Wenjuan MEI, Zhen LIU, Ouhang LI, Yuanzhang SU, Yusong MEI, Yongji Long, 2023. Mixture test strategy optimization for analog systems. *Frontiers of Information Technology & Electronic Engineering*, 24(9):1302-1315. https://doi.org/10.1631/FITEE.2200512

Mixture test strategy optimization for analog systems

Key words: Fault diagnosis; Heuristic searching; Dynamic programming; Test optimization

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Motivation

1. Test strategy optimziation for analog system provides automated diagnosis procedures, optimizes the detection procedures during maintenance, and shortens the time consumed for locations of faults.
2. The generation solutions of existed methods may fail due to system's topology and influence of information redundancy.
3. Independent tests operating sequentially on the generated strategies may increase the time consumption.

Method

Design a sequence matrix is to depict the relationships of tests and evaluate the dynamic cost of the test based on the system strategy.

$$l_{ij} = \begin{cases} p, & t_i \text{ is } p \text{ steps behind } t_j, \\ q, & t_i \text{ is } q \text{ steps ahead of } t_j, \\ 0, & t_i \text{ and } t_j \text{ have no orders.} \end{cases}$$

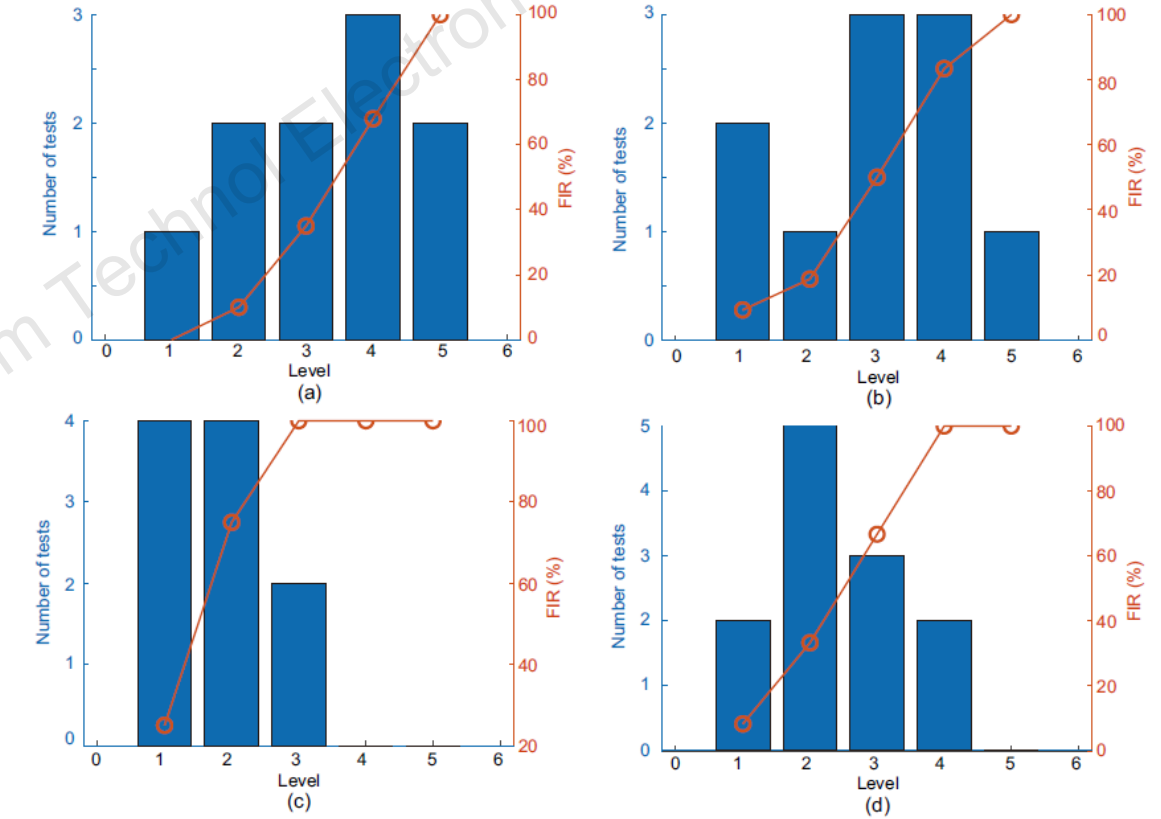

Fig. 1 Fault isolation rate (FIR) improvement and test assignment on the anti-tank system dataset: (a) sequential strategy; (b) MAO*-based strategy; (c) HP-based strategy; (d) Rollout-HP-based strategy

Method

Encode the topology of each test procedure and the dependence of the potential cost of test procedures into the structure information of test procedures.

Table 1 Performance comparison on the experimental datasets

Method	Number of search times					
	Amplifier	Anti-tank system	Bus system	Filter	Horizon system	Apollo aircraft
AO*	20	133	7	74	47	178
AOL	9	187	5	45	15	169
DP-AO*	15	118	5	63	36	167
Rollout-AO*	47	85	37	80	73	39
MAO*	9	84	5	48	29	44
HP	11	121	31	80	42	81
Rollout-HP	9	100	31	66	41	65

Method	Total cost					
	Amplifier	Anti-tank system	Bus system	Filter	Horizon system	Apollo aircraft
AO*	47.4	3.4	0.236	7.8	8.4	3.4
AOL	47.4	3.4	0.236	7.8	8.4	3.4
DP-AO*	47.4	3.4	0.236	7.8	8.4	3.4
Rollout-AO*	47.4	3.4	0.236	7.9	9	3.4
MAO*	42.6	1	0.236	3.9	7.4	1
HP	42.6	1	0.1	3.2	4.4	1
Rollout-HP	42.6	2.6	0.1	4.5	6.4	2.6

