Overview

- ISRO is advancing the Prognostics and Health Management (PHM) technology for its next-generation spacecraft propulsion.
- The objective is **to diagnose normal, bubble anomalies, solenoid valve faults, and unknown abnormal** cases using data measured from an experimental spacecraft propulsion simulation system.

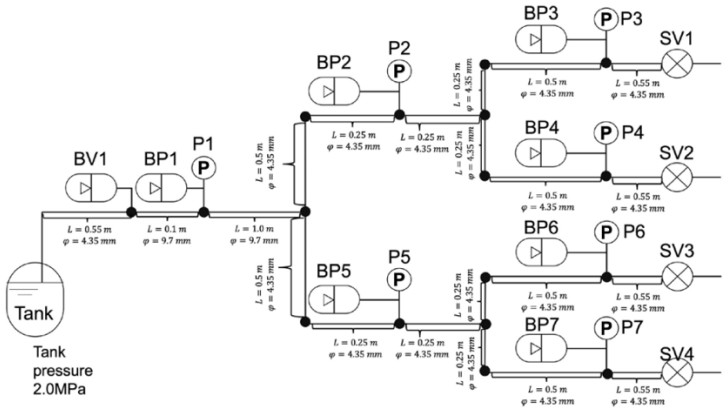


Figure 1: Schematic of experimental propulsion system.

- Figure 1 shows an experimental propulsion system. The working fluid is water pressurized to 2 MPa and discharged through four solenoid valves (SV1 - SV4) simulating thrusters.
- P1 – P7 shows the pressure sensor and the time series data is obtained at each location at a sampling rate of 1 kHz from 0-1200 ms.
- By opening and closing the solenoid valves, pressure fluctuation is observed due to the water hammer followed by acoustic modes inside the propulsion system.
- Typical time series data is shown in Fig. 2.
- The solenoid valve opens at 100 ms and closes at 300 ms. To account for individual differences of solenoid valve appearing in actual equipment, the valve movement has an uncertainty of 1 ms.
- The opening and closing times remain at 400 ms, even with the uncertainty (e.g., open for 99.7 ms and close for 300.3 ms). This sequence is conducted three times successively, resulting in a total measurement of 1200 ms.

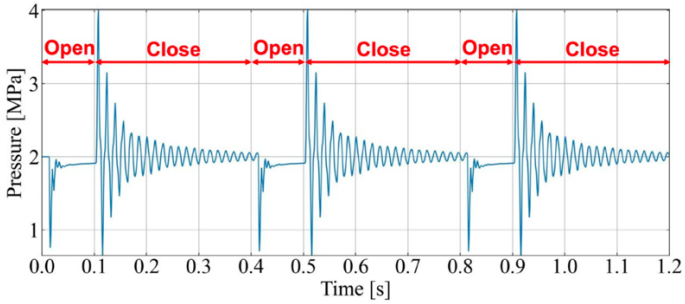


Figure 2: Typical pressure profile.

- In this dataset, anomalies due to bubble contamination and fault due to the abnormal opening of the solenoid valve are considered. Moreover, an unknown anomaly is also included in the test data.

Fault Types

Bubble anomaly:

Air bubbles occasionally appear in the pipes during the actual operation of a spacecraft. The existence of bubbles changes the speed of sound, causing slight changes in the pressure fluctuations. It is desirable to detect the appearance of bubble and their location.

- There are eight possible locations, BV1 and BP1 to BP7 as shown in Fig.1.
- The amount of bubbles contaminated in the propulsion system is constant in all cases for simplicity.

Solenoid valve faults:

This is one of the major failure modes in spacecraft propulsion systems. It is required to find which solenoid valves failed and their opening ratio.

- Solenoid valves open and close at the opening ratio of 100% and 0%, respectively.
- In case of faults, solenoid valves open at a degree between 0% and 100%, which results in a reduced volume of fluid through the solenoid valve.

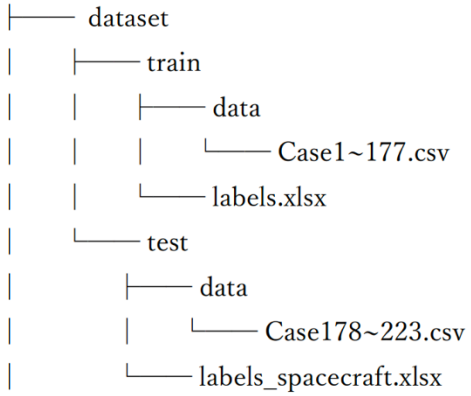
Unknown anomaly:

In the practical operation, completely unforeseen and unknown anomalies or faults may occur. It is also required to distinguish unknown anomalies without confusing them with known anomalies and faults. Some unknown anomalies or faults are mixed in the test data. Identifying them is also part of the task.

Individual differences in spacecraft:

Since solenoid valves have individual differences, such as the timing of opening and closing, time series data acquired from the spacecraft propulsion system show differences, which in turn lead to individual differences in the spacecraft. In this dataset, four spacecraft (No.1 to 4) are considered. Results for the three of them, No.1 to No.3, are included in the training data, but test data is composed of the results for No.1 and No.4.

Dataset (https://drive.google.com/drive/folders/1FZ1AIFi-893au_77MQ5A3zxL8h2wWimS?usp=sharing)



- In each CSV file, the first column is time, and the remaining columns are pressure at the measurement points P1 – P7 as shown in Fig. 1.
- **Training data**:
  - Number of normal data for Spacecraft-1: 35

- Number of normal data for Spacecraft-2: 35
- Number of normal data for Spacecraft-3: 35
- Number of abnormal data for Spacecraft-1: 24
- Number of abnormal data for Spacecraft-2: 24
- Number of abnormal data for Spacecraft-3: 24
- `labels.xlsx` describes detailed information on training data such as case name, spacecraft number, and experimental condition. Please note that there is no Spacecraft-4 data in the training data.

- **Test data**:
  - Number of data for Spacecraft-1: 23
  - Number of data for Spacecraft-4: 23
  - `labels_spacecraft.xlsx` describes the information of case name and spacecraft number. The opening ratio of the valve is randomly chosen between 0% and 100% in case of fault.

Evaluation of the Algorithm

- **5 major tasks will have to be completed in the test data.**
- **Task 1**: Classification of normal/abnormal condition (2 points).
- **Task 2**: For the data correctly detected as abnormal, classification of bubble contamination anomaly/solenoid valve fault/ unknown fault (2 points).
- **Task 3**: For the data correctly identified as bubble contamination, identification of bubble location (2 points).
- **Task 4**: For the data correctly identified as solenoid valve fault, identification of the failed valve (2 points).
- **Task 5**: For the solenoid valve correctly identified as fault, prediction of the opening ratio (2 points).
- Submit results in a CSV file. A template for submission will be shared separately.

Evaluation of your Team

You can form a team of maximum 2 students. Each student will be marked based on the breakdown provided below:

1. A 5-page report – 5 marks
2. Presentations – 5 marks
3. Data Mining Task – 10 marks

Note: Being a single member team doesn't carry any disadvantage as proper consideration will be given while marking as per their efforts, relative to any two-member team.