

APARM 2022

The 10th Asia-Pacific International Symposium on Advanced Reliability and Maintenance

Conference Program Book

Organized by

National Yang Ming Chiao Tung University, Taiwan
National Tsing Hua University, Taiwan

Sponsored by

National Science and Technology Council (NSTC), Taiwan
Operations Research Society of Taiwan.
Chinese Institute of Industrial Engineers (CIIE), Taiwan
Industrial Engineering and Management Program of NSTC, Taiwan
IEEE Reliability Society Japan Joint Chapter (RSJC), Japan

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Welcome Message

Welcome to the 10th Asia Pacific International Symposium on Advanced Reliability and Maintenance Modeling (APARM 2022), in Hsinchu, Taiwan, October 21-24, 2022. The APARM conference series, held bi-annually, has been providing a friendly platform for the exchanges of state-of-the-art research ideas and their practices among academics and industry practitioners in the fields of quality & reliability assurance, maintenance modeling & optimization, prognosis & health management of engineering systems.

APARM 2022 is organized by the department of Industrial Engineering and Engineering Management at National Tsing Hua University in association with National Yang Ming Chiao Tung University. Given the challenges and the uncertainties caused by the ongoing COVID-19 pandemic, we have eventually decided to change the originally planned face-to-face conference to a hybrid format, in order to make a successful and safe event for all conference participants both onsite and remote. If traveling is not possible or you cannot join us physically, you still can be with us virtually.

We have created an exciting conference program for all attendees of APARM 2022. It includes 7 keynote speeches from world leaders in the field of reliability and maintenance modeling. A total of 107 papers were submitted to the conference this year. The authors are from 11 countries around the world, including Japan, Korea, China, Vietnam, New Zealand, Australia, the Philippines, Indonesia, Canada, the USA, and Taiwan. The papers were evaluated on the basis of their significance, novelty, and technical quality. 91 papers were selected and will be presented by topics in 18 sessions at the conference. Many thanks to all the authors for participating and contributing valuable works to this conference.

APARM 2022 would not have been able to go ahead as scheduled without the earnest efforts of all our organizing committee and program committee members. It is our great honor and privilege to serve as the General Chairs of APARM 2022. We would like to thank the Steering Committee Chair, Professor Yi-Kuei Lin for the leadership at the conference. This conference is also indebted to hundreds of volunteers who contributed to paper reviews, managed the parallel tracks, and chaired sessions.

Finally, we would like to express our sincere appreciation to all distinguished guests, speakers, session chairs, and participants of the APRAM 2022. We hope that you will enjoy the conference, have many good presentations, fruitful discussions, see old friends and/or meet new friends.

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Tieling Zhang	University of Wollongong, Australia
Xian Zhao	Beijing Institute of Technology, China
Xufeng Zhao	Nanjing University of Aeronautics & Astronautics, China
Xiaoyan Zhu	University of Chinese Academy of Sciences, China
Hongfu Zuo	Nanjing University of Aeronautics & Astronautics, China

Program

(Day 1) 21 October 2022, Friday			
17:30-19:30	Welcome Reception (Engineering Building I, National Tsing Hua University)		
(Day 2) 22 October 2022, Saturday			
09:10-16:30	Registration Desk Open (Engineering Building I, National Tsing Hua University)		
09:30-09:45	Opening Ceremony (Physical, International Conference Hall 107) https://nationalyangmingchiaotunguniversity-tgn.my.webex.com/meet/APARM_1		
09:45-10:20	Keynote Speech #1: "AI Transformation in FEOL Semiconductor Manufacturing" Prof. Shu-Kai Fan (35 mins) Host: Prof. Chien-Wei Wu (General Co-Chair) (Physical, International Conference Hall 107) https://nationalyangmingchiaotunguniversity-tgn.my.webex.com/meet/APARM_1		
10:20-10:50	**Coffee Break**		
10:50-11:25	Keynote Speech #2: "Do Mathematical Reliability Models of Systems With Time Delays Matter?" Prof. Hoang Pham (35 mins) Host: Prof. Chien-Wei Wu (General Co-Chair) (Physical, International Conference Hall 107) https://nationalyangmingchiaotunguniversity-tgn.my.webex.com/meet/APARM_1		
11:25-12:00	Keynote Speech #3: "Operations Research in Disaster Management" Prof. Kuo-Hao Chang (35 mins) Host: Prof. Chien-Wei Wu (General Co-Chair) (Physical, International Conference Hall 107) https://nationalyangmingchiaotunguniversity-tgn.my.webex.com/meet/APARM_1		
12:00-13:10	**Lunch**		
13:10-14:30	Session A1 (Physical) Room: 102	Session A2 (Physical) Room: 103	Session A3 (Online)
14:40-16:00	Session B1 (Physical) Room: 102	Session B2 (Physical) Room: 103	Session B3 (Physical) Room: 104
16:00-16:20	**Coffee Break**		
16:20-17:40	Session C1 (Physical) Room: 102	Session C2 (Physical) Room: 103	Session C3 (Physical) Room: 104
18:30	**Banquet (4F, Sheraton Hsinchu Hotel)**		

(Day 3) 23 October 2022, Sunday (Engineering Building I, National Tsing Hua University)			
09:10-09:45	Keynote Speech #4: "Data-Driven Pandemic Management" Prof. Way Kuo (35 mins) Host: Prof. Mingchih Chen (General Co-Chair) (Online) https://nationalyangmingchiaotunguniversity-tgn.my.webex.com/meet/APARM_1 (International Conference Hall 107)		
09:45-10:20	Keynote Speech #5: "The Studies on Consecutive-k Systems" Prof. Hisashi Yamamoto (35 mins) Host: Prof. Mingchih Chen (General Co-Chair) (Online) https://nationalyangmingchiaotunguniversity-tgn.my.webex.com/meet/APARM_1 (International Conference Hall 107)		
10:20-10:40	**Break**		
10:40-11:15	Keynote Speech #6: "Shocks Models with Damage Evolutions" Prof. LiRong Cui (35 mins) Host: Chair Prof. Min Xie (City University of Hong Kong) (Online) https://nationalyangmingchiaotunguniversity-tgn.my.webex.com/meet/APARM_1 (International Conference Hall 107)		
11:15-11:50	Keynote Speech #7: "System Reliability Analysis of Lamp Systems" Prof. Won Young Yun (35 mins) Host: Prof. Min Xie (City University of Hong Kong) (Online) https://nationalyangmingchiaotunguniversity-tgn.my.webex.com/meet/APARM_1 (International Conference Hall 107)		
11:50-13:00	**Lunch**		
13:10-14:30	Session D1 (Online)	Session D2 (Online)	Session D3 (Online)
14:30-14:40	**Break**		
14:40-16:10	Session E1 (Online)	Session E2 (Online)	Session E3 (Online)
(Day 4) 24 October 2022, Monday (Engineering Building I, National Tsing Hua University)			
09:30-10:50	Session F1 (Online)	Session F2 (Online)	Session F3 (Online)
Closing Ceremony			

Keynote Speech #1

AI Transformation in FEOL Semiconductor Manufacturing

Shu-Kai Fan

Professor, National Taipei University of Technology, Taiwan

About the speaker:

Shu-Kai Fan is a Professor of Industrial Engineering and Management, National Taipei University of Technology (NTUT), Taipei, Taiwan. His research interests include quality engineering, image processing, big data analytics, machine/deep learning applications, and advanced process control of semiconductor manufacturing. He serves as an Editor-in-Chief for Engineering Optimization published by Taylor & Francis, an international multidisciplinary journal that focuses on optimization methods and innovative applications in engineering. He also serves as the Convener for the Industrial Engineering and Management (IEM) Program, National Science and Technology Council (NSTC), Taiwan, from 2020 to 2022.

Keynote Speech #2

Do Mathematical Reliability Models of Systems With Time Delays Matter?

Hoang Pham

Distinguished Professor, Rutgers University, USA

About the speaker:

Hoang Pham is a Distinguished Professor and former Chairman (2007-2013) of the Department of Industrial and Systems Engineering at Rutgers University. He is also a co-founding member and an Associate Director of the Rutgers Center for Information Assurance. Before joining Rutgers, he was a Senior Engineering Specialist with the Idaho National Engineering Laboratory and Boeing Company, Seattle. His research areas include reliability modeling and prediction, software reliability, and statistical inference. He is editor-in-chief of the International Journal of Reliability, Quality and Safety Engineering and editor of Springer Series in Reliability Engineering and has been conference chair and program chair of over 40 international conferences and workshops. Dr. Pham is the author or coauthor of 7 books and has published over 200 journal articles and edited 20 books including Springer Handbook in Engineering Statistics and Handbook in Reliability Engineering. He has delivered over 40 invited keynote and plenary speeches at many international conferences and institutions. His numerous awards include the 2009 IEEE Reliability Society Engineer of the Year Award. He is a Fellow of the IEEE, AAIA, and IISE.

Keynote Speech #3

Operations Research in Disaster Management

Kuo-Hao Chang

Professor, National Tsing Hua University, Taiwan

About the speaker:

Kuo-Hao Chang is a Professor of Industrial Engineering and Engineering Management at National Tsing Hua University and the deputy director of National Science and Technology Center for Disaster Reduction. He has won several prestigious international awards, including the 2012 Bonder Scholar Research Award from INFORMS, 2015 IIE Transactions Best Application Paper Award, 2015 K.D. Tocher Medal from The OR Society, and 2017 IEEE Transactions on Semiconductor Manufacturing Best Paper Award. He has led a team to successfully finish many consultant projects with industrial companies including TSMC, UMC, VisEra, YOMURA, ITRI etc. He is now serving as Associate Editor of IEEE Transactions on Automation Science and Engineering and Asia-Pacific Journal of Operational Research. He is a member of INFORMS, IIE, and a senior member of IEEE. His research interests include big data analytics, simulation optimization, and stochastic models.

Keynote Speech #4

Data-Driven Pandemic Management

Way Kuo

President and University Distinguished Professor, City University of Hong Kong, Hong Kong

About the speaker:

Way Kuo is a president and university distinguished professor of City University of Hong Kong. He is a member of the US National Academy of Engineering and Academia Sinica in Taiwan, A Foreign Member of the Chinese Academy of Engineering, and a Foreign Member of the Russian Academy of Engineering, and an International Fellow of the Canadian Academy of Engineering, elected in 2000, 2002, 2007, 2014, and 2021, respectively. A pioneer in reliability research of systems in their infant stage, He is renowned for his work in designing the reliability of electronics systems and nuclear energy and has made breakthroughs in nano-reliability research.

Keynote Speech #5

The Studies on Consecutive-*k* Systems

Hisashi Yamamoto

Visiting professor and Professor emeritus, Tokyo Metropolitan University, Japan

About the speaker:

Hisashi Yamamoto received the B.S., M.S., and Ph.D. degrees in industrial engineering from the Tokyo Institute of Technology, Tokyo, Japan, in 1981, 1983, and 1996, respectively. He had worked with the Faculty of System Design, Tokyo Metropolitan University, Japan since 2005 and retired March 2022. He is now a visiting professor and a professor emeritus at Tokyo Metropolitan University. His main research interests include system reliability theory, operations research, and applications of probability and statistics in various fields.

Keynote Speech #6

Shocks Models with Damage Evolutions

LiRong Cui

Professor, Qingdao University, China

About the speaker:

Lirong Cui is a professor in the College of Quality & Standardization at Qingdao University, China. He received his Bachelor degree from Tiangong university in 1983, Master degree in Science from Institute of System Sciences, Chinese Academy of Sciences in 1986, PhD degree in Probability and Statistics from the University of Wales, UK, in 1994, respectively. He had worked in Chain Aerospace industry from 1986 to 1999. From 2000 to 2002, He was a Research Fellow in National university of Singapore. From 2003 to 2021, He had worked at Beijing Institute of Technology. Since May of 2021 He joined to Qingdao University. He has worked on quality and reliability-related problems since 1986, and published more than 130 papers and technical reports. In 2000, he co-authored a book on reliability which was published by Kluwer Academic Publishers. He was the person from mainland China to serve as an associate editor of IEEE Transactions on Reliability from 2005 to 2015. He also serves as an associate editor for IISE Transactions, Quality Technology & Quantitative Management, Communications in Statistics: Theory and Methods, Simulation and Computation and E-Journal of Reliability: Theory & Applications. In 2005, He was awarded the new century excellent talents in university of China. He has gotten 6 general programs and 1 key program from NSFC since he joined BIT. His recent research interests are in aggregated stochastic processes and maintenance modelling, degradation reliability analysis, finite Markov chain imbedding approach, cascading failures, balanced system reliability, optimal matching, Hawkes processes, model-based problems, data-driven problems etc.

Keynote Speech #7

System Reliability Analysis of Lamp Systems

Won Young Yun

Professor, Pusan National University, South Korea

About the speaker:

Won Young Yun is a Professor in Department of Industrial Engineering, Pusan National University, Korea. He received his B.S. degree in Industrial Engineering from Seoul National University, Korea, in 1982 and his M.S. and Ph. D. degrees in Industrial Engineering from KAIST, Korea, in 1984 and 1988, respectively. His research interest includes maintenance optimization of complex systems, spare-parts problems and simulation applications in reliability and maintenance. He has published his papers in international journals of reliability and operations research, for example, IEEE Transactions on Reliability, Reliability and System Safety, IIE Transactions, International Journal of Production Economics, etc.

Parallel Sessions

Venue: Engineering Building I, National Tsing Hua University
Session (A) 13:10 – 14:30 Saturday, October 22

【A1】Regular Session: AI and big data in reliability/maintenance

Room: 102

Chair: Prof. Chia-Yu Hsu

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0009	Health Estimation of Railway Wheels Based on Recurrent Plots and Deep Learning Xception Model	Kuan-Jung Chung, Chia-Wei Lin, Chia-Pang Hung	28
0016	Multi-agent Framework for Maintenance Modelling and Optimization in Flexible Manufacturing Systems	Christian John Immanuel S. Boydon, Zhang Bin, Cheng-Hung Wu	29
0026	Quality Prediction for Resin Sand using Machine Learning Approaches	Feng-Chi Yen, Yu-Chung Tsao, You-Shian Chen	30
0107	Multi-Classification System Combining Convolutional Neural Network and Ensemble Transfer Learning on Breast Cancer using Digital Mammogram with Special Image Processing	Wei-Kai Yu, Hao-Chun Lu	31
0092	Transfer Learning for Equipment Prognostic and Health Management and Empirical Study	Chia-Yu Hsu, Yi-Jing Huang	32

【A2】Special Session: Modern methodologies for quality evaluation

Room: 103

Chair: Prof. Zih-Huei Wang

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0011	The Generally Weighted Moving Average with Applications in Forecasting and Quality Engineering	Wei-Teng Sheu, Shih-Hao Lu, Ying-Lin Hsu	33
0019	Generally Weighted Moving Average combining forecast technique	Wei-Teng Sheu, Shih-Hao Lu, Ying-Lin Hsu	34
0036	Loss-based process selection with non-normal data	Cheng-ju Yu, Chen-ju Lin	35
0069	The production and inventory model of supply chain companies focusing on quality practices and ESG sustainable action	Cheng-Ju Chuang	36
0056	Developing a Cumulative Results Sampling Plan with the Advanced Capability Index	Zih-Huei Wang, Chien-Wei Wu	37

【A3】Special Session: Advanced reliability and performance modeling

https://nationalyangmingchiaotunguniversity-tgn.my.webex.com/meet/APARM_3

Chairs: Prof. Junjun Zheng and Prof. Mitsutaka Kimura

Session (B) 14:40 – 16:00 Saturday, October 22

【B1】Special Session: Fuzzy evaluation method for quality and reliability

Room: 102

Chair: Prof. Chun-Min Yu

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0021	Using Seasonal LSTM Method to Predict MTBF in Semiconductor Test Equipment	Kuo-Ping Lin, Li-Han Chen	44
0022	A study on determining optimal production planning strategy under order promising system	Lu-Wen Liao	45
0040	A fuzzy method to identify the influenced factors of service quality in long-term healthcare	Chen-Tung Chen, Wei-Shen Tai	46
0029	Fuzzy lifetime performance assessment model for electronic products with redundant backup systems	Kuen-Suan Chen, Chun-Min Yu, Thi-Phuong Nguyen	47

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Room: 103

Chair: Prof. Ding-Hsiang Huang

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0039	Network reliability evaluation of supply chain under sustainable performance and limited production capacity constraints	Kuan-Yu Lin, Yi-Kuei Lin	49
0042	Solar cell manufacturing network reliability maximization using Absorbing Markov Chain and Genetic Algorithm	Yu-Lun Chao, Cheng-Ta Yeh, Yi-Kuei Lin	50
0063	System Reliability Assessment for a Time-dependent Stochastic Production Network	Ping-Chen Chang, Cheng-Fu Huang	51
0076	A mathematical model for generation of all minimal capacity vectors in a multi-capacity flow network	Ding-Hsiang Huang	52

【B3】Regular Session: Remaining useful life estimation and data mining in reliability

Room: 104

Chair: Prof. Yu-Hsiang Hsiao

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0008	An Adaptive Lot-Traceability Sampling Plan Qualified by Weibull-Lifetime Capability with Warranty Return Rate Consideration and Development of Its Smart Information System	To-Cheng Wang, Ming-Hung Shu, Chien-Wei Wu	54
0015	Auto-Machine Learning Methods to Forecast the State of Health of Lithium-Ion Battery	Lei Qin, Xiaomei Zhang, Yang Chen, Jian Li, Linglong Ye, Jianping Zhu, Yi-Hsien Tai, Mingchih Chen	55
0028	A Decision Support System for Dengue Fever Warning and Prediction	Yao-Huei Huang, Ting-Yu Tai	56
0094	Online Review Analytics for Hotel Service Quality Diagnosis Using MTGS	Yu-Hsiang Hsiao, Ching-Wei Chen	57

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【C1】Regular Session: Optimal production policies & applications

Room: 102

Chair: Prof. Yu-Min Chiang

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0020	Joint Design of Quality Investment and Tolerance by Considering Inspection for Product Protection	Chung-Ho Chen	59
0032	A Modified Sampling Scheme for Lot Sentencing Based on the Third-Generation Capability Index	Armin Darmawan, Chien-Wei Wu	60
0057	Exploration of the Best-Operating Conditions to Balance Efficiency and Quality of the Wafer Probing Process	Chris-Woonyoung Yeo, Yung-Chia Chang	61
0096	Implementing Lean and Simulation Optimization to Improve Production Efficiency in a Taiwan SME: a Case Study	Yu-Min Chiang, Pei-Ci Li, Ting-Pu Su	62

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Chair: Prof. Shih-Wen Liu

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0079	Reliability assessment of an air transport network with the elasticity of demand by flight class	Thi-Phuong Nguyen	64
0067	Developing an alterable sampling plan for lot determination by considering multiple quality characteristics	To-Cheng Wang, Shih-Wen Liu	65
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Chair: Prof. Hsin-Nan Tsai

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0013	Cost Efficiency of Resilience Capability for Weibull life-time Products under Random Shocks	Min-Hsuan Chiang, Ting-Yu Hong, Ruey-Huei Yeh	68
0027	Strategical approach for assessing the reliability information during product development: Perspective of the partially accelerated degradation test	Siil Sung	69
0047	Optimal Exact Design for Gamma Accelerated Degradation Tests with Two Accelerating Variables	Hung-Ping Tung	70
0090	The optimal decision analysis of manufacturing equipment based on random working times and Industry 4.0 sensor fault diagnosis	Hsin-Nan Tsai	71

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【D1】Special Session: Artificial intelligence approach in reliability issues

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Chair: Prof. Hiroyuki Okamura

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0024	A note on finding boundary values of programs with neural networks	Xiujing Guo, Hiroyuki Okamura, Tadashi Dohi	73
0054	A Note on Prediction of Source Code Changes with Natural Language Processing	Yuto Kaibe, Hiroyuki Okamura, Tadashi Dohi	74
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0101	Towards Predicting Safety Integrity Level in Functional Safety with Neural Networks	Shintaro Kita, Hiroyuki Okamura, Tadashi Dohi	76

【D2】Special Session: Optimization models in reliability and warranty

https://nationalyangmingchiaotunguniversity-tgn.my.webex.com/meet/APARM_2

Chair: Prof. Won Young Yun

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0103	Simulation-based Optimization of a Two-dimensional Warranty Policy under Korean Lemon Law	Seung Hoon Jung, Young Jin Han, Won Young Yun	85

【D3】Regular Session: Software reliability and remaining useful life estimation

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Chair: Prof. Yan-Fu Li

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Abstract

Health Estimation of Railway Wheels Based on Recurrent Plots and Deep Learning Xception Model

Kuan-Jung Chung*
Dept of Mechatronics Engineering
Natl Changhua Univ. of Education
Changhua 500, Taiwan
kjchung@cc.ncue.edu.tw

Chia-Wei Lin
Dept of Mechatronics Engineering
Natl Changhua Univ. of Education
Changhua 500, Taiwan
winter19971120@gmail.com

Chia-Pang Hung
Dept of Mechatronics Engineering
Natl Changhua Univ. of Education
Changhua 500, Taiwan
d1051002@gm.ncue.edu.tw

Abstract

In this study, the piezoelectric sensors were installed on the railway track to collect the dynamic voltage-and-strain signals when the train wheels pressed the sensors. These one-dimensional time series signals were transformed to the two-dimensional RP images as an input data sets of the deep learning Xception model, and the binary classification: Normal or Faulty as the output to indicate the health state of the train wheels. The prediction results for 101 test images show the high model accuracy 0.911, sensitivity (Recall) 0.915, low miss rate (False Negative Rate, FNR) 0.085, and reasonable AUC 0.760. In summary, the Xception is an exceptional deep learning classifier for diagnosing the health state of rolling stock wheels to provide the effective Condition Monitoring of these asset.

