Detection and Classification of Cracks on Transportation Infrastructure using UAV Based Aerial Imagery

Design Document

May20-13
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Revised: October 2, 2019 Version 1

Executive Summary

Development Standards & Practices Used

Software -

- PyTorch - library for machine learning

Hardware -

- UAV - for taking photographs of the pavement
- UAV mounted photography equipment - for taking photographs of pavement

Standards -

- IEEE 12207 - Software life-cycle processes

Summary of Requirements

- UAV can take photographs of pavement
- Photos will be taken on sunny or overcast days with no precipitation
- Software will be able to detect cracks in asphalt
- Software will be able to detect cracks and joints within concrete
- Software will be able to correctly classify cracks and joints

Applicable Courses from Iowa State University Curriculum

- COMS 309
- COMS 311

New Skills/Knowledge acquired that was not taught in courses

- Machine learning
- Image processing
- Knowledge of how concrete with joints crack

Table of Contents

List of figures/tables/symbols/definitions

Definitions:

UAV - Unmanned Aerial Aircraft; a drone that can fly via remote control

Appendix:

Appendix 1 - Project Plan Flow

1 Introduction

1.1 Acknowledgement

Our team would like to acknowledge our client for the assistance he has provided throughout the project. At the beginning, Ahmed has been proactive in assisting our team with design specifications, equipment, and initial data. Throughout the project, Ahmed was available to answer questions and was willing to help us in whatever manner he could.

1.2 Problem and Project Statement

Problem Statement: Due to the weather fluctuations in Iowa and throughout the midwest, concrete and other road surfaces are constantly changing causing potholes, cracks, and other problems that create hazardous and at times, undrivable road conditions.

Project Statement: The purpose of our project is to provide a way to identify cracks and their classifications in pavement via an Unmanned Aerial Vehicle (UAV).

This will be accomplished by using a UAV, artificial intelligence, and image processing. The UAV will take photos of various roads which will be run through through image processing which will teach artificial intelligence to identify cracks.

By being able to identify cracks and their classifications, any department charged with fixing and maintaining roads will be able to identify roads in the most critical conditions. As a result, crews will be able to prioritize their work and create safer driving conditions.

1.3 Operational Environment

The main operational environment for this project will consist of days with clear or overcast skies and no precipitation. While the overcast conditions will alter the pictures will still be able to run through image processing whereas precipitation could alter the photos beyond our capabilities. In addition, the UAVs that are used in this project will only fly with no precipitation.

1.4 Requirements

Economic -

- Software cost will be kept minimal (use free/open source software)
- The cost to operate the UAV will stay to a minimum

Environmental -

- UAV flights will not impact the surrounding environments
- Conditions for flight must be taken into account when flying

Outcome -

- Software will be able to detect cracks within concrete and asphalt roads
- Software will be able to detect different surface areas (concrete, asphalt, gravel)
- Software will be able to categorize different cracks (joints vs. cracks)

1.5 Intended Users and Uses

This project is intended to be used by professionals as an additional resource to evaluate existing infrastructure including roads and bridges. This will assist in prioritizing repairs and maintenance to roads and bridges in critical conditions in order to ensure they stay safe and drivable.

1.6 Assumptions and Limitations

Assumptions -

- Initial data will be provided to us (client has notified us that data is available)
- Surfaces will have cracks to identify (most surfaces have some form of crack or joints)

Limitations -

- UAV flying must be planned and will not always be available for use (FAA laws since ISU is within 5 miles of an airport)
- UAV can only fly to a certain height for picture to be useful (photo equipment limitation)
- UAV flight cannot be continuous (UAV hardware limitations)

1.7 Expected End Product and Deliverables

The expected end product and deliverable to the client will be a software that can intake photographs of roads and identify and classify cracks and joints. This software can be used to help those assessing infrastructure conditions and help prioritize roads for maintenance and repair. The software will be delivered in two phases. The first phase will be delivered by December 13, 2019 and will be a software that identifies any type of cracking in pavement or asphalt. The second phase will be delivered no later than May 1, 2020 and will be a software that, in addition to phase 1, will also be able to classify the cracks into different types.

