CAAP Quarterly Report

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Prepared for: *U.S. DOT Pipeline and Hazardous Materials Safety Administration*

Contract Number: 693JK31850013CAAP

Project Title: A Fast and Low-cost Method to Automate Detecting, Locating, and Mapping Internal Gas Pipeline Corrosion using Pig-mounted Thermal and Stereo Cameras

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Business and Activity Section

(a) Contract Activity

1) **Contract modification**: No contract modification is expected in this quarter.

2) **Material purchased:** No major material was purchased in this quarter except miscellaneous hard drives and inventory computer parts at a total cost of $241.44

(b) Status Update of Past Quarter Activities

In this quarter, the PI and the two Ph.D. students focused on developing new algorithms for detecting corrosion features using deep convolutional neural network (DCNN). The DCNN is for video processing, and smart-pig positioning. The team also start testing the parts received from the vendors in last quarter. Prototype design work was extended from last quarter. A pilot testing bed was set up to prepare for the initial evaluation of the parts and the system.

1) Cost share activity

The PI dedicated 0.4 FTE in this quarter to the project, which is equivalent to 0.4 x 3 months = 1.2 months of cost share. The portion of cost share in this quarter is $25,506. The primary task included in this cost-share is the prototype design and testing. The PI is expected to dedicate total 2.91-month research time in the first year, which is amounted to $61,853.

2) Part 1 Technology / platform development

Task 1.1: Design, prototype, and test the pig device with all the mounted devices and cameras

This task is approx. 80% completion by the end of the quarter. The prototype design was modified based on some preliminary testing results of the received parts.

Task 1.2 Setup the testing pipe platform in the working space of UNL Structural Lab.

A preliminary pilot testing bed was set up in the basement of UNL Structural Lab for initial evaluation of the device parts and the system. This task is 50% completion.

Task 1.3 Identify, develop, and test algorithms for internal pipe surface RGB-D mapping after Task 1.1 and Task 1.2 completed. The inputs for the algorithms are stereo video frames of the pipelines' internal surface. The outputs are the unfolded 3D profile and 2D texture maps of the pipelines' internal surface.

Many different image processing methods were investigated. One thermographic image processing algorithm was developed and tested. This task is 20% completion by the end of this quarter.

Detailed discussion and descriptions for the following:

1. **Background and Objectives in the 2nd Quarter**

   - ***Background***

   The goal of this project is to detect and locate the corrosion spots in the pipelines. The proposed approach will heavily rely on image processing technologies, including optical images and infrared images. So, while the team was developing traditional detecting algorithms, the team also expanded the investigation to include more recent emerging image/video processing technologies.

   As a result of the expanded research, deep convolutional neural network (DCNN) approaches in image and video processing caught the investigators' attention. The team found it promising because: 1) it enables automated image processing due to its learning capacity; 2) its ability of positioning based on video may provide us a way to locating the corrosion spots without relying on GPS. Further evaluation is needed to better understand its capacity, and its accuracy performance.

   - ***Objectives***

     a. To setup the testing bed and get it ready for preliminary evaluations of the prototype device and the developed algorithms.

     b. To develop and evaluate algorithms of image processing for corrosion detection and location.

2. **Experimental Program in the 1st Quarter:** N/A

   2.1 Experimental design *N/A*

3. **Results and Discussions**

   New technology emerged from the literature review. Based on the recent studies, the research team found that deep convolutional neural network (DCNN) can potentially be a viable tool for both corrosion feature detection and the pig-device positioning. The team is further evaluating the new technology.

   One algorithm, "regularized grayscale morphological reconstruction method", was developed for processing infrared images for thermographic corrosion detection. The principle of the algorithm is

illustrated in Fig. 1. This algorithm was preliminarily tested to detect any local temperature gradient changes under noise. The initial results indicated it is a feasible way to detect pipe corrosion spots. Further testing is needed for robustness evaluation.

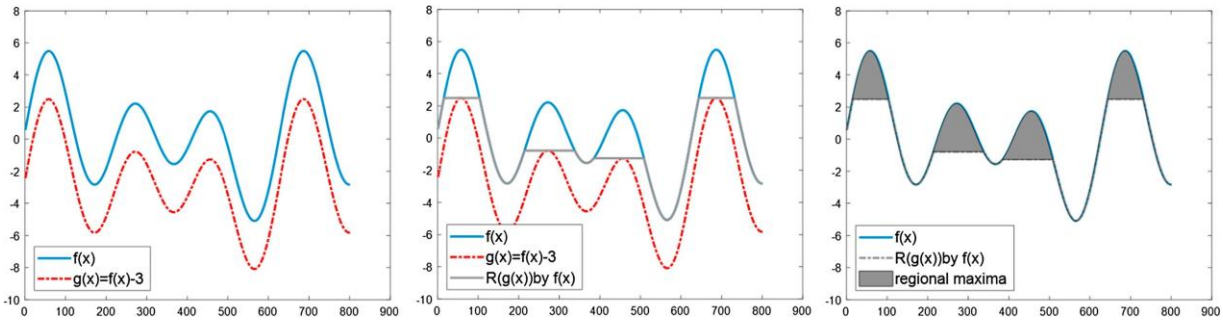

Fig 1. Graphical Illustration of Regularized Grayscale Morphological Reconstruction Method

4. Future work

In the 3rd quarter the team will further investigate the potential of deep convolutional neural network (DCNN) in pig-device-positioning without GPS. The accuracy performance will the key concerned parameter to investigate. This new technology was found promising. If successful, it will provide a robust way to locate the detected corrosion signs.

References

1) S. Hiasa, R. Birgul, F.N. Catbas "Investigation of effective utilization of infrared thermography (IRT) through advanced finite element modeling", Constr. Build. Mater., 150 (2017), pp. 295-309
2) M. Coster, J.-L. Chermant, "Image analysis and mathematical morphology for civil engineering materials Cem. Concr. Compos., 23 (2001), pp. 133-151
3) L. Vincent. "Morphological grayscale reconstruction in image analysis: applications and efficient algorithms", IEEE Trans. Image Process., 2 (1993), pp. 176-201
4) Abhinav Valada, Noha Radwan, Wolfram Burgard (2018). "Deep Auxiliary Learning for Visual Localization and Odometry", 2018 IEEE International Conference on Robotics and Automation (ICRA).