Infrastructure Surface Crack Detection

Fall 2022 - CS7641 ML - Group Project Proposal

Team Members (alphabetical order): Botao Li, Inshira Seshie, Kaiqin Bian, Lawrence Bradley, Qinghao Zeng

Introduction/Background:

Defect detection constitutes a significant factor in environment and build maintenance, and it is a key process of Structural Health Monitoring (SHM) for infrastructures including buildings, bridges, and roads. Surface cracks, one of the most frequent defects, are superficial line-shaped damages, which in most cases initially appear as a minor gap on the surface. Without timely intervention and precaution, its size and severity could possibly extend beyond a superficial scope, causing grave structural damage (Zou, et al., 2019). This form of decay is preventable through the use of real-time crack detection and monitoring, which can ensure a development's structural health and improve its resilience against natural disasters.

Traditionally, crack detection is conducted by manual inspection by humans deployed to the site, which can be both time consuming and labor-intensive (Munawar, et al., 2021). As a result, Computer Vision (CV) and Machine Learning (ML) algorithms have the potential to be utilized for assisting in improving crack detection accuracy and efficiency, thereby circumventing the need for human inspection. In this project, a combination of these approaches will be employed to design an automated surface crack detection model which will make use of an image dataset showing cracked and uncracked concrete material surfaces. The overall goal of this process is to not only detect these defects but also to evaluate their severity.

Problem definition: Manual inspection is an inefficient use of time and manpower, and the quality and accuracy of inspection cannot be guaranteed. Therefore, the application of CV and ML should be considered as new ways of detecting surface cracks.

Methods:

We intend to use supervised learning (we are currently considering the use of stochastic gradient descent on image features) on the labeled dataset described above for crack detection on concrete surface images. Ideally, after training, this classifier will be able to identify images as positive or negative based on the presence or absence of these superficial defects.

We will also implement an unsupervised learning algorithm to gauge the severity of any cracks detected in the image. Currently we plan to apply clustering based on image features of detected cracks (such as width and length), which will enable efficient defect

reporting to project and maintenance supervisors with detailed descriptions of the structural flaw and its severity.

We are considering the use of the following packages to assist us with our project:

1. NumPy for linear algebra.
2. Pandas for data processing of csv files.
3. Os for operating the system to open, read, and write files.
4. TensorFlow for deep neural networks.
5. OpenCV-python library, cv2 package for computer vision methods.
6. Keras and Python Imaging Library (PIL) for deep learning and image processing.
7. Matplotlib for data visualization.

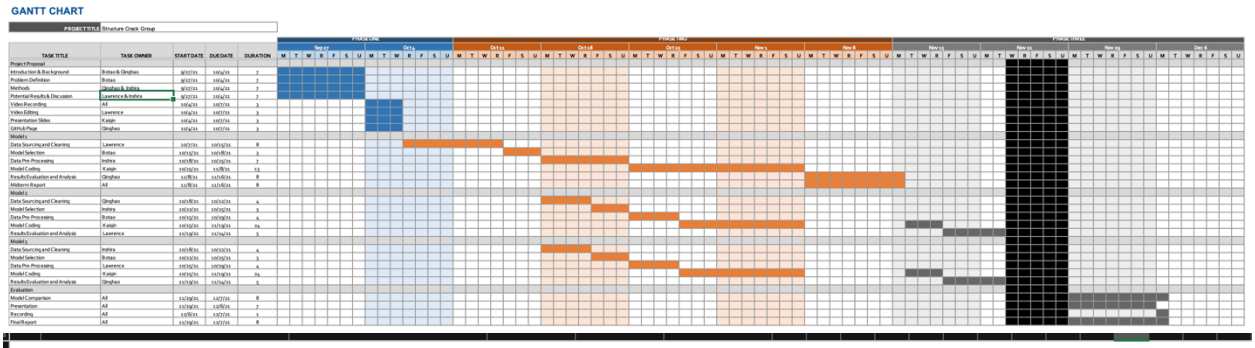
Potential Results:

We expect results concerning the effectiveness of the classifier and the clustering model. We currently intend to apply metrics such as the accuracy, F1, recall, precision, mutual information, homogeneity, and rand scores. These functions will be used to evaluate our model's usefulness in a real-world application using the test data.

