Assignment 2 Response Sheet

2025 Semester 2

1 Instructions

Submission deadline: 31 August 2025, 23:00 (Week 4, Sunday) Please type your answers in the spaces provided. Do not repeat the questions in your answers. All tasks are compulsory.

Note that you must correctly cite and reference any sources you have consulted. You may use any internationally recognized referencing style such as APA or IEEE referencing.

Submit this document to the "Assignment 2 Main Submission" inbox by the published deadline.

Type your student ID number in the space provided below.

Student ID number: 490051481

2 Task 1: Research Questions

I would like to first list the research questions below and then provide further explanation. The method I used to derive these two research questions is based on the approach outlined in the Assignment 2 instructions. The research questions are mainly derived from a review paper[1], which identifies four main research areas of UAV-based powerline inspection: inspection of power components, inspection of power lines, inspection of power towers, and defect inspection. Among these areas, I am most interested in the inspection of power lines and defect inspection. In addition, I believe it is easier to identify research gaps in these two areas, as they represent more challenging tasks.

- How could we achieve robust tracking of power lines in real time during UAV-based inspection?
- How could we achieve a standardized framework for defect definition across different power components?

Research Question 1: How could we achieve robust tracking of power lines in real time during UAV-based inspection?

The two most important factors in power line inspection are extraction and tracking[1]. In this paper[2], although the high computational cost of extracting power lines from the entire image is addressed, the method still fails to handle cases where the power line temporarily disappears from view (e.g., when it is briefly occluded by tall trees) and then reappears in the camera's field of view. In addition, another study [3] tackles the tracking problem by using UAVs to follow power lines in parallel at a safe distance of about 15 m. However, this distance cannot be considered very close to the power lines, meaning that the robustness and accuracy of tracking still leave room for improvement. In conclusion, I believe that tracking power lines with UAVs for inspection is a very active research area, and I can devote more effort to identifying potential research gaps.

Research Question 2: How could we achieve a standardized framework for defect definition across different power components?

There is no standard detection method for power line component defect inspection [1]. Some papers [4], [5] report using infrared thermal imaging to detect defects, while others [6] employ image enhancement methods based on illumination correction and compensation to improve defect detection performance. Additionally, some studies [7] use convolutional neural networks (CNNs) for defect detection. Clearly, there is no widely accepted method for defect detection, and therefore, further investigation in this research area has a high probability of identifying research gaps.

3 Task 2: Annotated Bibliography

There are 5 parts should be included in each annotated bibliography, that is Citation, Introduction, Summary, Evaluation, and Relevance.

Research Question 1 Annotated Bibliography

How could we achieve robust tracking of power lines in real time during UAV-based inspection?

1. O. B. Schofield, K. H. Lorenzen, and E. Ebeid, "Cloud to cable: A drone framework for autonomous power line inspection," in *2020 23rd Euromicro Conference on Digital System Design (DSD)*, IEEE, 2020, pp. 503–509

   In this paper, the authors present a cloud-based autonomous drone system for inspecting power lines. The system workflow is as follows: first, the drone uses geo-location services and onboard sensors for autonomous localization; second, it applies path planning algorithms to navigate along the powerlines while avoiding obstacles; third, it integrates cable grasping and monitoring mechanisms to inspect and evaluate powerline conditions. To enable precise cable localization for inspection and landing, the authors implemented a line detection algorithm combining camera and LiDAR data, including edge detection, vanishing point filtering, line matching, and an Extended Kalman Filter (EKF) to estimate the 3D pose of the power transmission line relative to the UAV. The framework was validated in simulation, showing improved inspection efficiency, enhanced safety, and reduced human labor requirements. Furthermore, operating closer to the powerlines allows higher-quality image capture, benefiting defect detection. This paper is valuable for researchers interested in UAV-based intelligent powerline inspection, particularly for combining autonomous navigation with sensor fusion and innovative cable-grasping mechanisms.

2. C. Xu, Q. Li, Q. Zhou, *et al.*, "Power line-guided automatic electric transmission line inspection system," *IEEE Transactions on instrumentation and measurement*, vol. 71, pp. 1–18, 2022

   In this paper, the authors propose an end-to-end CNN framework to detect power lines from aerial images and a real-time motion planning strategy to guide UAVs along the lines. The system first uses a CNN-based detection network with multilevel feature aggregation (MLFA) and a JA module to enhance global context and suppress background noise, achieving accurate power line detection. The detected power lines are then reconstructed into 3D coordinates via a binocular stereo vision system, employing skeletonization, pixel-tracking, and disparity-based reconstruction to enable precise 3D localization. Finally, a real-time motion planning strategy generates minimal-waypoint trajectories for safe UAV navigation, adjusting altitude, yaw, and direction, while YOLO-based transmission tower detection allows the UAV to automatically complete inspections. This paper is particularly useful for researchers aiming to extract power lines from complex backgrounds and introduces the innovative idea of using the next transmission tower as a navigation target, which can improve the accuracy and robustness of UAV-based power line tracking.

