DIP 2022 Fall Final Project – Object-Detection-Group 3

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1 introduction

We conduct two different solutions to improve the performance of yolov7 model on given images.

One of the above is to fine-tune yolov7 model on VisDrone dataset which is basic and usual.

Another one is betti-number filtering. Combining topological data analysis and image processing skill, we do our best but found no related research on it. So it interested us to dig into.

2 Method

1. **Fine-tuning YOLOV7 model on VisDrone dataset.**

   Train basic yolov7.pt on VisDrone dataset for 50 epochs.

2. **Betti-number filtering combined with local histogram equalization.**

step 1. Reshape image into 640x640.

step 2. Split image into 8x8 of 80x80-small graphs and 32x32 of 20x20-small graphs.

step 3. Apply Betti-number filter on each of small graph

- A. Create a topological graph by the following rule (which will give a legal simplicial 2-complex):
  - a. If the L2-distance between two nearby pixels is smaller than a given threshold, then we add an edge.
  - b. If the distances between each of three nearby pixel, i.e. a smallest right angle triangle are all smaller than a given threshold, then we add a black triangle.
  - c. Avoid any intersection between any two edges.
- B. Use disjoint set with weighted-priority and path-compression to count the number of cycles
- C. Number of cycles minus number of black triangles will be 1-betti-number.
  Correctness:
  By definition, 1-betti-number is the number of free dimensions of the 1-homology group of the given simplicial complex.
  "1-cycle group" of a given simplicial complex is the free Abelian group generated by all the cycles with direct sum.
  "1-boundary group" of a given simplicial complex is the free Abelian group generated by all the black triangles with direct sum.
  Homology group H=Z quotient B, where Z is the "1-cycle group" and B is the "1-boundary group".
  Hence, (number of free dimensions of H)=((number of free dimensions of Z)-(number of free dimensions of B))=(number of cycles calculated in Method.2.step3.B)-(number of black triangles calculated in Method.2.step3.A.b)
- D. Calculate the number of filtered holes in each of 80x80-small graphs by (betti-number of that 80x80-small graph)-(sum of all 20x20-small graphs' betti numbers within that 80x80-small graph)

step 4. Apply local histogram equalization on those filtered position(having non-zero number of filtered holes) on original image.

step 5. Use YOLOV7 original model to get bounding-boxes with classification.