2. Specifications and Analysis

2.1 Proposed Design

We have decided that our project will use machine learning to identify cracks in the pavement. After looking at a few options, we decided upon using PyTorch due to its ease of use and extensive documentation. Since it is open source, it is also free to use. This meets our economic requirement of our project, as it will dramatically reduce man-hours previously required to examine every picture, and there is no cost associated with using the software.

2.2 Design Analysis

After looking at different options for machine learning algorithms, we decided that PyTorch would be a better option than its closest competitor TensorFlow. This is because of PyTorch being easier to use and also having more documentation. We have also created a Python script that crops images down so that they can be easily analysed by the software.

2.3 Development Process

We will follow an Agile-like development process. As the majority of our project revolves around the machine learning algorithm, most of our tasks will involve removing errors and improving its accuracy. Working in 2 week sprints will also allow us to always have something new to present to our client.

2.4 Design Plan

For our design plan, we will make a flowchart that illustrates the process we will be taking for this project. This flowchart will contain the data collection process, the machine learning algorithm and how we train it to correctly identify cracks in concrete. Then if need be, we will use the trained algorithm to predict cracks in video footage of concrete.

3. Statement of Work

3.1 Previous Work And Literature

Include relevant background/literature review for the project

– If similar products exist in the market, describe what has already been done

– If you are following previous work, cite that and discuss the **advantages/shortcomings**

– Note that while you are not expected to “compete” with other existing products / research groups, you should be able to differentiate your project from what is available

Detail any similar products or research done on this topic previously. Please cite your sources and include them in your references. All figures must be captioned and referenced in your text.

3.2 Technology Considerations

Highlight the strengths, weakness, and trade-offs made in technology available.

Discuss possible solutions and design alternatives

3.3 Task Decomposition

In order to solve the problem at hand, it helps to decompose it into multiple tasks and to understand interdependence among tasks.

3.4 Possible Risks And Risk Management

Include any concerns or details that may slow or hinder your plan as it is now. These may include anything to do with costs, materials, equipment, knowledge of area, accuracy issues, etc.

3.5 Project Proposed Milestones and Evaluation Criteria

What are some key milestones in your proposed project? Consider developing task-wise milestones. What tests will your group perform to confirm it works?

3.6 Project Tracking Procedures

What will your group use to track progress throughout the course of this and next semester?

3.7 Expected Results and Validation

What is the desired outcome?

How will you confirm that your solutions work at a **High level**?

4. Project Timeline, Estimated Resources, and Challenges

4.1 Project Timeline

• A realistic, well-planned schedule is an essential component of every well-planned project

• Most scheduling errors occur as the result of either not properly identifying all of the necessary activities (tasks and/or subtasks) or not properly estimating the amount of effort required to correctly complete the activity

• A detailed schedule is needed as a part of the plan:

– Start with a Gantt chart showing the tasks (that you developed in 3.3) and associated subtasks versus the proposed project calendar. The Gantt chart shall be referenced and summarized in the text.

– Annotate the Gantt chart with when each project deliverable will be delivered

• Completely compatible with an Agile development cycle if that's your thing

How would you plan for the project to be completed in two semesters? Represent with appropriate charts and tables or other means.

Make sure to include at least a couple paragraphs discussing the timeline and why it is being proposed. Include details that distinguish between design details for present project version and later stages of project.

4.2 Feasibility Assessment

Realistic projection of what the project will be. State foreseen challenges of the project.

4.3 Personnel Effort Requirements

Include a detailed estimate in the form of a table accompanied by a textual reference and explanation. This estimate shall be done on a task-by-task basis and should be based on the projected effort required to perform the task correctly and not just "X" hours per week for the number of weeks that the task is active

4.4 Other Resource Requirements

Identify the other resources aside from financial, such as parts and materials that are required to conduct the project.

4.5 Financial Requirements

If relevant, include the total financial resources required to conduct the project.