References:

1. Zou, Q., Zhang, Z., Li, Q., Qi, X., Wang, Q., & Wang, S. (2019). DeepCrack: Learning Hierarchical Convolutional Features for Crack Detection. IEEE Transactions on Image Processing, 28(3), 1498-1512. https://doi.org/10.1109/tip.2018.2878966
2. Munawar, H. S., Hammad, A. W. A., Haddad, A., Soares, C. A. P., & Waller, S. T. (2021). Image-Based Crack Detection Methods: A Review. Infrastructures, 6(8), 115. https://doi.org/10.3390/infrastructures6080115
3. Mansuri, L. E., & Patel, D. A. (2021). Artificial Intelligence-based automatic visual inspection system for Built Heritage. *Smart and Sustainable Built Environment*. https://doi.org/10.1108/sasbe-09-2020-0139
4. Mishra, M. (2021). Machine learning techniques for structural health monitoring of heritage buildings: A state-of-the-art review and case studies. *Journal of Cultural Heritage*, *47*, 227–245. https://doi.org/10.1016/j.culher.2020.09.005
5. Lei Zhang, Fan Yang, Yimin Daniel Zhang, and Y. J. Z., Zhang, L., Yang, F., Zhang, Y. D., & Zhu, Y. J. (2016). Road Crack Detection Using Deep Convolutional Neural Network. In 2016 IEEE International Conference on Image Processing (ICIP). http://doi.org/10.1109/ICIP.2016.7533052

Timeline and Responsibilities:



