, A220 and A320. The SAR data is manually labeled according to the corresponding optical images, as shown in Fig. 8. The specific categories of civil airplanes and the target number of each category are shown in Fig. 9.

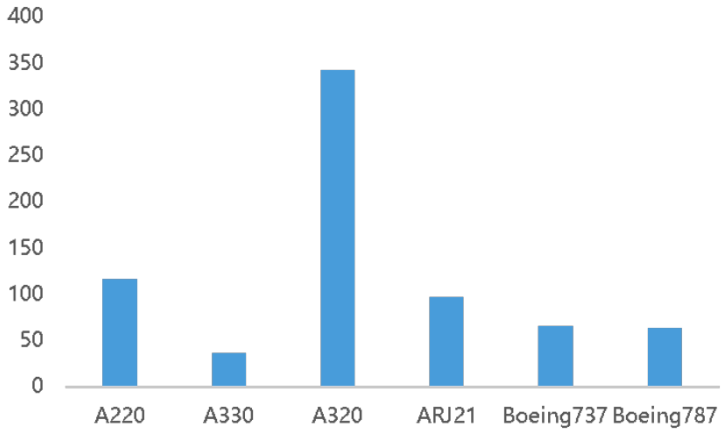

Fig. 9. The original number of each type of civil airplanes in the AIR-SAR-ACD dataset.

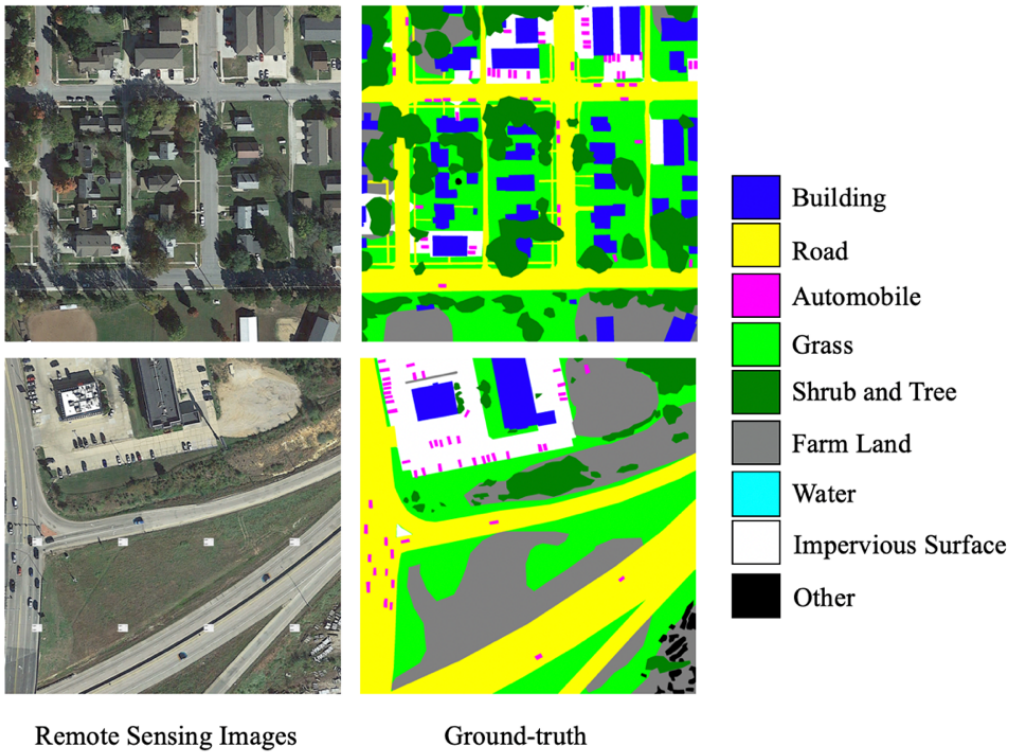

Fig. 10. Examples of the AIR-SEG dataset.