5. Testing and Implementation

Testing is an **extremely** important component of most projects, whether it involves a circuit, a process, or a software library

Although the tooling is usually significantly different, the testing process is typically quite similar regardless of CprE, EE, or SE themed project:

1. Define the needed types of tests (unit testing for modules, integrity testing for interfaces, user-study for functional and non-functional requirements)
2. Define the individual items to be tested
3. Define, design, and develop the actual test cases
4. Determine the anticipated test results for each test case 5. Perform the actual tests
6. Evaluate the actual test results
7. Make the necessary changes to the product being tested 8. Perform any necessary retesting
9. Document the entire testing process and its results

Include Functional and Non-Functional Testing, Modeling and Simulations, challenges you've determined.

5.1 Interface Specifications

– Discuss any hardware/software interfacing that you are working on for testing your project

5.2 Hardware and software

– Indicate any hardware and/or software used in the testing phase

– Provide brief, simple introductions for each to explain the usefulness of each

5.3 Functional Testing

Examples include unit, integration, system, acceptance testing

5.4 Non-Functional Testing

Testing for performance, security, usability, compatibility

5.5 Process

– Explain how each method indicated in Section 2 was tested

– Flow diagram of the process if applicable (should be for most projects)

5.6 Results

– List and explain any and all results obtained so far during the testing phase

- – Include failures and successes
- – Explain what you learned and how you are planning to change it as you progress with your project
- – If you are including figures, please include captions and cite it in the text

• This part will likely need to be refined in your 492 semester where the majority of the implementation and testing work will take place

-**Modeling and Simulation**: This could be logic analyzation, waveform outputs, block testing. 3D model renders, modeling graphs.

-List the **implementation Issues and Challenges**.

6. Closing Material

6.1 Conclusion

Summarize the work you have done so far. Briefly re-iterate your goals. Then, re-iterate the best plan of action (or solution) to achieving your goals and indicate why this surpasses all other possible solutions tested.

6.2 References

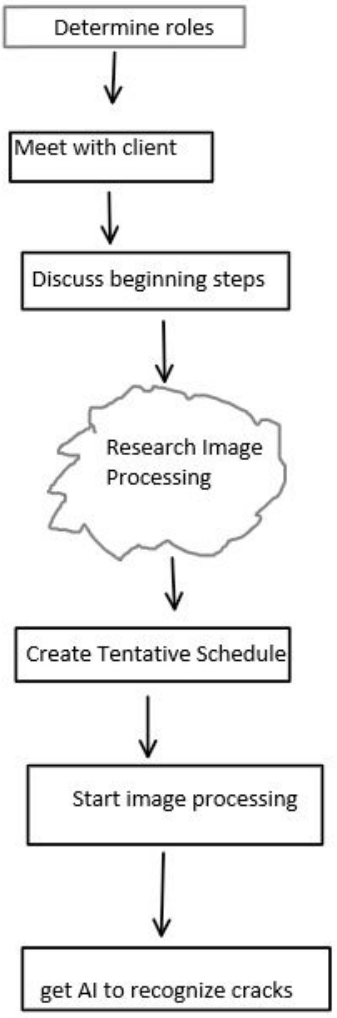
This will likely be different than in project plan, since these will be technical references versus related work / market survey references. Do professional citation style(ex. IEEE).

6.3 Appendices

Any additional information that would be helpful to the evaluation of your design document.

If you have any large graphs, tables, or similar that does not directly pertain to the problem but helps support it, include that here. This would also be a good area to include hardware/software manuals used. May include CAD files, circuit schematics, layout etc. PCB testing issues etc. Software bugs etc.

Appendix 1



9/10 Determine group roles for admin

9/12 Met with client initially

Meeting on 9/26 to start processing data

9/26-10/23 Research image processing and data collection
This will be continuous as needed for the project

9/28 - Script made to break down images

10/3 Begin creating schedule for the rest of the year

10/9 - begin to process the images and train AI to recognize cracks

The group will work on the project and continue to have meetings with the client about specifications and necessary project changes

12/6 - Get first half of senior design finished;
next steps: data processing to recognize types of cracks