Research Highlight 1: Artificial Neural Network (ANN) Models for Ship Fuel Efficiency with Applications to In-Service Ship Fuel Consumption Management , by Dr. Du Yuquan (Track Leader: Professor MENG Qiang)

Background

Shipping companies are paying more and more attention to ship fuel efficiency. In the environmental aspect, the shipping industry contributes to around 3% of global CO2 emissions in 2007 and these emissions are estimated to be double or even triple by 2050. On the commercial side, bunker cost in fact dominates the operating cost structure of a commercial ship (60%).

However, it is hard to understand and model a ship's fuel efficiency in practice, since a ship's fuel consumption rate (FCR, MT/day) at sea is determined by many factors, such as sailing speed, draft/displacement, trim, and weather and sea conditions. The synergetic influence of these determinants on ship fuel efficiency, or say FCR, has not clearly addressed by existing academic studies.

Shipping companies recently make great efforts on ship fuel efficiency analysis to share their industrial data and collaborate with academia, especially the voyage report data.

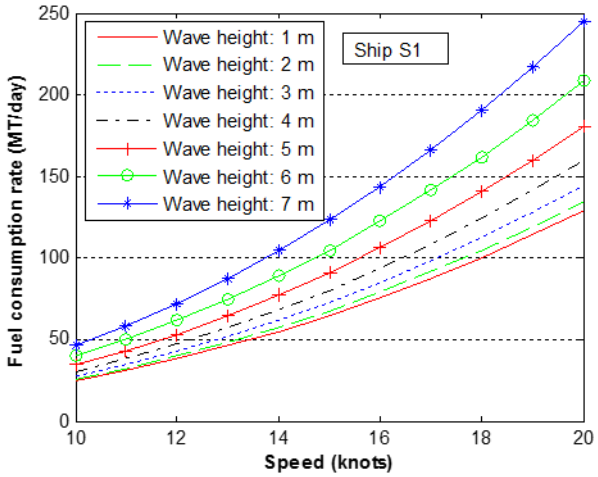

Figure 1. Fuel consumption rate of a 13000-TEU container ship (S1) in bow waves

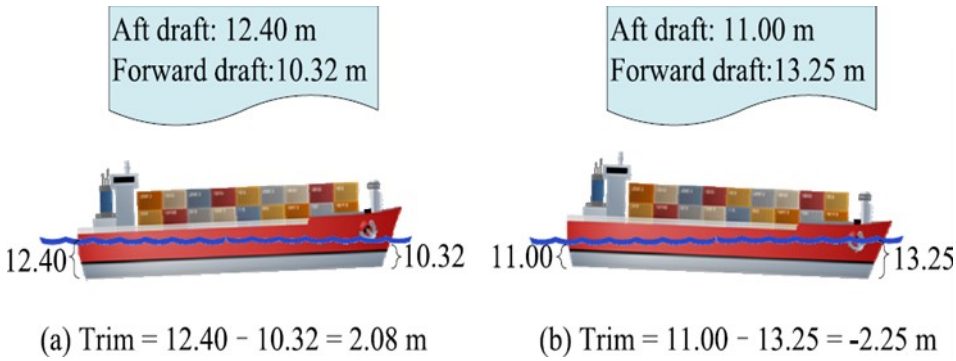

Figure 2. Trim of a containership

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Objectives and Contributions

This study aims to propose an artificial neural network (ANN) model which for one thing complies with the fundamentals of ship propulsion and for another can precisely quantify the synergetic influence of several determinants on ship fuel efficiency. Meanwhile, this study also develops a practical in-service ship fuel consumption management scheme based on the tangible ANN models.

There are three major contributions.

- Driven by shipping log data, three ANN-based ship fuel efficiency models complying with the fundamentals of ship propulsion are proposed.
- Some insights into model choice are also provided based on their fitting performance to real shipping log data.
- A practical in-service ship fuel management scheme is developed, inspired by the concept of statistical process control and the competence of the ANN model in FCR estimation.

ANN Ship Fuel Efficiency Models

We adopt a two-step procedure for ship fuel efficiency estimation.

