**duid一、项目名称：**基于模型-数据混合驱动的故障诊断与信号处理关键技术研究

**二、项目简介：**

当前国内外设备用户的日常维修策略通常采用预防性维修保养，即通常根据制造商指示的当量运行小时数来决定是否需要小修、中修、大修。对于设备的停机检修，无论是计划内的还是计划外的，以及普遍存在的失修和过修情况，总是意味着高昂的运行和维修成本代价。为避免失修和过修，提高设备的可靠性和可用性，降低运维成本，用户宜采用预知维修策略。利用模式识别和机器学习等基于数据驱动的人工智能技术，需要建立在已有设备故障样本集上，对于样本集中未涉及的故障类型，这些方法难以给出准确的诊断结果。且对于一种新型或刚投运的设备，由于缺乏标定的故障数据，难以在短时间内建立能够覆盖所有故障类型的完备故障样本集，且通过运维经验和监测数据来积累故障模式与故障征兆之间的关系规则库是艰难而费时费力的，且不易对故障严重程度作量化评估，制约了基于数据驱动的人工智能技术的应用。

本项目属于故障诊断领域，重点围绕复杂强非线性热力系统、动力系统、机械系统故障诊断与预测的关键技术问题，开展基于模型-数据混合驱动的故障诊断与信号处理关键技术研究，主要创新点有：

（1）提出了一种基于粒子群优化算法辨识的部件特性线修正方法，使修正后的模型的部件特性线与实际目标系统的真实部件特性线相匹配，提高了计算精度。

（2）提出了基于热力模型与粒子群优化算法相结合的非线性诊断方法，从全局优化的角度改善了诊断结果的准确性。

（3）提出了基于灰色关联理论与热力模型相结合的混合型非线性气路诊断方法，从故障系数矩阵降维的角度兼顾了诊断结果的准确性和实时性。

（4）采用高斯数据调和方法解决了诊断准确性高度依赖传感器可靠性的问题，降低了部件健康参数对传感器测量偏差的敏感性。

（5）提出了基于多维特征提取与灰色关联算法的诊断方法，能够准确有效的识别不同的故障类型及故障严重程度；其中，故障识别成功率能够达到100%，而对不同故障类型及故障严重程度的总体识别成功率也能达到96%以上；算法简单易编程，能够较好地解决模式识别算法易用性与准确性的矛盾问题。

本项目所形成科技成果是一种对正在演变或即将发生的恶化情况发布早期预警信息的有效技术手段，从原理上实现设备性能分析—诊断—预测方法的有效耦合，为实现复杂强非线性热力系统、动力系统、机械系统故障诊断与预测提出新方法；在功能上实现详尽的、量化的、准确的各主要部件的故障诊断与预测目的，给制定恰当合理的优化控制和维修策略提供理论指导，对其推动从预防性维修保养过渡到预测性维修保养的维修理念改革起到重要的理论意义和实践价值。2016年，已将该项目相关研究成果应用于重庆群峰科技发展有限公司下的重庆天海星两江数码工坊的建筑施工过程，累计产生经济效益2080万元。同年，已将本项目相关技术应用到“重庆东水门P+R换成中心项目”的停车设备制造及安装过程中，累计产生经济效益640万元，在国内外SCI检索期刊上发表论文20余篇，发明专利20项。

1. **知识产权情况**

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| --- | --- | --- | --- | --- | --- |
| 国别 | 知识产权类别 | 授权号 | 名称 | 核心专利 | 本年度3月31日时的有效状态 |
| 中国 | 授权发明专利 | 201410111726.2 | 齿轮箱故障诊断方法及装置 | 是 | 有效专利 |
| 中国 | 授权发明专利 | 201110361602.6 | 基于传感器网络的复杂环境下多目标信息融合方法 | 是 | 有效专利 |
| 中国 | 授权发明专利 | 201110347523.X | 复杂环境下一种新的通信电台个体识别方法 | 是 | 有效专利 |
| 中国 | 授权发明专利 | 201410318559.9 | 旋转编码器 | 否 | 有效专利 |
| 中国 | 授权发明专利 | 201510943574.7 | 海上漂浮式风力发电机之运输安装装置 | 否 | 有效专利 |
| 中国 | 授权发明专利 | 201110336558.3 | 基于小波包去噪和功率谱熵的线性调频信号参数估计方法 | 否 | 有效专利 |