Keywords: Recurrence Plot, Deep Learning, Condition Monitoring, Train Wheel, Xception

Multi-agent Framework for Maintenance Modelling and Optimization in Flexible Manufacturing Systems

Christian John Immanuel S. Boydon*
Institute of Industrial Engineering
National Taiwan University
Taipei City, Taiwan
d08546003@ntu.edu.tw

Zhang Bin
Institute of Industrial Engineering
National Taiwan University
Taipei City, Taiwan
d05221001@ntu.edu.tw

Cheng-Hung Wu
Institute of Industrial Engineering
National Taiwan University
Taipei City, Taiwan
wuchn@ntu.edu.tw

Abstract

Factory automation in Industry 4.0 adopt multi-agent systems to achieve scalability and reconfigurability in response to the need for flexible mass production and the rapid advancement of process technologies. Multi-agent systems coordinate autonomous shop-floor agents to come up with superior manufacturing policies as compared to the agents acting independently. In recent production control literature, optimization of preventive maintenance plans alongside the production control policy provides significant improvement in manufacturing performance. That is, correctly deciding when to take deteriorated machines offline to perform maintenance and restore processing rates achieves better long-run performance than allowing accumulated machine wear to impede production efficiency and eventually lead to failure. This research develops a multi-agent framework that enables rapid and adaptive preventive maintenance modelling for flexible manufacturing systems. Utilizing smart factory technologies (i.e., high data communication bandwidth, real-time access to work-in-process and machine health status from sensor systems), we develop a multi-agent architecture that accesses this information as needed and modifies manufacturing policies correspondingly. A distribution agent (workstation-level) optimizes workload distribution based on on-line estimation of production parameters (e.g., job arrival/processing rate, machine health deterioration) from the factory knowledge database, enabling a modular production control approach that allows re-optimization whenever changes in the manufacturing floor occur (e.g., change in production priority, machine breakdown). Autonomous machine agents (machine-level) solve local Markov decision processes based on real-time machine health and shop floor status, allowing linear scalability of maintenance modelling and optimization. A production control agent (manufacturing floor-level) dynamically reassesses the local machine policies and ensures optimal factory-level production. Simulation results show that the multi-agent framework reduces cycle time by up to 90% compared with the traditional C-mu rule in a wide range of manufacturing settings.

Keywords: Multi-agent system, Preventive maintenance modelling, Flexible job-shop

Quality Prediction for Resin Sand using Machine Learning Approaches

Feng-Chi Yen
Chung Yuan Christian University, Taiwan
Industrial Development Bureau, Ministry of Economic Affairs, Taiwan
fcyan@moeaidb.gov.tw

Yu-Chung Tsao*
Department of Industrial Management, National Taiwan University of Science and Technology, Taiwan
yctsao@mail.ntust.edu.tw

You-Shian Chen
Department of Industrial Management, National Taiwan University of Science and Technology, Taiwan
M11001205@mail.ntust.edu.tw

Abstract

Machine learning is one of the disciplines of artificial intelligence that allows computers to learn without a lot of pre-written programs; that is, computers can accumulate "experience" and automatically search for information to catch patterns and trends. In this study, machine learning methods are applied to predict the quality of the production process of resin sand, which the data was collected from a resin sand manufacturer in Taiwan. The process parameters of the production machine are used to predict the quality of the future production. Silica sand type, resin ratio, mixing temperature, and batch heating are selected as the inputs to predict the outputs (grain size, flexural strength, point of unity, and falling test). Several machine learning approaches are used to predict the quality. The results show that the Stack Regssion + Kmeans method has the lowest mean absolute error (MAE). Compare the experienced recipe and the AI-recommended recipe, we also find that the computer-recommended recipe achieves higher more stable quality.

Keywords: machine learning, quality prediction, production process, resin sand

Multi-Classification System Combining Convolutional Neural Network and Ensemble Transfer Learning on Breast Cancer using Digital Mammogram with Special Image Processing

Wei-Kai Yu[1]
Institute of Information Management
National Cheng Kung University
Tainan, Taiwan
r76091113@gs.ncku.edu.tw

Hao-Chun Lu*[2]
Department of Management Science
National Yang Ming Chiao Tung University
Hsinchu, Taiwan
haoclu@gmail.com

Abstract

This study proposes a deep convolutional neural network model that could classify each breast imaging reporting and data system (BI-RADS) category. Because there is a lack of a model that can effectively classify five BI-RADS categories of Mammogram images of breast cancer, this study proposes a specific model that combines convolutional neural network and ensemble transfer learning to conquer this problem. The training and test data consist of BI-RADS 1 to BI-RADS 5 clinical mammograms for a total of 9,670 images. This study sequentially performed the following image preprocesses: (i) removing the unuseful image background, (ii) image resizing, (iii) data augmentation, (iv) median filter, and (v) contrast limited adaptive histogram equalization (CLAHE).

In the training phase, we divide the training set into six independent sub-datasets and use resnet-50 as the pre-trained model of the transfer learning method. Then, we construct and train six classifying models based on the six independent sub-datasets. Finally, the proposed ensemble model uses a proposed weighting voting mechanism to determine the final predictive BI-RADS category from the six classifying models. In the experiment result, the area under the receiver operating characteristic curve (AUC-ROC) reaches nearly 0.87.

Keywords: BI-RADS Diagnosis, Convolutional Neural Network, Ensemble Learning, Image Preprocessing, Mammogram, Transfer Learning

Transfer Learning for Equipment Prognostic and Health Management and Empirical Study

Chia-Yu Hsu*
Department of Industrial Management
National Taiwan University of Science and Technology
Taipei, Taiwan
cyhsu@mail.ntust.edu.tw

Yi-Jing Huang
Department of Industrial Engineering and Management
National Taipei University of Technology
Taipei, Taiwan
t108378057@ntut.org.tw

Abstract

Prognostic and Health Management (PHM) is important for avoid unexpected breakdown in smart manufacturing. Based on the collected sensor time series data, data-driven method has been applied for PHM including abnormality detection early and prediction of the remaining useful life (RUL). However, it's difficult to collect enough information with the complete life cycle and the various conditions of equipment failure are not easy to directly compare difference among the equipment. To overcome the challenges including feature extraction from time series, few abnormal sample, and different length of sensor data, this study aims to propose a transfer learning framework for PHM, which consists of anomaly detection and RUL estimation. First, AutoEncoder-Bidirectional Long Short-Term Memory (AE-BiLSTM) is used to detect abnormality. Moreover, this study adopts a transfer learning model by Domain Adversarial Neural Networks (DANN) to predict the RUL of the abnormal machine. To validate the proposed transfer learning framework of PHM, an empirical study from a leading panel display company was conducted. To reduce the reconstruction error of AE-BiLSTM, a Reshape layer is adopted and the errors are reduced about 20%. The experiment results indicate that the DANN can effectively predict the RUL within few abnormal samples. The proposed methods have also demonstrated the practical visibility of the proposed transfer learning framework.

Keywords: Prognostic and Health Management, AutoEncoder-Bidirectional Long Short-Term Memory (AE-BiLSTM), Domain Adversarial Neural Networks, Remaining Useful Life, Time Series Data

The Generally Weighted Moving Average with Applications in Forecasting and Quality Engineering

Wei-Teng Sheu*
Department of Business Administration, National Taiwan University of Science and Technology, Taipei, Taiwan.
bensheu@outlook.com

Shih-Hao Lu
Department of Business Administration, National Taiwan University of Science and Technology, Taipei, Taiwan.
shlu@mail.ntust.edu.tw

Ying-Lin Hsu
Department of Applied Mathematics and Institute of Statistics, National Chung Hsing University, Taichung, Taiwan.
ylhsu@nchu.edu.tw

Abstract

The exponentially weighted moving average forecasting techniques are widely used in the management science. Sheu and Lin (2003) extended the exponentially weighted moving average (EWMA) technique to generally weighted moving average (GWMA) technique. In this paper, the definition and properties of general weighted moving average are being further analyzed and investigated. The generally weighted moving average (GWMA) control chart has been studied extensively. GWMA control chart outperforms EWMA control chart in terms of finding small process shifts quickly. In this paper, we use the generally weighted moving average (GWMA) technique to construct forecasts of future value as weighted averages of past observations with the more recent observations carrying more weight in determining forecasts than observations in the more distant past. The weights depend on the period. The exponentially weighted moving average technique and the weighted moving average technique can be shown to be special cases of the generally weighted moving average technique. One of the most common applications of the EWMA and GWMA is generating one-step-ahead forecasts of time series. Our empirical analysis uses the monthly Australian sales of rose wine from January 1980 to April 1995. The results show that our GWMA forecasting technique outperforms EWMA forecasting technique.

Keywords: Control chart, EWMA, Forecasting, GWM

Generally Weighted Moving Average combining forecast technique

Wei-Teng Sheu*
Department of Business Administration, National Taiwan University of Science and Technology, Taipei, Taiwan.
bensheu@outlook.com

Shih-Hao Lu
Department of Business Administration, National Taiwan University of Science and Technology, Taipei, Taiwan.
shlu@mail.ntust.edu.tw

Ying-Lin Hsu
Department of Applied Mathematics and Institute of Statistics, National Chung Hsing University, Taichung, Taiwan.
ylhsu@nchu.edu.tw

Abstract

Financial forecasting has always been considered a challenging task in financial markets for both academic scholars and business professionals due to the unforeseen magnitude of external or internal factors. The recent trend to implement the accuracy of predictions is focusing on combining models by applying a simple average or weighted average in which the weight demonstrates the prediction error. To enhance combining forecasting's performance, this study proposed a new approach by using an extension of exponentially weighted moving average which so-called generally weighted moving average to combine individual models. In this study, the acquired results from four single models; Generalized Auto Regressive Conditional Heteroskedastic (GARCH), Holt's Winter Linear Trend (Holt's linear trend), General Weighted Moving Average (GWMA), and Random Walk; are aggregated based on a weight that indicates the inverse of generally weighted moving average of Mean Absolute Percentage Error (MAPE), Mean Absolute Error (MAE), and Residual of Root Mean Square Error (RMSE) of each single forecasting model. The empirical result indicated that the proposed methodology performed with superior accuracy than the existing combining method; Exponential Weighted Moving Average combining method; simultaneously with four proposed individual models.

Keywords: Combined methodology, EWMA, Forecasting, GWMA, GARCH, Holt's linear trend, Random Walk

Loss-based process selection with non-normal data

Cheng-ju Yu
Department of Industrial Engineering and Management
Yuan Ze University
Taoyuan, Taiwan
s1105428@mail.yzu.edu.tw

Chen-ju Lin*
Department of Industrial Engineering and Management
Yuan Ze University
Taoyuan, Taiwan
chenju.lin@saturn.yzu.edu.tw

Abstract

Process capability indices (PCIs) have been widely applied in the manufacturing industry to evaluate process capability based on different criteria. A departure of a product quality characteristic from its target value would cause quality loss. The $C_{pp(q)}$ index is a loss-based capability index that contains information about process inaccuracy and imprecision. Non-normal percentiles are used to replace sample mean and standard deviation to calculate the index. However, the distribution of the estimator of $C_{pp(q)}$ is mathematically intractable. To choose the better process with the lower quality loss between the two processes with non-normal data, this research uses the biased corrected percentile bootstrap (BCPB) resampling technique to construct the confidence interval for the difference in the $C_{pp(q)}$ index. The simulation results show that the proposed confidence interval can reach the confidence level with a satisfactory level of power.

Keywords: quality loss, process selection, Bootstrap method, non-normal data

The production and inventory model of supply chain companies focusing on quality practices and ESG sustainable action

Cheng-Ju Chuang*
Business Administration
Providence University
Shalu, Taichung
chuang0321@pu.edu.tw

Abstract

From the traditional quality perspective, products produced by a company can be regarded as perfect ones as they are within the specification limits. But, from a more realistic quality perspective, the traditional quality perspective ignores many additional losses caused by the user in using the product after purchasing, such as the expenses of maintenance and warranty, thus the quality related costs are underestimated. Investing in quality is the main way the companies apply to improve quality, and the trend of quality improvement is changing from reducing defective rates to reducing process variation. In addition, the setting of process mean is also an important way in minimizing total cost. Because of the gradual increase in consumer awareness, the requirements of specification of a product is getting higher, that makes asymmetric specification limits common. In recent years, with the rise of international ESG sustainable actions, supply chain companies must take environmental protection actions in line with the international situation, such as purchasing green electricity, energy saving and carbon reduction. The behavior among these supply chain companies can be very effectively analyzed by Game Theory. This study provides a preliminary framework for theoretical research to discuss the above mentioned issues.

Keywords: Quality, ESG, Sustainable, Supply chain, Game Theory

Developing a Cumulative Results Sampling Plan with the Advanced Capability Index

Zih-Huei Wang*
Department of Industrial Engineering and Systems Management
Feng Chia University
Taichung, Taiwan
zhwang@fcu.edu.tw

Chien-Wei Wu
Department of Industrial Engineering and Engineering Management
National Tsing Hua University
Hsinchu, Taiwan
cweiwu@ie.nthu.edu.tw

Abstract

Acceptance sampling plan plays an important role in quality assurance. It provides the ability to statistically judge if submitted lots meet quality standards based on partial samples. Different from traditional acceptance sampling plans, Dodge (1977) proposed a new strategy called Chain Sampling ChSP-1 which is a typical example of using cumulative results of preceding lots to achieve reduction of samples while maintaining protections for both producers and consumers. Subsequently, Govindaraju and Lai (1998) proposed a modified chain sampling plan (MChSP-1) and stated that the historical information from the past lots always be referenced for sentencing each submitted lot, thereby reducing the required sample size. This paper aims to propose a new type of sampling plan considering the advanced process capability index which is suitable for a high-quality process. The plan is developed to minimize the average sample number (ASN) required for inspection and take the constraints related to quality and risk requirements specified by the producer and the consumer into account. A mathematical model for the proposed plan's parameters is also constructed. Further analysis and comparisons on the proposed plan and traditional plans in terms of operating characteristic (OC) curve and ASN curve are examined and discussed. Finally, a case study is presented to demonstrate how the proposed plan can be applied in practical situations.

Keywords: Chain sampling plan, cumulative results, advanced capability index, nonlinear optimization problem

Stochastic Evaluation Model Focusing on Single Bit Errors on the CAN Bus

Ryohei Sato*
Department of Electrical Engineering and Computer Science
Tokyo Metropolita University
Hino, Tokyo, Japan sato-ryohei@ed.tmu.ac.jp

Tomoki Kitabayashi
Department of Electrical Engineering and Computer Science
Tokyo Metropolita University
Hino, Tokyo, Japan kitabayashi-tomoki@ed.tmu.ac.jp

Satoshi Fukumoto
Department of Electrical Engineering and Computer Science
Tokyo Metropolita University
Hino, Tokyo, Japan
s-fuku@tmu.ac.jp

Abstract

The environment surrounding controller area networks (CANs), the de-facto industry standard for in-vehicle network protocols, has become increasingly harsh due to electromagnetic noise in recent years. Thus, designers of CANs need to accurately estimate the response time of data frames taking into account communication errors to ensure that the frames meet real-time requirements. Although many response time analysis (RTA) methods for CANs have been proposed, they assume that the transmission time of all frames is always the worst (i.e., maximum) value, which leads to overly pessimistic estimates. This paper proposes a transmission time analysis (TTA)-model for error frames, i.e., a mathematical model to analytically determine the probability distribution of the transmission time. The TTA-model can be an elemental technique to improve the accuracy of existing RTA models.

Keywords: controller area networks (CANs), error models, stochastic analysis, transmission time analysis

Reliability Evaluation of Cloud-Based Railway Signalling Systems Using COTS-Based Asynchronous Processing

Takashi Toyama*
Graduate School of System Design
Tokyo Meteopolitan University
Tokyo, Japan
toyama-takashi@ed.tmu.ac.jp

Mamoru Ohara
Graduate School of System Design
Tokyo Meteopolitan University
Tokyo, Japan
ohara@iel.sd.tmu.ac.jp

Masayuki Arai
College of Industrial Technology
Nihon University
Chiba, Japan
arai.masayuki@nihon-u.ac.jp

Satoshi Fukumoto
Faculty of System Design
Tokyo Meteopolitan University
Tokyo, Japan
s-fuku@tmu.ac.jp

Abstract

Railway signalling systems are required to have high level of safety and reliability. In order to meet the safety requirements, specially designed failsafe computers have been used. Recently there is a need to realize railway signalling systems using COTS computers. In this paper, we overview the effects of the network failures of a railway signalling system using COTS computers in the cloud, in preparation for the reliability modeling. Monte Carlo simulations confirmed that the effect of random failure in the network can be negligible by using a protocol where messages packed with multi-round past data are exchanged. We obtained the prospect that the configuration using COTS computers provides the same level of reliability as the configuration using fail-safe computers.

Keywords: Railway Signalling, Cloud Computing, COTS, Asynchronous Processing

Reliability Model of Congestion Control Scheme with Two Stages of Error Correcting Code

Mitsutaka Kimura*
Faculty of Business Administration
Aichi University
Nagoya, Japan
kimuram@vega.aichi-u.ac.jp

Mitsuhiro Imaizumi
Affiliated Research Center
Aichi Gakusen University
Okazaki, Japan
imaizumi@gakusen.ac.jp

Toshio Nakagawa
Department of Business Administration
Aichi Institute of Technology
Toyota, Japan
toshi-nakagawa@aitech.ac.jp

Abstract

This paper considers a reliability model of congestion control scheme with two stages of error correcting code for data transmission. That is, we consider a reliability problem of communication system with congestion control scheme and error correcting code. When network congestion occurs, a router disposes some packets and some packet losses have been occurred. In order to solve this problem, High-performance and Flexible Protocol (HpFP) has been proposed in a communication protocol. On the other hand, Hybrid Automatic Repeat request (Hybrid ARQ) has been proposed as code error correction method. That is, loss packets have been restored by using the error correction packet. In this paper, we formulate the stochastic model of congestion control scheme with two stages of error correcting code. Further, the mean time until packet transmissions succeed is derived and a optimal policy which maximizes throughput is discussed.

Keywords: Reliability, Error Correcting Code, HpFP, Congestion Control Scheme, Optimal Policy

A Note on Epistemic Uncertainty Propagation in Generalized Stochastic Petri Nets

Jiahao Zhang*
Graduate School of Advanced Science Engineering Hiroshima University
Higashihiroshima, Japan
jiahaozhang@hiroshima-u.ac.jp

Junjun Zheng
Department of Information Science and Engineering Ritsumeikan University
Kusatsu, Japan
jzheng@fc.ritsumei.ac.jp

Hiroyuki Okamura
Graduate School of Advanced Science Engineering Hiroshima University
Higashihiroshima, Japan
okamu@hiroshima-u.ac.jp

Tadashi Dohi
Graduate School of Advanced Science Engineering Hiroshima University
Higashihiroshima, Japan
dohi@hiroshima-u.ac.jp

Abstract

Generalized stochastic petri net (GSPN) as an extension of stochastic petri net (SPN) can model the dynamics of the system. Usually the GSPN is applied for obtaining the system performance through several measures like system reliability, system availability and etc. However, the evaluation of the measures relies on the parameters of system, which is essentially estimated from the data samples or expert guesses. Since the parameters are estimated from the fixed value of the above information, there will exist uncertainty in the model parameters if such an information is incomplete. This phenomenon is called epistemic uncertainty propagation. Since the outputs of system can be affected by this phenomenon, uncertainty analysis on the GSPN should be taken into account. However, the analytical method on the GSPN is seldom considered. Fortunately, the GSPN is equivalent in power to a continuous time Markov chain (CTMC), which means the uncertainty analysis based on CTMC can be applied. In this paper, we focus on the epistemic uncertainty propagation of GSPN through the uncertainty propagation of CTMC. In particular, the conversion from GSPN to CTMC and parametric sensitivity analysis are considered.

Keywords: Generalized stochastic petri net, stochastic petri net, epistemic uncertainty propagation, continues-time Markov chain, moment-based approximation

On the Interval Reliability of Intrusion Tolerant Systems Using Semi-Markov Models

Junjun Zheng*
Depart. Info. Sci. Eng.
Ritsumeikan Univ.
Kusatsu, Japan
jzheng@fc.ritsumei.ac.jp

Hiroyuki Okamura
Grad. Sch. Adv. Sci. Eng.
Hiroshima Univ.
Higashihiroshima, Japan
okamu@hiroshima-u.ac.jp

Tadashi Dohi
Grad. Sch. Adv. Sci. Eng.
Hiroshima Univ.
Higashihiroshima, Japan
dohi@hiroshima-u.ac.jp

Abstract

This paper focuses on the transient behavior of intrusion tolerant systems with preventive maintenance subject to DoS (Denial-of-Service) attacks. The system behavior is described by a semi-Markov model. The interval reliability is a unified dependability measure from the viewpoint of both system reliability and system availability. The paper considers how to calculate the interval reliability of intrusion tolerant systems. Particularly, we formulate the transient behavior of the interval reliability analytically at an arbitrary operation time using the renewal reward process and Laplace-Stieltjes (LS) transform technique.