3. H. Guan, X. Sun, Y. Su, *et al.*, "Uav-lidar aids automatic intelligent powerline inspection," *International Journal of Electrical Power & Energy Systems*, vol. 130, p. 106 987, 2021

   This paper presents a LiDAR-based UAV system designed for both powerline tracking and defect detection. The authors address the limitation of traditional methods that rely on manually preset routes, which are often inefficient and inflexible. Instead, their approach uses LiDAR to extract key points along the powerline, enabling the generation of collision-free inspection routes and highlighting areas requiring focused attention. PointNet is employed to classify pylons with high accuracy, achieving precision, recall, and F1 scores above 0.9. The study demonstrates that LiDAR can provide a strong foundation for intelligent, autonomous powerline inspection. While the method shows promise, it is heavily dependent on the availability of high-quality LiDAR data, which may limit its applicability in some environments. Overall, this paper provides valuable insights into integrating LiDAR and deep learning for efficient UAV-based powerline inspection and route planning.

4. L. Zhao, X. Wang, H. Yao, *et al.*, "Power line extraction from aerial images using object-based markov random field with anisotropic weighted penalty," *IEEE Access*, vol. 7, pp. 125 333–125 356, 2019

   This paper presents an advanced method for detecting power lines in aerial images. The approach consists of three main steps: first, a line segment detector (LSD) extracts multiple line segments from the images and constructs a graph model; second, an enhanced object-based Markov random field (OMRF) identifies the power line segments; finally, the complete power lines are reconstructed using an envelope-based piecewise fitting algorithm. The method effectively handles complex backgrounds and outperforms existing approaches such as LSD+OMRF, LSD+pMRF, TA-PLD, AEPL, and CRT, based on evaluations of true positive and false positive rates across various scenarios. The incorporation of anisotropic weighted penalties further improves sensitivity to spatial variations, resulting in robust extraction under diverse imaging conditions. Ultimately, this research is particularly valuable as it provides a robust and accurate solution for power line extraction in complex aerial images, incorporating anisotropic weighted penalties to improve sensitivity to spatial variations

5. Ö. E. Yetgin and Ö. N. Gerek, "Automatic recognition of scenes with power line wires in real life aerial images using dct-based features," *Digital Signal Processing*, vol. 77, pp. 102–119, 2018

   In this paper, the authors present a novel feature extraction strategy based on discrete cosine transform. The method focuses on feature extraction and classification. For feature extraction, three strategies using the Discrete Cosine Transform (DCT) are tested, including low-frequency selection, high-frequency selection, and patch-based selection. Additionally, Local Binary Patterns (LBP) and Histogram of Oriented Gradients (HOG) are used to capture local texture and gradient information. For classification, Naïve Bayes, Random Forest, and Support Vector Machines (SVM) are employed to determine whether aerial images contain power lines. In order to make sure robust evaluation, A 10-fold cross-validation strategy is applied. Experimental results show that the patch-based DCT (64×64) combined with Random Forest on infrared images achieves the highest classification accuracy of 97.38%, outperforming conventional methods while maintaining low computation time (3.8 ms), suitable for real-time UAV applications. In conclusion, This paper is valuable as it introduces a new perspective on power line detection and provides a solid foundation for improving scene-level classification methods.

Research Question 2 Annotated Bibliography

How could we achieve a standardized framework for defect definition across different power components?

1. Y. Wang, H. Liu, D. Wang, *et al.*, "Image processing in fault identification for power equipment based on improved super green algorithm," *Computers & Electrical Engineering*, vol. 87, p. 106 753, 2020

   This paper focuses on detecting powerline defects from UAV infrared video data using an improved image processing technique. The authors propose an improved super green algorithm, which subtracts the minimum value among the RGB channels to produce transformed channels (R, G, B). This suppresses the common intensity component and enhances color contrast, thereby highlighting green information in images. Such enhancement is particularly effective for separating non-plant objects from vegetation backgrounds and for detecting rusted insulators. Experimental results demonstrate that this method significantly outperforms traditional grayscale-based approaches, especially in scenarios with dense vegetation. The study makes a valuable contribution by providing a practical solution for UAV-based defect detection in mountainous or grassland regions where vegetation interference is prominent. However, its applicability may be limited in urban environments with less greenery, requiring further adaptation for broader deployment.