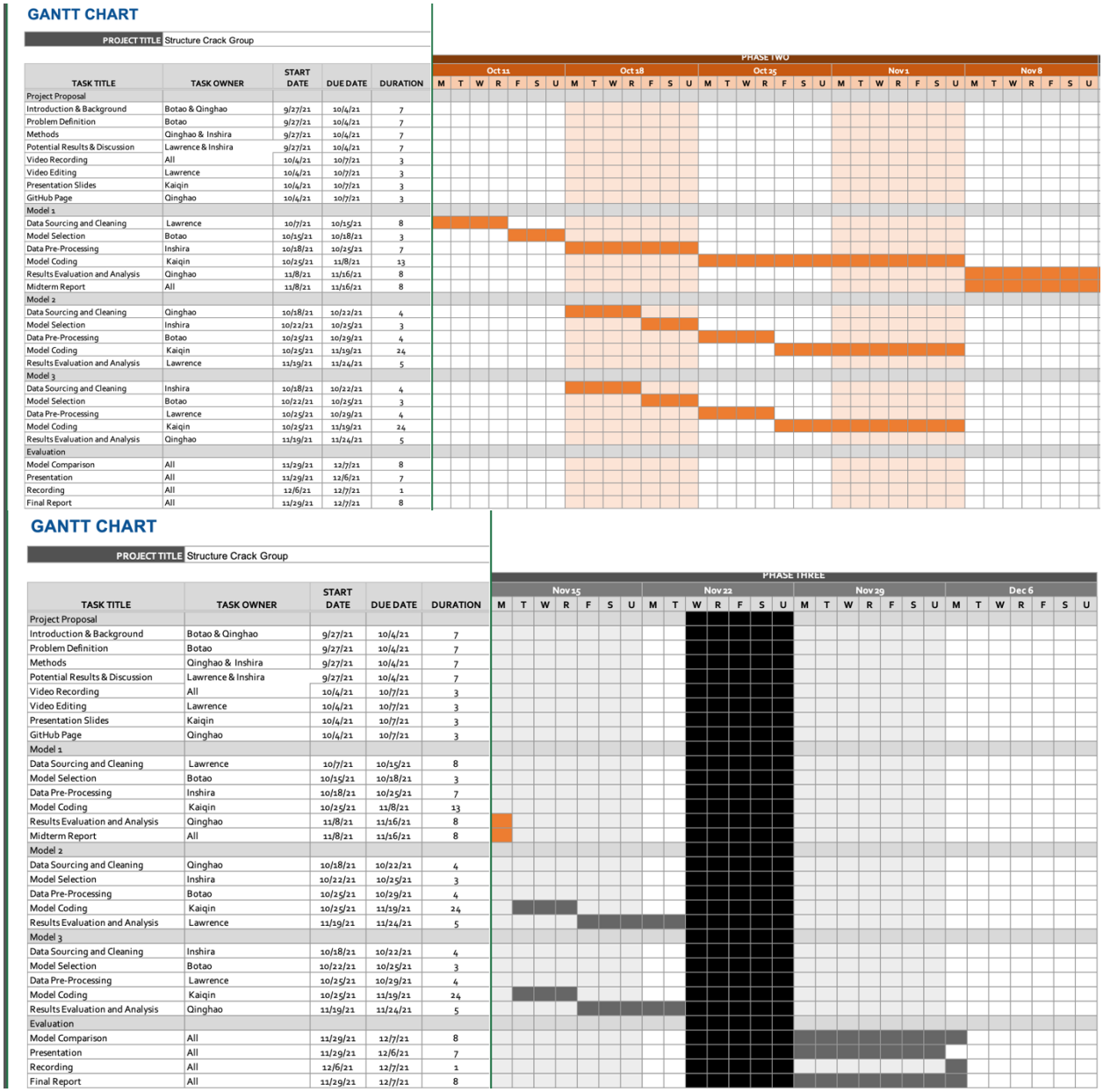
GANTT CHART

PROJECT TITLE Structure Crack Group

TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION
Project Proposal				
Introduction & Background	Botao & Qinghao	9/27/21	10/4/21	7
Problem Definition	Botao	9/27/21	10/4/21	7
Methods	Qinghao & Inshira	9/27/21	10/4/21	7
Potential Results & Discussion	Lawrence & Inshira	9/27/21	10/4/21	7
Video Recording	All	10/4/21	10/7/21	3
Video Editing	Lawrence	10/4/21	10/7/21	3
Presentation Slides	Kaiqin	10/4/21	10/7/21	3
GitHub Page	Qinghao	10/4/21	10/7/21	3
Model 1				
Data Sourcing and Cleaning	Lawrence	10/7/21	10/15/21	8
Model Selection	Botao	10/15/21	10/18/21	3
Data Pre-Processing	Inshira	10/18/21	10/25/21	7
Model Coding	Kaiqin	10/25/21	11/8/21	13
Results Evaluation and Analysis	Qinghao	11/8/21	11/16/21	8
Midterm Report	All	11/8/21	11/16/21	8
Model 2				
Data Sourcing and Cleaning	Qinghao	10/18/21	10/22/21	4
Model Selection	Inshira	10/22/21	10/25/21	3
Data Pre-Processing	Botao	10/25/21	10/29/21	4
Model Coding	Kaiqin	10/25/21	11/19/21	24
Results Evaluation and Analysis	Lawrence	11/19/21	11/24/21	5
Model 3				
Data Sourcing and Cleaning	Inshira	10/18/21	10/22/21	4
Model Selection	Botao	10/22/21	10/25/21	3
Data Pre-Processing	Lawrence	10/25/21	10/29/21	4
Model Coding	Kaiqin	10/25/21	11/19/21	24
Results Evaluation and Analysis	Qinghao	11/19/21	11/24/21	5
Evaluation				
Model Comparison	All	11/29/21	12/7/21	8
Presentation	All	11/29/21	12/6/21	7
Recording	All	12/6/21	12/7/21	1
Final Report	All	11/29/21	12/7/21	8

PHASE ONE

Sep 27							Oct 4						
M	T	W	R	F	S	U	M	T	W	R	F	S	U



GANTT CHART

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PHASE TWO

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Contribution Table:

Name	Contributions
Botao Li	Literature reviews, intro/problem definition/potential results writing
Inshira Seshie	GANTTs chart filling, assisted writing Methods/potential results section
Kaiqin Bian	Literature reviews, slides making.
Lawrence	General edits for clarity, rewrote methods and potential results sections.
Qinghao Zeng	Methods and potential results writing, GitHub page set up