1. **发表论文著作情况**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 序号 | 论文著作 | 通讯作者 | 被 SCI、EI收录 | 引用次数 |
| 1 | Jingchao Li, Yulong Ying. A Method to Improve the Robustness of Gas Turbine Gas-Path Fault Diagnosis Against Sensor Faults[J]. IEEE Transactions on Reliability, March 2018, 67(1): 3-12.  | Yulong Ying（应雨龙） | 是（ESI高被引） | 12 |
| 2 | [Yulong Ying](https://www.researchgate.net/profile/Yulong_Ying?_iepl%5BviewId%5D=S069OYW1BgQ5njzqePhF6BWOrBIbwJ4H7iCw&_iepl%5Bcontexts%5D%5B0%5D=prfhpi&_iepl%5Bdata%5D%5BstandardItemCount%5D=2&_iepl%5Bdata%5D%5BuserSelectedItemCount%5D=0&_iepl%5Bdata%5D%5BtopHighlightCount%5D=2&_iepl%5Bdata%5D%5BtopHighlightIndex%5D=2&_iepl%5Bdata%5D%5BfeaturedItem1of2%5D=1&_iepl%5BtargetEntityId%5D=PB%3A321341667&_iepl%5BinteractionType%5D=publicationViewCoAuthorProfile), [Jingchao Li](https://www.researchgate.net/profile/Jingchao_Li8?_iepl%5BviewId%5D=S069OYW1BgQ5njzqePhF6BWOrBIbwJ4H7iCw&_iepl%5Bcontexts%5D%5B0%5D=prfhpi&_iepl%5Bdata%5D%5BstandardItemCount%5D=2&_iepl%5Bdata%5D%5BuserSelectedItemCount%5D=0&_iepl%5Bdata%5D%5BtopHighlightCount%5D=2&_iepl%5Bdata%5D%5BtopHighlightIndex%5D=2&_iepl%5Bdata%5D%5BfeaturedItem1of2%5D=1&_iepl%5BtargetEntityId%5D=PB%3A321341667&_iepl%5BinteractionType%5D=publicationViewCoAuthorProfile), [Zhimin Chen](https://www.researchgate.net/scientific-contributions/2131574988_Zhimin_Chen?_iepl%5BviewId%5D=S069OYW1BgQ5njzqePhF6BWOrBIbwJ4H7iCw&_iepl%5Bcontexts%5D%5B0%5D=prfhpi&_iepl%5Bdata%5D%5BstandardItemCount%5D=2&_iepl%5Bdata%5D%5BuserSelectedItemCount%5D=0&_iepl%5Bdata%5D%5BtopHighlightCount%5D=2&_iepl%5Bdata%5D%5BtopHighlightIndex%5D=2&_iepl%5Bdata%5D%5BfeaturedItem1of2%5D=1&_iepl%5BtargetEntityId%5D=PB%3A321341667&_iepl%5BinteractionType%5D=publicationViewCoAuthorProfile), [Jian Guo](https://www.researchgate.net/scientific-contributions/2135734371_Jian_Guo?_iepl%5BviewId%5D=S069OYW1BgQ5njzqePhF6BWOrBIbwJ4H7iCw&_iepl%5Bcontexts%5D%5B0%5D=prfhpi&_iepl%5Bdata%5D%5BstandardItemCount%5D=2&_iepl%5Bdata%5D%5BuserSelectedItemCount%5D=0&_iepl%5Bdata%5D%5BtopHighlightCount%5D=2&_iepl%5Bdata%5D%5BtopHighlightIndex%5D=2&_iepl%5Bdata%5D%5BfeaturedItem1of2%5D=1&_iepl%5BtargetEntityId%5D=PB%3A321341667&_iepl%5BinteractionType%5D=publicationViewCoAuthorProfile). [Study on rolling bearing on-line reliability analysis based on vibration information processing](https://www.researchgate.net/publication/321341667_Study_on_rolling_bearing_on-line_reliability_analysis_based_on_vibration_information_processing?_iepl%5BviewId%5D=S069OYW1BgQ5njzqePhF6BWOrBIbwJ4H7iCw&_iepl%5Bcontexts%5D%5B0%5D=prfhpi&_iepl%5Bdata%5D%5BstandardItemCount%5D=2&_iepl%5Bdata%5D%5BuserSelectedItemCount%5D=0&_iepl%5Bdata%5D%5BtopHighlightCount%5D=2&_iepl%5Bdata%5D%5BtopHighlightIndex%5D=2&_iepl%5Bdata%5D%5BfeaturedItem1of2%5D=1&_iepl%5BtargetEntityId%5D=PB%3A321341667&_iepl%5BinteractionType%5D=publicationTitle)[J]. Computers & Electrical Engineering, July 2018(69):842-851. | [Jingchao Li](https://www.researchgate.net/profile/Jingchao_Li8?_iepl%5BviewId%5D=S069OYW1BgQ5njzqePhF6BWOrBIbwJ4H7iCw&_iepl%5Bcontexts%5D%5B0%5D=prfhpi&_iepl%5Bdata%5D%5BstandardItemCount%5D=2&_iepl%5Bdata%5D%5BuserSelectedItemCount%5D=0&_iepl%5Bdata%5D%5BtopHighlightCount%5D=2&_iepl%5Bdata%5D%5BtopHighlightIndex%5D=2&_iepl%5Bdata%5D%5BfeaturedItem1of2%5D=1&_iepl%5BtargetEntityId%5D=PB%3A321341667&_iepl%5BinteractionType%5D=publicationViewCoAuthorProfile)（李靖超） | 是 | 6 |