2. M. F. Ahmed, J. Mohanta, and A. Sanyal, "Inspection and identification of transmission line insulator breakdown based on deep learning using aerial images," *Electric Power Systems Research*, vol. 211, p. 108 199, 2022

   This paper presents a comprehensive UAV-based inspection system for powerline component defect detection. The system design covers quadcopter construction, camera selection, image acquisition strategies, and the application of deep learning for anomaly detection. A key contribution is the introduction of a two-stage fine-tuning strategy in SSD training, which addresses common challenges such as limited aerial image datasets and class imbalance. The system operates in three main stages: (1) UAV navigation along powerlines, with hovering at loiter points for image capture; (2) classification of powerline component defects using the fine-tuned SSD model; and (3) repetition of this process until the inspection route is completed. Experimental evaluation demonstrates strong performance, achieving an average precision of 92.31%, a balanced accuracy of 90.4%, a Kappa statistic of 0.85, and an average detection time of 0.6 seconds per image. The results highlight the effectiveness of deep learning in identifying insulator anomalies from aerial images. This work provides a valuable reference for researchers in UAV-based defect detection, particularly in advancing deep learning applications for powerline monitoring.

3. Y. Li, M. Ni, and Y. Lu, "Insulator defect detection for power grid based

on light correction enhancement and yolov5 model," *Energy reports*, vol. 8, pp. 807–814, 2022

In this paper, the authors propose an image enhancement method based on illumination correction and compensation. They further integrate this method with the YOLOv5 model to achieve improved results in detecting insulator defects. The image enhancement method steps are following: Firstly, convert image from RGB to HSV. Secondly, enhance S by using $S' = S \times \left(\frac{1}{2} + \frac{4}{7} + \frac{\max(R,G,B)+\min(R,G,B)+1}{2\cdot mean(R,G,B)+1}\right)$. Thirdly, decompose the reflected component $R(x, y)$, apply 2D adaptive Gamma transformation to $F'(x, y)$, and fuse with $R(x, y)$ to get corrected brightness: $V' = \exp[\log F'(x, y) + \log R(x, y)]$. Fourthly, fuse S' and V' to obtain the illumination-corrected image, then apply improved homomorphic filtering to produce the final enhanced image $V' = \exp[\log F'(x, y) + \log R(x, y)]$. The PSNR of this new method is 16.56, which is much higher than that of ALTM (10.96), CLAHE (14.56), and DONG (10.96). Furthermore, combining this method with YOLOv5 achieves an insulator defect detection accuracy of 95%. Overall, this paper offers a valuable image preprocessing approach for UAV-based power component defect detection, especially under poor aerial image quality conditions, making it a useful reference for researchers in this domain.

4. Y. Wang, J. Wang, F. Gao, *et al.*, "Detection and recognition for fault insulator based on deep learning," in *2018 11th International Congress on Image and Signal Processing, BioMedical Engineering and Informatics (CISP-BMEI)*, IEEE, 2018, pp. 1–6

   In this paper, the authors propose an efficient deep learning–based algorithm for insulator defect recognition, aiming to improve detection accuracy and robustness in complex backgrounds. The method first applies Faster R-CNN to detect insulators from drone-collected aerial images, then uses fully convolutional networks (FCN-8s) for precise segmentation, and finally employs GoogLeNet with Inception modules to classify whether the detected insulators exhibit faults (explosions). Compared with previous methods, this approach achieves the lowest false detection rate and an average accuracy of 99.29%, significantly enhancing recognition performance. In conclusion, although the study focuses primarily on detecting explosion faults of insulators, it provides a robust framework for automated inspection of power transmission systems, eliminating the need for manual feature design and threshold selection.

5. H. Guan, X. Sun, Y. Su, *et al.*, "Uav-lidar aids automatic intelligent powerline inspection," *International Journal of Electrical Power & Energy Systems*, vol. 130, p. 106 987, 2021

   In this paper, the authors present a LiDAR-based UAV system designed for both powerline tracking and defect detection. With regard to defect inspection, the procedure involves three main steps: firstly, LiDAR is employed to identify vegetation encroachment and excessive sag; secondly, thermal imaging is applied to detect abnormal components, as faulty components typically display elevated temperatures; and thirdly, the combined system allows for efficient localization of visible faults. This study is valuable because it introduces LiDAR as a new technology for defect inspection, providing an effective means to detect obvious faults. However, the approach may be limited in identifying smaller defects that require higher precision. Overall, this paper offers useful insights for researchers aiming to enhance the efficiency and reliability of powerline fault detection.

References

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[8] H. Guan, X. Sun, Y. Su, *et al.*, "Uav-lidar aids automatic intelligent powerline inspection," *International Journal of Electrical Power & Energy Systems*, vol. 130, p. 106 987, 2021.

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[11] Y. Wang, J. Wang, F. Gao, *et al.*, "Detection and recognition for fault insulator based on deep learning," in *2018 11th International Congress on Image and Signal Processing, BioMedical Engineering and Informatics (CISP-BMEI)*, IEEE, 2018, pp. 1–6.