Zhenhua Xu

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Education

Hong Kong University of Science and Technology **Sep. 2018 – Jan. 2023 (Expect)**

4th year Ph.D. candidate of CSE, supervised by Prof.Ming Liu and Prof.Huamin Qu *Hong Kong, China*

University of California, Los Angeles **Jul. 2017 – Sep. 2017**

CSST (Cross-disciplinary Scholars in Science and Technology) program (GPA 4.0/4.0) *LA, USA*

Harbin Institute of Science and Technology **Sep. 2014 – Jun. 2018**

Bachelor in Electronics and Information Engineering (Score 91.19/100, ***ranking 1/88****)* *Harbin, China*

Zhengzhou Foreign Language School **Sep. 2011 – Jun. 2014**

Zhengzhou, China

Research Keywords

Automatic Generation of Vector Map, Aerial Image Understanding, Remote Sensing, GIS, Imitation Learning, Autonomous Driving, Robotics

Research Topics

Automatic generation of vector maps in aerial images for autonomous driving | *Remote Sensing, Robotics*

- Vector maps (e.g., standard-definition map and high-definition map) are critical for autonomous vehicles since they provide navigation and planning algorithms of autonomous vehicles with essential information of static line-shaped objects in the surroundings, such as road boundaries, road curbs, road networks, etc. However, manually creating vector maps is inefficient and labor-intensive. Therefore, approaches to automatically generate vector maps of target objects with high efficiency and effectiveness are required.
- We propose to realize automatic vector map generation by detecting the graph of target objects. Thus, our problem is formulated as "detecting the graph structure of target line-shaped objects from images (**image-to-graph detection**)". We analyze this problem from the perspective of semantic segmentation, decision making and graph prediction. Deep learning models and techniques are utilized, such as deep segmentation networks and transformers.
- **Segmentation perspective:** Deep semantic segmentation can obtain pixel-wise predictions of the line-shaped objects, but it suffers from degraded topology-level correctness since it cannot fully utilize spatial and topology information of the image. We propose to design more powerful network structures and loss functions to handle the aforementioned problems. A demo video is available at CP-Loss demo.
- **Decision making perspective:** To conquer the problem of segmentation-based approaches, we propose to train an agent network that iteratively creates the graph of target objects (e.g., road curbs). The agent moves along the target object vertex by vertex, and the trajectory of the agent is outputted as the graph of the target object. Then the problem of object detection turns into a robot navigation problem, which can be solved by imitation learning at this stage. This category of approaches presents a much more powerful performance on topology correctness. A demo video of our work for road curb detection is available at iCurb demo. Demo videos of our work for road network graph detection are available at RNGDet demo RNGDet++ demo .
- **Graph prediction perspective:** Another idea to detect the graph of target objects is two-step graph prediction. We first obtain the heatmap of graph vertices (i.e., keypoints of the object), and then predict the adjacency matrix of the vertices based on transformer. A demo video of our work for city-scale road boundary detection is available at csBoundary demo.
- Several papers are accepted by top journals and conferences in the robotics and remote sensing communities (e.g., TGRS, RA-L, ICRA, IROS).

Automatic creation of HD maps with vehicle mounted sensors for autonomous driving | *Robotics*

- HD maps are critical for downstream tasks of autonomous vehicles, such as prediction and planning. Restricted by the blocking issue and resolution ability of aerial images, vehicle-mounted sensors are more suitable for the HD map mapping task. The main challenges of this task are: (1) how to detect the vector structure (i.e., graph) of road elements and (2) how to merge the detection results of multiple frames into a global map. In our recent work CenterLineDet, we trained an agent to iteratively complete this task. A demo video of our work for HD map generation with vehicle-mounted sensors is available at CenterLineDet demo.

Research Plans

Automatic generation of High-definition map | *Robotics, Aerial Image Understanding*

- High-Definition (HD) maps can provide precise geometric and semantic information of static traffic environments for autonomous driving, so almost all autonomous driving systems require high-quality HD maps. Unlike the aforementioned navigation maps, HD maps have centimeter accuracy, thus manually creating HD maps would significantly delay the autonomous vehicle deployment and raise the cost. However, at this stage, there are still very few industrial products or academic research works on the automatic generation of HD maps, leaving this important problem unexplored. Considering the huge market and academic potential, this could be a great research direction in the following decays.
- Target journals/conferences: ISPRS, TGRS, RA-L, etc./ICRA, IROS, CVPR, ICCV, ECCV, etc.

Automatic map update| *Robotics, Aerial Image Understanding*

- In real-world applications, due to the development of cities, the map may change as time goes by (e.g., some new roads are built and some old roads are removed). Different from the map generation task, in this problem, we need to detect map changes and update the map without harming the topology correctness. The map changes could be detected from aerial images, point cloud data, traffic data, etc. This problem is also of great value but there is still a lack of related industrial solutions or academic works.
- Target journals/conferences: ISPRS, TGRS, RA-L, etc./ICRA, IROS, CVPR, ICCV, ECCV, etc.

HD Map from vehicle-mounted sensors | *Robotics*

- Compared with satellite aerial images, data obtained by vehicle-mounted sensors (e.g., AV, UAV) is free from serious occlusion (e.g., tree occlusion) and presents better resolution ability. Thus, HD map created from vehicle-mounted sensors is expected to be more accurate. However, how to build the global vector map from sequential input data has not been studied by the research community very well.
- Target journals/conferences: RA-L, TITS, TIP, etc./ICRA, IROS, CVPR, ICCV, ECCV, etc.