Keywords: Interval reliability, semi-Markov model, renewal function, Laplace-Stieltjes transform, preventive maintenance

Fuzzy judgment model of deep learning network system with better recognition capability

Tsang-Chuan Chang*
Department of Intelligent Production Engineering
National Taichung University of Science and Technology
Taichung, Taiwan
changtc@gm.nutc.edu.tw

Abstract

Artificial intelligence (AI) is a technology that helps humans make better decisions through a series of processes including learning, reasoning, and judgment. It is therefore widely applied in a number of fields. Diverse market needs have also promoted the rapid evolution of AI, producing various emerging technological services with AI as a Service. Many studies endeavored to develop learning algorithms techniques for AI, including machine learning and deep learning (DL), in hopes of helping industries solve cognitive problems associated with human thinking and make accurate judgment and predictions. Furthermore, DL uses multilayered networks comprising artificial neurons to perform complex calculations, thereby enabling computers or machines to display the judgment and behavior of humans. Thus, DL can process all classification problems associated with perceptrons, becoming the mainstream technology in the current AI era. To understand whether the DL network systems designed in various studies have better recognition capabilities, confusion matrices are commonly used as evaluation tools, and indices such as accuracy, sensitivity, and specificity are calculated for assessment and analysis. However, the values of these indices change with the degree of learning achieved by the network system each time it is trained, which unavoidably creates some uncertainty in the index values and means that using a single index value or the mean to determine the image recognition capabilities of a network system may lead to misjudgment. For this reason, this paper used accuracy to define a recognition performance index to compare the recognition capabilities of various DL network systems. Furthermore, we further proposed its triangular fuzzy number and used it to develop a fuzzy test model for recognition performance index so as to more reliably aid researchers in determine whether the DL network systems they designed have better recognition capabilities.

Keywords: Deep learning network system, recognition performance index, triangular fuzzy number, fuzzy testing

Using Seasonal LSTM Method to Predict MTBF in Semiconductor Test Equipment

Kuo-Ping Lin*
Department of Industrial Engineering and Enterprise Information,
Tunghai University, Taiwan
kplin@thu.edu.tw

Li-Han Chen
Department of Industrial Engineering and Enterprise Information,
Tunghai University, Taiwan
hankisprofessional@gmail.com

Abstract

Since the 21st century, semiconductors have become an important industry in the world. However, Taiwan's foundry and packaging and testing industry ranks first in the world, and integrated circuits made of semiconductors are widely used in daily life. Packaging and testing are the last quality control step in the semiconductor manufacturing process, and its machine reliability is one of the most important keys. If the mean time between failures (MTBF) of the machine can be accurately predicted, the machine can effectively be controlled. Preventive maintenance and repairs are carried out before the machine fails. Therefore, this study will predict the MTBF of semiconductor test machines to improve machine utilization. This study takes the packaging and testing process of Company A as an example. A set of machine learning is used as the model training framework. Finally, the performance of the model framework of this study is verified by comparing with traditional forecasting methods.

Keywords: MTBF, LSTM, Seasonal Adjustment, Prediction, Chaos Theory, Semiconductor, Package Test

A study on determining optimal production planning strategy under order promising system

Lu-Wen Liao*
Department of Intelligent Production Engineering,
National Taichung University of Science and Technology, Taichung, Taiwan
lwliao@gm.nutc.edu.tw

Abstract

In Taiwan, many bag manufacturers have faced competitive challenges from the companies in China or Southeast Asia. Therefore, Taiwan's bag manufacturers dedicate to upgrade their manufacturing capabilities to enhance their manufacturing flexibility, so as to effectively utilize production resources and quickly satisfy the customized requirements for customers. A well-designed and highly reliable order promising system can help bag manufacturers effectively utilize material resources and production capacities, as well as improve the performance in the supply chain.

Order promising mechanism provides a decision making mechanism for allocating unreserved product quantities or manufacturing capacity to incoming customer orders, in order to give promises and determine order quantities and due dates of these orders. Chen et al. (2001, 2002) stated that the batching interval size is an important parameter that affects both company's profit and customer service while executing order promising to commit customer request. In addition, Octavia (2004) denoted that the production planning strategy for items is another critical factor that has significant impact on the nature of order promising. Therefore, how to help the bag manufacturers to establish an appropriate order promising system is an important and urgent task. The aim of this research is to investigate the order promising problem where the length of batching interval and the production planning strategy of bill of material (BOM) items for a final product are considered simultaneously while maximize manufacturer's profit.

Keywords: Order Promising, Production Planning Strategy, MTO, MTS, Mixed Integer Linear Model

A fuzzy method to identify the influenced factors of service quality in long-term healthcare

Chen-Tung Chen*
Department of Information Management,
National United University
Miao-Li, Taiwan
ctchen@nuu.edu.tw

Wei-Shen Tai
Department of Information Management,
National Taichung University of Science and Technology
Taichung, Taiwan
wstai@nutc.edu.tw

Abstract

Due to the progress of medical science and rapid development of smart medical technologies recently, people life getting longer and measuring the service quality became an important issue in long-term healthcare. Actually, many factors will influence the service quality level of long-term healthcare institutions. Therefore, it is an important issue to explore the critical factors of service quality in long-term healthcare. Because patients always cannot describe their opinions clearly, it is suitable to express their evaluations by using the interval linguistic variables in the evaluation process of service quality. Under this situation, the DEMATEL (decision-making trial and evaluation laboratory) technique is applied to indicate influential relationships and to compute the importance of all factors. Based on the linguistic opinions and DEMATEL, this paper proposed a systematic way to explore the critical factors of measuring service quality in long-term healthcare.

Keywords: Service quality, Long-term healthcare, Interval linguistic variables, DEMATEL

Fuzzy lifetime performance assessment model for electronic products with redundant backup systems

Kuen-Suan Chen
Department of Industrial Engineering and Management,
National Chin-Yi University of Technology,
Taichung, Taiwan, R. O. C.
kuensuan.chen@gmail.com

Chun-Min Yu*
Department of Industrial Engineering and Management,
National Chin-Yi University of Technology,
Taichung, Taiwan, R. O. C.
yu2013000@gmail.com

Thi-Phuong Nguyen
Department of Distribution Management,
National Chin-Yi University of Technology,
Taichung, Taiwan, R.O.C.
phuongnt@ncut.edu.tw

Abstract

Enhancing product quality and reliability can not only increase product value but also reduce rework and scrap rates and lengthen failure-induced maintenance schedules, thereby decreasing maintenance rates. When electronic products have no spare electronic components, their lifespan equals the lifespan of their components. With electronic components that have overly short lifespans on average, redundant backup systems are a way of increasing electronic product reliability. In other words, when spares are available for electronic components, in the case of failure the product can switch over to the spare immediately. This paper proposes an electronic product lifetime performance index with redundant backup electronic components. Then, we find a uniformly minimum variance unbiased estimator (*UMVUE*) for the proposed index. Furthermore, we develop for this index a uniformly most powerful (*UMP*) test and formulate a fuzzy testing approach based on its confidence interval. The proposed approach makes it convenient for the industry to assess and grasp improvement opportunities and increase product reliability so as to conserve energy and reduce carbon emissions.

Keywords: Capacitor, Relative lifetime performance index, Reliability function, Confidence interval, Fuzzy testing

Network Reliability Analysis on Casualty Rescue for Natural Disaster Evaluation

Cheng-Hao Huang
Department of Industrial Engineering and Management
National Yang Ming Chiao Tung University
Hsinchu 300, Taiwan
robert86315tw@gmail.com

Chi-Ting Hsu
Department of Industrial Engineering and Management
National Yang Ming Chiao Tung University
Hsinchu 300, Taiwan
krlly10050068@gmail.com

Yi-Kuei Lin*
Department of Industrial Engineering and Management
National Yang Ming Chiao Tung University
Hsinchu 300, Taiwan
yklin@nycu.edu.tw

Abstract

The route problem for ambulance rescue is always a critical issue in an earthquake situation. The road condition on the rescue route may change due to damage from an earthquake or buildings collapsed. However, previous studies essentially considered such a problem by assuming a fixed travel time for each road for the ambulance. This paper aims to involve road failure during the earthquake by considering the stochastic travel time for each road. Moreover, the network reliability is adopted in this paper to evaluate the rescue efficiency of ambulance, which is defined as the probability that the number of casualties can be successfully transported to the CCP in a given rescue time by ambulance. To evaluate the network reliability, the data transformation procedure is firstly developed to convert the road data into the travel time probability table, which addresses the stochastic travel time of each road. Second, the stochastic rescue network is established to represent the whole rescue operation, and the algorithm for network reliability calculation in terms of all upper bound vectors is proposed. Finally, an example of a real earthquake disaster in Tainan, Taiwan is adopted to demonstrate the practicality of the proposed algorithm. Finally, the experimental results with different numbers of ambulances and rescue time can provide the commander with several decision recommendations for immediate emergency responses.

Keywords: stochastic rescue network (SRN), rescue efficiency, network reliability, upper bound vectors, stochastic travel time

Network reliability evaluation of supply chain under sustainable performance and limited production capacity constraints

Kuan-Yu Lin
Department of Industrial Engineering and Management
National Yang Ming Chiao Tung University
Hsinchu 300, Taiwan
eq3308889@gmail.com

Yi-Kuei Lin*
Department of Industrial Engineering and Management
National Yang Ming Chiao Tung University
Hsinchu 300, Taiwan
yklin@nycu.edu.tw

Abstract

In the face of global challenges and competition, manufacturers must not only meet customer needs but also consider issues related to sustainability. A limited number of studies in the literature have addressed the sustainability performance of suppliers and the network reliability issues simultaneously. This article proposes a model to evaluate the network reliability for a supply chain network, in which a node denotes a supplier, an assembler, a warehouse, or a market, while a route connecting a pair of nodes denotes a carrier. Initially, sustainable supplier evaluation is used by multi-criteria decision making (MCDM) approaches to determine the supplier's sustainable performance. Subsequently, the available transportation capacity of each carrier is not deterministic since the transportation capacity may be partially reserved by other markets and regarded as a random variable. Thus, the supply chain network can be regarded as a stochastic supply chain network (SSCN). In an SSCN with multiple suppliers, assemblers, warehouses, and a market, suppliers. Network reliability is calculated by minimal paths in this article to evaluate the performance of SSCN, which is defined as the probability that the SSCN can successfully deliver goods to a market under the constraints of a budget, supplier limited production capacity and sustainable performance. Finally, an algorithm is proposed to evaluate the network reliability, and a real case study of an audio supply chain network is utilized to demonstrate the utility of the proposed algorithm.

Keywords: Sustainability, Stochastic supply chain network (SSCN), Network reliability, multi-criteria decision making (MCDM)

Solar cell manufacturing network reliability maximization using Absorbing Markov Chain and Genetic Algorithm

Yu-Lun Chao
Department of Industrial Engineering and Management
National Yang Ming Chiao Tung University
Hsinchu, Taiwan
ronron.iem09g@nctu.edu.tw

Cheng-Ta Yeh*
Department of Information Management
Fu Jen Catholic University
New Taipei City, Taiwan
145712@mail.fju.edu.tw

Yi-Kuei Lin
Department of Industrial Engineering and Management
National Yang Ming Chiao Tung University
Hsinchu, Taiwan
yklin@nycu.edu.tw

Abstract

This paper attempts to maximize the network reliability for a flow shop manufacturing system with the reworking characteristic. Given the production lines and workstations, the network reliability is maximized by searching for the machine configuration that is to determine the machine suppliers and the number of machines for each workstation under a cost constraint. In particular, each workstation is configured with several binary-state machines, each workstation's production capacity follows a binomial distribution and thus the manufacturing system is regarded a stochastic-flow network, and network reliability is thus defined as a probability that the system can successfully d units of demand. Because the product flow traveling through a production line can be regarded as a type of state transition, the Absorbing Markov Chain is integrated with a minimal path concept to evaluate network reliability. Also, machine configuration is a strategy to optimize the system performance, a Genetic Algorithm based approach is developed to determine the best configuration with maximal network reliability subject to a cost constraint. A real case of solar cell manufacturing with 2 production lines and 8 workstations is adopted to demonstrate that the proposed approach can solve the address problem and support decision making in the stage of system planning. The experimental results show that the proposed approach can determine the best machine configuration within a reasonable time.

Keywords: Flow shop manufacturing system, Network reliability, Absorbing Markov Chain, Genetic Algorithm, Solar cell manufacturing

System Reliability Assessment for a Time-dependent Stochastic Production Network

Ping-Chen Chang
Dept. of Industrial Engineering and Management
National Quemoy University
Kinmen County, Taiwan
pcchang@nqu.edu.tw

Cheng-Fu Huang*
Dept. of Business Administration
Feng Chia University
Taichung City, Taiwan
cfuhuang@fcu.edu.tw

Abstract

The reliability analysis for production systems is an essential aspect for companies to understand the capability of demand satisfaction. In general, a production system can be modeled as a stochastic production network, because each arc which is presented a workstation of identical machines has a stochastic capacity owing to the possibility of a partial or full maintenance and machine malfunctions. However, in practical production environment, each machine has its own scheduled maintenance or life cycle which will cause that the reliability of a workstation varies with operating time. When evaluating the reliability of a machine, it is necessary to consider it as time-dependent. This study focuses on a time-dependent stochastic production network (TSPN) in which a machine's capacity is stochastic with time. Utilizing the Weibull reliability function to characterize the time-dependent reliability of each machine, the workstation reliability is evaluated based on the reliability of each constituent machine. Under a demand and a constrained process time, system reliability for a TSPN is calculated in terms of workstation reliability. The system reliability for machines with different operated times is further developed. A practical case for system reliability for a TSPN is presented and discussed.

Keywords: Time-dependent stochastic production network (TSPN), Weibull reliability function, Operating time, system reliability

A mathematical model for generation of all minimal capacity vectors in a multi-capacity flow network

Ding-Hsiang Huang*
Dept. of Industrial Engineering and Enterprise Information
Tunghai University
Taichung City, Taiwan
dhhuang@thu.edu.tw

Abstract

System reliability is defined as a probability that a demand can be transmitted from a source to a terminal in a multi-capacity flow network (MCFN). Because system reliability evaluation is an NP-hard problem, one of efficient approach is to generate all minimal capacity vectors (MCVs) and to calculate unions of the probability the MCVs. Hence, one of the most important missions to compute system reliability is to obtain all the MCVs. Even thought, based on minimal paths (MPs), existing algorithms have been developed to obtain all the MCVs for the further network reliability evaluation, this paper manages to construct a mathematical model to improve the efficiency to generate all the *d*-MPs. All the solutions satisfying the constructed formulations of the proposed mathematical model are all the MCVs for a certain demand *d*. That is, the proposed model can generate all the MCVs directly, without using multiple steps in the existing algorithms. A numerical example is provided to demonstrate the proposed mathematical model for a demand *d*.

Keywords: Multi-capacity flow network (MCFN), System reliability, mathematical model, minimal path

Integrating feature engineering with deep learning to conduct diagnostic and predictive analytics for remaining useful life

Chih-Hsuan Wang*
Department of Industrial Engineering & Management
National Yang Ming Chiao Tung University
Hsinchu, Taiwan
chihswang@nycu.edu.tw

Ji-Yu Liu
Department of Industrial Engineering & Management
National Yang Ming Chiao Tung University
Hsinchu, Taiwan
a0978979219@gmail.com

Abstract

Typical applications in industry 4.0 include predictive maintenance, smart factory, and productivity enhancement. Among them, the prediction of remaining useful life (RUL) is a critical issue in predictive maintenance and smart manufacturing for aircrafts, ships, automobile, facility equipment, and so on. because it can assist practitioners in precise for many sectors. Although numerous methods have been presented to address this issue, most of them do not consider the impacts of feature engineering. In brief, feature engineering includes feature extraction (generation of new components), feature selection (direct removal of redundant features), and feature transformation (transformed from temporal domain to frequency domain). In this study, feature extraction consists of principal component analysis (PCA) and sliced inverse regression (SIR). Machine learning is used in feature selection to prioritize the degrees of importance of input features. Research findings show that PCA outperforms SIR and feature-selection techniques in the prediction of the RUL. In terms of minimal forecasting errors, convolutional neural network (CNN) performs the best. However, with considering both predictive performances and computational complexity, random forest is more recommended than CNN.

Keywords: Feature engineering, Remaining useful life, Forecasting, Deep learning

An Adaptive Lot-Traceability Sampling Plan Qualified by Weibull-Lifetime Capability with Warranty Return Rate Consideration and Development of Its Smart Information System

To-Cheng Wang*
Department of Aviation Management,
Republic of China Air Force Academy, Taiwan
cafa101001@gmail.com

Ming-Hung Shu
Department of Industrial Engineering and Management,
National Kaohsiung University of Science and Technology, Taiwan
Department of Healthcare Administration and Medical Informatics,
Kaohsiung Medical University, Taiwan
workman@nkust.edu.tw

Chien-Wei Wu
Department of Industrial Engineering and Engineering Management
National Tsing Hua University, Taiwan
cweiwu@ie.nthu.edu.tw

Abstract

Companies generally provide a warranty to demonstrate their products' quality and reliability in today's highly competitive market. Validation and verification of product lifetime whether it satisfies the warranty requirement is important for companies to control the warranty cost and sustain their brand reputation. Acceptance sampling plans (ASPs) are a practical tool to help practitioners validate products' quality and reliability and decide the lot disposition. Recently, the multiple-dependent-state sampling plan (MDSP), an ASP with the lot-traceability technology, has been introduced based on a lifetime capability index to reduce the time and cost of the time-consuming and expensive life testing. However, the efficiency of MDSP decreases as more historical lifetime-capability information is included in the decision rule. From the managerial point of view, this behavior is against the original intention of constructing the lot traceability in MDSP. In this paper, we proposed an adaptive lot-traceability sampling plan (ALTSP) to address the disadvantage of MDSP. The ALTSP manipulates a more flexible lot-tracing mechanism to reverse the trend of declining efficiency in MDSP. More specifically, the ALTSP activates an ability of sustainably increased efficiency by accommodating more historical lifetime-capability information. We derived the ALTSP's operating characteristic function with a Weibull-lifetime capability and failure-censoring. An optimization model is constructed to determine the optimal plan design of ALTSP by considering the risks of Type-I and Type-II sampling errors and their corresponding warranty return rates. Compared with the existing MDSP, the proposed ALTSP can significantly reduce the number of failures required for life testing. On the other hand, the proposed ALTSP has superior discrimination power for the degradation of lots' reliability. In addition, we created a smart information system with an interactive user interface to help practitioners obtain the optimal plan design easily. Finally, an industrial case is illustrated to demonstrate the ALTSP's applicability.

Keywords: adaptive lot-traceability sampling plan, multiple-dependent-state sampling plan, historical lifetime-capability information, warranty return rate, smart information system

Auto-Machine Learning Methods to Forecast the State of Health of Lithium-Ion Battery

Lei Qin
School of Statistics,
University of International Business and Economics,
Beijing, China
qinlei@uibe.edu.cn

Xiaomei Zhang
School of Statistics,
University of International Business and Economics,
Beijing, China
zhangxmuibe@163.com

Yang Chen
School of Statistics,
University of International Business and Economics,
Beijing, China
17862922732@163.com

Jian Li
Product research center,
Jiufeng healthcare Co., Ltd.,
Nanchang, China
lijian.fju@gmail.com

Linglong Ye
School of Public Affairs,
Xiamen University,
Xiamen, China
leyloria@gmail.com

Jianping Zhu
National Institute for Data Science in Health and Medicine,
Xiamen University,
Xiamen, China
xmjpzhu@163.com

Yi-Hsien Tai
Graduate Institute of Business,
Fu Jen Catholic University,
New Taipei City, Taiwan
king3300258@gmail.com

Mingchih Chen*
Graduate Institute of Business,
Fu Jen Catholic University,
New Taipei City, Taiwan
081438@mail.fju.edu.tw

Abstract

Machine learning methods are widely used to predict the state of health (SOH) of lithium-ion batteries, but usually have two limitations: (1) the parameters of the prediction models are difficult to determine; (2) most current models are for a single battery. To address this challenge, this paper employs the auto-machine learning algorithm to perform SOH prediction on experimental data (NASA dataset). In this paper, two machine learning methods, automatic extreme gradient boosting (AutoXgboost), automatic deep neural network (H2oDeepLearning), are used to select their parameters in an automated data-driven manner. The experimental results show that the auto machine learning methods maintain good stability in SOH prediction.

