Unmanned System Health Management

(1) Background

Intelligent unmanned systems have been widely used due to their high level of autonomy and intelligence, such as unmanned aerial vehicles, unmanned car and unmanned underwater vehicles. However, the intelligent unmanned system performs tasks in a complex and unknown environment. Once it fails and abnormal conditions, it may lead to serious accidents. Therefore, intelligent unmanned systems must have perfect fault diagnosis abilities to ensure their safety and reliability.

Figure 1. Various unmanned systems

(2) The research object of this project

Research object: small quadrotor autonomous underwater vehicle (AUV).

AUV ‘s Role: Investigate and monitor the environment of inland waters (eg, lakes, reservoirs).

The AUV is installed with 4 brushless motors, 4 propellers, 4 electronic speed control, 1 depth sensor, 1 nine-axis inertial measurement unit, and 1 microcontroller unit.

The unmanned underwater vehicle contains five health conditions, including normal state (F1), abnormal load (F2), depth sensor failure (F3), major propeller failure (F4), and minor propeller failure (F5).

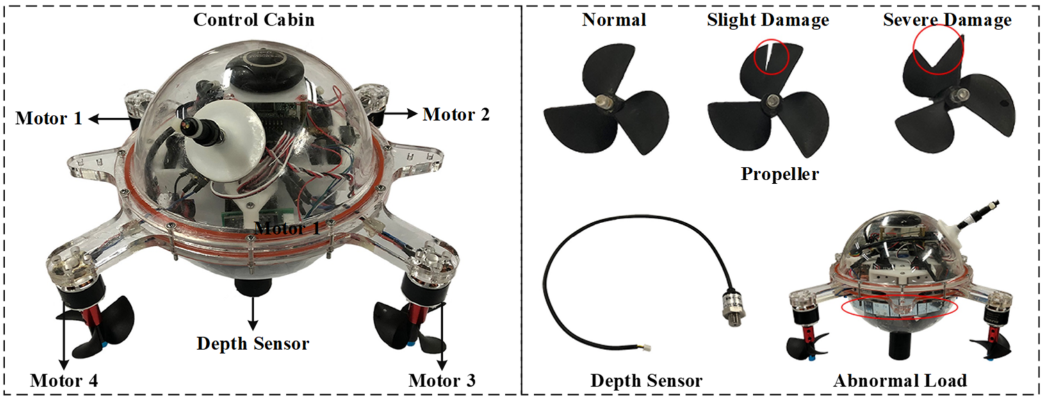


Figure 2. Unmanned underwater vehicle and its five health categories.

(3) Data Acquisition

In this study, we used 16 different sensor data such as motor control signals, battery voltage, depth, angular velocity, acceleration, and vehicle attitude information. The table below shows all collected sensor data.

About 250 data samples were acquired for each health conditions, for a total of 1220 data samples.

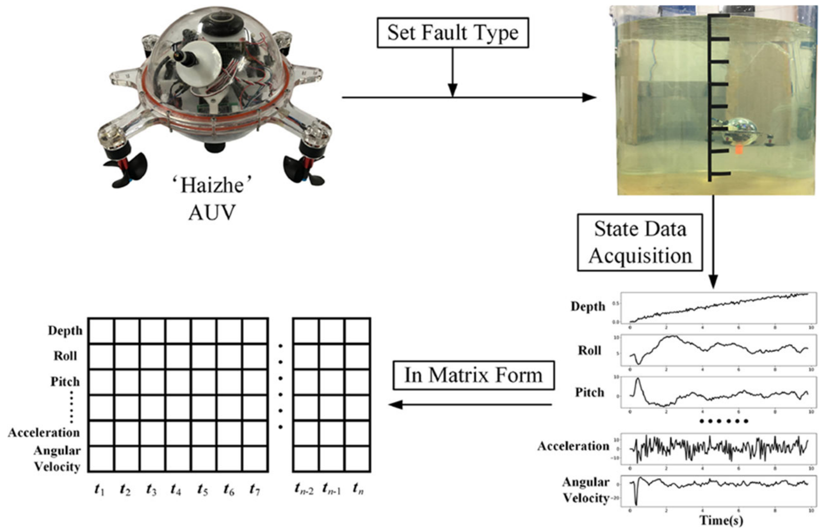


Figure 3. The Data Collection Process of Unmanned Underwater Vehicle.

