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Hydraulic directional valve fault diagnosis using a weighted adaptive fusion of multi-dimensional features of a multi-sensor

Key words:

Hydraulic directional valve; Internal fault diagnosis; Weighted multi-dimensional features; Multi-sensor information fusion

Fault Category

Table 1 Fault type and location		
Label	Fault type	Fault Location
1	Mild wear of the spool (the clearance is 0.015 mm-0.035 mm)	Main spool surface
2	Moderate wear of the spool (the clearance is 0.035 mm-0.060 mm)	Main spool surface
3	Severe wear of the spool (the clearance > 0.060 mm)	Main spool surface
4	Wear between valve core and the housing	Surface of main spool and the housing
5	Wear of the housing	The housing surface
6	Blocked spool	Solenoid valve spool
7	Failure of return spring	Solenoid valve return spring
8	The power remaining 80%.	Solenoid
9	The power remaining 60%.	Solenoid
10	Normal	Normal

Experimental Setup

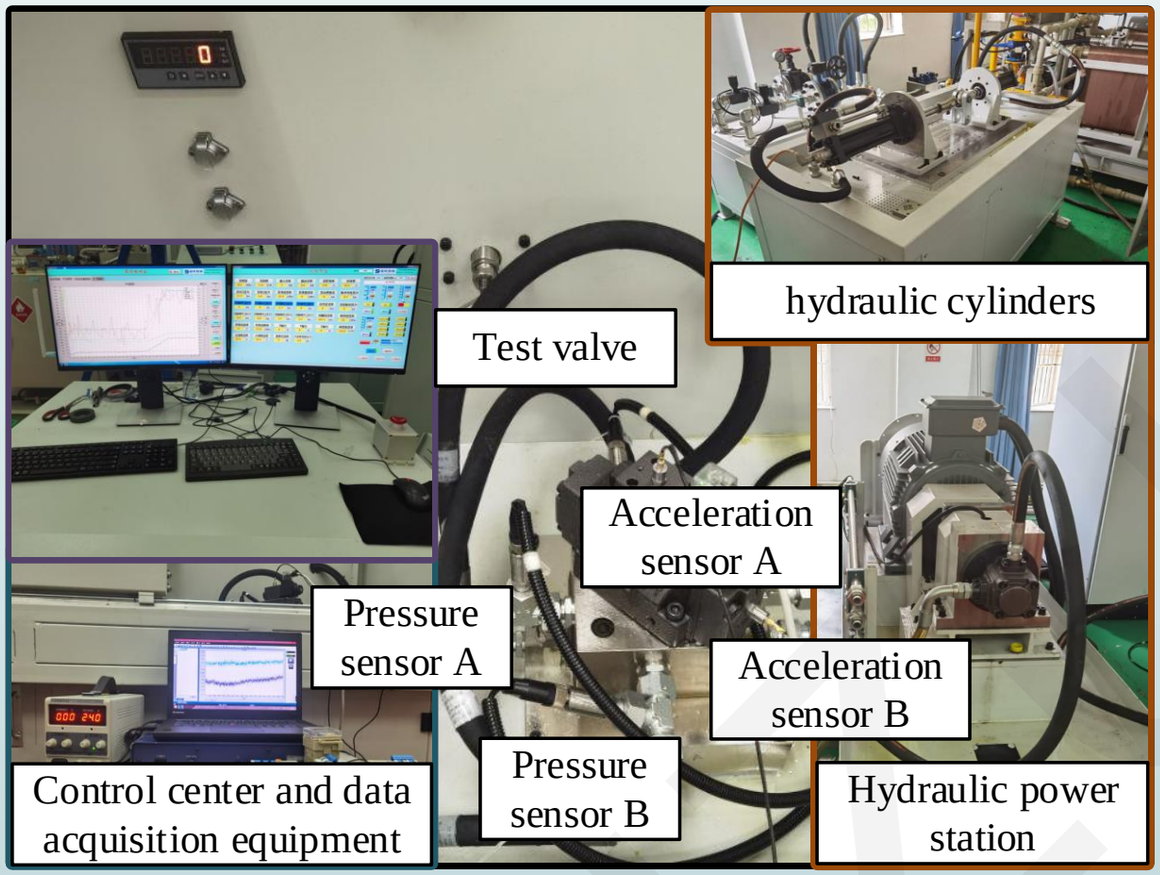


Fig. 1 A total test rig used for the experiments

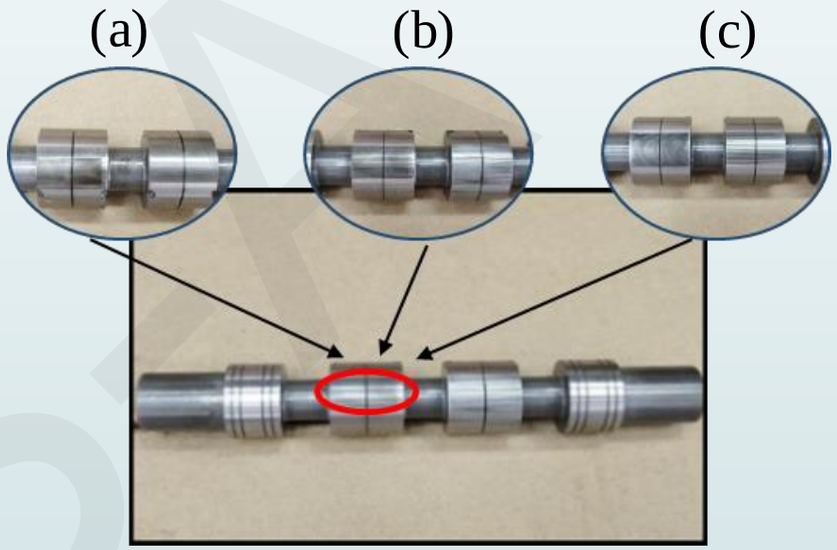


Fig. 2 Different severities of valve spool wear; (a) Mild wear; (b) Moderate wear; (c) Severe wear

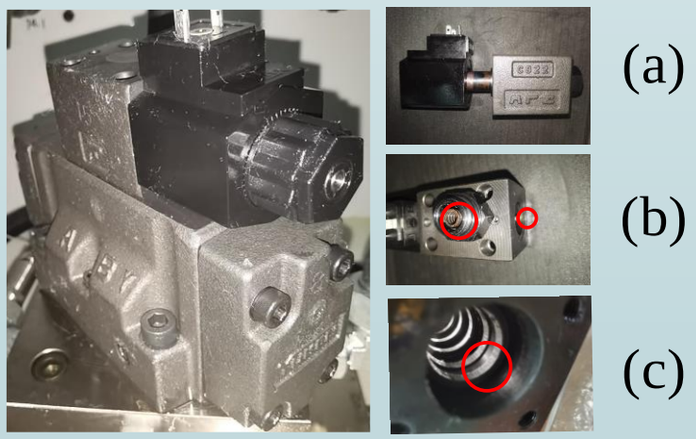


Fig. 3 Partial fault position of the directional valve; (a) electromagnetic fault location; (b) spring failure fault location; (c) valve body wear fault location