Keywords: Lithium-ion battery, State of health, automatic extreme gradient boosting, automatic deep neural network

A Decision Support System for Dengue Fever Warning and Prediction

Yao-Huei Huang*
Department of Information Management,
Fu Jen Catholic University,
New Taipei City, Taiwan
yaohuei.huang@gmail.com

Ting-Yu Tai
Department of Information Management,
Fu Jen Catholic University,
New Taipei City, Taiwan
tyiyi22@gmail.com

Abstract

So far, the dengue fever is an infectious disease and there is no cure. With global warming, climate change, and the prevalence of international tourism, the dengue fever epidemic in Southeast Asian countries has not slowed down, but it has become more serious. The dengue virus spreads with Aedes mosquitoes, causing the epidemic to become uncontrollable situations which people fear. In the past, the local government in Taiwan, with sufficient budget, would use labor to capture Aedes mosquitoes in specific areas. If the number of Aedes mosquitoes increases rapidly, the work of cleaning and disinfection in the specific areas would carry out to prevent dengue fever virus infection. In view of this, this study is to develop a decision support system including the smart mosquito trapping lamp device with IoT (Internet of Things) modules (i.e., a microprocessor with camera, wifi, and 5G modules) and the function of data analysis. The device can capture mosquitoes, automatically take a photo, and immediately send to the remote database for detecting the number of Aedes and Culex in the area where the device placed. Once the proposed system finds that the increase of the number of Aedes mosquitoes in the area exceeds the threshold value (within a setting time interval), the system may automatically notify the relevant government unit to carry out cleaning and disinfection of the area to combat the mosquito vectors. This study also utilizes a mixed integer linear programming (MILP) model to effectively allocate smart mosquito trap devices in relevant areas. Next, referring to the past literature, the meteorological information is related to the breeding of dengue vector mosquitoes. Therefore, this study analyses the dengue fever confirmed dataset from 2015 to 2019 by Taiwan Centers for Disease Control and the information provided by Taiwan Central Weather Bureau. By using decision-making methods (e.g., decision tree method), this study is to find important factors and rules for epidemic prevention, which aims to explore another way to prevent the spread of dengue virus.

Keywords: Dengue fever, Aedes/Culex mosquito, Smart mosquito trapping lamp, Object detection, IoT, Mixed integer linear programming model

Online Review Analytics for Hotel Service Quality Diagnosis Using MTGS

Yu-Hsiang Hsiao*
Department of Business Administration
National Taipei University
New Taipei City, Taiwan
yhhsiao@mail.ntpu.edu.tw

Ching-Wei Chen
Department of Business Administration
National Taipei University
New Taipei City, Taiwan
chingwei8010@gmail.com

Abstract

Online reviews provide valuable information regarding customer perceptions, opinions and expectation on services. Lot of research has been done to extract knowledge from online reviews for general service development and management decisions. However, the applications for personalized service diagnosis are few. This study integrates online review analysis and the Mahalanobis-Taguchi Gram-Schmidt System (MTGS) to provide personalize service quality diagnosis for individual hotels. For this purpose, the topic modeling technique, Latent Dirichlet Allocation (LDA), is applied to identify and quantify the measurement of service properties from positive and negative customer reviews. The MTGS then employs high-quality hotels to construct a continuous scale of Mahalanobis distance for building a hotel quality assessment and diagnosis model. The model can provide specific and personalized quality evaluation for individual hotels and identify the service properties of significant gap to high-quality hotels which are needed to be improved. This contributes to the follow-up strategy making for achieving high quality service. The hotels and online reviews from Booking.com are employed to demonstrate the effectiveness of the proposed method.

Keywords: topic modelling, text mining, online review, Mahalanobis-Taguchi system, Hotel service, quality diagnosis

Age Replacement Models with Deviation Times Between Failure and Replacement Policies

Mingchih Chen*
Fu Jen Catholic University
New Taipei City, Taiwan
081438@mail.fju.edu.tw

Xufeng Zhao
Nanjing University of
Aeronautics and Astronautics
Nanjing, China
zx.peak@outlook.com

Hongshuang Feng
Nanjing University of
Aeronautics and Astronautics
Nanjing, China
fengshuang0518@163.com

Toshio Nakagawa
Aichi Institute of Technology
Toyota, Japan
toshi-nakagawa@aitech.ac.jp

Abstract

We usually use the renewal reward theorem to formulate the expected cost rates for age replacement policies. However, it has been shown in literatures that this kind of modeling cannot solve the models when the failure time has an exponential distribution. Not only that, since the assumptions are ideal states, it limits the extension and application of the replacement policies to a certain extent. It is necessary to consider any way to develop appropriate maintenance countermeasures for more random and complex systems with exponential failure times for further research. From the above viewpoints, this paper introduce the deviation time between planned replacement and random failures as the measure for age replacement model, leaving many assumptions behind and make the replacement plans in reasonable ways. It is shown that when the failure time is exponential, a finite time exists by introducing the deviation time. In addition, the random age replacement is proposed and similar discussions are made. Furthermore, the replacement first policies are also discussed. For each model, the expected deviation time for one cycle are given and the optimal replacement policies which minimize them are derived analytically.

Keywords: Age replacement, deviation time, replacement first, random failure

Joint Design of Quality Investment and Tolerance by Considering Inspection for Product Protection

Chung-Ho Chen*
Department of Industrial Management and Information
Southern Taiwan University of Science and Technology
Tainan, Taiwan
chench@stust.edu.tw

Abstract

In this work, the author proposes the integrated design of process parameters and tolerance. For the process parameters setting, one considers the Taguchi's quadratic quality loss for product and process adjustment cost is proportional to the square of process mean and reciprocal to the process variance. In the tolerance setting model, the quality investment and 100% inspection for product are addressed with the specified value of process capability index for quality protection.

Keywords: Process Parameters, Tolerance, Quality Investment, Process Capability Index, Taguchi's Quadratic Quality Loss Function

A Modified Sampling Scheme for Lot Sentencing Based on the Third-Generation Capability Index

Armin Darmawan*
Department of Industrial Engineering and Engineering Management
National Tsing Hua University
Hsinchu City, Taiwan
Department of Industrial Engineering
Hasanuddin University
Makassar, Indonesia
darmawanarmin@gmail.com

Chien-Wei Wu
Department of Industrial Engineering and Engineering Management
National Tsing Hua University
Hsinchu City, Taiwan
cweiwu@ie.nthu.edu.tw

Abstract

In assuring the quality of goods and services, statistical quality control (SQC) is a powerful tool in maintaining quality in material receiving processes, production processes, product finishing, and delivery. The acceptance sampling plan is a procedure that is integrated into SQC and widely used in many industries, which functions to ensure whether a lot meets the specifications or not. Various acceptance sampling plans have improved efficiency and flexibility in various contexts. Besides, it also protects producers and consumers to maintain their quality standards and requirements. The multiple sampling plan (MSP) is a generalized version of the single sampling plan (SSP) and double sampling plan (DSP). The real benefit of MSP is that the sample size required at each stage is usually smaller than in SSP or DSP; consequently, there are some cost savings associated with its use. The MSP has been proved to be an efficient method in sentencing a lot for meeting quality and risk requirements specified by the producer and the consumer. However, the operating characteristic (OC) function of MSP for variables is complicated and challenging to derive since the judgment at the current sampling is dependent on the sample results of the previous sampling. Further, it is envisaged that the reflection of modern quality theory and current challenges connected to high-quality customer requirements would develop effective and efficient process performance. The advanced process capability index C_{pmk} offers improved high-quality assurance on process performance related to the combination of process yield and quality loss. This research emphasizes the development of an MSP with an independent stage mechanism for lot sentencing based on the C_{pmk} index. A mathematical model is constructed to determine the developed plan's parameters, which considers ASN as the objective function to be minimized, and two constraints are set by the required quality levels and tolerated risks. Besides, two commonly used performance measures of sampling plans, average sample number (ASN) and OC curve are investigated to evaluate and compare the performance. The result reveals that the proposed plan is more efficient with a smaller sample size compared to C_{pmk}–based traditional sampling plans under the same conditions, which indicates that the proposed plan requires less sampling but would offer the same desired protection to both the producer and the consumer. Lastly, an application example is also presented to demonstrate and validate the practicability of the proposed plan.

Keywords: acceptance sampling, average sample number, process capability indices, process yield, quality loss, operating characteristic function

Exploration of the Best-Operating Conditions to Balance Efficiency and Quality of the Wafer Probing Process

Chris-Woonyoung Yeo*
Department of Industrial Engineering and Management, National Yang Ming Chiao Tung University
1001 University Road, Hsinchu, Taiwan 300, ROC
chris.yeo.c@nycu.edu.tw

Yung-Chia Chang
Department of Industrial Engineering and Management, National Yang Ming Chiao Tung University
1001 University Road, Hsinchu, Taiwan 300, ROC
jasmine.chang@g2.nctu.edu.tw

Abstract

The yield and equipment downtime are critical issues related to the productivity in the wafer probing process. When the yield of a wafer probing process is low, it may result from the product itself or the wafer probing equipment. A certain level of check ups on the equipment is usually required to confirm the causes of low yield situation but also would increase the equipment downtime and hurt the productivity. This study conducted experiments on a wafer-probing production line in order to explore the best operating conditions that could short the equipment downtime while not hurting the resulted testing yield. It is found that using the settings found in this study on the size of cleaning sheet, the depth of probing overdrive, the number of touchdown times could improve the overall equipment effectiveness (OEE) while maintaining a certain level of the wafer probing yield.

Implementing Lean and Simulation Optimization to Improve Production Efficiency in a Taiwan SME: a Case Study

Yu-Min Chiang*
Department of Automation Engineering
National Formosa University
Yunlin, Taiwan
ymchiang@nfu.edu.tw

Pei-Ci Li
Department of Industrial Engineering and Management
National Quemoy University
Kinmen, Taiwan
s110811535@student.nqu.edu.tw

Ting-Pu Su
Department of Industrial Engineering and Management
National Quemoy University
Kinmen, Taiwan
s110811525@student.nqu.edu.tw

Abstract

In recent years, competition in the Taiwan metal processing industry has significantly increased. Challenges and global competition have forced metal processing companies to search for manufacturing strategies to increase their level of efficiency, such as lower cost and higher productivity. A popular approach to increase efficiency is known as the lean production.

This research adopts lean production principles and simulation optimization techniques to improve the production efficiency of a stainless steel pipe fittings manufacturer in southern Taiwan. The case company have two types of products - regular and customized products. The study focused on reducing production lead time, reducing changeover time and reducing waiting waste. Through training courses and interviews, supervisors and site operation personnel understood the necessity for lean flow and reducing wastes. Value stream mapping (VSM) was the main tool used to identify the problems and opportunities for improvement. This study utilized the simulation optimization technique to decide production equipment and manpower allocation. Small-batch production and Single Minute Exchange of Die (SMED) were also implemented. Through a series of improvement activities, the lead time has been reduced by 61.7% and the production efficiency increased by 41%. The results illustrate the benefits of lean approach.

Keywords: lean production, simulation optimization, value stream mapping (VSM), metal processing industry

Risk-Averse Multi-Stage Stochastic Resource Provisioning in Cloud Computing

Tzu-Li Chen*
Department of Industrial Engineering and Management
National Taipei University of Technology
Taipei, Taiwan
chentzuli@gmail.com

Abstract

With the rapid development of the cloud computing, cloud service providers, such as Amazon Elastic Compute Cloud (EC2), Google App Engine and Microsoft Azure, build geo-distributed data centers around the world to lease various computational resources to satisfy the demand of the cloud consumers. The cloud service providers usually offer two deployment options for computing resources, namely reservation plan and on-demand plan. With the reservation plan, cloud consumers can reserve computing resources for a fixed time period in advance at a discounted and smaller price but require a full commitment and payment for the entire contract duration. Conversely, the on-demand plan is charged by pay-per-use basis to dynamically provide computing resources at the moment to meet the fluctuated and unpredictable demands. In addition, with the dynamic and uncertain nature in demand and price, the cloud consumers face a challenging decision, so-called stochastic resource provisioning problem, to dynamically adjust a mix of reserved and on-demand cloud resources to hedge against the spikes in demand for minimizing total cost. This paper provides a risk-averse multi-stage stochastic programming model (RSMSSP) with expected conditional risk measures (ECRMs) to enable a cloud consumer to manage and optimize the stochastic cloud resource provisioning problem in a risk-averse manner. Furthermore, we also consider a minimum service level met from reserved capacity, so-called the concept of system reliability, to derive the RSMSSP with chance constraints (RSMSSP_CC). We implement a stochastic dual dynamic programming (SDDP)-based decomposition algorithm to attack the RSMSSP_CC model efficiently. We conduct empirical studies using the public data available on actual Amazon EC2 to demonstrate the value of the proposed models and quantifying the value of the risk-averse stochastic solutions.

Keywords: Multi-stage stochastic programming, Risk aversion, Cloud computing, Expected conditional risk measure, Stochastic dual dynamic programming

Reliability assessment of an air transport network with the elasticity of demand by flight class

Thi-Phuong Nguyen*
Department of Distribution Management
National Chin-Yi University of Technology
Taichung 411, Taiwan
phuongnt@ncut.edu.tw

Abstract

Reliability has been widely used as a crucial performance index of several networks in real life. This paper evaluates the reliability of a stochastic air transport network with the elasticity of demand by flight class. The SATNC's reliability is defined as the probability of satisfying the set of travel demands of different flight classes. This study employs the method of the recursive sum of disjoint products and the lower boundary points to efficiently compute reliability. Besides, a numerical example is adopted to indicate how the proposed assessment algorithm works. Some management suggestions to improve the reliability are also provided to prove the implications of this research.

Keywords: stochastic air transport network, flight class, dependent demands, reliability, transit times

Developing an alterable sampling plan for lot determination by considering multiple quality characteristics

To-Cheng Wang
Department of Aviation Management
The Republic of China Air Force Academy
Kaohsiung, Taiwan
cafa101001@gmail.com

Shih-Wen Liu*
College of Management
National Chin-Yi University of Technology
Taichung, Taiwan
swenliu@ncut.edu.tw

Abstract

The evaluation of an overall product yield by measuring multiple quality characteristics has become more widespread in the current era due to the tendency for sophisticated design of products' functionality and usability. An acceptance sampling plan is recommended to verify the overall process yield of these products because it can provide a definite sample size for inspection and a clear-cut standard for acceptance and rejection. In a recent study, a repetitive group sampling plan (RGSP) has been proposed based on the overall process yield index to construct a rechecking mechanism for lot disposition. More specifically, the RGSP allows practitioners to resample a group of samples for inspection when the lot with a marginal yield level. However, the marginal process yield intervals of RGSP are fixed no matter resampling how many times. Thus, the lot with a marginal process yield level may be resampling infinite time theoretically which leads to high inspection costs. To overcome this drawback, we proposed an alterable RGSP (ARGSP) to design a dynamic mechanism for the adjustment of marginal process yield intervals. The ARGSP tightens the marginal process yield intervals after every resampling process. This dynamic tightening mechanism can accelerate the decision process for lot disposition. We derived the operating characteristic function of ARGSP based on the overall process yield index and constructed a nonlinear optimization model to determine the optimal plan design. By comparing with the RGSP, the proposed ARGSP can reduce the average sample size, which implies it is more cost-efficient. Finally, we illustrated an industrial case to show the applicability of the proposed ARGSP.

Keywords: Overall process yield index, multiple quality characteristics, repetitive group sampling plan, marginal process yield intervals, dynamic tightening mechanism

A new variables independence-based sampling scheme for lot verification

Shih-Wen Liu*
College of Management
National Chin-Yi University of Technology
Taichung, Taiwan
swenliu@ncut.edu.tw

Chien-Wei Wu
Department of Industrial Engineering and Engineering Management
National Tsing Hua University
Hsinchu, Taiwan
cweiwu@ie.nthu.edu.tw

Abstract

To make a reliable decision on lot acceptance, a practical statistical quality control tool, called acceptance sampling is frequently used in various industries. The most well-known conventional acceptance sampling plan (ASP) is the single sampling plan (SSP) due to its advantages of intuition and simplicity. The SSP provides a one-time sampling inspection for the submitted lot and makes the judgment under decision parameters. In some cases, such as the supplier's limitation of redelivery and the disrupted partnership caused by a one-time inspection, the SSP might become unsuitable and undesirable to users. Thus, the development of double sampling plan (DSP) ameliorates the weakness of SSP by providing an additional chance of the questionable submission and it has been proven to be superior to SSP in sample size reduction and discrimination. Although the DSP performs better than SSP, it is difficult to extend the conventional DSP into variables inspection since the inspection results are dependent and the calculation of conditional probability is mathematically complicated. In this article, we proposed a new independence-based two-phase sampling strategy to overcome the drawback of complexity of conventional DSP by variables inspection. The operating characteristic (OC) function and average sample number (ASN) are derived by using the Markovian approach and further be used to construct a minimization model for solving the unknown decision parameters. The performance comparisons with the conventional SSP are detailedly investigated under the same quality requirements and we can conclude that the proposed new method (*i*) has a more idealized shape of OC curve (i.e. a better discriminatory power) under the equal sample consumption, (*ii*) requires a smaller ASN for the long-term inspection (*iii*) provides a flexible operating procedure, which may avoid the disruption of good business partnership. Finally, an example taken from the real-world application is illustrated to show the practicability of the proposed method.

Keywords: variables inspection, double sampling plan, discriminatory power, Markovian approach, operating characteristic function

Replacement policy for a two-unit system under shock damage interaction

Shey-Huei Sheu*
Department of Business Administration
Asia University
Taichung, Taiwan
Department of Medical Research
China Medical University Hospital, China Medical University
Taichung, Taiwan

Department of Industrial Management
National Taiwan University of Science and Technology
Taipei, Taiwan
shsheu@mail.ntust.edu.tw

Tzu-Hsin Liu
Department of Finance
Chaoyang University of Technology
Taichung 413310, Taiwan
t2011119@cyut.edu.tw

Wei-Teng Sheu
Department of Business Administration
National Taiwan University of Science and Technology
Taipei, Taiwan
bensheu@outlook.com

Yu-Hung Chien
Department of Applied Statistics
National Taichung University of Science and Technology
Taichung 404, Taiwan
yhchien@nutc.edu.tw

Zhe-George Zhang
Department of Decision Sciences
Western Washington University
Bellingham, USA
Beedie School of Business
Simon Fraser University
Burnaby, BC, Canada
zhangg@wwu.edu

Abstract

We study a bivariate replacement policy for a two-unit system under shock damage interaction. Unit 1 is subject to shocks which occurs according to a non-homogeneous Poisson process. When a shock arrives, unit 1 has two types of failures. Type 1 failure (minor failure) is fixed by a minimal repair, while type II failure (catastrophic failure) requires a replacement. The occurrence probabilities of type I failure and type II failure depend on the number of shocks since the last replacement. Each minor failure of unit 1 will cause a random damage to unit 2, and these damages are accumulative. In addition, unit 2 whose accumulative damage is y will have a minor failure with probability $\omega(y)$ at unit 1 failure instant. Such a failure is corrected by minimal repair. The system is replaced at age T, or at the nth type I failure, or at damage level K, or at type II failure, whichever comes first. The average cost rate is derived and the structure of the optimal replacement policy is characterized.

Keywords: Minimal repair, Shock damage interaction, Replacement policy, Optimization

Cost Efficiency of Resilience Capability for Weibull life-time Products under Random Shocks

Min-Hsuan Chiang
Department of Industrial Engineering
National Taiwan University of Science and Technology
Taipei City 10607, Taiwan
M10901207@mail.ntust.edu.tw

Ting-Yu Hong
Department of Industrial Engineering
National Taiwan University of Science and Technology
Taipei City 10607, Taiwan
M11001018@mail.ntust.edu.tw

Ruey-Huei Yeh*
Department of Industrial Engineering
National Taiwan University of Science and Technology
Taipei City 10607, Taiwan
rhyeh@mail.ntust.edu.tw

Abstract

Most products deteriorate and will eventually fail as time goes by. The reasons of failure mostly come from both the internal degradation and the external random shocks. In general, when a repairable product fails, usually minimal repair is performed to restore the products back to an operating state. To avoid frequent repairs, replacement is needed to prevent the unstable performance and the cost burden caused by the increasing number of failures. With the ever-changing technology, many new products on the market may be designed in the capability of resilience, which may mitigate the impact of shocks on the product in order to reduce the impact of the external random shocks and the number of failures. However, an extra cost is required to possess this resilience capability. Hence, there is a need to evaluate the cost efficiency of the resilience capability. In this paper, cost models are established for a Weibull life-time product with and without resilience capability under random shocks. Based on the cost models, the optimal replacement policies are derived. Finally, the cost efficiency of resilience capability is demonstrated through numerical examples.

Keywords: Resilience, Minimal repair, Weibull, Replacement policy

Strategical approach for assessing the reliability information during product development: Perspective of the partially accelerated degradation test

Siil Sung*
Department of Industrial and Systems Engineering
Kyonggi University
Suwon, South Korea
sisung@kgu.ac.kr

Abstract

In this paper, the strategical approach for assessing the reliability information during product development is provided based on the perspective of the partially accelerated degradation test (PADT) scheme. The strategical characteristic of partially accelerated test (PAT) is presented, which does not exist in the classical accelerated test (AT). In addition, the advantage and suitability of adopting PADT rather than adopting partially accelerated life test (PALT) is investigated for effectively assessing the reliability information during product development. For developing mathematical model of the PADTs, Wiener process is utilized and the constant- and step-stress loading scheme is adopted.

