Road and Field Boundary Detection in Satellite Imagery

Group 15

Harshavardhan Reddy Mallannagari, Preethi Vahitha Sankineni, Sasidhar Yalamanchili

Problem statement

Road and field boundary detection in satellite or aerial view images is very important in specific areas such as agriculture and urban plan designing. To perform tasks such as managing the field areas supplying resources, it is necessary that the maps of the roads and fields should be accurate and detailed. The clarity of the images is the key. But in this case, the landscapes are very complex and complicated with many interconnections. Hence, the automation process will be a little bit difficult. To overcome this, the project requires a method that can identify the roads and field boundaries in increased pixels to have large and clear images.

Thus, the main problem statement of this project is to detect the roads and field boundaries. And to differentiate the roads and field boundaries from other line features such as waterbodies, railway lines, etc.

Data

The project utilizes two data sets. The images utilized for this project are satellite-captured aerial images of various places in the United States. These images provide visual information about the landscape.

The first set is the development data, which is used to train the models, and the second set is for evaluation and validation, which determines how good and efficient the model is. The images in the dataset are provided by the U.S. Department of Agriculture from the agricultural fields in the USA. They are in jpeg format. These images are cropped from the sections of the large images, and their pixel size is 1 m^2.

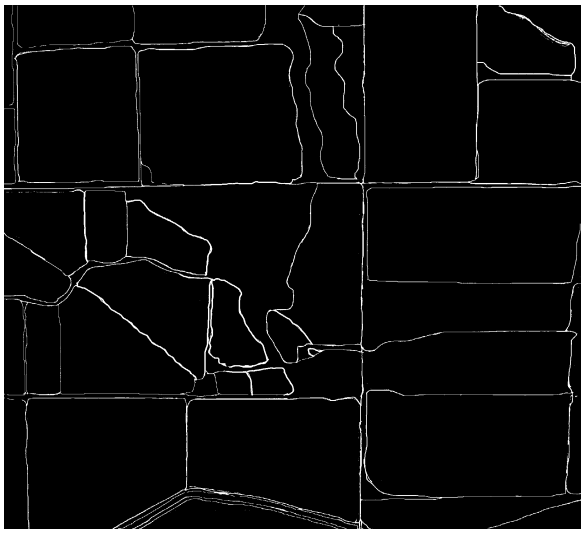
Pic.1. field.jpg

Method

To perform this project there are many methods that need to be followed. They are mentioned below:

1. **Data Acquisition and preprocessing:** This includes techniques such as Noise reduction, increasing the contrast, resizing the image, using filters for better results, etc.
    - **Gaussian Filter**: This is an image preprocessing technique. To prevent noise and to get smooth images, Gaussian Filtering method is used.
    - **Median Filter**: Sorts the pixels in increasing order and then takes the median value. This filter is applied to avoid blurring edges and details in an image.
    - **Histogram Stretching**: Histogram Stretching is an image analysis method. It is an image enhancement technique which gives clear images with enhanced contrast and clarity. The histogram obtained is expected to have a full range of colors.
    - **Histogram Equalization**: This technique performs uniform distribution on the image histogram in order to obtain high contrast. Also, the image intensity will be adjusted resulting in vivid images.

2. **Ground Truth of the images:** Ground truth of the images in the dataset acts as an asset in evaluating the models' predictions. We compare the results obtained from the models with the ground truth images. They serve as a benchmark for the models' performances. To get the ground truth images, we perform manual annotation. Arivis Cloud website or apeer.com was used to do the manual annotation[1].



Pic.2. Ground Truth of field.jpg

3. **Model Design:** The model is designed using MATLAB including the steps mentioned below:
    - Only one image (field.jpg) is used for the pre analysis. The manual annotation to get the ground truth image is also done only for the field.jpg.
    - To perform the pre-analysis, first we read the image using imread() and convert the image into grayscale image.
    - To confirm that the image is converted into grayscale image, we check the dimensions of the image. If the image has a single channel, then it means that it is converted into grayscale.
    - Let's convert the grayscale image into a binary image to view the boundaries clearly.
    - Applying different types of Edge Detectors –

      Sobel Edge Detector – This filter is a built–in function in MATLAB. It is a technique to detect edges in an image both vertically and horizontally. Initially, this method is implemented without using any filters on the image data. Later, Sobel Edge Detector method is applied under various threshold values to identify the best threshold value that provides the highest accuracy. We use ground truth as a benchmark to find out the accuracy of the model. The intersection and union values of the ground truth image and the initial image are calculated to find the accuracy. Filters are added to the grayscale image of the original image such as Gaussian filter, Histogram Equalization, Histogram Stretching and Median filter. The accuracy and threshold values of the Sobel Edge Detector after applying each filter are observed. The following table shows how the accuracy varies for each filter.