Preprints

[1] **Z. Xu**, Y. Liu, Y. Sun, L. Wang, and M. Liu, "RNGDet++: Road Network Graph Detection by Transformer with Instance Segmentation and Multi-scale Features Enhancement," RAL, Under review. Web Page

[2] **Z. Xu**, Y. Liu, Y. Sun, L. Wang, and M. Liu, "CenterLineDet: Road Lane CenterLine Graph Detection With Vehicle-Mounted Sensors by Transformer for High-definition Map Creation," ICRA 2023, Under review. Web Page

[3] H. Liu, L. Zheng, X. Yan, B. Xue, **Z. Xu**, and M. Liu, "V2HDM-Mono: A Framework of Constructing a Marking-and-Lane Level HD Map with One or More Monocular Cameras," ICRA 2023, Under review.

[4] Y. Liu, **Z. Xu**, H. Huang, L. Wang, and M. Liu, "FSNet: Redesign Self-Supervised MonoDepth for Full-Scale Depth Prediction for Autonomous Driving," IEEE Transactions on Automation Science and Engineering, Under review.

Publications

[1] **Z. Xu**, Y. Liu, L. Gan, Y. Sun, L. Wang, and M. Liu, "RNGDet: Road Network Graph Detection by Transformer," in IEEE Transactions on Geoscience and Remote Sensing (TGRS), 2022. Web Page

[2] **Z. Xu**, Y. Liu, L. Gan, X. Hu, Y. Sun, L. Wang, and M. Liu, "csBoundary: City-scale Road-boundary Detection in Aerial Images for High-definition Maps," in IEEE Robotics and Automation Letters (RAL), 2022. Web Page

[3] Y. Liu, **Z. Xu**, and M. Liu, "Star-Convolution for Image-Based 3D Object Detection," in 2022 IEEE/RSJ International Conference on Robotics and Automation (ICRA), 2022.

[4] **Z. Xu**, Y. Sun, L. Wang, and M. Liu, "CP-loss: Connectivity-preserving Loss for Road Curb Detection in Autonomous Driving with Aerial Images," in 2021 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2021. Web Page

[5] **Z. Xu**, Y. Sun, and M. Liu, "Topo-Boundary: A Benchmark Dataset on Topological Road-Boundary Detection Using Aerial Images for Autonomous Driving," in IEEE Robotics and Automation Letters (RAL), 2021. Web Page

[6] **Z. Xu**, Y. Sun, and M. Liu, "iCurb: Imitation Learning-Based Detection of Road Curbs Using Aerial Images for Autonomous Driving," in IEEE Robotics and Automation Letters (RAL), 2021. Web Page

[7] T. Liu*, Q. Liao*, L. Gan, F. Ma, J. Cheng, X. Xie, Z. Wang, Y. Chen, Y. Zhu, S. Zhang, Z. Chen, Y. Liu, M. Xie, Y. Yu, Z. Guo, G. Li, P. Yuan, D. Han, Y. Chen, H. Ye, J. Jiao, P. Yun, **Z. Xu**, H. Wang, H. Huang, S. Wang, P. Cai, Y. Sun, Y. Liu, L. Wang, and M. Liu, "The Role of the Hercules Autonomous Vehicle During the COVID-19 Pandemic: An Autonomous Logistic Vehicle for Contactless Goods Transportation," in IEEE Robotics and Automation Magazine (RAM), 2021.

[8] Q. Wang, **Z. Xu**, Z. Chen, Y. Wang, S. Liu and H. Qu, "Visual Analysis of Discrimination in Machine Learning," in IEEE Transactions on Visualization and Computer Graphics, 2021.

[9] Y. Zhang, S. Yang, H. Li, **Z. Xu**. "Shadow tracking of moving target based on CNN for video SAR system." in IGARSS 2018-2018 IEEE International Geoscience and Remote Sensing Symposium. IEEE, 2018.

[10] **Z. Xu**, Y. Zhang, H. Li, H. Mu, Y. Zhuang. "A new shadow tracking method to locate the moving target in SAR imagery based on KCF." in International Conference in Communications, Signal Processing, and Systems. Springer, Singapore, 2017.

Awards and Honors

- **2018-2022** HKPF (Hong Kong PhD Fellowship, 26,600 HKD/month)
- **2018** Outstanding Graduate of Harbin Institute of Technology
- **2018** Guanghua Scholarship
- **2017** CSST (Cross-disciplinary Scholars in Science and Technology)
- **2017** National Scholarship
- **2016** Meritorious Winner in MCM/ICM
- **2014-2018** Renmin Scholarship
- **2014-2018** University Merit Student
- **2013** Provincial 1st prize in National High School Mathematics League (NO.49 in Henan province)

Technical Skills

Computer Science: Python, LaTex, Ubuntu, C/C++, ROS, MATLAB
Language: Chinese, English (TOEFL 105)

Academic services

- **Reviewer**:
  IEEE Robotics and Automation Letters (RA-L),
  IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS),
  IEEE/RSJ International Conference on Robotics and Automation (ICRA),
  The British Machine Vision Conference (BMVC),
  Autonomous Vehicle Vision (AAV)
- **Teaching assistant:**
  COMP3711 (Design and Analysis of Algorithms),
  COMP3311 (Database Management Systems)