| 3 | Yulong Ying, Yunpeng Cao, Shuying Li, Jingchao Li, and Jian Guo. Study on gas turbine engine fault diagnostic approach with a hybrid of gray relation theory and gas-path analysis[J]. Advances in Mechanical Engineering, 2016, 8(1): 1-14. | [Jingchao Li](https://www.researchgate.net/profile/Jingchao_Li8?_iepl%5BviewId%5D=S069OYW1BgQ5njzqePhF6BWOrBIbwJ4H7iCw&_iepl%5Bcontexts%5D%5B0%5D=prfhpi&_iepl%5Bdata%5D%5BstandardItemCount%5D=2&_iepl%5Bdata%5D%5BuserSelectedItemCount%5D=0&_iepl%5Bdata%5D%5BtopHighlightCount%5D=2&_iepl%5Bdata%5D%5BtopHighlightIndex%5D=2&_iepl%5Bdata%5D%5BfeaturedItem1of2%5D=1&_iepl%5BtargetEntityId%5D=PB%3A321341667&_iepl%5BinteractionType%5D=publicationViewCoAuthorProfile)（李靖超） | 是 | 21 |
| 4 | Jingchao Li, Dongyuan Bi, Yulong Ying, et al. [An Improved Algorithm for Extracting Subtle Features of Radiation Source Individual Signals](https://www.researchgate.net/publication/331278931_An_Improved_Algorithm_for_Extracting_Subtle_Features_of_Radiation_Source_Individual_Signals?_sg=9I7jJmk7GwhOhskpJ-GCrP3XA9zIa2DAvpG36b0UOhxxXWLFf8kl1K3_XVfoJdpxG3ok3ReEnYDgyz5EiNrMPUESQhrXSsvuAYmYzdOv.0e4pC0RoPy0bId2SeA6qAS2JGPY4z_ByGcAdP4VKd6NFfLzXWb7vaCpnOJ0UxiQBDCfqvp_7hvbIAw_cO0eoZA)[J]. Electronics, February, 2019, 8(2): 246. | Yulong Ying（应雨龙） | 是 | 0 |
| 5 | Jingchao Li, Yulong Ying, Xingdan Lou, et al. Integrated Energy System Optimization based on Standardized Matrix Modeling Method[J]. [Applied Sciences](http://www.letpub.com.cn/index.php?page=journalapp&view=detail&journalid=9954), November 2018, 8(12):2372. | Yulong Ying（应雨龙） | 是 | 0 |
| 6 | Jingchao Li. A New Robust Signal Recognition Approach Based on Holder Cloud Features under Varying SNR Environment[J]. KSII Transactions on Internet and Information Systems, 9(12), pp.4934-4949, 2015. 12.31 | [Jingchao Li](https://www.researchgate.net/profile/Jingchao_Li8?_iepl%5BviewId%5D=S069OYW1BgQ5njzqePhF6BWOrBIbwJ4H7iCw&_iepl%5Bcontexts%5D%5B0%5D=prfhpi&_iepl%5Bdata%5D%5BstandardItemCount%5D=2&_iepl%5Bdata%5D%5BuserSelectedItemCount%5D=0&_iepl%5Bdata%5D%5BtopHighlightCount%5D=2&_iepl%5Bdata%5D%5BtopHighlightIndex%5D=2&_iepl%5Bdata%5D%5BfeaturedItem1of2%5D=1&_iepl%5BtargetEntityId%5D=PB%3A321341667&_iepl%5BinteractionType%5D=publicationViewCoAuthorProfile)（李靖超） | 是 | 11 |
| 7 | Jingchao Li, Jian Guo. A New Feature Extraction Algorithm Based on Entropy Cloud Characteristics of Communication Signals[J]. Mathematical Problems in Engineering, 2015. | [Jingchao Li](https://www.researchgate.net/profile/Jingchao_Li8?_iepl%5BviewId%5D=S069OYW1BgQ5njzqePhF6BWOrBIbwJ4H7iCw&_iepl%5Bcontexts%5D%5B0%5D=prfhpi&_iepl%5Bdata%5D%5BstandardItemCount%5D=2&_iepl%5Bdata%5D%5BuserSelectedItemCount%5D=0&_iepl%5Bdata%5D%5BtopHighlightCount%5D=2&_iepl%5Bdata%5D%5BtopHighlightIndex%5D=2&_iepl%5Bdata%5D%5BfeaturedItem1of2%5D=1&_iepl%5BtargetEntityId%5D=PB%3A321341667&_iepl%5BinteractionType%5D=publicationViewCoAuthorProfile)（李靖超） | 是 | 4 |
