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**Object detection for rotated and densely packed targets in aerial images using path aggregated feature pyramid networks**

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**Purpose**

With the development of commercial satellites and unmanned aerial vehicles (UAV), aerial images with many recognizable targets are becoming easy to access. Several large-scale datasets with well-annotated aerial objects have been promoting the progress of object detection in aerial images. Object detection in aerial images is an important yet challenging problem due to the overhead perspective, complicated backgrounds and large variations in scale, orientation and appearance of objects in aerial images. Object detection in ground-based images has benefited from remarkable researches on deep learning approaches, nevertheless, directly utilizing these technologies for object detection in aerial images is nontrivial. This paper aims to propose a pipeline that can accurately detect objects of variant scales, orientations and appearances in high resolution aerial images.

**Methods**

**Feature extraction** As the backbone of convolutional neural networks, the quality of extracted feature has an impact on the performance of the following regression and classification tasks. To address the problem of scale variations of objects in aerial images, feature pyramid structure is used to extract multi-scale features. Experiments[1], [2] have shown that shortening information path and making information propagation more easily are useful for object detection. For better information propagation of multi-scale objects, we add a bottom-up path with lateral connections to corresponding FPN levels like Liu et al. [3] did, which ensures our network accurately extracts multi-scale features from complicated backgrounds.

**Regression of oriented bounding-box** One of the problems in transitioning generic object detection technologies into object detection in aerial images is that the arbitrary orientations due to the overhead perspective. The most effective way to handle this problem is to use rotated PSRoI align[4] or deformable PSRoI pooling[5] to obtain rotation-invariant feature representation of orientated targets. Our experiments found that it’s essential to get better detection performance for oriented densely packed targets in aerial images.

**Bells and whistles** The problem of class imbalance is often encountered in object detection in aerial images because of the unbalanced distribution of different targets in real world. We applied the Stratified Online Hard Example Mining which feeds hard examples to the back-propagation process to overcome the dilemma of unbalanced data. Another problem which may affect the performance of detector is appearance ambiguity, that is to say, small inter-class difference on target appearance. For example, appearances of bridge and road, basketball court and soccer ball field are quite similar from overhead perspective. Including contextual information of RoI can help our detector distinguish ambiguous targets.

The architecture of our algorithm is shown as follows.

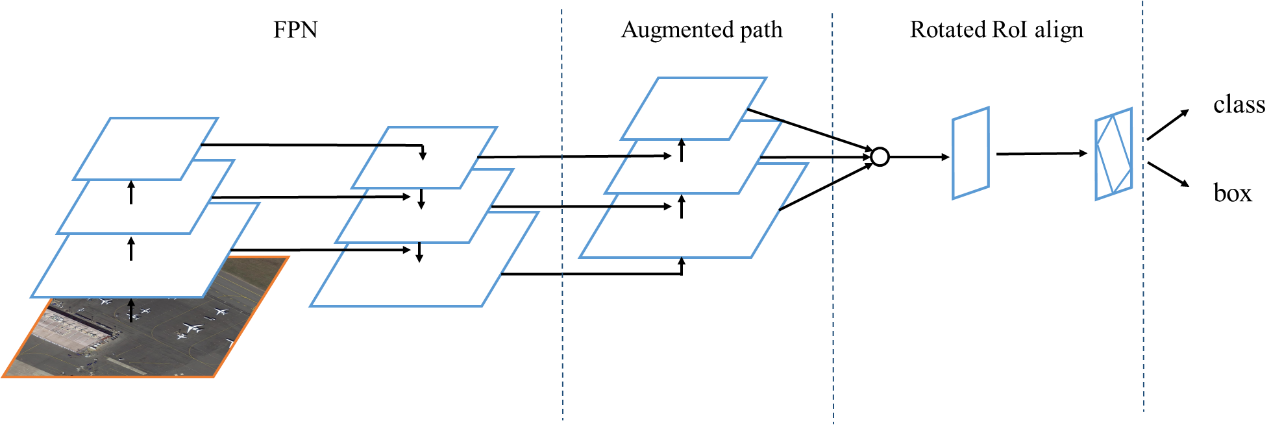


Figure 1. The architecture of our algorithm. We use FPN as our backbone, then the augmented bottom-up path is added through lateral connections with FPN. Multi-scale features are fused and rotated RoI align is conducted afterwards. Note that channel dimension is omitted for brevity.

**Results**

We tested our network on a large-scale dataset named DOTA[6], which consists of high resolution aerial images with oriented bounding box annotated. It contains 2806 images with objects of 15 categories, including plane, baseball diamond(BD), bridge, ground track field(GTF), small vehicle(SV), large vehicle(LV), ship, tennis court(TC), basketball court(BC), storage tank(ST), soccer-ball field(SBF), roundabout(RA), harbor, swimming pooling(SP) and helicopter(HC). Our experiment results are listed in Table 1.

Table 1. Experiment results of our algorithm and some popular generic object detection networks on DOTA dataset.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | YOLOv2 | Faster R-CNN | YOLOv3 | ours |
| *Plane* | 78.72 | 87.96 | 88.04 | **89.27** |
| *BD* | 39.11 | 79.61 | 62.04 | **81.92** |
| *Bridge* | 22.64 | 51.12 | 44.56 | **56.35** |
| *GTF* | 34.71 | 62.2 | 56.06 | **69.85** |
| *SV* | 32.26 | 54.97 | 76.53 | **66.35** |
| *LV* | 23.12 | **69.23** | 57.31 | 65.76 |
| *Ship* | 49.53 | **85.20** | 78.59 | 84.99 |
| *TC* | 76.15 | **90.86** | 90.46 | 90.68 |
| *BC* | 43.53 | 78.69 | 77.15 | **82.67** |
| *ST* | 36.6 | 75.88 | 80.42 | **84.49** |
| *SBF* | 23.93 | 54.31 | 44.86 | **59.05** |
| *RA* | 43.88 | 61.72 | 58.56 | **65.57** |
| *Harbor* | 40.99 | 73.12 | 59.86 | **75.68** |
| *SP* | 40.53 | 68.53 | 62.29 | **72.17** |
| *HC* | 4.69 | 58.59 | 55.62 | **69.57** |
| ***mAP*** | 39.36 | 70.13 | 66.16 | **74.29** |

**Conclusion**

In this paper, we developed an object detection network for aerial images. Our network focuses primarily on oriented and densely packed objects, which is challenging for generic object detectors due to the overlap of neighbored horizontal bounding boxes. We tested our network on a large-scale aerial images dataset which includes many small, dense packed targets with arbitrary orientations. Experimental results show the effectiveness of our method.

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