Keywords: Reliability Test, Accelerated Test, Partially Accelerated Test, Strategical approach

Optimal Exact Design for Gamma Accelerated Degradation Tests with Two Accelerating Variables

Hung-Ping Tung*
Department of Industrial Engineering and Management
National Yang Ming Chiao Tung University
Hsinchu, Taiwan
hptung@nycu.edu.tw

Abstract

Gamma accelerated degradation tests are widely used to assess timely lifetime information of highly reliable products with degradation paths that follow a gamma process. In the existing literature, several papers attempted to address the problem of deciding how to conduct an efficient, accelerated degradation test that includes determinations of higher stress-testing levels and their corresponding sample-size allocations. The results mainly focused on the approximated design or assumed that numbers of measurements are equal under different stress levels. However, this may not be practically applicable. To overcome this difficulty, this study proposes a semi-analytical approach to address this decision-making problem when the underlying model follows a gamma process with two accelerating variables. Specifically, based on the cost constraint, we can obtain the optimal integer design, and determine number of test units and number of measurements simultaneously.

Keywords: accelerated degradation tests, gamma process, optimal allocation rule, V-optimality

The optimal decision analysis of manufacturing equipment based on random working times and Industry 4.0 sensor fault diagnosis

Hsin-Nan Tsai*
Department of Applied Statistics
National Taichung University of Science and Technology
Taichung, Taiwan
hntsai@nutc.edu.tw

Abstract

This article considers the optimal preventive replacement policy for manufacturing equipment based on random working times and Industry 4.0 sensor fault diagnosis. We consider manufacturing equipment that needs to continuously execute multiple projects. This equipment will encounter two different types of failure modes (i.e., Type I failure and Type II failure) when operating. Type I failure should be repaired, and Type II failure should be replaced with new equipment. For each project execution, the sensor will collect data for predictive analysis of fault diagnosis. Therefore, we set up the following four replacement conditions: (i) when the Nth project is completed; (ii) when the cumulative random working time of the equipment has reached the scheduled replacement age T, we will not replace the equipment immediately at this time, but will delay the replacement of the equipment until the current project is completed to comply with actual operation situation; (iii) when the first Type II failure occurs; (iv) when the sensor performs the fault diagnosis predictive analysis and shows that the equipment needs to be replaced. However, the replacement of the equipment will depend entirely on which replacement condition occurs first. Finally, the minimum total expected cost per unit of time is derived, and some numerical examples that fit our proposed replacement model are presented.

Keywords: Replacement delayed policy, Random working time, Minimal repair, Optimization, Preventive replacement

Genetic Algorithm with Search Reduction using Neighborhood in Bi-Objective Network

Natsumi Takahashi*
Electrical and Computer Engineering
National Defense Academy
Yokosuka, Kanagawa, Japan
ntaka@nda.ac.jp

Tomoaki Akiba
Management Information Science
Chiba Institute of Technology
Narashino, Chiba, Japan
tomo@akiaki.net

Shao Chin Sung
Industrial and Systems Engineering
Aoyama Gakuin University
Sagamihara, Kanagawa, Japan
son@ise.aoyama.ac.jp

Xiao Xiao
Electrical Engineering and Computer Science
Tokyo Metropolitan University
Hino, Tokyo, Japan
xiaoxiao@tmu.ac.jp

Abstract

There are many network systems in the real world, for example, Internet, electricity network and traffic network. In this study, we consider Bi-objective network design problem, in which all-terminal reliability is maximizing and construction/operation/maintenance costs are minimized. We need more efficient algorithm for obtaining the Pareto solutions of above bi-objective network problem. Solving the problem is to find the set of all Pareto solutions. However, evaluating all-terminal reliability is computationally intractable, so that this bi-objective problem is also computationally intractable. In the existing several studies, the algorithm for Pareto solutions of the all-terminal reliability and cost are proposed by genetic algorithm. Hence, we set our goal to develop a solution method for finding a set of quasi-Pareto solutions, i.e., a set of non-dominated "good" solutions in terms of our objectives. So, in this study, we improve previous GA-based algorithm to add neighborhood solutions to population. And we evaluate that the accuracy of algorithms of quasi-Pareto solutions to previous proposed.

Keywords: Multi-objective network, All-terminal reliability, Pareto solutions, Genetic Algorithm, Quasi-optimization

A note on finding boundary values of programs with neural networks

XIUJING GUO*
Graduate School of Advanced Science and Engineering
Hiroshima University
Hiroshima, Japan
guoxiujing6@gmail.com

HIROYUKI OKAMURA
Graduate School of Advanced Science and Engineering
Hiroshima University
Hiroshima, Japan
okamu@hiroshima-u.ac.jp

TADASHI DOHI
Graduate School of Advanced Science and Engineering
Hiroshima University
Hiroshima, Japan
dohi@hiroshima-u.ac.jp

Abstract

This paper presents a novel random testing method MCMC-BRT (Markov chain Monte Carlo-Boundary Random Testing) with neural networks to automatically generate boundary test cases to improve test efficiency. Zhou et al. [1] proposed a software random testing scheme based on the MCMC method. However, sometimes it is difficult to express the distribution of the objective function mathematically, such as the distribution of boundary values in software testing. In this paper, we replace the Bayesian inference part in the MCMC algorithm with a neural network. We use two methods to calculate the probability density of boundary values. One is based on the path information of the program. In this method, the neural network learns the path information between two test inputs and predicts whether the test data is close to the boundary or not. The other is based on the branch cost functions, and the neural network learns the cost of branches in a program and predicts how close the data is to the boundary. We conduct a set of experiments on a simple program and the results show that the MCMC-BRT method could generate test cases close to the boundary for testing.

Keywords: Software testing, Random testing, Boundary values, Markov chain Monte Carlo, Neural network

A Note on Prediction of Source Code Changes with Natural Language Processing

Yuto Kaibe
Graduate School of Advanced Science and Engineering, Hiroshima University 1-4-1 Kagamiyama, Higashihiroshima, Japan
m215713@hiroshima-u.ac.jp

Hiroyuki Okamura*
Graduate School of Advanced Science and Engineering, Hiroshima University 1-4-1 Kagamiyama, Higashihiroshima, Japan
dohi@hiroshima-u.ac.jp

Tadashi Dohi
Graduate School of Advanced Science and Engineering, Hiroshima University 1-4-1 Kagamiyama, Higashihiroshima, Japan
okamu@hiroshima-u.ac.jp

Abstract

This paper discusses a statistical model for predicting the number of changes on source codes. The prediction of source code changes is one of the important measures to evaluate the stability of software development. For example, if the quantitative stability of open-source software (OSS) is known, it is useful for us to decide what OSS should be used in our system design. In the paper, by considering the similarity between the prediction of source code changes and the traditional bug prediction problem, we discuss a regression model to predict the number of total changes on source codes. Furthermore, in the traditional bug prediction, software metrics such as line of codes and complexity are used as independent variables in the regression model. However, since it is essentially difficult to extract the effective software metrics in advance, we also consider the approach directly from source codes themselves based on the natural language processing (NLP). In recent years, NLP is one of the most advanced research area where the deep learning technique is applied. The paper uses an NLP model called BERT to predict the number of changes of source codes.

Keywords: Prediction of source code changes, Poisson regression, BERT

Predicting Software Reliability by a Daubechies Wavelet-based Approach

Jingchi Wu*
Graduate School of Advanced Science and Engineering, Hiroshima University
1-4-1 Kagamiyama, Higashi-Hiroshima 739-8527, Japan
d220580@hiroshima-u.ac.jp

Tadashi Dohi
Graduate School of Advanced Science and Engineering, Hiroshima University
1-4-1 Kagamiyama, Higashi-Hiroshima 739-8527, Japan
dohi,@hiroshima-u.ac.jp

Hiroyuki Okamura
Graduate School of Advanced Science and Engineering, Hiroshima University
1-4-1 Kagamiyama, Higashi-Hiroshima 739-8527, Japan
okamu@hiroshima-u.ac.jp

Abstract

Prediction of software failure times caused by software faults is an important issue in the field of software reliability engineering. In this paper we concern the prediction problem of the time-to-software failure with the time-domain data, where two approaches are taken for the non-homogeneous process-based software reliability models (NHPP-based SRMs); parametric approach by means of the maximum likelihood estimation and non-parametric approach based on the Daubechies wavelet. Especially, we develop a novel method to predict the software failure time sequence via the Daubechies wavelet and overcome the weak point for the non-parametric approach. In a numerical example, we compare the non-parametric approach with the parametric approach, which can be categorized into two methods; normalized mean time between software failures (MTBF) predictor and the normalized median predictor.

Keywords: software reliability, Daubechies wavelet, non-parametric approach, time-domain data, normalized MTBF predictor, normalized median predictor

Towards Predicting Safety Integrity Level in Functional Safety with Neural Networks

Shintaro Kita*
Graduate School of Advanced Science and Engineering, Hiroshima University, 1–4–1 Kagamiyama, Higashiroshima, Japan
m216990@hiroshima-u.ac.jp

Hiroyuki Okamura
Graduate School of Advanced Science and Engineering, Hiroshima University, 1–4–1 Kagamiyama, Higashiroshima, Japan
okamu@hiroshima-u.ac.jp

Tadashi Dohi
Graduate School of Advanced Science and Engineering, Hiroshima University, 1–4–1 Kagamiyama, Higashiroshima, Japan
dohi@hiroshima-u.ac.jp

Abstract

In the development of systems such as vehicles, it is important to reduce risk through the functioning of the system. Therefore, safety analysis is required at the system design stage. Safety analysis involves analysing the system from its functions, e.g. HAZOP, and analysing how each function affects the system safety risk. This process has the problem that the analysis is very costly. In this paper, machine learning techniques are considered and the NLP model BERT is used to predict SIL. SIL refers to the priority of safety analysis, and if this can be accurately predicted, the cost can be significantly reduced. In this study, a classification model was trained to classify the severity levels of the results in HAZOP analysis reports, and an evaluation of adaptability was carried out.

Keywords: Hazop, NLP, BERT

Reliability Optimization for Redundant Load Sharing Systems

Kyungmee O. Kim*
Department of Industrial Engineering
Konkuk University
Seoul, Korea
kyungmee@konkuk.ac.kr

Abstract

Many engineering systems are designed in a load sharing configuration to improve their reliability values. A load sharing k out of n:G system functions if no fewer than k components work to share the entire system workload. A redundancy exists in the system if k is smaller than n. Previous researchers have expressed reliability of a redundant load sharing system using either the accelerated life model or the degradation model to incorporate that the operating load of each surviving component increases with the increased number of failed components. Using the component reliability operating at its lowest load as the baseline, the previous system reliability is useful only if both n and k are fixed in advance, because the baseline changes with the value of n.

However, the number of components used in a system is not a constant but a decision variable in the early design stage. When a total of n components is used and the redundancy level is fixed at m, the corresponding system is reduced to a load sharing n-m out of n system. In this case, the system configuration changes if n changes. Previously, reliability maximization of load sharing systems has been partially studied where (i) m=0 for a general distribution, and (ii) m=1 for an exponential distribution.

This presentation considers the optimal number of components for maximizing reliability of a load sharing n-m out of n system, assuming that the component lifetime follows a general distribution, and the surviving components share the system load equally. The system has the highest design load when a total m+1 of components is used under which each component is rated in the design to carry the entire system load. The system is reduced to a load sharing 1 out of m+1 system. As n increases from m+1, the level of the system overdesign decreases, but the minimum number of surviving components required for the system working increases. If n approaches to infinite, the design load of each component goes to zero, and the corresponding system is reduced to the series system.

In this research, two models are developed to quantify system reliability in terms of n and m, using the baseline component which is independent of n and operates at its design load. The first model assumes that the effect of design and operational loads is equivalent to altering the rate at which time passes, and the second one adopts a time-independent transformation, specifying the way that the design and operational loads affect the failure rate function. For each of the two models, two link functions are introduced for relating the component lifetime with the design load and the operational load, respectively. As a result, system reliability is expressed in terms of (1) the baseline reliability, (2) the number of components used in the system, and (3) two link functions. System reliability with the first case must be computed numerically, and system reliability is obtained in a closed from with the second case.

A numerical example is given to illustrate the result for the liquid rocket propulsion system. The number of engines used in the historical launch vehicles is highly variable, and it is qualitatively known that reliability of a rocket propulsion system can be improved if the rocket has multiple engines that incorporates the engine out design. We illustrate the optimal number of engines depending on the propellant assuming that the power function explains the effect of the design load and the exponential decay function explains the effect of the operational

derating, when the engine lifetime follows a general distribution.

Keywords: design uprating, operational derating, accelerated life model, link function

Optimization of the Post-Warranty Maintenance Strategy Based on the Number of Failures for the Second-Hand Product

Dae-Kyung Kim
Department of Statistics
Chonbuk National University
Jeonju, Korea
dkkim@jbnu.ac.kr

Dongho Park
Industry Academic Cooperation Foundation
Hallym University
Chuncheon, Korea
dhpark@hallym.ac.kr

Jae-Hak Lim*
Department of Accounting
Hanbat National University
Daejon, Korea
jlim@hanbat.ac.kr

Abstract

Automobiles and production facilities in industrial sites are subject to receive repair or replacement services for failures that occur during the contracted length of period after dealer sells the product to customers. This is called a warranty service. Warranty service of the products play an important role both in developing marketing strategy for dealers and in making a purchase decision for customers. Lim(2017) proposes a warranty cube which shows various factors considered when dealers design warranty service. Some important factors of warranty service are warranty period, repair and replacement policy, inspection policy and so on. Since dealers pursue both their profit and customer satisfaction, they develop a compromised warranty strategy that guarantees their profit as well as satisfies customers during warranty period.

After the warranty period is expired, customers are fully responsible for inspection, maintenance and repair of failure of product while dealers are free from the responsibility for all about product. In the view of customer's point, customers may want to use the product as long as possible since the cost for replacement is generally much higher than the repair cost. However, sometimes serious failure results in high opportunity cost due to production delay or inability to perform task. Hence it is important for customers to develop optimal maintenance strategy including replacement time during post-warranty period.

In recent years, the lifetime of products has significantly increased due to highly developed science and technology. Accordingly, the market of the second-hand products(SHP) has increased rapidly. For example, the trade volume for the used cars in China rose to 9.42 million in 2015, which accounted for 43.79% of that for new cars (Statista(2016) and Wang, Liu, Liu and Li(2017)). Moreover, in automobile market of U.S., the sales of used cars exceed the sales of new cars (Lim, Kim and Park(2019)). Customers of the SHP tend to concern more about the reliability of the SHP, especially when lacking information on the usage intensity and maintenance history of the first user (Lo and Yu(2013)). Therefore, the optimal warranty strategy incorporating maintenance action of the SHP has attracted a great attention from scholars.

Warranty strategy of the SHP has been studied by many researchers since Chatopadhyay and Murthy(2000) conducted a warranty cost analysis. Shafiee and Chukova(2013) classify researches on warranty and maintenance into three categories which are warranty servicing with only corrective maintenance(CM) actions, warranty servicing with both CM and preventive maintenance(PM) actions and maintenance during the post-warranty period. Based on the framework proposed by Shafiee and Chukova(2013), Lim(2017) summarizes researches on warranty service and maintenance policy of the SHP among which decision criteria for finding an optimal warranty strategy are dealer's expected warranty servicing cost or dealer's expected profit in two categories. Researches in the third category focus on studying maintenance policy during the post-warranty period whose general scheme is as follows.

- A SHP of age x (> 0) sold with warranty.

- During warranty period, dealer conducts PM and performs CM at intervening failures between PMs.
- During warranty period, CM cost is free of charge to user while PM cost is either free of charge to user or pro-rated.
- After the warranty period is expired, the user of the SHP is solely responsible for maintaining the product, including paying all the maintenance costs.
- During the self-maintenance period, the SHP undergoes either CM only or both PM and CM. CM is typically assumed to be minimal repair.

Recently, Lim, Kim and Park(2021) consider a problem of maintenance policy of the SHP during post-warranty period which is similar to the scheme mentioned except that the SHP undergoes CM only at failure during the fixed self-maintenance period. They obtain the long-run expected cost rate by formulating the expected length of life cycle and evaluating the expected total cost incurred during the life cycle of the SHP and determine the optimal length of self-maintenance period minimizing the long-run mean cost rate. They also investigate the effect of relevant parameters including the age of the SHP and remaining warranty period when purchased, cost for minimal repair and deteriorating pattern of the SHP on the optimal length of self-maintenance period and the long-run mean cost rate.

In this study, we consider a post-warranty maintenance strategy whose scheme is basically same as Lim, Kim and Park(2021) except that the SHP is replaced by another one at the time of the N-th failure during self-maintenance period while the SHP is replaced at the first failure after self-maintenance period in Lim, Kim and Park(2021). As Park(1979) mentions, models with a maintenance period as time are natural and mathematically convenient because the probabilistic pattern of failure is generally expressed as a function of time. However, it becomes difficult to apply this model to products whose lifespan is difficult to measure with time. For example, in products such as printers or rotors, the number of uses is lifetime. In addition, if cumulative operating time of a product is unavailable or it is very difficult to persuade management to replace a product just because it is time to replace it, more convincing replacement policy should be used which is not based on the decision variable 'time'.

In order to evaluate the long-run mean cost rate incurred during the life cycle of the SHP from the user's perspective, we derive the mean cycle length, $\mathrm{E[Z(N)]}$, and the expected total cost under a certain cost structure, $\mathrm{E[C(N)]}$, as follows.

$$\mathrm{E[Z(N)]} = \mathrm{E}[Y_N - x],$$

where x represents age of the SHP when purchased and Y_N is a random variable representing time at which the N-th failure occurs after warranty period is expired.

$$\mathrm{E[C(N)]} = C_{IW} + \mathrm{E}\left[C_{fw}\right] + \mathrm{E}[C_m] + \mathrm{E}\left[C_{fm}\right] + c_r,$$

where C_{IW} is the imperfect PM cost prorated to the user during the warranty period, $\mathrm{E}\left[C_{fw}\right]$ represents the expected failure cost incurred during the warranty period, $\mathrm{E}[C_m]$ and $\mathrm{E}\left[C_{fm}\right]$ are the expected minimal repair cost and the expected failure cost during the self-maintenance period, respectively, and c_r represents the replacement cost at the end of the life cycle.

And the long-run mean cost during the life cycle, denoted by $\eta(\mathrm{N})$, is defined by

$$\eta(\mathrm{N}) = \mathrm{E[C(N)]}/\mathrm{E[Z(N)]}.$$

Then the optimal number of failures can be obtained by finding N^* which satisfies the following inequalities:

$$\eta(N^* - 1) \geq \eta(N^*) \text{ and } \eta(N^* + 1) \geq \eta(N^*).$$

However, the exact solution for the optimal number of failures, N^*, may not be obtainable analytically because of the complexity of the mathematical formula for $\eta(\mathrm{N})$. Instead, we numerically determine the optimal number of failures, assuming the power law model for the SHP failures. And we also analyze the impacts of relevant parameters on the optimal number of failures.

Keywords: Second-hand item, maintenance strategy, post-warranty, virtual age, long-run mean cost

Frailty model for missing recurrent failure data of multiple repairable systems

Suk Joo Bae*
Department of Industrial Engineering
Hanyang University
Seoul, Korea
sjbae@hanyang.ac.kr

Byeong Min Mun
Department of Industrial Engineering
Hanyang University
Seoul, Korea
stat@hanyang.ac.kr

Xiaoyan Zhu
School of Economics and Management
University of Chinese Academy of Sciences
Beijing, China
xzhu5@ucas.ac.cn

Abstract

We occasionally encounter the practical circumstances that we conduct the data recording after the systems have begun operations and cease data collection at a predetermined time or a predetermined number of failures. In such circumstances, there exist various types of incompleteness in the aspect of missing number of failures and their occurrence times beyond the duration of pilot study. Additionally, multiple repairable systems may present system-to-system variability caused by the differences in operation environments or working loads of individual systems. With respect to doubly-censored recurrent failure data from multiple repairable systems, we propose a reliability modeling based on the proportional intensity model with frailty and study optimization of an aperiodic age-based preventive maintenance policy for the systems. The frailty model explicitly models unobserved heterogeneity among the systems. Covariates incorporated into the proportional intensity model additionally account for the heterogeneity between different operating conditions. To estimate the model parameters for doubly-censored recurrent failure data, the Monte Carlo expectation maximization algorithm is proposed. Details on estimation of the model parameters and construction of their confidence intervals are examined. We also propose and derive an optimal maintenance policy for the population of heterogeneous repairable systems under the proposed reliability modeling framework. A real case study shows prominent applications of the proportional intensity model with frailty to doubly-censored multiple repairable systems for the purpose of reliability prediction and maintenance optimization.