| 8 | Jingchao Li. A Novel Recognition Algorithm Based on Holder Coefficient Theory and Interval Gray Relation Classifier[J]. KSII Transactions on Internet and Information Systems (TIIS), 9(11), pp.4573-4584, 2015. | [Jingchao Li](https://www.researchgate.net/profile/Jingchao_Li8?_iepl%5BviewId%5D=S069OYW1BgQ5njzqePhF6BWOrBIbwJ4H7iCw&_iepl%5Bcontexts%5D%5B0%5D=prfhpi&_iepl%5Bdata%5D%5BstandardItemCount%5D=2&_iepl%5Bdata%5D%5BuserSelectedItemCount%5D=0&_iepl%5Bdata%5D%5BtopHighlightCount%5D=2&_iepl%5Bdata%5D%5BtopHighlightIndex%5D=2&_iepl%5Bdata%5D%5BfeaturedItem1of2%5D=1&_iepl%5BtargetEntityId%5D=PB%3A321341667&_iepl%5BinteractionType%5D=publicationViewCoAuthorProfile)（李靖超） | 是 | 10 |
| 9 | Hui Han, Jingchao Li, Xiang Chen. The Individual Identification method of Wireless Device Based on A Robust dimensionality reduction model of Hybrid Feature Information, Mobile Networks and Applications, 23(4):709-716,2018. | [Jingchao Li](https://www.researchgate.net/profile/Jingchao_Li8?_iepl%5BviewId%5D=S069OYW1BgQ5njzqePhF6BWOrBIbwJ4H7iCw&_iepl%5Bcontexts%5D%5B0%5D=prfhpi&_iepl%5Bdata%5D%5BstandardItemCount%5D=2&_iepl%5Bdata%5D%5BuserSelectedItemCount%5D=0&_iepl%5Bdata%5D%5BtopHighlightCount%5D=2&_iepl%5Bdata%5D%5BtopHighlightIndex%5D=2&_iepl%5Bdata%5D%5BfeaturedItem1of2%5D=1&_iepl%5BtargetEntityId%5D=PB%3A321341667&_iepl%5BinteractionType%5D=publicationViewCoAuthorProfile)（李靖超） | 是 | 0 |
| 10 | Xiang Chen, Jingchao Li, Hui Han and Yulong Ying. Improving the signal subtle feature extraction performance based on dual improved fractal box dimension eigenvectors, Royal society open science, 2018.5.2,5(5):1-12. | [Jingchao Li](https://www.researchgate.net/profile/Jingchao_Li8?_iepl%5BviewId%5D=S069OYW1BgQ5njzqePhF6BWOrBIbwJ4H7iCw&_iepl%5Bcontexts%5D%5B0%5D=prfhpi&_iepl%5Bdata%5D%5BstandardItemCount%5D=2&_iepl%5Bdata%5D%5BuserSelectedItemCount%5D=0&_iepl%5Bdata%5D%5BtopHighlightCount%5D=2&_iepl%5Bdata%5D%5BtopHighlightIndex%5D=2&_iepl%5Bdata%5D%5BfeaturedItem1of2%5D=1&_iepl%5BtargetEntityId%5D=PB%3A321341667&_iepl%5BinteractionType%5D=publicationViewCoAuthorProfile)（李靖超） | 是 | 1 |
| 11 | [Li Jiandun](https://www.engineeringvillage.com/search/submit.url?CID=quickSearchCitationFormat&implicit=true&usageOrigin=recordpage&category=authorsearch&searchtype=Quick&searchWord1=%7bLi,+Jiandun%7d&section1=AU&database=1&yearselect=yearrange&sort=yr" \o "Search Author), [Ji Chunlei](https://www.engineeringvillage.com/search/submit.url?CID=quickSearchCitationFormat&implicit=true&usageOrigin=recordpage&category=authorsearch&searchtype=Quick&searchWord1=%7bJi,+Chunlei%7d&section1=AU&database=1&yearselect=yearrange&sort=yr" \o "Search Author), [Wang Xin](https://www.engineeringvillage.com/search/submit.url?CID=quickSearchCitationFormat&implicit=true&usageOrigin=recordpage&category=authorsearch&searchtype=Quick&searchWord1=%7bWang,+Xin%7d&section1=AU&database=1&yearselect=yearrange&sort=yr" \o "Search Author). Energy sensor on the horizon: An accurate, agile and scalable energy metering framework for large-scale wired computing resources[C]. ISSCT 2014. 2015. | [Ji Chunlei](https://www.engineeringvillage.com/search/submit.url?CID=quickSearchCitationFormat&implicit=true&usageOrigin=recordpage&category=authorsearch&searchtype=Quick&searchWord1=%7bJi,+Chunlei%7d&section1=AU&database=1&yearselect=yearrange&sort=yr" \o "Search Author)(计春雷) | 是 | 0 |