Diagnostic Schematic

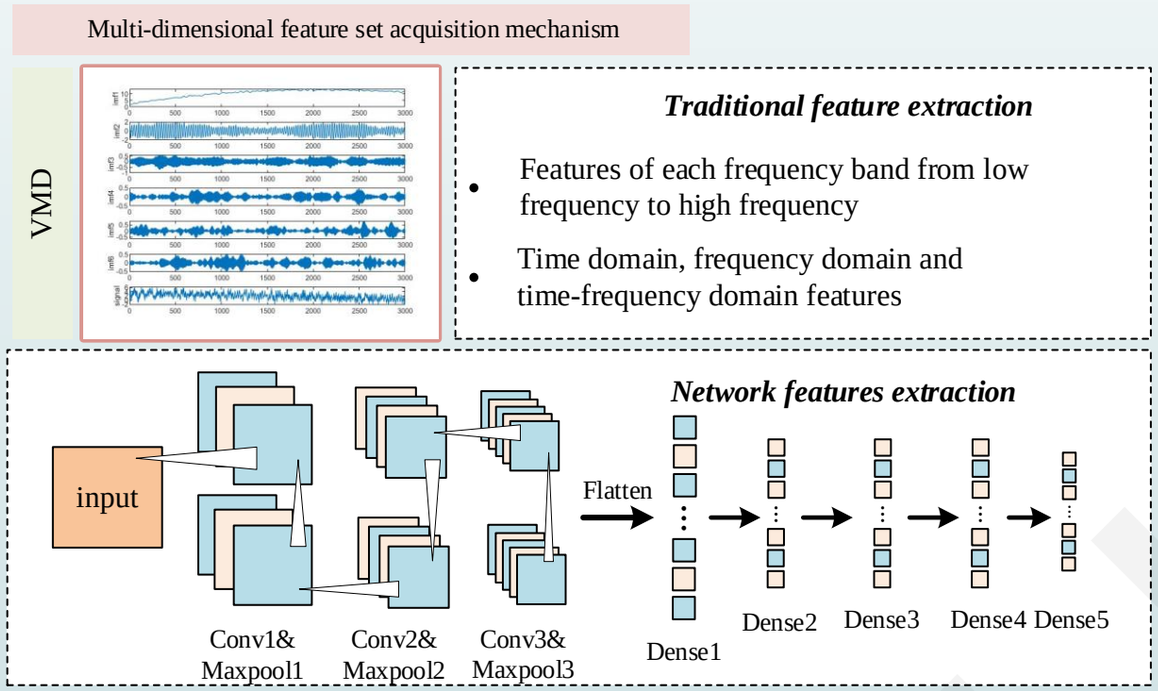


Fig. 4 Multi-dimensional feature set acquisition mechanism

- First, the features of the diverter valve fault signals collected by two pressure and two vibration sensors are extracted. Then, the entropy weight method is used to objectively weight the feature set after homogeneous sensor feature fusion. Finally, combined with the improved CNN using the attention mechanism, the information of heterogeneous sensors is fused to realize the fault diagnosis of the hydraulic reversing valve.