4. AIR-SEG Dataset

Available online: https://www.gaofen-challenge.com/challenge

4.1 Image Collection

Images in this dataset are collected from the Gaofen-2 satellite and Digital Globe, with a spatial resolution ranging from 0.5m to 3m. In total, there are more than 1000 images with side lengths of 512-5000 pixels. Thus, this dataset is rich in scenes, including cities, villages, airports, ports, parking lots, etc. around the world. In each image, each pixel is labeled with a category addressing either ground cover or structural scene elements.

4.2 Category Design

There are 9 common categories in this dataset, including road, building, shrub and tree, grass, farm land, water, automobile, impervious surface and other, as shown in Fig. 10.

RELATED ACTIVITIES AND INFLUENCE

As a follow-up activity of the ISPRS scientific initiative, the 2021 Gaofen Challenge on Automated High-Resolution Earth Observation Image Interpretation was successfully held based on these benchmark datasets (https://www.gaofen-challenge.com/challenge). The Challenge has drawn great attention in the field of remote sensing since its start in June 2021. Nearly 500 teams with more than 1200 competitors from about 15 countries all over the world have joined in it, including China, Germany, America, Spain, Japan, Australia, Singapore, India, etc. The datasets have been downloaded more than 5000 times by competitors and researchers from different countries. Fig. 11 shows the download statistics of the benchmark dataset.

Fig. 11. Download statistics of the benchmark dataset.

The submitted results for each track in the 2021 Gaofen Challenge were evaluated and published on the leaderboard page at the website. In the whole challenge, the total number of submissions for all tracks is as high as 9000 times. Hundreds of teams have a fierce competition in the leaderboard. Fig. 12 shows the leaderboard of the FAIR1M benchmark dataset.

