Project Title: Machine Learning Percussion Method Approach for PIG Pipeline Detection

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Problem Statement

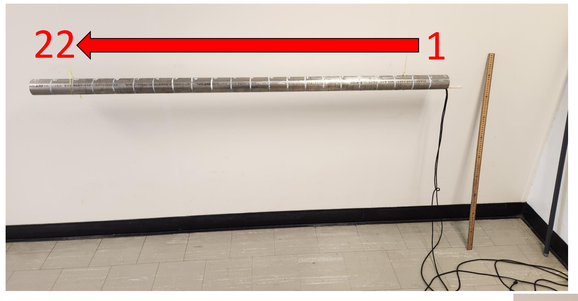
PIG Devices are common industries will long piping. They are used to clear out any remaining debris or residue in the pipe. These devices can get lost and stuck in the pipe, with pipe that extend several dozens of feet finding them could prove difficult. A percussion method has been proposed to find these PIGs. This experiment looks to the accuracy of machine learning methods to properly classify PIG location based on percussion method.

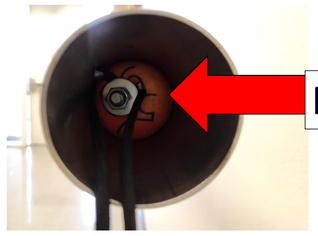
Brief Literature Review

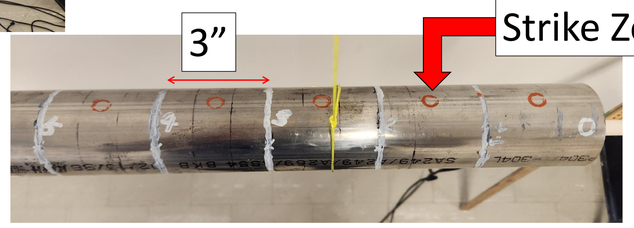
Percussion method monitoring has been proven to be effective in several applications. In underwater application it was used to monitor bolt looseness with CNN to classify tightness. K Means study was conducted to classify drummer types based on their sound of hitting a drum.

Experimental Setup and Collection of Data

A 5.5 ft. hallow metal pipe was suspended from the ceiling with a PIG device inside the pipe. The pipe was divided into 22 sections every 3” with a red circle in the middle of each section as the strike zone. On both sides of the PIG a rope was attached to allow the device to move along the pipe. Data was collected by striking the pipe at the location of the PIG 20 times and all over sections of the pipe 5 times then moving the PIG to the next location then repeating for all sections of pipe. Data wasn’t taken at 2 end points of pipe due to vibration error. A ruler was used to verify PIG location.

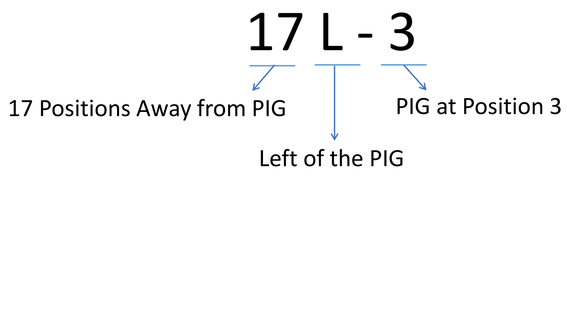






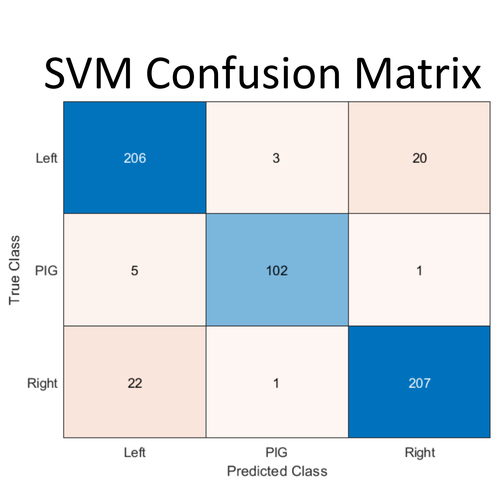
Method(s)

To process the raw data signals a feature extraction method was used where the amplitude of the signal was found identify the signal. Data was labeled by section distance from PIG and whether if it was to the left or right of the PIG. For signals at PIG location data was just labeled PIG. An MFCC matrix was extracted from each dataset. These matrices were used for both SVM and GMM clustering. These methods were used to determine whether signal was coming from left or right of the PIG or was directly on the PIG.



Results, Analysis and Discussion

A SVM model was built classifying PIG from left and right position, a confusion matrix was constructed 92% accuracy detecting the position of the PIG. This model has been proven very accurate with actual PIG detection showing to be the fewest, but this is due to fewer data points taken a PIG location. For the SVM method the most inaccurate area was predictions of left to the PIG. As expected there were a few inaccuracies between left and right which can be cured by more data points or adding a distinct feature to each side since they were symmetrical to the PIG. Using CNN shown good results as well with an accuracy of 94%. The confusion matrix of this shows the same issue as for with the SVM method with left and right.

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    0.9174
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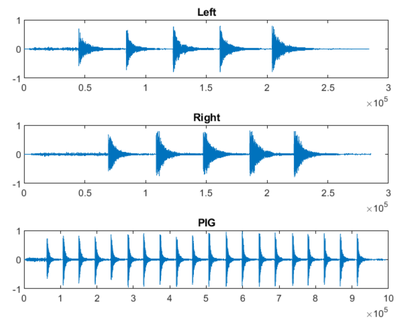

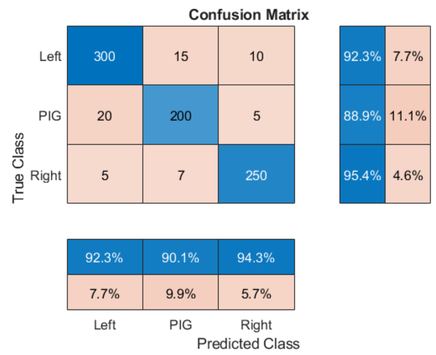


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Overall Accuracy: 94.3333%
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Conclusion

This project studied SVM and CNN methods to detect PIG location in a pipeline using a percussion approach. The accuracy for both of these methods were above 90% proving to be reliable methods. The GMM shown better results. In future use of this method a GMM clustering approach could prove to be more useful.

Acknowledgements

The financial support from Midstream Integrity Services (MIS) and technical support from Smart Materials & Structures Lab (SMSL) and Artificial Intelligence Lab for Monitoring & Inspection (AILMI) at UH.

References (brief)

[1] Zhou, Ying, et al. “Percussion-based Bolt looseness identification using vibration-guided sound reconstruction.” *Structural Control and Health Monitoring*, vol. 29, no. 2, 28 Oct. 2021, https://doi.org/10.1002/stc.2876.
[2] Kong, Qingzhao, et al. “A CNN-integrated percussion method for detection of FRP–concrete interfacial damage with FEM reconstruction.” Structural Health Monitoring, vol. 22, no. 1, 15 Apr. 2022, pp. 216–231, https://doi.org/10.1177/14759217221082007.
[3] He, Sihong, et al. “An exploratory study of underwater bolted connection looseness detection using percussion and a shallow machine learning algorithm.” Acta Mechanica Sinica, vol. 39, no. 4, 24 Apr. 2023, https://doi.org/10.1007/s10409-023-22360-x.