TABLE I
THE COLLECTED SENSOR INFORMATION OF THE AUTONOMOUS UNDERWATER VEHICLE

Term	Description	Term	Description
Pwm1	Control signal for motor 1	Pitch	Pitch angles measured by IMU
Pwm2	Control signal for motor 2	Yaw	Yaw angles measured by IMU
Pwm3	Control signal for motor 3	Acc_X	Acceleration (x-axis)
Pwm4	Control signal for motor 4	Acc_Y	Acceleration (y-axis)
Depth	Depth value of UUA	Acc_Z	Acceleration (z-axis)
Press	External pressure value of UUA	W_Row	Angular velocity of rotation around the x-axis
Voltage	Voltage value of battery	W_Pitch	Angular velocity of rotation around the y-axis
Roll	Roll angles measured by IMU	W_Yaw	Angular velocity of rotation around the z-axis

(4) Dataset Introduction

Autonomous Underwater Vehicle Fault Diagnosis Dataset.

- Training Set File; Test Set File (The training and testing sets have been divided)
- F1: Normal; F2: AddWeight; F3: PressureGain_constant; F4: PropellerDamage_bad; F5: PropellerDamage_slight (The data in these 5 folders belong to different categories)
- Each folder contains multiple CSV files, and one CSV file is a training sample
- Project Address: https://cloud.tsinghua.edu.cn/d/5a4a3a9020a94c40b323/

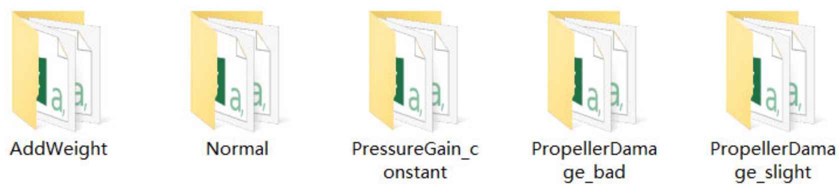
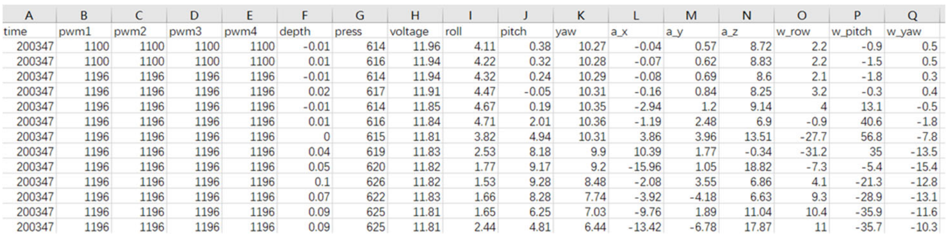