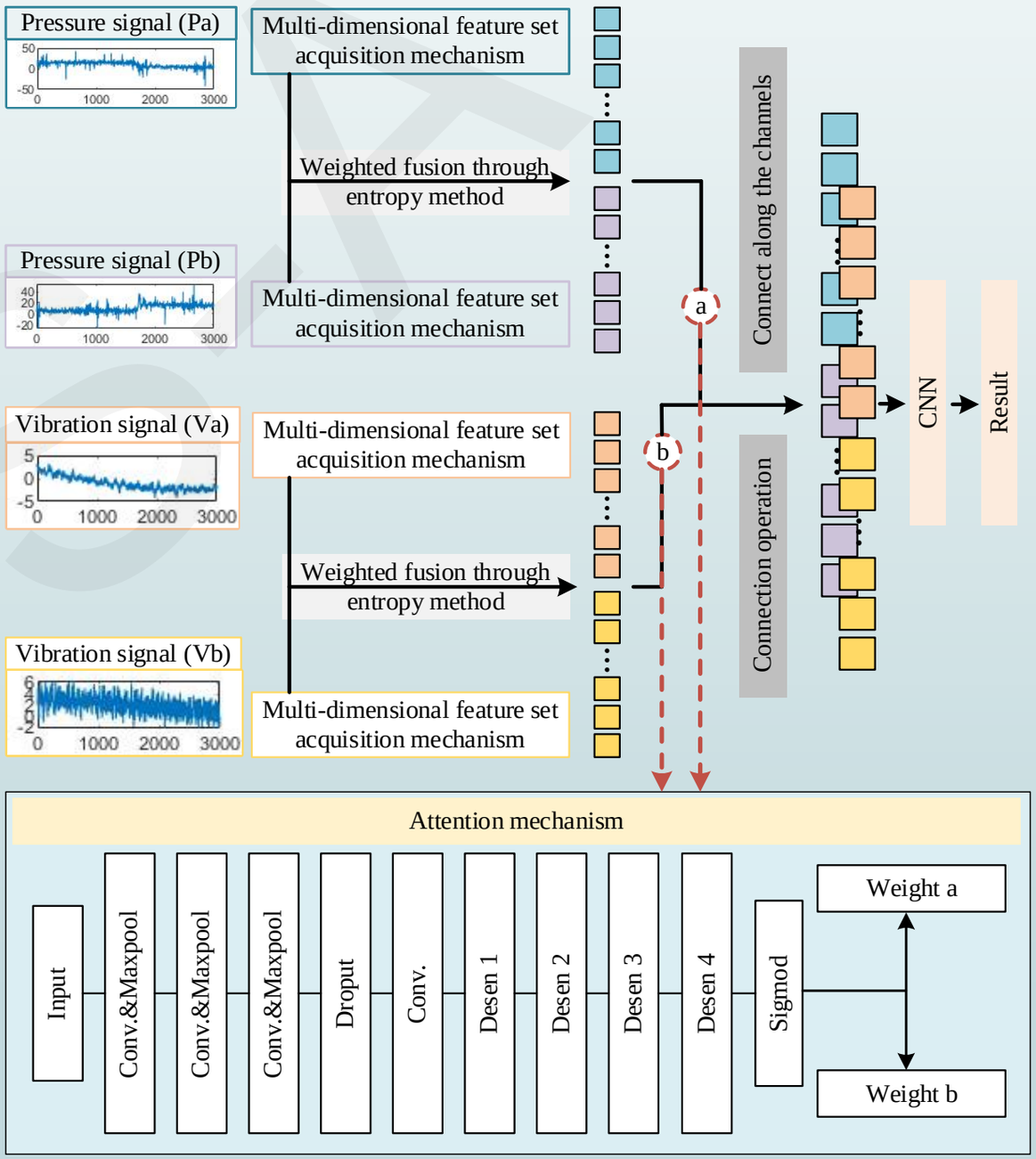