| 12 | Zhang Chunjie, Hao Dongbin, Hou Changbo\*, Yin Xiangjun. A New Approach for Sparse Signal Recovery in Compressed Sensing Based on Minimizing Composite Trigonometric Function, IEEE ACCESS, 2018.7.16, 6(44) : 44894~44904. | Hou Changbo（侯长波） | 是 | 1 |
| 13 | Tu Y, Lin Y, Wang J, et al. Semi-Supervised Learning with Generative Adversarial Networks on Digital Signal Modulation Classification[J]. CMC-Computers Materials & Continua, 2018, 55(2): 243-254. | Lin Y（林云） | 是（ESI高被引） | 27 |
| 14 | Yulong Ying, Yunpeng Cao, Shuying Li, Jingchao Li. Nonlinear Steady-State Model Based Gas Turbine Health Status Estimation Approach with Improved Particle Swarm Optimization Algorithm[J]. Mathematical Problems in Engineering, 2015(3): 1-12. | Yulong Ying（应雨龙） | 是 | 8 |
| 15 | Jingchao Li, Yulong Ying. [Marine](https://www.researchgate.net/profile/Yulong_Ying/publication/304019769_Gas_Turbine_Gas_Path_Fault_Diagnosis_Based_on_Adaptive_Nonlinear_Steady-state_Thermodynamic_Model/links/576393a808ae570d6e15c7cf/Gas-Turbine-Gas-Path-Fault-Diagnosis-Based-on-Adaptive-Nonlinear-Steady-state-Thermodynamic-Model.pdf%22%20%5Ct%20%22_blank) three-shaft intercooled-cycle gas turbine engine transient thermodynamic simulation[J] International Journal of Performability Engineering, October 2018, 14(10): 2289-2301. | Yulong Ying（应雨龙） | 是 | 0 |
| 16 | Lin Y, Li Y, Yin X, et al. Multisensor Fault Diagnosis Modeling Based on the Evidence Theory[J]. IEEE Transactions on Reliability, 2018, 67(02): 513-521. | Lin Yun（林云） | 是 | 8 |
| 17 | Lanxin Hu, Yulong Ying, Jingchao Li. A fuzzy logic controller application for marine power plants[C]. 2nd International Conference on Systems and Informatics (ICSAI), Shanghai, China, NOV 15-17, 2014: 124-131. | Yulong Ying（应雨龙） | 是 | 0 |
| 18 | [Yulong Ying](http://ieeexplore.ieee.org/search/searchresult.jsp?searchWithin=%22Authors%22:.QT.Yulong%20Ying.QT.&newsearch=true), [Jingchao Li](http://ieeexplore.ieee.org/search/searchresult.jsp?searchWithin=%22Authors%22:.QT.Jingchao%20Li.QT.&newsearch=true)\*, [Zhimin Chen](http://ieeexplore.ieee.org/search/searchresult.jsp?searchWithin=%22Authors%22:.QT.Zhimin%20Chen.QT.&newsearch=true), [Jing Li](http://ieeexplore.ieee.org/search/searchresult.jsp?searchWithin=%22Authors%22:.QT.Jing%20Li.QT.&newsearch=true). [Rolling Bearing Vibration Signal Analysis Based on Dual-Entropy, Holder Coefficient and Gray Relation Theory](http://ieeexplore.ieee.org/document/8004313/)[C]. [2017 IEEE International Conference on Software Quality, Reliability and Security Companion (QRS-C)](http://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=8004065), 2017.7.25, 190-194. | [Jingchao Li](https://www.researchgate.net/profile/Jingchao_Li8?_iepl%5BviewId%5D=S069OYW1BgQ5njzqePhF6BWOrBIbwJ4H7iCw&_iepl%5Bcontexts%5D%5B0%5D=prfhpi&_iepl%5Bdata%5D%5BstandardItemCount%5D=2&_iepl%5Bdata%5D%5BuserSelectedItemCount%5D=0&_iepl%5Bdata%5D%5BtopHighlightCount%5D=2&_iepl%5Bdata%5D%5BtopHighlightIndex%5D=2&_iepl%5Bdata%5D%5BfeaturedItem1of2%5D=1&_iepl%5BtargetEntityId%5D=PB%3A321341667&_iepl%5BinteractionType%5D=publicationViewCoAuthorProfile)（李靖超） | 是 | 1 |