Model Name	**Filter**	**Threshold**	**Accuracy**

Sobel	None	Default	7.875558
Sobel	Gaussian	0.05	7.849831
Sobel	Median	0.01	6.200332
Sobel	Histogram Equalization	Default	6.428086
Sobel	Histogram Stretching	Default	6.417841

Canny Edge Detector – This filter aims at finding the strongest edges and the edges that are connected. This technique blurs the image to suppress noise and detects the edges accurately with very few false edges. Canny edge detector is implemented without using any filters on the image data. Later, various threshold values are used as parameters to identify the best threshold value that provides the highest accuracy. We use ground truth as a benchmark to find out the accuracy of the model. The intersection and union values of the ground truth image and the initial image are calculated to find the accuracy. The following filters are added to the grayscale image of the original image - Gaussian filter, Histogram Equalization, Histogram Stretching and Median filter. And the accuracy and threshold values of the Canny Edge Detector are calculated when each of the filter is applied to the image. The following table shows the variance in the accuracy for each filter.

Model Name	**Filter**	**Threshold**	**Accuracy**
Canny	None	Default	4.363802
Canny	Gaussian	0.15 – 0.24	8.080580
Canny	Median	0.15 – 0.24	7.679530
Canny	Histogram Equalization	Default	3.991448
Canny	Histogram Stretching	Default	6.928220

Various methods are performed on the images to detect the edges clearly. Later we evaluate each method using the evaluation metrics.

4. **Evaluation:** Evaluate the models' performance using different evaluation metrics. The accuracy and precision of the methods is calculated. The result depends on various factors such as image normalization, equalization, noise reduction, and suitable parameters etc. The accuracy of different methods when different parameters are given will also be obtained.

Evaluation

Evaluation is one of the most important parts of developing a model. In this project, evaluation of the models' performance is done using evaluation metrics like precision, recall, F1-score, and Intersection over Union (IOU) on the validation dataset, shows how good the developed model is. By evaluating, we can also configure how a model can be improved.

The table below shows the evaluation methodology:

Name	Size	Type	Filter	Accuracy	Precision
field	2048 x 2048	JPG	Sobel, Canny	7.875, 4.363	Pending
L88a	2048 x 2048	JPG	-	Pending	Pending
L88b	2048 x 2048	JPG	-	Pending	Pending
L96a	2048 x 2048	JPG	-	Pending	Pending
L96b	2048 x 2048	JPG	-	Pending	Pending
L97a	2048 x 2048	JPG	-	Pending	Pending
L97b	2048 x 2048	JPG	-	Pending	Pending
W107a	2048 x 2048	JPG	-	Pending	Pending
W107b	2048 x 2048	JPG	-	Pending	Pending

Table.1. Evaluation Metrics

Timeline

List of activities	Timeline	Team Member
Project Kickoff and planning	Sep 15 – Sep 30	Working together.
Data acquisition and initial preprocessing.		Harsha, Sasidhar
Begin model selection and setup.		Harsha, Preethi
Continue model selection and setup.	Oct 1 – Oct 15	Harsha, Preethi
Try different hyperparameters to improve performance.		Working together.
Complete the model.	Oct 16 – Oct 30	Working together.
Evaluate the model.	Nov 1 – Nov 15	Working together.
Report	Nov 16 – Nov 30	Expected equal Contribution

Table.2. Project Timeline

Expected Outcome

List of activities	Expected Outcome
Project Kickoff and planning	Begin the project
Data acquisition and initial preprocessing.	Dataset gathering Dataset preprocessing by applying filters to remove noise, Histogram Stretching, Equalization, Median Filtering etc.
Begin model selection and Ground Truth setup.	Performing manual annotations to create ground truth for the dataset. Models' selection such as Sobel edge detectors, Canny edge detectors etc.
Continue model selection and setup.	Ground Truth images. Working models of edge detectors to achieve project goal. Application of models on the ground truth images.

Try different hyperparameters to improve performance.	By applying different thresholds for different methods to improve models' performances.
Complete the model.	Final models should be able to detect the lines along with points detection. Hough Transform.
Evaluate the model.	Models' accuracy and precision calculation. Compare the models.
Report	Problem Statement, Methods Description, Evaluation, Results, Models' comparison, Future Scope.

Table.3. Expected Project Outcome

REFERENCES:

[1] Apeer.com https://www.apeer.com/app/dashboard.