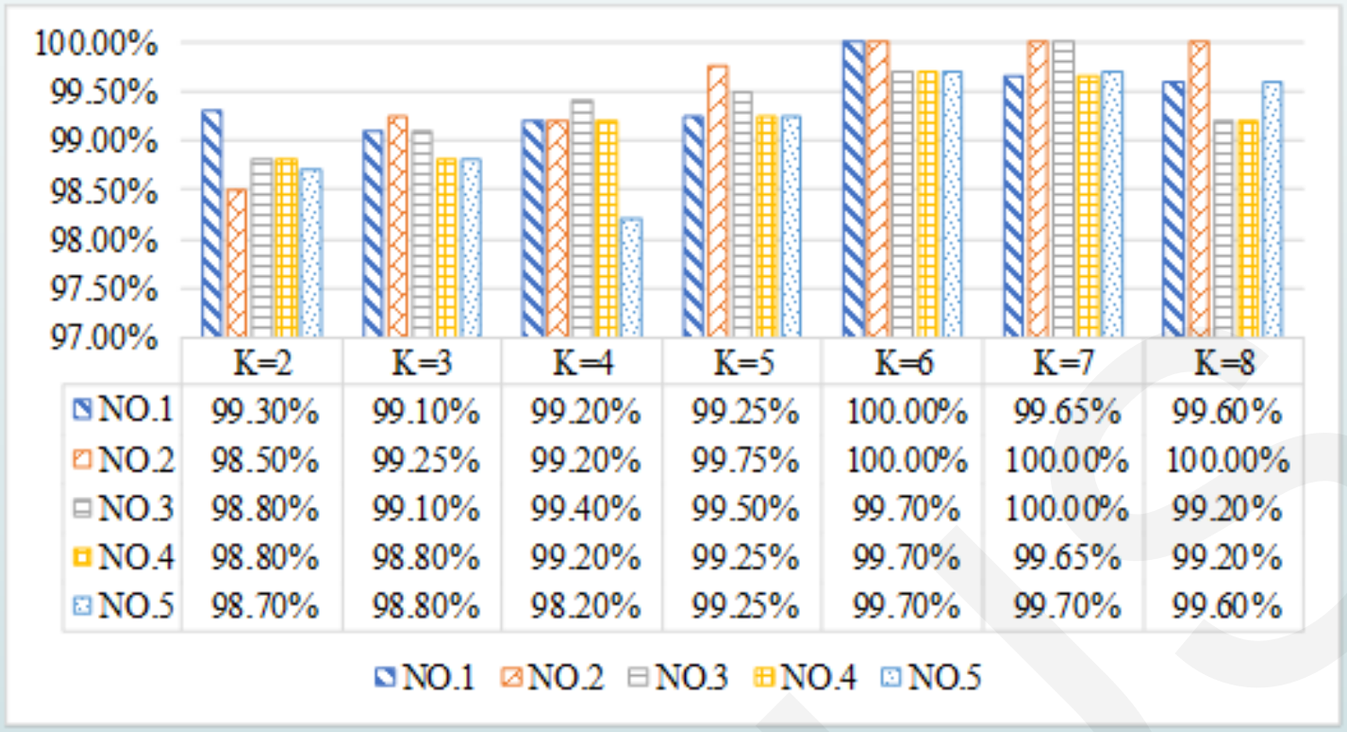


