Acoustic Precision: AI-Driven Localization of Stuck PIGs in Pipelines

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Problem Statement

- Challenge:
  - Pipeline Inspection Gauges (PIGs) are crucial for maintaining pipeline integrity, but can disrupt operations when they become stuck
  - Traditional methods for locating stuck PIGs are often inefficient and inaccurate
- Objective:
  - Develop a 1D convolutional neural network model to detect and accurately locate stuck PIGs by analyzing acoustic data.

Brief Literature Review

- Bernasconi and Giunta [1] (2020) propose methods for tracking Pipeline Inspection Gauges (PIGs) using passive acoustic signals. Their study outlines three techniques: cross-correlation analysis, acoustic transient counting, and resonance frequency analysis of pipeline segments. These methods leverage strategically placed sensors for accurate, real-time PIG localization, offering a viable alternative to traditional active tracking systems (Bernasconi & Giunta, 2020)

Experimental Setup and Collection of Data

- For each segment of the pipeline we measure the distance from the PIG and we apply impulse input 10 times for each audio file
- The data will be a time series of 10081 sample and we label the data based on the location of the PIG with respect to the location of the impulse input

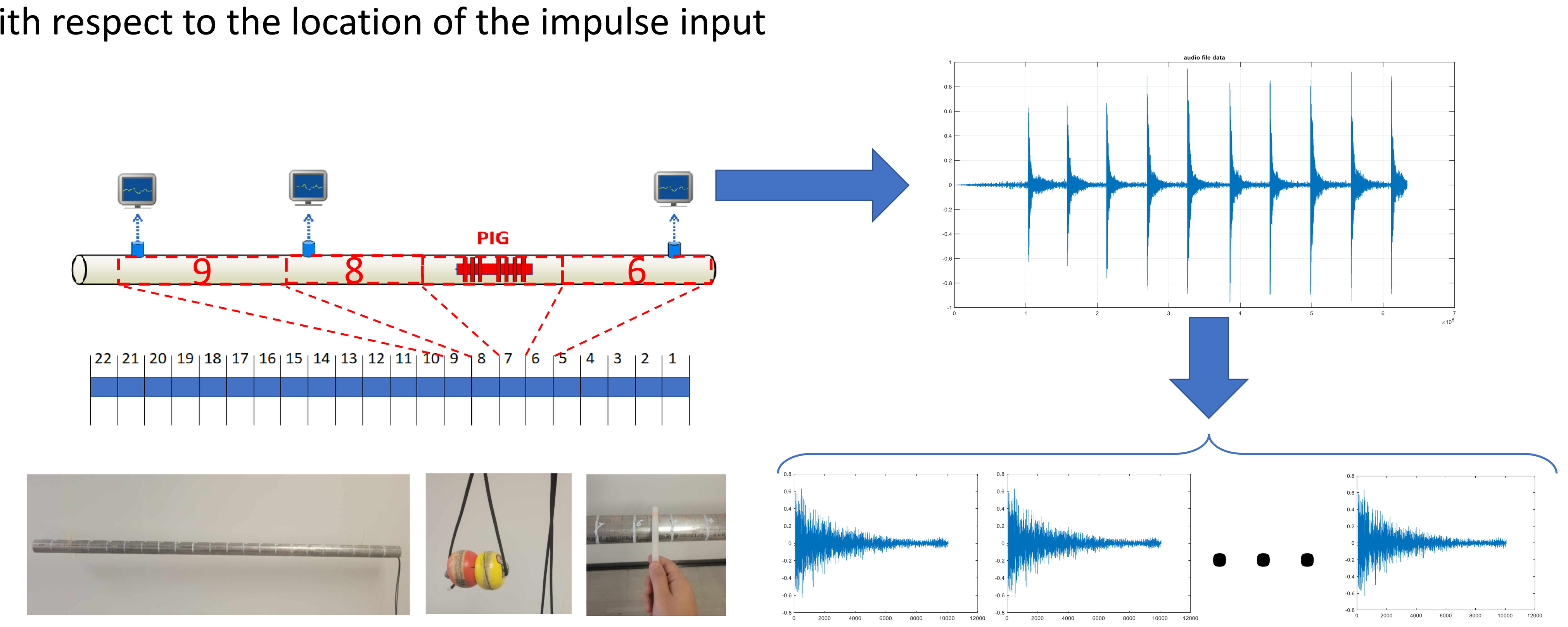

Fig 1: Data collection workflow

Method

- The dataset is highly unbalanced, with only 5% of the data falling under the category labeled as PIG.
- To achieve balance, we augment the dataset by applying a random scaling factor and adding noise to each data point.