Keywords: Doubly-censored data, frailty model, minimal repair, Nonhomogeneous Poisson process, power law process

Condition-based Maintenance for Tires in Rubber-tired Metro Vehicles

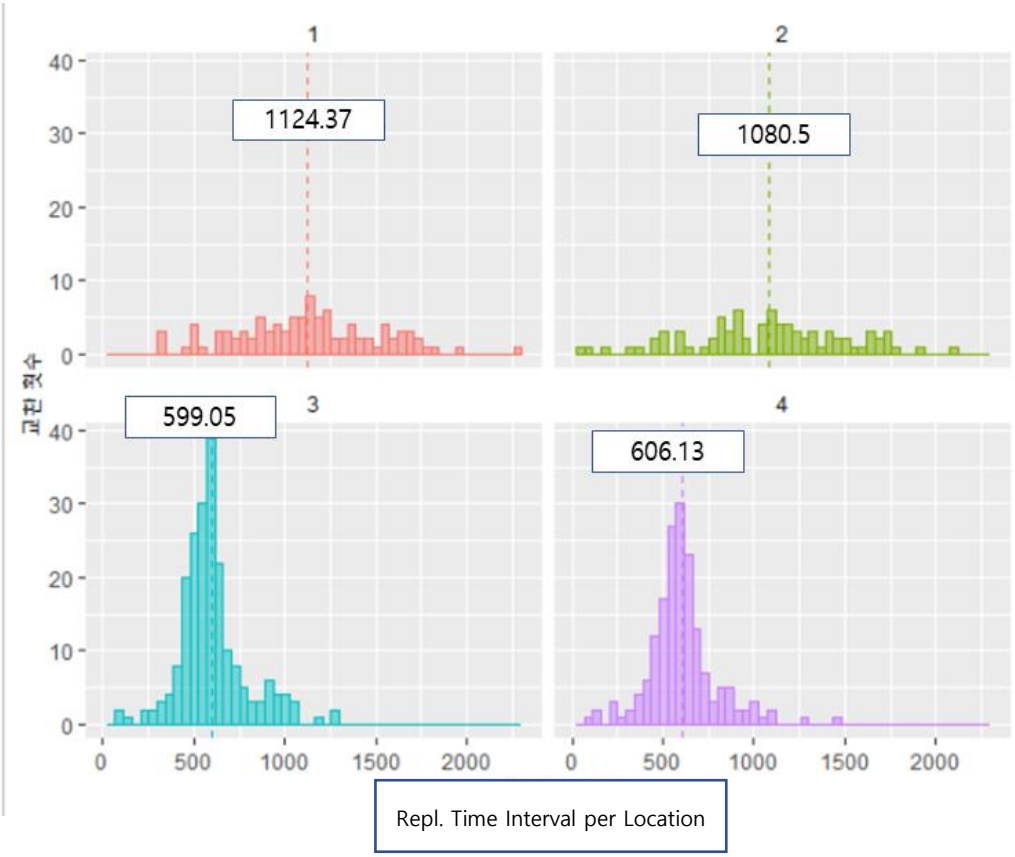
Alfonsus Julanto Endharta*
R&D Center
Nemosys, Co., Ltd
Uiwang, Korea
alfon@nemosys.kr

Jae Yoon Yoo
R&D Center
Nemosys, Co., Ltd
Uiwang, Korea
jyyoo@nemosys.kr

Jongwoon Kim
CEO
Nemosys, Co., Ltd
Uiwang, Korea
jwkim@nemosys.kr

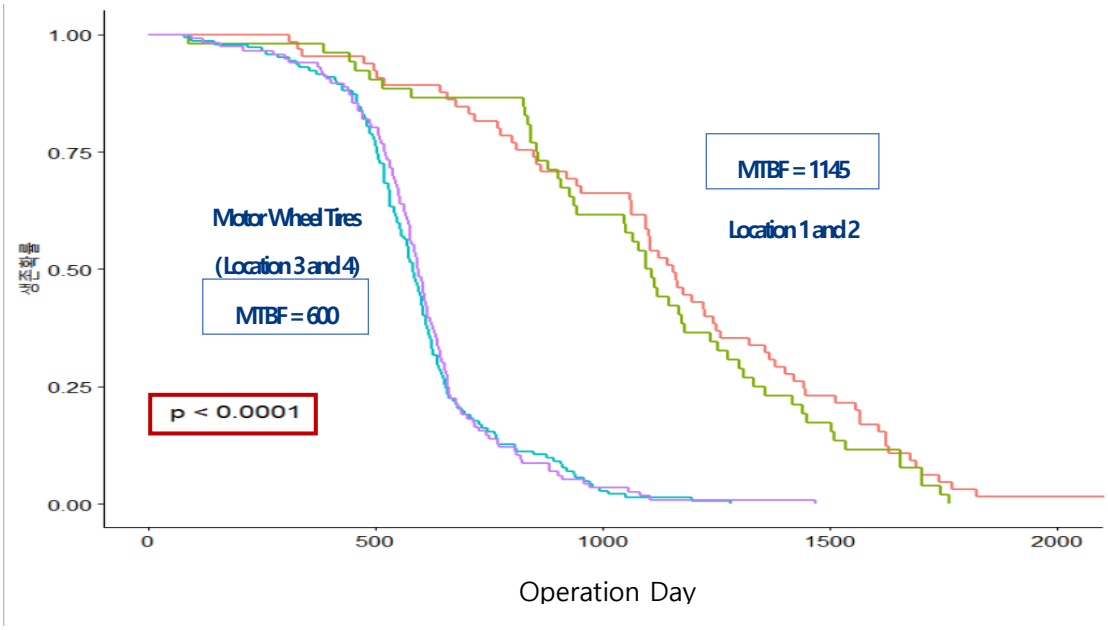
Abstract

This paper studies the maintenance problem for tires in rubber-tired metro vehicles. The condition of the tires, such as the tire tread depth, are inspected periodically. The failure/maintenance records are used together with the tread depth data to illustrate the deterioration of the tires. The failure/maintenance records shows that the replacement times of tires in location 1 and 2 (trailing wheel-type tires) are uniformly distributed with mean of 1124.37 days for tires in location 1 and mean of 1080.5 days for tires in location 2, while the replacement times of tires in location 3 and 4 (motor wheel-type tires) are bell-shaped distributed with mean of 599.05 for tires in location 3 and 606.13 for tires in location 4 as shown in the figure below.



Cox proportional hazard model is used to illustrate the deterioration of the tires by considering the location of tires in the vehicle as the variates. Visually the deterioration of the tires by cox model can be seen in the following figure. It shows the type of the wheel (motor wheel and trailing wheel) affects the deterioration of the tires, in which the motor wheel tires' condition deteriorates faster than the trailing wheel tires do. The MTBF of tires in location 1 and 2 (trailing

wheel-type tires) are 1145 days (3.1 years) and that of tires in location 3 and 4 (motor wheel-type tires) are 600 days (1.6 year).



Keywords: tire maintenance, proportional hazard model, condition-based maintenance

Acknowledgement

This study was conducted by the Ministry of Land, Infrastructure and Transport and the Korea Agency for Infrastructure Technology Advancement under the support of research funds for the railway technology research project (22LTSM-B156032-03).

Simulation-based Optimization of a Two-dimensional Warranty Policy under Korean Lemon Law

Seung Hoon Jung
Department of Industrial Engineering
Pusan National University
Busan, Republic of Korea
jsh2689@naver.com

Young Jin Han
Department of Industrial Management Engineering
Ulsan College
Ulsan, Republic of Korea
yjhan@uc.ac.kr

Won Young Yun*
Department of Industrial Engineering
Pusan National University
Busan, Republic of Korea
wonyun@pusan.ac.kr

Abstract

In order to protect the rights and interests of consumers, automobile manufacturers also implement a warranty policy that provides free support for repairing damaged automobiles for a certain period of time after the sale of the automobile. The warranty period differs for each manufacturer, but in Korea, engines and power transmission systems are generally guaranteed for 5 years or 100,000km, and vehicle systems and general parts are guaranteed for 3 years or 60,000km. If the same type of defect occurs continuously in automobiles due to the low-quality level of the automobile, the loss of consumers cannot be compensated fully. regardless of the existing warranty policy. Therefore, in January 2019, South Korea enacted the "Korean Lemon Law" to protect more strongly the rights and interests of consumers who purchased automobiles. The Lemon Law is a federal law enacted in the United States in 1975 to protect consumers related to automobiles and electronic products. Although the application standards are different for each state in the United States, the applicable items are the same for mileage, period of use, period of repair, and the number of repairs. The Korean Lemon Law is based on the American Lemon Law and is suitable for the Korean automobile market.

Within one year after purchasing a car or within 20,000km, if the same type of critical failure occurs more than 2 times, the same type of the general failure occurs more than 3 times is exceeded or the cumulative repair period for 30 days is exceeded, consumers can get a new car or a refund from the manufacturer. In the three years since the introduction of the Korean Lemon Law (Jan. 2019-Jan. 2022) 1454 applications have been filed, and a total of 781 have been completed. Among them, 3 replacement and refund cases, 661 cases of manufacturer's voluntary damages (conditions for withdrawal of application), and the remaining 176 cases are ongoing. Through the research and tasks of universities and institutions related to the Korean Lemon Law, the systematically insufficient parts are continuously being supplemented. In other words, as time goes by, the rights and interests of consumers are more protected, and it is expected that the number of exchanges or refunds due to automobile failures will increase in the future. With the enforcement of the Korean Lemon Law, automobile manufacturers will feel a greater economic burden in the future. Therefore, it is necessary for manufacturers to accurately analyze the warranty costs incurred during the warranty period under the Korean Lemon Law and establish an effective and efficient warranty strategy based on the results of the analysis.

First, in the Korean Lemon Law, it is a critical issue how to identify the same type of failures and count the number of failure times. In other words, in a multi-level structure of an automobile composed of many modules, if the upper module is the unit to count the number of failures of all components included in the modules, the probability of satisfying the refund condition of the law is high. On the other hand, if the lower-level modules or components in the lowest level are units to count the number of failures, the probability is low. Determining the appropriate warranty unit according to the reliability and cost of modules or components in the automobile is an interesting optimization problem. In addition, the Korean Lemon Law gives a restriction

on the total accumulated repair time required to repair the failures during the warranty period. In a multi-level structure of an automobile, in general, the upper module has a shorter maintenance time than the lower modules, then the probability of satisfying the refund condition is lower than that of the lower module. Hence, determining appropriate maintenance units for automobiles under the Korean Lemon Law is also one way for automakers to reduce costs during the warranty period. In addition, the total warranty cost, which is one of the important criteria for determining the warranty unit and maintenance unit, can be calculated as the sum of the repair cost of failed components and the refund cost according to the customer's request.
In this paper, we deal with the two-dimensional warranty policy for an automobile with a multi-level structure under Korean Lemon Law. The purpose of the study is to determine the automobile warranty unit and maintenance unit that minimizes the total warranty cost within the warranty period under Korea Lemon Law. The total warranty cost is the sum of repair and refund costs and is estimated by simulation. Heuristics is proposed to find the near-optimal strategy and numerical examples are also studied to investigate the effect of the model parameters on the total warranty cost.

Keywords: Korea Lemon Law, Automobile, Warranty policy, Simulation

Interval Prediction of Remaining Useful Life based on Long Short-Term Memory and Kernel Density Estimation

Liudong Gu
School of Mathematics
Southeast University
Nanjing, China
guliudong@foxmail.com

Guanjun Wang
School of Mathematics
Southeast University
Nanjing, China
wgjmath@seu.edu.cn

Yifan Zhou*
School of Mechanical Engineering
Southeast University
Nanjing, China
yifan.zhou@seu.edu.cn

Abstract

The point estimation of remaining useful life (RUL) predicted by deep learning methods cannot provide adequate information for maintenance decision making. This paper develops an interval prediction method for RUL based on Long Short-Term Memory (LSTM) and kernel density estimation (KDE). LSTM is utilized to predict the point estimation of the RUL. The distribution of the prediction errors is fitted by KDE in order to give the uncertainty expression of RUL. The effectiveness of the proposed methods is verified by the turbofan engine dataset. The results show that the prediction intervals constructed by proposed method are better than those constructed by other methods in all metrics.

Keywords: Interval prediction, Remaining useful life, Long Short-Term Memory, Kernel density estimation

A preventive maintenance policy considering imperfect inspection and imperfect repair for a three-stage degradation

Xia Tang*
Department of Management Science and Engineering,
Southwestern University of Finance and Economics,
Chengdu, China
tangxia5983@163.com

Hui Xiao
Department of Management Science and Engineering,
Southwestern University of Finance and Economics,
Chengdu, China
msxh@swufe.edu.cn

Gang Kou
School of Business Administration,
Faculty of Business Administration,
Southwestern University of Finance and Economics,
Chengdu, China
kougang@swufe.edu.cn

Rui Peng
School of Economics and Management,
Beijing University of Technology,
Beijing, China
pengrui1988@bjut.edu.cn

Abstract

Due to the limitation of technology, perfect inspection is difficult to achieve in engineering applications. Meanwhile, perfect repair always means “replacement” which is expensive and may lead to over-maintenance. As a result, imperfect inspection and imperfect repair are more common in real-world application. This paper presents a preventive maintenance policy which considers imperfect inspection and imperfect repair for a system subject to a three-stage degradation process. The concept of delay time is used in the preventive policy and different defects are detected with different probabilities. In addition, different imperfect repair is adopted to remove different defect and the virtual age is adopted to characterize the imperfect repair effect. Then a modification on the virtual age is performed to solve the history-dependent problem caused by the imperfect repair for multi stages. After giving the corresponding probabilities for different renewal scenarios, the steady-availability model and maintenance cost model are presented to characterize the optimization problem. Then, the genetic algorithm (GA) is developed to search for the optimal solution. To investigate the effects of the probabilities of imperfect inspection and the improvement factors of imperfect repair, sensitivity analyses are essential. Last but not least, the effectiveness of the modification about the virtual age is verified by comparison with the simulation.

Keywords: Three-stage degradation, Imperfect inspection, Imperfect repair, Virtual age

Exact Pareto Optimal Network Design based on Rough Reliability Estimation

Rei Sakagami*
Management Technology Course
Aoyama Gakuin University
Kanagawa, Japan
c5621218@aoyama.jp

Natsumi Takahashi
Electrical and Electronic Engineering
National Defense Academy
Kanagawa, Japan
ntaka@nda.ac.jp

Shao-Chin Sung
Industrial and Systems Engineering
Aoyama Gakuin University
Kanagawa, Japan
son@ise.aoyama.jp

Abstract

We are dealing with a network design problem which aims to maximize the all-terminal reliability and to minimize the total building costs. The problem is to be solved by finding the set of all Pareto optimal solutions, i.e., the Pareto frontier, based on those objectives. While calculating (total building) cost is easy, finding (all-terminal) reliability is known to be *#P*-complete, i.e., computationally intractable, and so is the Pareto dominance test if the exact reliabilities are required. Fortunately, we found out that a certain kind of rough estimation is sufficient to do the job.

In this study, we propose a data structure which maintains a set of pairwise non-dominated solutions, and provides an insertion operation of solutions. In our proposed data structure, each solution is stored with its cost and the so-called rough reliability estimation, an interval in which the reliability is included. The insertion operation is done by updating reliability estimations of some solutions and performing a modified Pareto dominance test based on costs and updated reliability estimations. For exact approaches, we show that our proposed data structure can be used not only to sequential implementations but also to parallel implementations. By numerical experiments, we show that exact approaches with our proposed data structure are superior to previous works of heuristic approaches in the sense that, *exact Pareto frontiers* for *larger networks* can be obtained with *shorter running time*.

For networks beyond the limit of exact approaches, we show that our proposed data structure can be used to heuristic approaches as well. Indeed, we propose frameworks for several major heuristic approaches, including genetic algorithms, ant colony optimization, and local search with our proposed data structure. The effectiveness of these frameworks is shown by numerical experiments.

Keywords: Network Design, Bi-Objective Optimization, All-Terminal Reliability, Exact Approaches, Heuristic Approaches

A CNN-BiLSTM network for rolling bearings remaining useful life prediction with self-attention mechanism

Jiang Wang
School of Mechatronic Engineering
Southwest Petroleum University
Chengdu, China
W668877JABC@163.com

Junyu Guo*
School of Mechatronic Engineering
Southwest Petroleum University
Chengdu, China
junyguo@163.com

Abstract

Rolling bearing is one of the key components in machinery and equipment. Accurate prediction of the remaining useful life (RUL) of rolling bearings contributes to the smooth realization of production plans and the safe service of machinery and equipment. In order to extract deep features in complex nonlinear vibration signals and predict the RUL, a novel prediction framework for RUL of rolling bearings based on convolutional neural network (CNN) and bidirectional long short-term memory network (BiLSTM) model with self-attention mechanism is proposed in this paper. The proposed method consists of two parts: a health index construction model by the CNN and the BiLSTM with self-attention mechanism RUL prediction method. The prognostic performance of the proposed method is evaluated on XJTU-SY bearing datasets.

Keywords: Remaining useful life, Convolutional Neural Networks, Bi-directional Long Short-Term Memory Network, Self-Attention Mechanism

The Development of Software and Hardware-in-the-loop Test System for Autopilot Suit

Wenqiang Zheng
Department of Industrial Engineering
Tsinghua University
Beijing, China
zhengwq20@mails.tsinghua.edu.cn

Yan-Fu Li*
Department of Industrial Engineering
Tsinghua University
Beijing, China
liyanfu@tsinghua.edu.cn

Abstract

Automatic driving technology is the most promising frontier technology at present, which is a typical safety-critical technology. The reliability of autonomous vehicles has a direct impact on the life safety of passengers. Therefore, it is necessary to test the reliability of autonomous vehicles, especially in some extreme conditions, such as high/low temperature, high/low humidity, as well as vibration. At present, there are dozens of papers devoted to the reliability testing of autonomous vehicles. Among them, some studies have been dedicated to constructing the testing platform for the reliability testing of the autonomous vehicle. These methods are called software-in-the-loop (SIL) test and hardware-in-the-loop (HIL) test. However, the autonomous vehicle is a complex system that is integrated with software modules and hardware modules. The reliability testing of autonomous vehicles can be better carried out by a software and hardware-in-the-loop (SHIL) test platform. In this study, we first built a SHIL test platform for the autopilot suite, which is composed of the automatic driving system, computer motherboard, camera sensors, environment controller, and scene playback device. The platform can effectively evaluate the performance of the autopilot suite under different conditions. In addition, the test platform is utilized to design orthogonal experiments (DOE) on temperature, humidity, and vibration factors. The results of the experiments can be used as guidelines to improve the performance of automatic driving technology.

Keywords: Software and hardware-in-the-loop test, Automatic driving technology, Reliability testing, Design orthogonal experiments

Availability of two echelon repair system with common-cause failures and limited repair capacity

Naoto Okubo
Department of Electrical and Electronic Engineering
National Defense Academy
Yokosuka, Japan
em60002@nda.ac.jp

Tetsushi Yuge*
Department of Electrical and Electronic Engineering
National Defense Academy
Yokosuka, Japan
yuge@nda.ac.jp

Natsumi Takahashi
Department of Electrical and Electronic Engineering
National Defense Academy
Yokosuka, Japan
ntaka@nda.ac.jp

Abstract

We propose an availability evaluation model of two echelon repair system with limited repair capacity considering the common-cause failures. It is an approximation method based on the METRIC model and an iteration method. The system in a base is a *k*-out-of-*n* system composed with identical components. The occurrence of a common-cause failure is considered to the arrival of demand that follows a complex Poisson process. We perform numerical analysis for the model to compare the system availability and verify the accuracy.

Keywords: METRIC, iteration method, CCF, availability, *k*-out-of-*n*

Optimal Nuclear Power Plant Personnel Training Plan using Maintenance Model

Shigeshi Yamashita
Department of Engineering,
Tottori University
Tottori-shi, Tottori, Japan
shigeshi.yamashita.pr@ds.mhi.com

Kenji Mashio
ICT Solution Headquarters,
Mitsubishi Heavy Industries, Ltd.
Kobe-shi, Hyogo, Japan
kenji.mashio.7c@nu.mhi.com

Truong Dinh Anh Khoa
Department of Engineering,
Tottori University
Tottori-shi, Tottori, Japan
m21j6016u@edu.tottori-u.ac.jp

Sho Kawakami
Department of Engineering,
Tottori University
Tottori-shi, Tottori, Japan
m21j6011m@edu.tottori-u.ac.jp

Kodo Ito*
Department of Engineering,
Tottori University
Tottori-shi, Tottori, Japan
itokodo@tottori-u.ac.jp

Abstract

Periodical training of nuclear power generation facility operators is indispensable because erroneous operation of operators may cause serious accidents. Training is held by the facility manufacturer and operators of electric power companies have to have the business trip during training. Recently, the supplementary education, such as e-learning which supports training is used and operators can be educated at their workplace by using such education. By using supplementary education and regular training together, we will consider the efficient education method which brings benefits to electric power companies. In this paper, training plans which maximize profits generated by operators, are considered.

Keywords: Nuclear plant, operator training, education plan, optimal policy, maintenance model, imperfect maintenance

A Defected Clients Analysis with Contact Data

Takahiro Nakamura*
Department of Social Management Engineering, Graduate school of Engineering
Tottori University, Tottori, Japan
d21t4002x@edu.tottori-u.ac.jp

Junji Koyanagi
Department of Social Management Engineering, Graduate school of Engineering
Tottori University, Tottori, Japan
junji@tottori-u.ac.jp

Kodo Ito
Department of Social Management Engineering, Graduate school of Engineering
Tottori University, Tottori, Japan
itokodo@tottori-u.ac.jp

Abstract

Some organizations are faced with the important task of strengthening their financial base to continue their activities when social uncertainties increase, as in the case of COVID-19. Clients include a variety corporate forms, such as business corporations and other for-profit corporations, as well as foundations and incorporated associations, which are non-profit organizations. As symbolized by the SDGs, efforts to solve social issues have become a common challenge for all corporate forms[1].