Fig. 5 Directional valve fault diagnosis flow chart

Results



	K=2	K=3	K=4	K=5	K=6	K=7	K=8
NO.1	99.30%	99.10%	99.20%	99.25%	100.00%	99.65%	99.60%
NO.2	98.50%	99.25%	99.20%	99.75%	100.00%	100.00%	100.00%
NO.3	98.80%	99.10%	99.40%	99.50%	99.70%	100.00%	99.20%
NO.4	98.80%	98.80%	99.20%	99.25%	99.70%	99.65%	99.20%
NO.5	98.70%	98.80%	98.20%	99.25%	99.70%	99.70%	99.60%

Fig. 6 Fault diagnosis accuracy based on K-fold cross validation

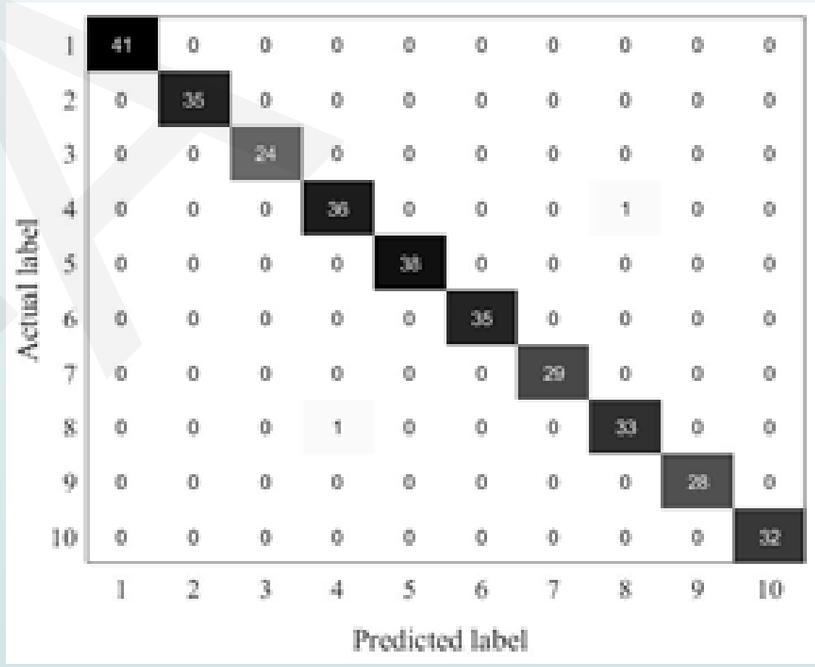


Fig. 8 Confusion matrix of multi-sensor diagnostic results

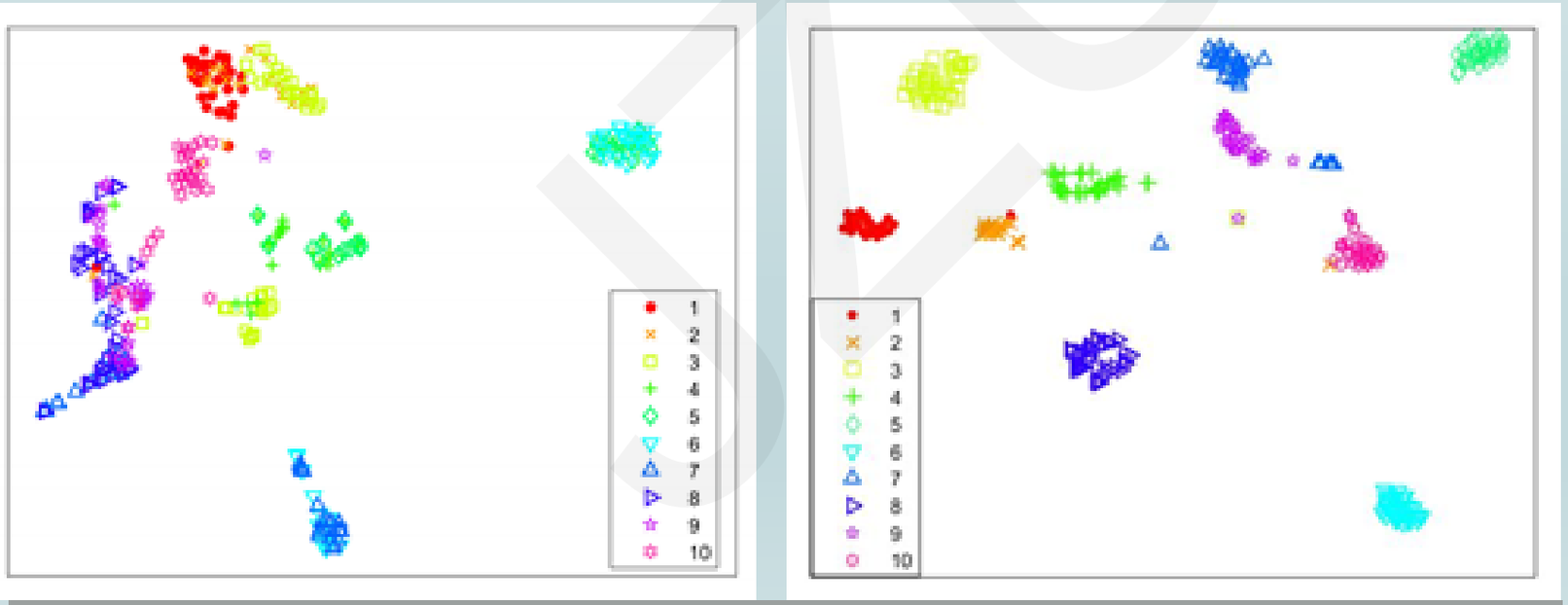


Fig.7 Unweighted and weighted T-SNE visualization results, Unweighted method (left);Weighted method(right)

- Theoretical and experimental results show that the information fusion of different types of sensors can solve the problem that a single sensor cannot accurately describe the fault of the hydraulic reversing valve.

Conclusions

Research Highlights:

- The heterogeneous sensor information fusion method enhances the fault expression ability of the feature set, which can characterize multiple fault types (electromagnetic fault and mechanical fault.
- Personalized weighting method (the use of entropy weight method and attention mechanism) enhances the effective signal, weakening the source of interference.
- A diversified feature extraction method is proposed, and the acquired multi-dimensional feature set has robust and complete health information.

Important Conclusions:

- The proposed method provides technical support for the internal fault diagnosis of the hydraulic reversing valve, and its highest average accuracy rate can reach 99.82%.
- The adoption of the proposed method in the process of multi-sensor information fusion of hydraulic reversing valve is adaptive, which can not only make full use of sensitive information of fault categories, but also help to reduce the interference of redundant information.