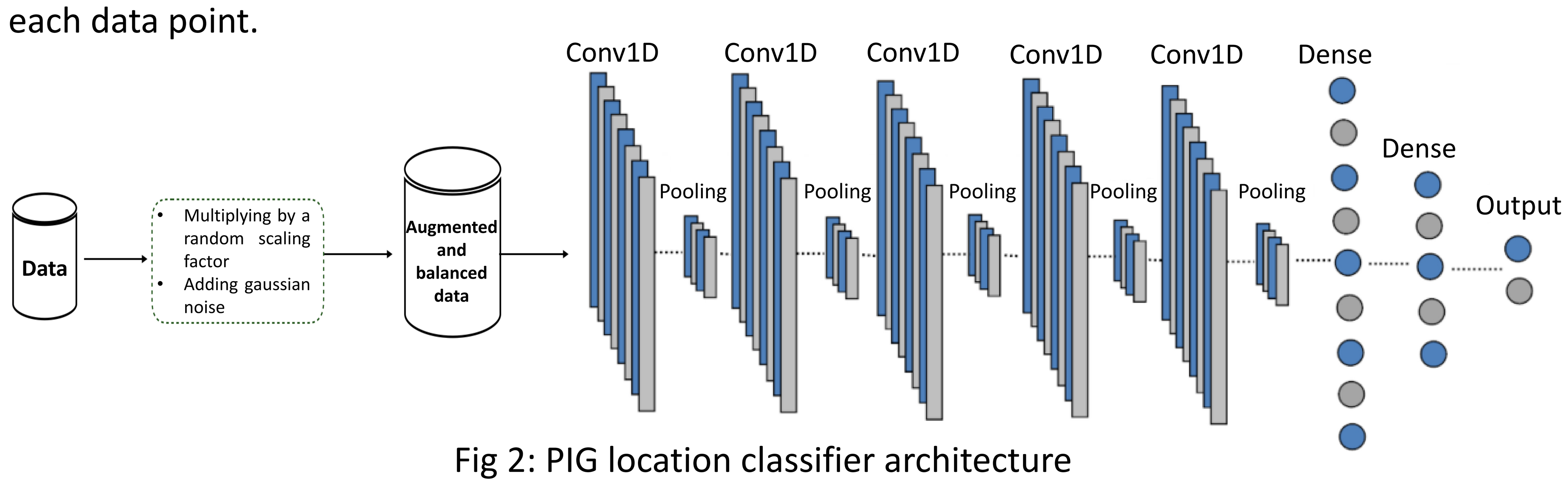

Fig 2: PIG location classifier architecture

layer	Conv1D_1	Pooling_1	Conv1D_2	Pooling_2	Conv1D_3	Pooling_3	Conv1D_4	Pooling_4	Conv1D_5	Pooling_5
Window size	16	3	16	3	16	3	16	3	16	3
stride	1	3	1	3	1	3	1	3	1	3
Output channels	8	8	16	16	32	32	64	64	64	64

Table 1: 1D CNN parameters details

Results, Analysis and Discussion

- Case 1: binary classification problem: for this part, we label the data by either the signal corresponding to an existent PIG or an absence of a PIG:

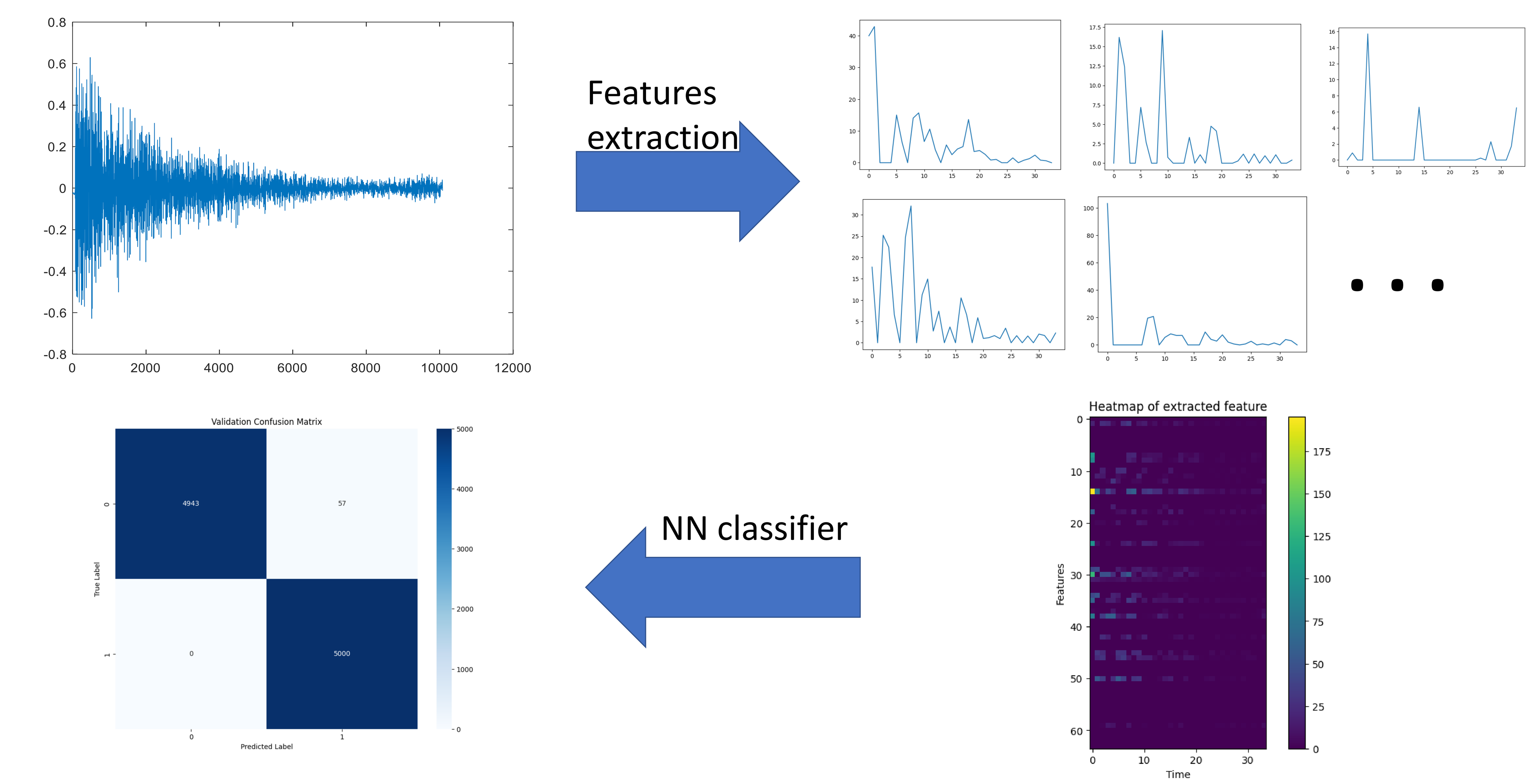

Fig 3: Experimental results for the classification on validation data. We see that the accuracy on validation data is 99.43

- Case 2: multi-class classification problem: for this part, we label the data from 1 to n with n corresponding to existent PIG, n-k corresponding to k step further from the PIG, and 0 is nor PIG location nor close to it:

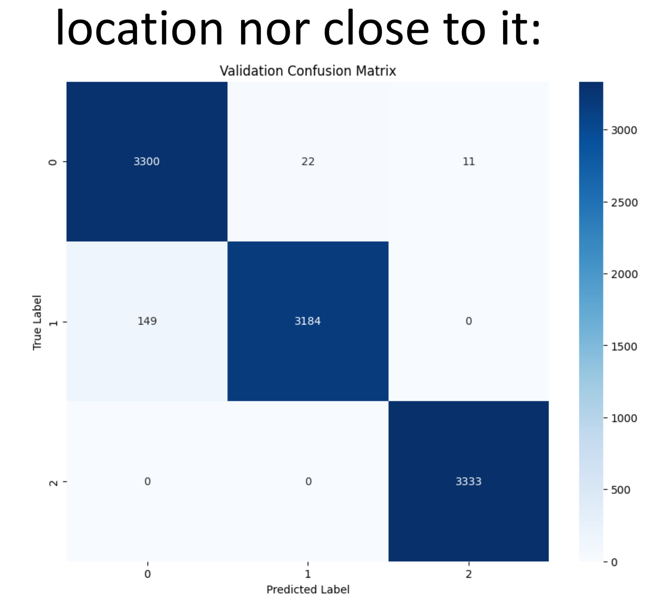

Fig 4: Experimental results for 3 class classification on validation data. Accuracy 98.18

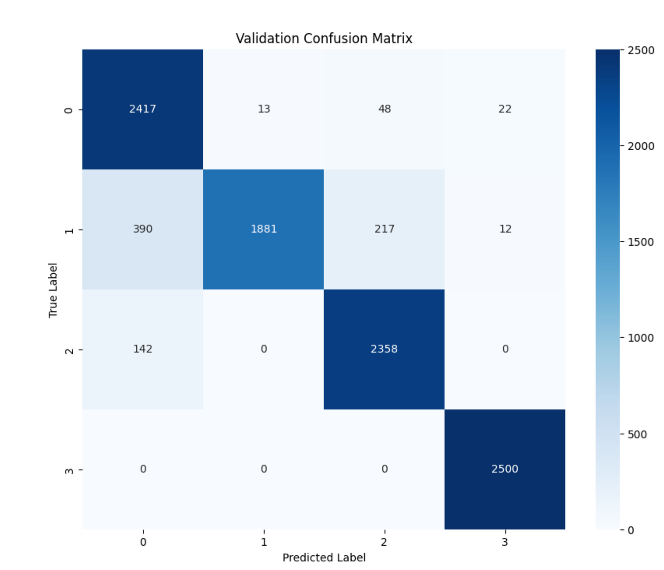

Fig 5: Experimental results for 4 class classification on validation data. Accuracy 91.56

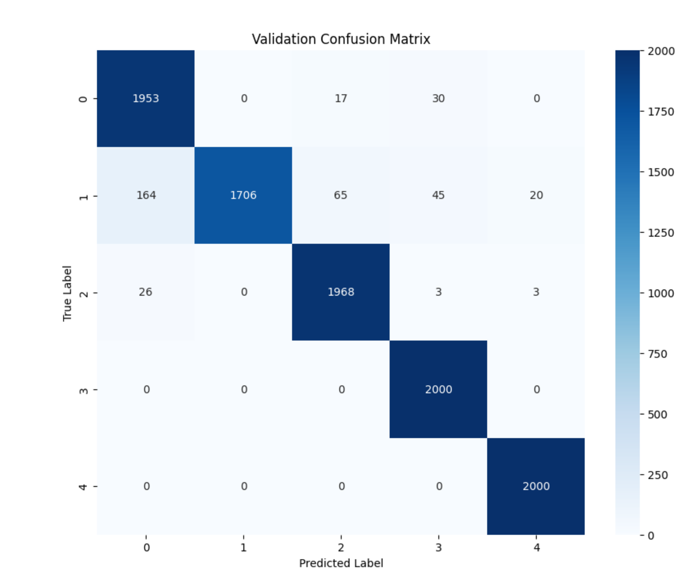

Fig 6: Experimental results for 5 class classification on validation data. Accuracy 96.27

Conclusion

- Achievements: Successfully developed a 1D convolutional neural network that accurately detects and locates stuck Pipeline Inspection Gauges (PIGs) using acoustic data. The model excels with a high accuracy rate of up to 99.43% in binary classifications and remains effective across various multi-class scenarios.
- Data Handling: Implemented data augmentation strategies to address the challenges of unbalanced acoustic datasets, enhancing the model's reliability and generalizability.
- Future Work : Model Enhancement: Plans to expand the range of acoustic signal variations covered and to test the model under a broader spectrum of environmental conditions to improve accuracy and robustness.

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. Bernasconi, G., & Giunta, G. (2020). Acoustic detection and tracking of a pipeline inspection gauge. Journal of Petroleum Science and Engineering, 194(107549).