The purpose of this study is to explore effective sales support measures to ensure that contact relationships continue between clients of financial institutions and sales representatives of financial institutions. Specifically, clients that sales representatives are in charge of from the beginning of the fiscal year to the end of the fiscal year are considered trading clients. The relationship between the number of telephone calls and visits and the number of trading clients and defected clients is analyzed in this paper.

Investigating properties of the optimal arrangement in multistate sliding window systems

Taishin Nakamura*
Department of Applied Computer Engineering, Tokai University
4-1-1 Kitakaname, Hiratsuka-shi, Kanagawa 259-1292 Japan
nakamura@tsc.u-tokai.ac.jp

Abstract

A multistate sliding window system (SWS) comprises *n* multi-state components arranged in a line, and each component may assume a different state, ranging from perfectly working to complete failure; the states indicate the performance rates of the components. A window is a collection of *r* consecutive multistate components. If the sum of the window's performance rates does not surpass the predetermined demand, the window is judged a failure. The SWS fails if at least one window fails. This study addresses the component assignment problem (CAP) for the SWS by finding an optimal arrangement (OA) of components that maximizes system reliability. A branch-and-bound-based algorithm for obtaining the OA has been reported; however, it would be inapplicable for large systems. This study derives the properties of the OA that would accelerate algorithms for solving the CAP. Moreover, the existing branch-and-bound-based algorithm was incorporated with the derived properties for efficiently finding the OA. The effectiveness of the properties was experimentally investigated. Determining the OA helps in achieving a reliable system; hence, the proposed algorithm would result in a system operating reliably for an extended period.

Keywords: Multistate sliding window system, Component assignment problem, Optimal arrangement

Reliability and Maintenance Analysis of General Redundant Systems

Toshio Nakagawa*
Department of Business Administration
Aichi Institute of Technology
Toyota, Japan
toshi-nakagawa@aitech.ac.jp

Satoshi Mizutani
Department of Business Administration
Aichi Institute of Technology
Toyota, Japan
mztn@aitech.ac.jp

Xufeng Zhao
College of Economics and Management
Nanjing University of Aeronautics and Astronautics
Nanjing, China
zx.peak@outlook.com

Abstract

This paper takes up a random *K*-out-of-*n* system and summarizes its reliability properties of failure distribution, failure rate and complexity. Such results are applied to general redundant systems with identical units. Four redundant systems are given, and their properties are computed and compared. Furthermore, using these results, optimal replacement policies for minimizing expected cost rates and deviation times of redundant systems are derived and are applied to two standard redundant systems.

Keywords: Redundant system, *K*-out-of-*n* system, Complexity, Replacement, Deviation time

Extended Sequential Inspection Times to Minimize Expected Cost Rates

Satoshi Mizutani*
Department of Business Administration
Aichi Institute of Technology
Toyota, Japan
mztn@aitech.ac.jp

Xufeng Zhao
College of Economics and Management
Nanjing University of Aeronautics and Astronautics,
Nanjing, China
zx.peak@outlook.com

Toshio Nakagawa
Department of Business Administration
Aichi Institute of Technology
Toyota, Japan
toshi-nakagawa@aitech.ac.jp

Abstract

We consider some problems for extended sequential inspection policies to compute optimal checking times which minimize the expected cost rates. Especially, we treat the following two models: (a) Random inspection model in which a unit is checked at both periodic and random times, and its failure is detected at either periodic or random check, whichever occurs first. (b) Mission time model with an additional cost when the failure has occurred at a mission time. First, using the iterative method, the algorithm for standard sequential inspection models to obtain optimal checking times are shown. Next, we discuss the extended sequential policies and their optimization algorithms for random inspection and mission time models.

Keywords: Inspection policy, random inspection, mission time, iterative method, cost rate

A Study on New Software Reliability Model Considering Dependent Fault Function

Kwang Yoon Song
Department of Computer Science and Statistics
Chosun University
Gwangju, Korea
csssig84@gmail.com

Youn Su Kim
Department of Computer Science and Statistics
Chosun University
Gwangju, Korea
imk92315@naver.com

Da Hye Lee
Department of Computer Science and Statistics
Chosun University
Gwangju, Korea
is_hye@chosun.ac.kr

In Hong Chang*
Department of Computer Science and Statistics
Chosun University
Gwangju, Korea
ihchang@chosun.ac.kr

Abstract

As software becomes more important in all areas, software reliability has become a very important field. When software breaks down due to large or small problems such as part of coding or system errors, social and economic damage occurs. Because of the inherent characteristics of software, it is not easy to verify it and improve its reliability. Also, software is developed and tested in various environments. Open source software (OSS) development is based on a relatively simple idea, where developers report bugs, propose new features, review code, modify code, and make decisions. Software defects appearing in OSS have an independent relationship between the defects, but they have a dependent relationship and can be accepted as a more sensitive problem and can suffer more damage than in the past software era, which had a simple structure. Accordingly, it is necessary to improve software reliability by predicting software faults. We aim to improve software reliability by proposing a new software reliability model that takes into account the dependency of faults. In addition, by applying software faults data appearing in OSS to the proposed software reliability model, the optimal parameters are found, and criteria are compared to show that the proposed model is better goodness-of-fit compared to the existing software reliability model.

Keywords: Open source software, software reliability, software reliability model, dependent fault

Discrete-time Opportunistic Replacement Last Policies with Restricted Duration

Jing Wu
Graduate School of Advanced Science and Engineering, Hiroshima University
1-4-1 Kagamiyama, Higashihiroshima 7398527, Japan
d210069@hiroshima-u.ac.jp

Cunhua Qian
School of Economics and Management, Nanjing Tech University
Nanjing, 211816, China
2304@njtech.edu.cn

Tadashi Dohi*
Graduate School of Advanced Science and Engineering, Hiroshima University
1-4-1 Kagamiyama, Higashihiroshima 7398527, Japan
dohi@hiroshima-u.ac.jp

Abstract

This paper considers simple age replacement problems in discrete time, where the inter-arrival times of replacement opportunities obeys a geometric distribution. Iskandar and Sandoh (2000) considered a similar problem in continuous time by introducing the opportunities in a restricted duration. We reformulate it in discrete time by taking account of the priority of replacement options, and give two replacement policies; replacement first and replacement last policies in the sense of Zhao and Nakagawa (2012). The optimal opportunity-based replacement policies are characterized by minimizing the long-run average costs.

Keywords: Discrete-time model, Age replacement, Opportunity, Replacement first/last, Long-run average cost

Bayesian Analysis for Lifetime Delayed Degradation Process with Destructive Testing and Non-destructive Testing

Siyi Chen, Qingpei Hu*, Dan Yu
Academy of Mathematics and Systems Science, Chinese Academy of Sciences, Beijing, China
chensiyi21@mails.ucas.ac.cn

Zitong Lu, Min Xie
Department of Advanced Design and Systems Engineering, City University of Hong Kong, Hong Kong SAR
minxie@cityu.edu.hk

Abstract

With the prosperity of degradation analysis for the reliability of modern products, attention has focused on a sequential degradation mechanism that includes two phases involving the degradation process that starts after an initiation period. The Lifetime Delayed Degradation Process (LDDP) provides an explanatory framework for this sequential hard failure and soft failure modes. The corresponding degradation phenomenon is presented as the product composed of sequential initiation and propagation phases. For example, the process of crack propagation is a degradation process with a stochastic delay. From the viewpoint of reliability analysis, the traditional fracture mechanics analysis cannot fully meet the assessment of the remaining useful life (RUL). The objective of this study is to present a comprehensive Bayesian analysis of the LDDP model to evaluate the reliability and the remaining useful life of the delayed degradation products. Both destructive testing and non-destructive testing are covered in the proposed Bayesian-LDDP model. Since the Bayesian method can incorporate prior information into data analysis, it provides a natural way to analyze degradation data and make remarkable improvements in precision. Besides, Bayesian methods can also provide computational simplification when fitting complex models. Based on the LDDP method, we proposed the Bayesian-LDDP model. Different from the LDDP method, which is based on the joint likelihood function for statistical inference, the Bayesian-LDDP method combines the prior distribution with the joint likelihood function to infer the posterior distribution of the parameters as well as consider both destructive tests and non-destructive tests in Bayesian perspective. Weakly information priors are widely used in this research. Moreover, to be more correspond to the actual situation, the time transformation is applied to describe the deterioration process. Based on the posterior distribution, the Bayesian estimation and further reliability inferences of predicting remaining useful life (RUL) as well as mean time to failures (MTTF) can be derived. Moreover, in terms of calculation, the MCMC algorithm is adopted for the Bayesian estimation of parameters, which greatly improves efficiency. In this paper, the numerical simulations for non-destructive tests and destructive tests are both implemented on the Bayesian-LDDP model. The results of numerical simulation illustrate that to achieve the same accuracy, destructive testing requires a larger sample size than non-destructive testing. In the meantime, as for small sample problems, the Bayesian-LDDP model has better performance than the LDDP model. Furthermore, the practical application with the real-time monitoring of crack degradation data of a transport aircraft and a center fuselage longeron is carried out on the proposed model for non-destructive tests and destructive tests respectively. The results of practical examples include the Bayesian estimation of parameters as well as the credibility interval estimation of each parameter. Besides, further inference based on the posterior distribution is provided under different combinations of the lifetime model and the degradation model, including the MTTF of cracks as well as the prediction of the RUL of each sample in the optimal model. Our Bayesian-LDDP model has drawn a clear picture of the lifetime delayed degradation process in the Bayesian aspect for both destructive testing and non-destructive testing.

Keywords: Degradation process, Delayed degradation, Gibbs sampling, Lifetime distribution, MCMC algorithm, Prior information

Recoverable degradation – How to model and analysis the reliability in ADT

Qingpei Hu*
Academy of Mathematics and Systems Science,
Chinese Academy of Sciences, Beijing, China
qingpeihu@amss.ac.cn

Abstract

The continuous monitoring of the key performance of the product provides a degradation-informed reliability modeling and analysis approach. Both data-driven and model-driven methods have been applied for the reliability assessment and remaining useful life prediction. However, the degradation process usually is driven by different physical processes, and the measurements could be taken in various manners as well. Therefore, in order to make a sound reliability assessment, specific attention should be paid to the specific characteristic of the accelerated testing conducted. Sometimes, when the measurements have to be taken with the stress released from high to normal, the performance status of the sample under testing could also change. Neglecting such kind of change, i.e. partial recoverability, may affect the result of reliability assessment. In this talk, we will present the new model with recoverability incorporated. Our findings show that an overestimation conclusion would be drawn if the partial recoverability is ignored and the assessment with the new model can provide more accurate results. Both simulation and practical case studies support such a conclusion.

Keywords: Accelerated Degradation Testing, Reliability, Recoverability

Bootstrap Calibration of Model Selection Among Bivariate Copulas

Watalu Yamamoto*
Graduate School of Health Management, Keio University
Kanagawa, Japan
watalu@keio.jp

Yuichi Asano
Department of Informatics
University of Electro-Communications
Tokyo, Japan
kuma@sixth.inf.uec.ac.jp

Abstract

The bivariate copula expresses the dependency of random variables using the joint distribution on the unit square. The copula allows for the modeling of joint distributions with marginal distributions that do not have extensions to joint distributions. Various copulas have been proposed, expanding the variety of bivariate dependencies to be modeled.

Chin et al. (2005) combine the maximum pseudo-likelihood estimator with Akaike's information criterion. Grønneberg et al. (2014) pointed out that the method ignored noise when converting observations to pseudo observations and proposed the copula information criterion (CIC) for a model selection among copulas. They also proposed cross-validated copula information criterion (xv-CIC). They derive CIC and xv-CIC using asymptotic approximations, and these criteria work well for large samples.

In this presentation, the problem of the model selection among copulas is examined for small samples where CIC and xv-CIC are not guaranteed to work well. The parameter of the copula is estimated with pseudo-inverses, which use the plugin estimators of the quantile functions of marginal distributions. This two-stage estimation is proposed by Shih et al. (1995).

We propose to resample the model criterion using Fractional Random Weight Bootstrap and to have the calibrated value from the median. This method improves the accuracy of the model selection with CIC or xv-CIC. The amount of improvement is not large for cases where CIC or xv-CIC works well. However, the true copula is not known prior to the data analysis. So we recommend using the median of the information criterion.

Keywords: Copula, copula information criterion, fractional random weight Bootstrap, Bootstrap calibration

Optimal Replacement Policy for Wireless Sensor Networks

Lu Jin*
Department of informatics
University of Electro-Communications
Tokyo, Japan
jin.lu@uec.ac.jp

Watalu Yamamoto
Graduate school of health management
Keio University
Kanagawa, Japan
watalu@keio.jp

Yuta Iwamoto
Department of informatics
University of Electro-Communications
Tokyo, Japan
0915iwamoto@sixth.inf.ac.jp

Abstract

With recent innovations in sensing and measuring technology, wireless sensor networks (WSNs) have been widely used in many application domains. On the other hand, WSNs are also faced with many technical limitations, including energy and memory constraints, available processing power, and coverage reliability. Maintenance is one effective way to overcome these limitations. Boardman et al. [3] proposed an optimal time-based replacement policy that balances cost and reliability. In their model, the reliability is evaluated at a pre-specified replacement time. Their model optimizes the replacement period to maximize reliability and minimize maintenance costs. This research considers the loss due to the deterioration of a WSN in a continuous-time model. It aims to find an optimal replacement policy that minimizes both replacement cost and loss per unit time without compromising the reliability of WSNs.

Keywords: Cost rate, coverage, destruction spectrum, Markov process, replacement interval

Modeling of multi-layer networks with redundancy and cascading failures

Heping Jia*
School of Economics and Management
North China Electric Power University
Beijing, China
jiaheping@ncepu.edu.cn

Yutong Wang
School of Electrical and Electronic Engineering
North China Electric Power University
Beijing, China
1164648893@qq.com

Rui Peng
School of Economics and Management
Beijing University of Technology
Beijing, China
pengrui1988@ustb.edu.cn

Daqing Li
School of Economics and Management
Beihang University
Beijing, China
daqingl@buaa.edu.cn

Abstract

With the tighter connectivity of complex networks, nodes in different sub-network usually interact with each other. Considering the reliability enhancement of redundancy, networks with redundancy is generally embedded when network emergencies occur. Considering cooperation of networks with redundancy, connectivity, and dependency, multi-layer networks can be obtained. In this paper, the model for multi-layer networks with connectivity links, dependency links, and redundancy links is proposed. Moreover, considering cascading failures during network operation, the algorithm for the proposed model of multi-layer networks with redundancy and cascading failures is conducted. Illustrative example is provided to verify the proposed model.

Keywords: multi-layer network, redundancy, cascading failures, modeling

Establishment of biochemical recurrence prediction model of prostate cancer Based on Deep Learning Algorithm

Tianyi Wang
Department of Industrial Engineering
Northwestern Polytechnical University
Xi'an, China
wangtianyi@mail.nwpu.edu.cn

Zhiqiang Cai*
Department of Industrial Engineering
Northwestern Polytechnical University
Xi'an, China
caizhiqiang@mail.nwpu.edu.cn

Abstract

Prostate cancer is one of the most common malignant tumors in urology. Radical prostatectomy is the main treatment for prostate cancer, but the postoperative biochemical recurrence (BCR) rate is high, indicating that there are still residual prostate cancer foci after radical prostatectomy, and BCR seriously affects the prognosis and survival of patients. The object of this paper is to establish a prediction model of biochemical recurrence for the patients who underwent radical prostatectomy based on deep learning algorithm, to provide reference for the early detection, early diagnosis and prolonged survival of patients after radical prostatectomy. Meanwhile this paper combines the Bayesian network (BN) with importance measures to identify the key factors that have great effect on the biochemical recurrence of prostate cancer, to help doctors make better treatment plans. Clinical data of 209 patients who received radical prostatectomy in department of urology, The Affiliated Hospital of Qingdao University from July 2018 to July 2021 were collected. The set of patients was divided into training set and testing set at the rate 8:2. Four different deep learning algorithms were used to establish prediction models for biochemical recurrence of prostate cancer and a Bayesian network model was established that could mine potential relationships among different factors. Finally, we found that the prediction model constructed by CNN-BiLSTM algorithm had the best accuracy 83.5% and AUC 0.81 which can provide certain reference for predicting biochemical recurrence. The importance ranking showed that puncture positive rate (0.3982), cutting edge position (0.2078), operation method (0.1564), whether seminal vesicle invasion (0.1536) and age (0.1293) are the top 5 features influencing the biochemical recurrence of prostate cancer.

Keywords: Prostate cancer, Prediction model, Biochemical recurrence, Deep learning, Bayesian network

Customer-Rsuh Based Reliability Estimation Using Hazard Rate Model for Automobile Warranty Data

Min Ki Kang
Department of Industrial Engineering
Hanyang University
Seoul, Korea
tak092@psm.hanyang.ac.kr

Munwon Lim
Department of Industrial Engineering
Hanyang University
Seoul, Korea
moonmunwon@psm.hanyang.ac.kr

Suk Joo Bae*
Department of Industrial Engineering
Hanyang University
Seoul, Korea
sjbae@hanyang.ac.kr

Abstract

Customer-Rush phenomenon is defined as a delayed report that the repair requests rapidly increase at the end of warranty expiration. Failure with usable characteristics, even if the product's performance decreases or exceeds the failure criteria, will be charged for repair upon expiration of the warranty period. Therefore, it is necessary to construct and analyze a model to predict and prevent the surge of claim request in this phenomenon. In order to analyze the Customer-Rush due to delay reporting, a univariate analysis was previously conducted considering only time and mileage. However, a one-dimensional analysis can lead to biased results in estimation.

In this paper, we propose a hazard rate that can express Customer-Rush phenomenon in consideration of delay reporting. By considering the mileage over time, repair requests that occur during the warranty period have different characteristics of delay reporting. So, the probability density function reflecting the customer's characteristics was applied as a continuous uniform distribution. For each section, the cumulative distribution function was expressed differently by modifying the parameters of the delay report distribution.

To evaluate the performance of the proposed approach, an automobile warranty data containing the customer rush phenomenon is utilized. Through the established model, the optimal parameters of the model were estimated by Maximum Likelihood Estimation (MLE). Using the estimated parameter, it was confirmed that the hazard rate function expressed the Customer-Rush phenomenon. As a result, experimental result by using the real warranty data show that considering the mileage over time is better than only one variable (time or mileage) in respect to MSE.

Keywords: Warranty data, Customer-Rush, Delay reporting, Hazard rate, MSE

A hybrid reliability assessment method based on CNN-Transformer network and Wiener process

Junyu Guo*
School of Mechatronic Engineering
Southwest Petroleum University
Chengdu, China
junyguo@163.com

Jiang Wang
School of Mechatronic Engineering
Southwest Petroleum University
Chengdu, China
W668877JABC@163.com

Lin Wang
School of Mechatronic Engineering
Southwest Petroleum University
Chengdu, China
lincw_wang@qq.com

Abstract

Reliability assessment has an important role in industrial equipment prognostics and health management (PHM). However, traditional reliability assessment methods based on statistical models have been difficult to meet the challenges of big data problems. In order to cope with the big data problems, the health index reflecting the product degradation process are extracted from the huge amount of big monitoring data. In this paper, we propose a hybrid reliability assessment framework for rolling bearings. In the first part, the CNN-Transformer network is used to extract deep features from the monitoring data and build the health index of the products. In this integrated network, both CNN and Transformer models can extract useful temporal features from the input data, and the integrated network can fuse the learned temporal features of these two components to take advantage of the strengths of both networks. In the second part, the Wiener process is employed to achieve reliability assessment of the products through the health index while quantifying uncertainties in the assessment process. We validated the effectiveness of the proposed framework on rolling bearings datasets for reliability assessment.

Keywords: reliability assessment, convolutional neural network, Transformer network, Wiener process, Bayesian method

Dynamic Risk-Based Maintenance for Marine Vessels

David Gordon
Faculty of Engineering & Information Sciences
University of Wollongong
Wollongong, Australia
dsg102@uowmail.edu.au

Tieling Zhang*
Faculty of Engineering & Information Sciences
University of Wollongong
Wollongong, Australia
tieling@uow.edu.au

Richard Dwight
Faculty of Engineering & Information Sciences
University of Wollongong
Wollongong, Australia
radwight@uow.edu.au

Abstract

In this paper, a dynamic risk-based maintenance (DRBM) methodology is developed as a tool for maintenance planning and decision-making to reduce the risk profile of an asset. A Bayesian network (BN) is designed to revise the risk profile incorporating failure prediction to produce an optimum maintenance plan. This methodology is then applied to a marine vessel where all operational capabilities of the asset are considered. The case study results in an optimized maintenance plan by ranking all components based on their criticality to overall risk. A sensitivity analysis is conducted to demonstrate its ability to prioritize particular mission profiles and thus schedule maintenance activities accordingly.