3 Results

1. **Fine-tuning YOLOV7 model on VisDrone dataset.**

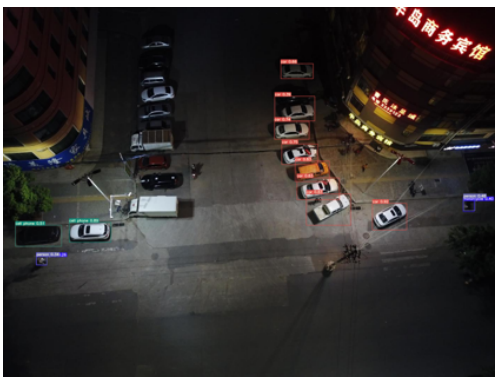

Figure 1: Original YOLOv7

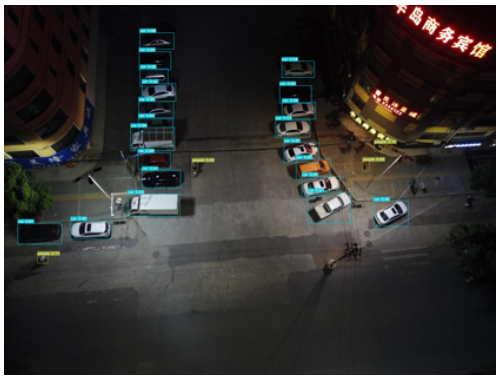

Figure 2: YOLOv7 with VisDrone Dataset

2. **Betti-number filtering combined with local histogram equalization.**

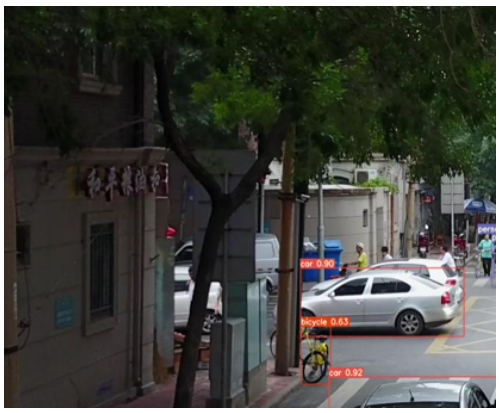

Figure 3: Original YOLOv7

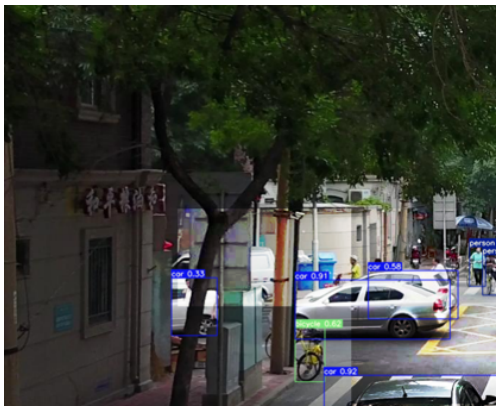

Figure 4: YOLOv7 with our enhancement

4 Discussion

1. **Fine-tuning YOLOV7 model on VisDrone dataset.**

   With VisDrone dataset, we can obtain a fine-tuned YOLOv7 model, which is nearly perfect. However, we aim to obtain a more general object-detection model, which doesn't require the use of certain dataset while training. Therefore, we perform Betti-number filtering and local histogram equalization on the testing image to improve the accuracy of the original YOLOv7 model.

2. **Betti-number filtering combined with local histogram equalization.**

   First, we try to enhance the image with local histogram equalization. Then, we encounter with two problems. The model can no longer detect some objects which it originally can. In contrast, it will also detect some objects that don't exist in the image.

Figure 5: without local histogram equalization

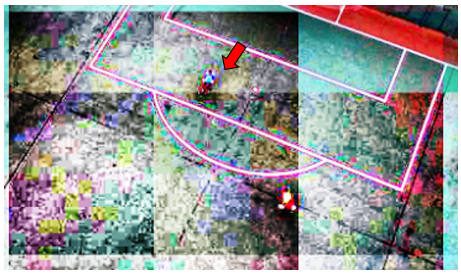

Figure 6: with local histogram equalization(less)

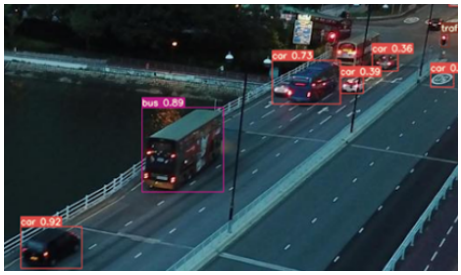

Figure 7: without local histogram equalization

Figure 8: with local histogram equalization(more)

To overcome the problems encountered, we perform local histogram equalization combined with Betti-number filtering. That is, instead of performing equalization on the whole image, we only perform local histogram equalization on regions with objects. With the help of Betti-number filtering, we successfully filter out those regions with objects.

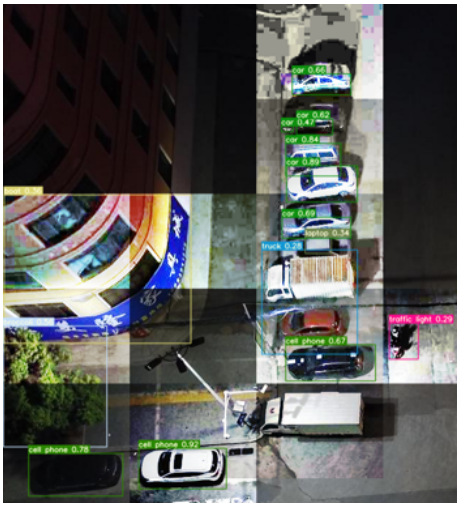

Figure 9: Betti-number filtering combined with local histogram equalization

However, Betti-number filtering also comes with new problems, such as detecting cars as phones.

Figure 10: detecting cars as phones

3. **Performances on a representative Image in Testing Data**

Figure 11: testing image

Model	Image	Performance
Original Yolov7 Model	raw image	18 persons, 6 bicycles, 16 cars
	betti_filtered image	22 persons, 9 bicycles, 18 cars
Fine-Tuned model	raw image	25 persons, 15 bicycles, 19 cars

5 Conclusion

To avoid using additional dataset to make an improvement on the given task, we study topological data analysis skill, which help us to evaluate the robust geographical properties of those testing-images.

Our contribution:

1. Design a valid way to change an 2D-image into simplicial complex.
2. Design a parallel version of the original algorithm.
3. Combine the outcome with local histogram equalization which we didn't found any similar research on it.
4. Develop all the code.

During our project's development, we have seen so many potential of topological data analysis on digital image processing. In this report, we just give a naive way to demonstrate how good it can be to apply such skill on object detection task.

For the future work, one can either try to combine the betti-number calculation with detection models such as yolov7 to further extract the power of topological data analysis or design efficient hardware to accelerate its calculation.

6 Work Distribution

Name	Work
何碩宸	find interpretable images
馮楷	conduct experiments
朱俊能	theory, coding

7 References

1. Delfinado, C. J. a., Edelsbrunner, H. (1993, July 1). An Incremental Algorithm for Betti Numbers of Simplicial Complexes.

2. https://www.youtube.com/watch?v=PeMIn4JKZLAlist=PLp24IEwWwtLJBhl1TvYjXF1-17q5lDpd3