Method

Develop a novel heuristic estimator to estimate the cost of potential solutions based on a sequence matrix and dependence information.

$$w(s_i, s_j) = \operatorname{argmin}\{c(t_k) \,|d_{ik} \oplus d_{jk} = 1\}.$$

$$h_{S^*} = \sum_{s_j \in S^*} p_j \max_{s_k \in S^*} (w(s_j, s_k)).$$

$$w(s_i, s_j) = \operatorname{argmin}\left\{c\left(t_k|\tilde{T}\right) |d_{ik} \oplus d_{jk} = 1, k \neq k_m\right.$$

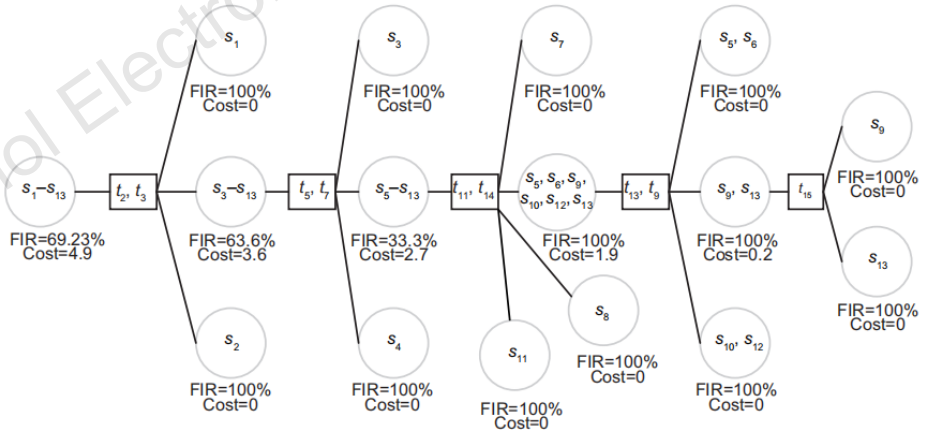

Fig. 3 The developed strategy for real-world applications by the HP algorithm (FIR: fault isolation rate)

Method

Propose heuristic programming (HP) and Rollout-HP to combine sequential extension and parallel extension during search tree generation.

Table 2 Time consumption for the experimental datasets

Method	Time consumption (s)					
	Amplifier	Anti-tank system	Apollo aircraft	Bus system	Filter	Horizon system
AO*	0.0460	0.0632	0.0432	0.0234	0.0322	0.0183
AOL	0.0200	0.0543	0.0422	0.0234	0.0543	0.0342
DP-AO*	0.0320	0.0465	0.0415	0.0253	0.0473	0.0132
MAO*	0.1030	0.1540	0.0231	0.0184	0.0824	0.0678
Rollout-AO*	0.0300	0.0345	0.0182	0.0232	0.0314	0.0120
HP	0.0350	0.0453	0.0345	0.0230	0.0567	0.0342
Rollout-HP	0.0210	0.0421	0.0232	0.0120	0.0345	0.0213

Table 3 Performance comparison on real-world applications

Method	Number of search times	Number of tests	Fault isolation rate (%)	Total cost
AO*	139	10	69.23	8.4
AOL	91	10	69.23	8.4
DP-AO*	120	10	69.23	8.4
MAO*	280	9	69.23	8.4
Rollout-AO*	95	13	69.23	9.3
HP	145	9	69.23	4.9
Rollout-HP	142	9	69.23	4.9

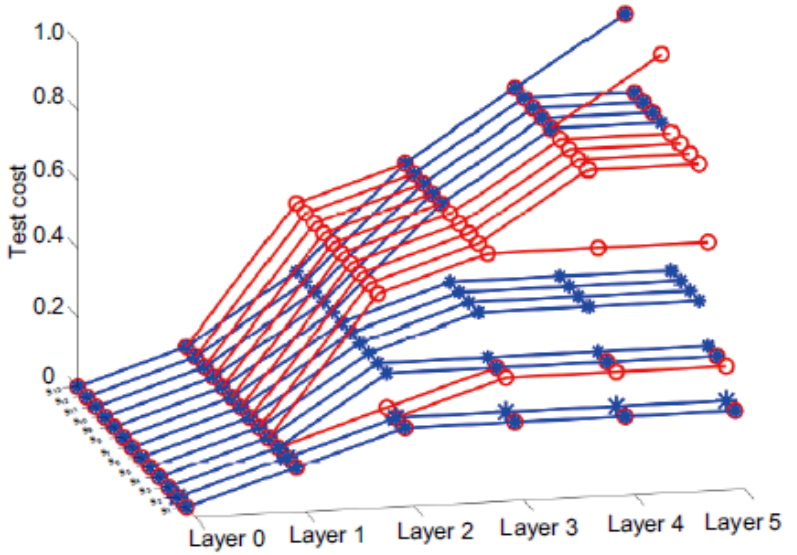

Fig. 4 Test cost on real-world applications (The red lines refer to the test cost of AO*-based methods and the blue lines refer to the test cost of HP-based methods. References to color refer to the online version of this figure)

Conclusions

1. We developed mixed search strategies called HP and Rollout-HP to generate the optimal test strategy considering the relationship between test procedures for diagnosis.
2. We introduced the sequence matrix to heuristic estimation based on a decision graph to guarantee the information usage efficiency durign solution construction.
3. We also designed a novel heuristic estimator based on the sequence matrix and dependence information.

Wenjuan MEI received her BS degree in 2019 and now she is currently pursuing her PhD degree in the School of Automation Engineering, University of Electronic Science and Technology of China. Since 2016, she became a research member at the Electronic Testing Technology and Instruments Engineering Research Center, Ministry of Education of China. Her research interests include ML-based degradation prediction for power semiconductor devices and systems.

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