1. **主要完成单位**

1上海电机学院,2上海电力大学,3哈尔滨工程大学,4重庆群峰科技发展有限公司

1. **主要完成人**

1李靖超,2应雨龙,3林云,4胡兰馨,5王致杰,6伍川,7计春雷,8候长波

1. **新增直接经济效益**

|  |  |  |  |
| --- | --- | --- | --- |
| 项目总投资额 | 3000 | 回收期 | 0 |
| 年份 | 新增产值 | 新增利润 | 新增税收 | 创收外汇（万美元） | 节约资金 |
| 2016 | 550 | 66 | 16.5 | 0 | 0 |
| 2017 | 680 | 81.6 | 20.4 | 0 | 0 |
| 2018 | 850 | 102 | 25.5 | 0 | 0 |
| 累计 | 2080 | 249.6 | 62.4 | 0 | 0 |
| 经济效益额的计算依据： |
| 近三年来，重庆群峰科技发展有限公司采用了本项目的相关技术，有效地解决了在园区物业建筑的过程中，由于设计、施工和监理环节的不完善所引发的质量隐患，显著降低了施工成本与维护成本。2016年，新增产值55万元，新增利润66万元，新增税收16.5万元，2017年，新增产值680万元，新增利润81.6万元，新增税收20.4万元，2018年，新增产值850万元，新增利润102万元，新增税收25.5万元。 |

1. **提名者**

上海市教育委员会

1. **提名等级**

2019年度上海市科学技术奖科技进步奖三等奖