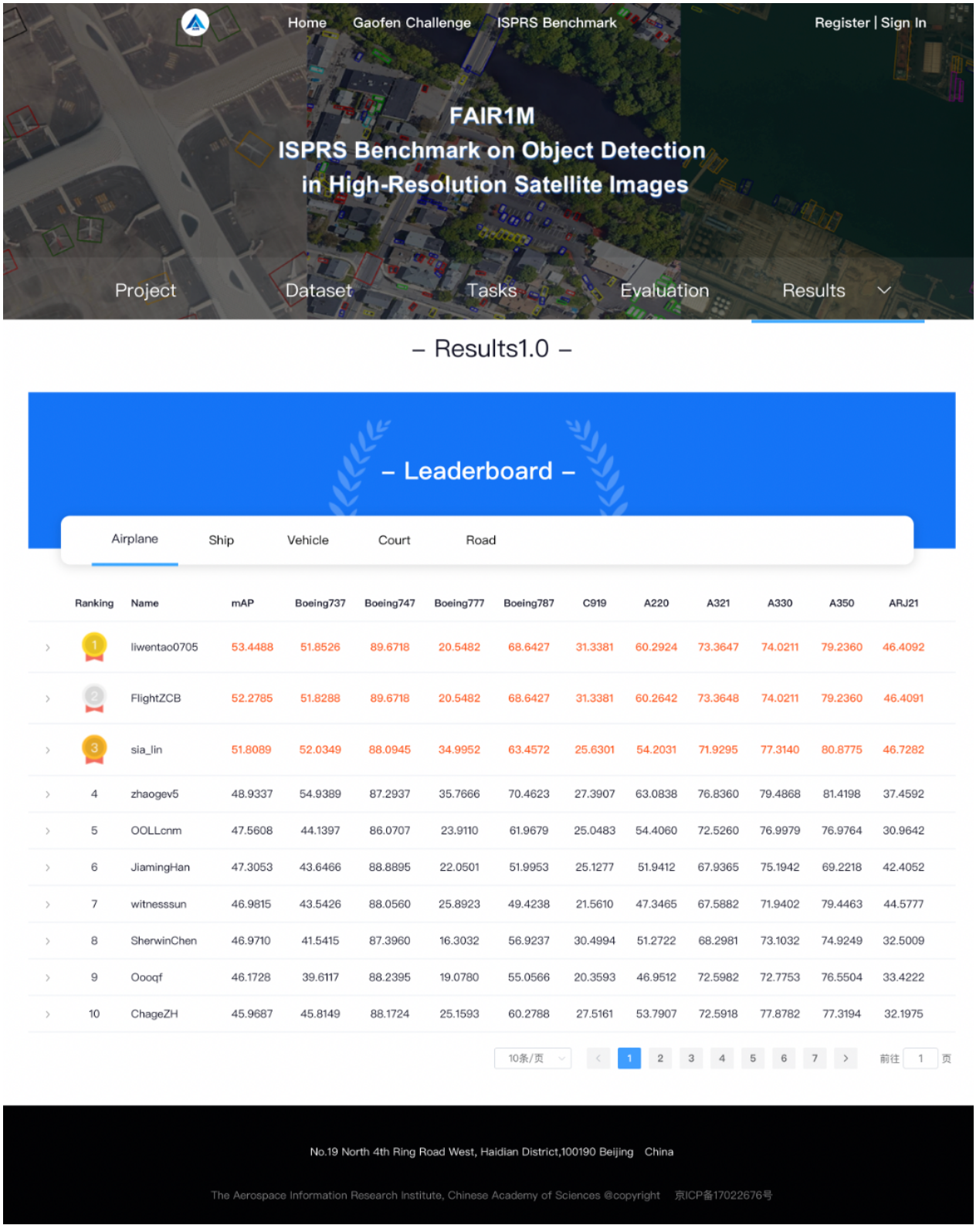

Fig. 12. Leaderboard of the FAIR1M benchmark dataset.

DISSEMINATION

The detailed descriptions of the benchmark dataset, sensor specifications, reference datasets, and the evaluation method as well as results of baseline approaches are provided in the following paper, which is related to the ISPRS Scientific Initiative.

[1] Xian Sun, Peijin Wang, Zhiyuan Yan, Feng Xu, Ruiping Wang, Wenhui Diao, Jin Chen, Jihao Li, Yingchao Feng, Tao Xu, Martin Weinmann, Stefan Hinz, Cheng Wang, Kun Fu. FAIR1M: A Benchmark Dataset for Fine-Grained Object Recognition in High-Resolution Remote Sensing Imagery, ISPRS Journal of Photogrammetry and Remote Sensing, 2022, 184: 116-130.

Besides, the benchmark dataset was reported by several authoritative medias at home and abroad as follows:

[1] CCTV News:
http://tv.cctv.com/2021/04/29/VIDErVxU5PCpyjRQMte9IqBa210429.shtml
http://m.news.cctv.com/2021/04/28/ARTIIh7rBLbgjCjYAq32lmHx210428.shtml

[2] Mirage News:
https://www.miragenews.com/china-releases-benchmark-dataset-for-fine-557252/

[3] People's Daily News:
https://baijiahao.baidu.com/s?id=1698959477883443255&wfr=spider&for=pc

[4] Official Website of Chinese Academy of Sciences:
https://english.cas.cn/newsroom/research_news/earth/202105/t20210510_269115.shtml

[5] Official Website of Aerospace Information Research Institute, Chinese Academy of Sciences:
http://english.aircas.cn/ne/focus/202105/t20210510_269113.html

PROJECT EXPENSES

The total grant received from the ISPRS for this project was CHF 10,000 (CNY 68,213).

Total Grant: CNY 68,213

Total Expenses: CNY 99,887

Chinese Academy of Sciences – as PI and manager of the SI funds – has co-financed the missing funds. The following is a breakdown of the project expenses.

- Data acquisition & Generation of the ground-truth CNY 94,200
- Travel CNY 5,687