Keywords: Bayesian network, dynamic risk-based maintenance, maintenance optimization, decision-making, very important personnel (VIP) transport vessel

Software Reliability Assessment with a Self-exciting Hawkes Process

Kazuki Iwamoto
Graduate School of Advanced Science and Engineering, Hiroshima University
Kagamiyama 1-4-1 Higashi-Hiroshima 739-8527, Japan
m214409@hiroshima-u.ac.jp

Tadashi Dohi*
Graduate School of Advanced Science and Engineering, Hiroshima University
Kagamiyama 1-4-1 Higashi-Hiroshima 739-8527, Japan
dohi@hiroshima-u.ac.jp

Hiroyuki Okamura
Graduate School of Advanced Science and Engineering, Hiroshima University
Kagamiyama 1-4-1 Higashi-Hiroshima 739-8527, Japan
okamu@hiroshima-u.ac.jp

Abstract

In this paper, we concern the non-Markovian software reliability model (SRM) with a self-exciting Hawkes process and investigate the goodness-of-fit and predictive performances with actual software development project data. Especially, we compare our self-exciting Hawkes process-based SRM with the common non-hmogeneous Poisson process (NHPP)-based SRMs with eleven deterministic intensity functions. It is shown that our self-exciting Hawkes process-based SRM could provide the nice performances in several cases.

Keywords: software reliability, non-Markovian process, self-exciting Hawkes process, goodness-of-fit, predictive performance, comparison

Incorporating software metrics data in software reliability prediction via penalized regression

Xiao Xiao*
Graduate School of Systems Design
Tokyo Metropolitan University
Tokyo, Japan
xiaoxiao@tmu.ac.jp

Hiroyuki Okamura
Graduate School of Advanced Science and Engineering
Hiroshima University
Hiroshima, Japan
okamu@hiroshima-u.ac.jp

Tadashi Dohi
Graduate School of Advanced Science and Engineering
Hiroshima University
Hiroshima, Japan
dohi@hiroshima-u.ac.jp

Abstract

It has been widely recognized that software metrics data is very useful to predict software reliability with higher accuracy. During the last two decades, several regression-based software reliability models (SRMs) have been proposed to incorporating software metrics data into software reliability prediction. However, there are still several difficulties remains to be solved in the regression-based SRMs. For example, unstable model estimation caused by the significantly increased number of model parameters, cumbersome variable selection based on some kind of information criteria, *etc*. This paper extends the existing regression-based SRMs by penalized regression, of which the well-known merit is that it executes the model estimation and the variable selection simultaneously. More specifically, the model parameters of the logistic regression-based SRM are estimated by the maximum likelihood (ML) method. In contrast, we estimate the model parameters by maximum penalized likelihood (MPL) method, which finds the model parameters by maximizing an elastic-net-penalty-term-added log-likelihood function of the logistic regression-based SRM. We discuss appropriate evaluation methods of our proposal. Additionally, we mention some ideas about how to predict software metrics because it directly affects the results of software reliability prediction by regression-based SRMs.

Keywords: software reliability prediction, software metrics, logistic regression, maximum penalized likelihood estimation, elastic net, non-homogenous Poisson process

Infinite NHPP-based Software Reliability Models with Burr-type Distributions

Siqiao Li*
Graduate School of Advanced Science and Engineering
Hiroshima University
Higashi-Hiroshima, Japan
rel-siqiao@hiroshima-u.ac.jp

Tadashi Dohi
Graduate School of Advanced Science and Engineering
Hiroshima University
Higashi-Hiroshima, Japan
dohi@hiroshima-u.ac.jp

Hiroyuki Okamura
Graduate School of Advanced Science and Engineering
Hiroshima University
Higashi-Hiroshima,
okamu@hiroshima-u.ac.jp

Abstract

This paper focuses on infinite non-homogeneous Poisson process (NHPP)-based software reliability models (SRMs) and develops eleven novel estimable SRMs with so-called Burr-type distributions. In numerical examples, we analyze eight software fault count time-domain data which are observed in several actual software development projects. To investigate the goodness-of-fit performance metrics of our SRMs, the maximum likelihood estimation was utilized to estimate the model parameters. By comparing our SRMs with three different type of existing SRMs: finite NHPP, infinite NHPP, and finite Burr-type in terms of goodness-of-fit performance, we found that the infinite Burr-type NHPP-based SRMs should be the possible candidates for selecting the best SRM in terms of goodness-of-fit in time-domain data sets.

Keywords: infinite software reliability models, non-homogeneous Poisson process, Burr-type distributions, maximum likelihood estimation, goodness-of-fit performance

An Experimental Evaluation of Parameter Estimation Algorithms in NHPP-based Software Reliability

Hiromu Yano*
Graduate School of Advanced Science and Engineering, Hiroshima University
1-4-1 Kagamiyama, Higashi-Hiroshima 739-8527, Japan
m212480@hiroshima-u.ac.jp

Tadashi Dohi
Graduate School of Advanced Science and Engineering, Hiroshima University
1-4-1 Kagamiyama, Higashi-Hiroshima 739-8527, Japan
dohi@hiroshima-u.ac.jp

Hiroyuki Okamura
Graduate School of Advanced Science and Engineering, Hiroshima University
1-4-1 Kagamiyama, Higashi-Hiroshima 739-8527, Japan
okamu@hiroshima-u.ac.jp

Abstract

In this paper we conduct an experiment to investigate the global convergence of five numerical optimization algorithms; quasi-Newton method, Nelder-Mead method, EM algorithm, ECM algorithm and LL-ECM algorithm, for the maximum likelihood estimation with no-homogeneous Poisson process (NHPP)- based software reliability models (SRMs). It is shown with two types of software fault-count data; time-domain data and group data that both EM and ECM algorithms enjoyed the rich property on the global convergence, but the latest LL-ECM algorithm did not.

Keywords: NHPP-based software reliability models, Global convergence, EM algorithm, ECM algorithm, LL-ECM algorithm

A Note on Bayesian Estimation of the Residual Number of Software Bugs

Yuki Hagihara*
Graduate School pf Advanced Science and Engineering, Hiroshima University
1-4-1 Kagamiyama, Higashi-Hiroshima 739-8527, Japan
m213879@hiroshima-u.ac.jp

Tadashi Dohi
Graduate School pf Advanced Science and Engineering, Hiroshima University
1-4-1 Kagamiyama, Higashi-Hiroshima 739-8527, Japan
dohi@hiroshima-u.ac.jp

Hiroyuki Okamura
Graduate School pf Advanced Science and Engineering, Hiroshima University
1-4-1 Kagamiyama, Higashi-Hiroshima 739-8527, Japan
okamu@hiroshima-u.ac.jp

Abstract

In this paper, we consider the posterior distribution of the residual number of software bugs in a heterogeneous testing environment with different bug-detection probabilities on each testing day, and compare two prior distribution cases; Poisson prior and negative binomial prior, where the former corresponds to the common non-homogeneous Poisson process (NHPP)-based software reliability model, the latter to its associated mixed Poisson process. Through a simple numerical example, it is shown that the both prior models in a heterogeneous testing environment could estimate the residual number of software bugs more accurately than those in a honogeneous testing environment with same bug-detection probability.

Keywords: software reliability, Bayesian estimation, residual number of software bugs, discrete-time model, Gibbs sampler, MCMC

A LAMP LOCATION PROBLEM CONSIDERING SYSTEM RELIABILITY

ZILONG FENG
Major in Industrial Data Science & Engineering, Department of Industrial Engineering, Pusan National University, Busan, Korea
fengzilong77@gmail.com

WON YOUNG YUN*
Major in Industrial Data Science & Engineering, Department of Industrial Engineering, Pusan National University, Busan, Korea
wonyun@pusan.ac.kr

Abstract

The paper studies one and two-dimensional lamp location problems considering system reliability. We use *n* same lamps to illuminate the service area. Each lamp illuminates a circle with a radius *r*, and the reliability of each lamp is given. The system state is working when the whole service area is illuminated by working lamps. The system reliability is the probability of no dark area in the whole area. The Voronoi diagram concept is used to check the system state, and a binary traversal tree search algorithm is used to compute the system reliability. A heuristic method and a genetic algorithm (GA) are proposed to find the lamp locations to maximize the system reliability. Numerical examples are studied to compare the two methods.

Unit age, technology age, maintenance experience age and their application in reliability analysis of repairable systems

Renyan Jiang
Zhejiang Provincial Key Laboratory of Laser Processing Robotics, College of Mechanical and Electrical Engineering; Wenzhou University; Wenzhou, China.
ry_jiang@163.com

Wei Xue
China International Science & Technology Cooperation Base for Laser Processing Robotics; Wenzhou University; Wenzhou, China.
xw@wzu.edu.cn

Yu Cao*
Zhejiang Provincial Key Laboratory of Laser Processing Robotics, College of Mechanical and Electrical Engineering; Wenzhou University; Wenzhou, China.
yucao@wzu.edu.cn

Abstract

Units of a fleet of repairable systems are often put into operation at different times. Since the unit's time to the next failure depends on maintenance depth and quality, the inter-failure time data are generally not independent and identically distributed and usually fitted to a failure point process model. The underlying variable of the process model is unit age or its variants (e.g., virtual age). Technology upgrade and maintenance quality improvement affect the system reliability while the unit age cannot reflect their influence on the reliability. To address this issue, the concepts of technology age and maintenance experience age of the system are introduced, and they (including unit age) are used as the underlying variables to analyze the system reliability. The concepts and analysis method presented in this paper have a potential for evaluating the effectiveness of a reliability improvement process. This is illustrated through reanalyzing a dataset collected from a fleet of air conditioning systems of jet airplanes. The results show that the system deteriorates with unit age and the fleet may undergo a maintenance quality improvement process.

Keywords: Repairable system, failure process, system deterioration, maintenance quality, reliability improvement

Reliability of Three-dimensional Consecutive *k*-type system

He Yi*
School of Economics and Management Beijing University of Chemical Technology
Beijing, China
yihe@mail.buct.edu.cn

Narayanaswamy Balakrishnan
Department of Mathematics and Statistics McMaster University
Hamilton, Ontario, Canada
bala@mcmaster.ca

Xiang Li
School of Economics and Management
Beijing University of Chemical Technology
Beijing, China
lixiang@mail.buct.edu.cn

Abstract

In this paper, several three-dimensional consecutive k -type systems are studied, namely, linear connected- (k_1, k_2, k_3) -out-of- $(n_1, n_2, n_3) : F$ system, linear connected- (k_1, k_2, k_3)! -out-of- $(n_1, n_2, n_3) : F$ system and linear l -connected- (k_1, k_2, k_3) -out-of- $(n_1, n_2, n_3) : F$ system without/with overlapping. Reliabilities of these systems are studied through finite Markov chain imbedding approach (FMCIA). Some numerical illustrative examples are also provided, and finally, some possible applications and generalizations are also pointed out.

Keywords: Reliability, three-dimensional consecutive *k*-type system, overlapping, non-overlapping, finite Markov chain imbedding approach (FMCIA)

Quantile EM Algorithm for Highly Censored Lifetime Data

Seung Hak Chai
Dept. of Industrial Engineering
Hanyang University
Seoul, Korea
csh630@psm.hanyang.ac.kr

Suk Joo Bae*
Dept. of Industrial Engineering
Hanyang University
Seoul, Korea
sjbae@hanyang.ac.kr

Abstract

The analysis of lifetime has been studied in many fields since ancient times. Especially in the manufacturing part, when developing a new product, reliability analysis must be conducted to reduce time and cost. In the conceptual design stage, field data are analyzed, past failure cases are reflected in the new product design, and reliability is predicted, and in the detailed design, product reliability analysis and reliability growth test are carried out together. Through these processes, censoring is a common case because of time, cost, and other experimental environments. Nevertheless, there is a need for an analysis method that can produce accurate results from incomplete data.

Maximum Likelihood Estimate (MLE) and Best Linear Unbiased Estimate (BLUE) have been intensively studied for parameter estimation of a lifetime distribution with highly censored samples. However, the weakness of MLE is revealed when there are only a few samples, a data that has lots of missing values. To solve these problems Mao and Chen[1] used a Bayesian method and Pang[2] used Monte Carlo EM Algorithm to analyze highly censored data. Furthermore, the Expectation-Maximization (EM) is already used as a powerful technique when finding the MLE of parametric models when there is no closed-form MLE or highly censored samples.

In this paper, we introduce applied EM algorithms and propose a new algorithm. Algorithms were compared by applying them to high-censored data, and which algorithm was most suitable was analyzed. The data used for the comparison is bearing failure data, which stopped because of economic reasons. It only has one complete failure observation. Before proposing a new algorithm, we verified whether the QEM algorithm[3] is more accurate than the MCEM algorithm in high-censored data. Through the results, QEM algorithm possesses more stable convergence properties and higher accuracy.

Then we propose a new algorithm. To improve accuracy, we changed the form of the deterministic sequences. Comparing four forms[4] and picking the best one, we combined them with a Gibbs sampling. We called it as GQEM (Gibbs sampling Quantile EM) Algorithm. The main point of this algorithm is to change a form of deterministic sequence and number of quantiles which the Quantile EM Algorithm can't do. We applied the high-censored data and concluded as follows. In computing time, GQEM Algorithm was much slower than MCEM and QEM algorithms. However, the accuracy was the highest compared to the two algorithms, and the convergence was almost the same as MCEM Algorithm. The convergence rate according to the initial value is almost no different. The 10th Asia-Pacific International Symposium on Advanced Reliability and Maintenance Modeling (APARM 2022 –Taiwan) Furthermore, the disadvantages of MLE, where sample number is the core, and the Bayesian method, where prior information is essential, were solved. All in all, the proposed algorithm is essential for industries that require high accuracy.

Keywords: Gibbs sampler, Interval censoring, Maximum likelihood estimation, MCEM Algorithm

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Estimation of Remaining Useful Life of Complex Systems Based on Autoencoder-Based Latent Variable Extraction

Sun Geu Chae
Department of Industrial Engineering
Hanyang University
Seoul, Republic of Korea
sgchae@psm.hanyang.ac.kr

Suk Joo Bae*
Department of Industrial Engineering
Hanyang University
Seoul, Republic of Korea
sjbae@hanyang.ac.kr

Abstract

Model-based approaches and data-based techniques are used in state-based maintenance, and the use of data-based techniques is increasing due to the limits of physical model-based techniques. However, data that has been tested until failure is normally required in order to develop a model for condition-based maintenance, but such data is difficult to collect in a high-reliability system and a system that costs a lot to test. As a result, it is critical to develop a model for identifying failure using extremely scarce failure data. Furthermore, due to the evolution of sensor technology and equipment, state-based maintenance including a high amount of data and variables is required. As a result, approaches such as autoencoders, which are useful for dimensionality reduction and high-dimensional data expression, are gaining attention. In addition to the challenges mentioned above, fresh data is used for defect diagnostics by distinguishing how it differs from previous data. However, there is a difficulty in that the current technique does not account for deterioration with time. As a result, in this study, we attempted to estimate the degradation over time of a complex system by modeling the deterioration over time using the autoencoder's estimated latent variable.

Keywords: Autoencoder, Degradation Path, Latent Variable, Complex System

The Revolution Lean Six Sigma 5.0

Benedictus Rahardjo*
Department of Industrial Management
National Taiwan University of Science and Technology
Taipei, Taiwan
D10901816@mail.ntust.edu.tw

Fu-Kwun Wang
Department of Industrial Management
National Taiwan University of Science and Technology
Taipei, Taiwan
fukwun@mail.ntust.edu.tw

Abstract

The vision of an innovative, resilient, socio-centered and competitive industry has been labelled Industry 5.0. Lean Six Sigma (LSS) has been proven to be a highly effective method for developing better production activities in the industrial field. Incorporating LSS into a human-centricity discipline enables a perfect blend of more human processes and a better result-oriented work environment. The present research explores this emerging area to examine the integration of LSS tools with Industry 5.0 technologies. Towards the achievement of process excellence, an inductive and integrative approach to the development of a sustainable innovation framework (SIF) is proposed. We identified 50 and 34 synergies between lean tools and the Six Sigma Define-Measure-Analyze-Improve-Control method with Industry 5.0 technologies, respectively. As a people-oriented concept, lean emphasizes caring for employees and customers while ensuring sustainable development. Meanwhile, Six Sigma and Industry 5.0 stress innovation to reduce variances and achieve continuous improvement. An analysis of a case study was conducted to illustrate how LSS 5.0 tools can be applied and their expected outcomes.

Keywords: Industry 5.0, Lean Six Sigma, Sustainable Innovation Framework

Optimization of Two-dimensional Warranty Policy for Repairable Product Considering Preventive Maintenance

Minjae Park
College of Business Administration
Hongik University
Seoul, Korea
mjpark@hongik.ac.kr

Dong Ho Park*
Industry Academic Cooperation Foundation
Hallym University
Chuncheon, Korea
dhpark@hallym.ac.kr

Abstract

This paper proposes a new two-dimensional warranty policy based on two factors of age and usage incorporating both warranty period and refund period simultaneously for a repairable product with an increasing failure rate. The product is warranted by taking into account both age and usage and the warranty is expired when the product reaches a specified age or a specified usage, whichever comes first. One unique framework of this work is to define a refund period under a specific type of lemon law, during which the purchased product should be either replaced by a new one or fully or partially refunded to the buyer by the manufacturer if the product failures meet certain conditions regarding either the number of failures or the length of each repair time. The refund period is, in general, assumed to be shorter than the warranty period and each failure following the refund period is only minimally repaired until the warranty is terminated. In this paper, we consider both age and usage to warrant the product and define an age-based univariate warranty period by utilizing the usage rate. Under a certain cost structure, we evaluate the expected total warranty cost during the age-based warranty period and determine the optimal age-based warranty period from the manufacturer's perspective. In addition, a heuristic method to obtain the optimal warranty premium is suggested under the two-dimensional warranty policy under study. To analyze the proposed warranty policy, relevant numerical examples are provided.

Keywords: failure rate, lemon law, preventive maintenance, repairable product, two-dimensional warranty, warranty cost analysis

An optimal rearrangement policy for a two-unit balanced system

Jingjing Wang
School of Management Engineering
Qingdao University of Technology
Qingdao, China
wangjingjing@qut.edu.cn

Tianran Lin*
Center for Structural Acoustics & Machine Fault Diagnosis
Qingdao University of Technology
Qingdao, China
trlin@qut.edu.cn

Abstract

Component rearrangement and maintenance policies are jointly optimized for a balanced system that consists of multiple interchangeable components in this paper. Degradation level of components on different positions follows gamma processes with different deterioration rates. The system is in the balanced state if and only if the difference of deterioration levels among different units is no more than a predetermined value. Otherwise, the system will be out of balance. To keep system balance, a rearrangement action, preventive and opportunistic maintenance actions may be performed on the system. Optimal thresholds of preventive and rearrangement actions are determined by minimizing the system maintenance cost per unit time. Finally, an illustrative example is used to demonstrate the efficiency of the proposed model in reducing the system maintenance fees.

Keywords: Rearrangement action, Preventive maintenance, Opportunistic maintenance, Balanced systems

Analysis of a maintenance problem for a deteriorating system under a Gamma process with hybrid repair and replacement

Nobuyuki Tamura*
Department of Industrial and Systems Engineering
Hosei University
Tokyo, Japan
tamura@hosei.ac.jp

Abstract

In this study, we consider a system whose deterioration is expressed as a gamma process. If the deterioration process reaches a level L, then the system fails, which is called major failure, and corrective replacement is conducted. Before a major failure, the system suffers minor failures which need a minimal repair. We observe a state (deterioration level) of the system periodically and undertake preventive maintenance if necessary. Then preventive replacement or hybrid repair is selected as a preventive maintenance action. For the system, we establish a total expected discounted cost for unbounded horizon and derive sufficient conditions that the optimal maintenance policy has a monotone structure on hybrid repair and preventive replacement. Furthermore, we investigate the behavior of the optimal maintenance policy focused on the age of the system.

Keywords: Gamma process, minor failure, hybrid repair, replacement, Markov decision process, monotone property

Modelling warranty claims using an alternating alpha-series process

Richard Arnold
School of Mathematics and Statistics
Victoria University of Wellington
Wellington, New Zealand
richard.arnold@vuw.ac.nz

Stefanka Chukova
School of Mathematics and Statistics
Victoria University of Wellington
Wellington, New Zealand
stefanka.chukova@vuw.ac.nz

Yu Hayakawa
School of International
Liberal Studies
Waseda University
Tokyo, Japan
yu.hayakawa@waseda.jp

Sarah Marshall*
Department of Mathematical Sciences
Auckland University
of Technology
Auckland, New Zealand
sarah.marshall@aut.ac.nz

Abstract

Fulfilling warranty obligations can have significant financial implications for manufacturers, therefore accurate estimation of the number of warranty claims, and the corresponding warranty costs, is crucial. For repairable systems, warranty claims can be estimated by modelling a system's lifetime as an alternating sequence of operational times and repair times. A typical approach is to use an alternating renewal process to model this alternating sequence of operational and repair times. However, in the case of ageing systems, operational times tend to decrease and repair times tend to increase, and thus the assumptions of independent and identically distributed operational and repair times are no longer valid. This work presents an alternative model, the alternating alpha-series process, in order to incorporate system ageing. The alternating alpha-series process will be introduced and its application in warranty cost analysis will be discussed. Examples using warranty claims data from the automotive industry will be provided.

Keywords: Warranty cost analysis, alternating alpha-series process, repairable systems