Figure 4. The data in these 5 folders belong to different categories



A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
time	pwm1	pwm2	pwm3	pwm4	depth	press	voltage	roll	pitch	yaw	a_x	a_y	a_z	w_row	w_pitch	w_yaw
200347	1100	1100	1100	1100	-0.01	614	11.96	4.11	0.38	10.27	-0.04	0.57	8.72	2.2	-0.9	0.5
200347	1100	1100	1100	1100	0.01	616	11.94	4.22	0.32	10.28	-0.07	0.62	8.83	2.2	-1.5	0.5
200347	1196	1196	1196	1196	-0.01	614	11.94	4.32	0.24	10.29	-0.08	0.69	8.6	2.1	-1.8	0.3
200347	1196	1196	1196	1196	0.02	617	11.91	4.47	-0.05	10.31	-0.16	0.84	8.25	3.2	-0.3	0.4
200347	1196	1196	1196	1196	-0.01	614	11.85	4.67	0.19	10.35	-2.94	1.2	9.14	4	13.1	-0.5
200347	1196	1196	1196	1196	0.01	616	11.84	4.71	2.01	10.36	-1.19	2.48	6.9	-0.9	40.6	-1.8
200347	1196	1196	1196	1196	0	615	11.81	3.82	4.94	10.31	3.86	3.96	13.51	-27.7	56.8	-7.8
200347	1196	1196	1196	1196	0.04	619	11.83	2.53	8.18	9.9	10.39	1.77	-0.34	-31.2	35	-13.5
200347	1196	1196	1196	1196	0.05	620	11.82	1.77	9.17	9.2	-15.96	1.05	18.82	-7.3	-5.4	-15.4
200347	1196	1196	1196	1196	0.1	626	11.82	1.53	9.28	8.48	-2.08	3.55	6.86	4.1	-21.3	-12.8
200347	1196	1196	1196	1196	0.07	622	11.83	1.66	8.28	7.74	-3.92	-4.18	6.63	9.3	-28.9	-13.1
200347	1196	1196	1196	1196	0.09	625	11.81	1.65	6.25	7.03	-9.76	1.89	11.04	10.4	-35.9	-11.6
200347	1196	1196	1196	1196	0.09	625	11.81	2.44	4.81	6.44	-13.42	-6.78	17.87	11	-35.7	-10.3

Figure 5. Data in CSV files

(5) Problem definition

This project needs to identify different health categories. **Please design a classification algorithm to identify AUV fault situations.** You can utilize any knowledge which you have learned in this course. Of course, you can also refer to the research papers and apply them to this project.

(6) Data loading and preprocessing

This dataset is relatively small, only 5.92M. The data of each training sample is saved in a CSV file. About 250 data samples were acquired for each health condition, for a total of 1220 data samples. Due to the different collection times of signals, the number of signal points collected for each sample is different. We need to intercept the first 180 points. In addition, standardization of sensor datasets is also very important.

The following is the data loading and preprocessing code for a CSV file:

```
#--------------------------------------#
import numpy as np
import pandas as pd
AW_Data = pd.read_csv('AddWeight/AddWeight_0.csv', header=None)    # Load CSV file
AW_Data = np.array(AW_Data)    # Convert to numpy format

if AW_Data[:,1].shape[0] >= 181: # Determine if the collected data points exceed 180
        Data_E1 = AW_Data[1:181,1:]      # Intercept the first 180 values and discard the header
        Data_E1 = Normal(Data_E1)         # Standardize the signal

list = [1200, 1200, 1200, 1200, 0.5, 700, 12, 15, 10, 200, 20, 10, 10, 10, 30, 40]    # Maximum value for each sensor set based on experience
def Normal(Data):
    Data = Data.astype(np.float32)
    for id in range(16):
        Data[:,id] = Data[:,id]/list[id]
    return Data
#--------------------------------------#
```

The above code explains how to read a CSV file and preprocess and standardize it. The processed data can be used for model training. You need to write a For loop to batch process data for each category and build a training set. Then build a simple classification model to achieve the expected excellent performance.

There are also several points to be noted:

i. **Do not use models that are pre-trained** by others.
ii. **Do not use other data sets**, that is, you can only use the training set given above.

We will mainly use Accuracy as the evaluation indicator, and it is recommended to include F1 score results.

$$Accuracy = \frac{TP + TN}{TP + FN + FP + TN} \times 100\%$$

where FP, FN, TN, and TP refer to the quantity of false positive samples, false negative samples, true negative samples, and true positive samples, respectively.

(7) *Scoring system*

The scoring criteria for this project presentation are as follows:

Scoring indicator	Scores (Out of 100 points)	Score
Innovation	**50**	
Methods	30	
Parameter tuning	20	
Model results	**50**	
Classification results	30	
Presentation	10	
Personal contribution	10	