- Step 1 (ANN). Estimate engine RPM from the situation outside of engine (speed, displacement/draft, trim, weather/sea conditions).
- Step 2 (ANN or regression). Estimate engine power (kW) and SFOC (specific fuel oil consumption, g/kWhr) based on engine RPM (engine speed, Revolution Per Minute).
- Estimate Ship fuel efficiency by using this formula: FCR (g/hr or MT/day) = Power (kW) * SFOC(g/kWhr).

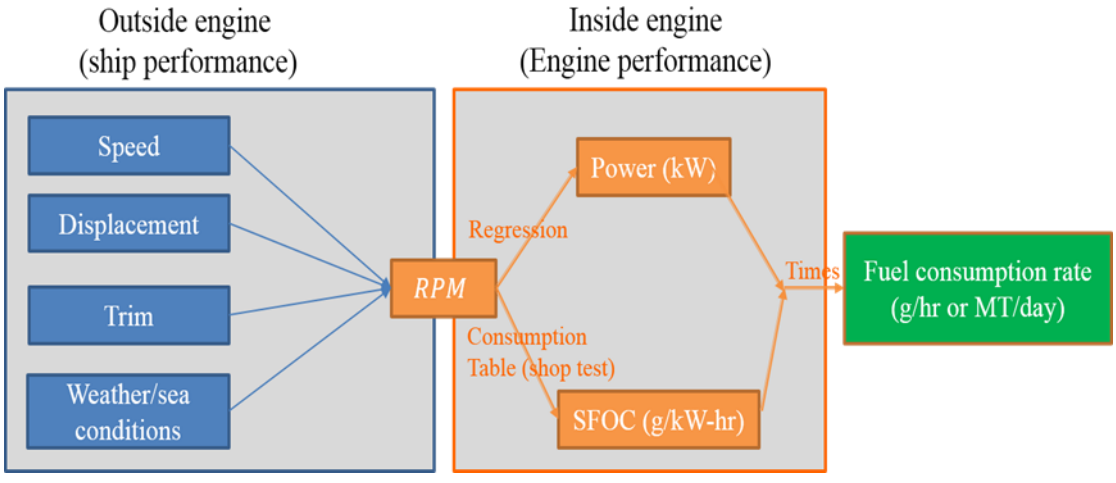

Figure 3. A two-step procedure for ship fuel efficiency estimation

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ANN Ship Fuel Efficiency Models

We evaluate three possible ANN-based ship fuel efficiency models.

- Model 1: Model 1 constructs an ANN model in the first step and two nonlinear regression models in the second step, which is illustrated by Figure 4.
- Model 2: Rationale behind Model 2 (compared to Model 1): an ANN model could achieve the fit performance of any polynomial regression model, at least in theory.
- Model 3: Rationale behind Model 3 (compared to Model 2): In Model 2, if we denote the fit function in two steps by and , respectively, the whole model is actually fitting a composite function . Theoretically, this composite function is surely could be approximated by a single ANN.

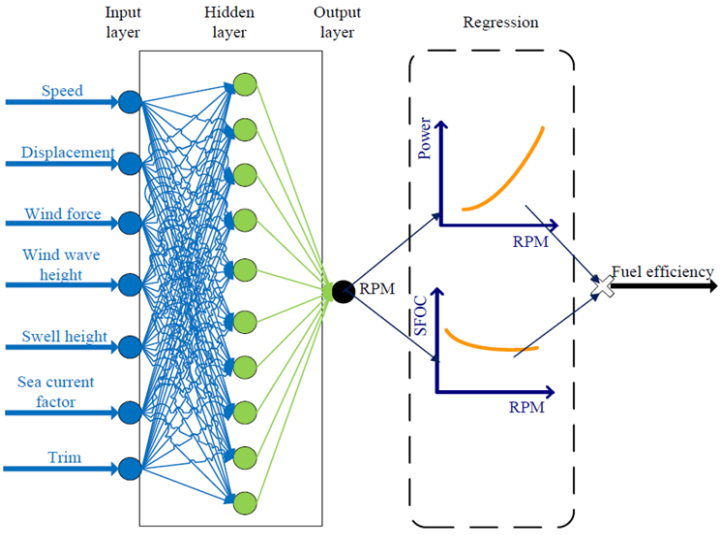

Figure 4. Model 1: ANN in step 1 and regression in step 2

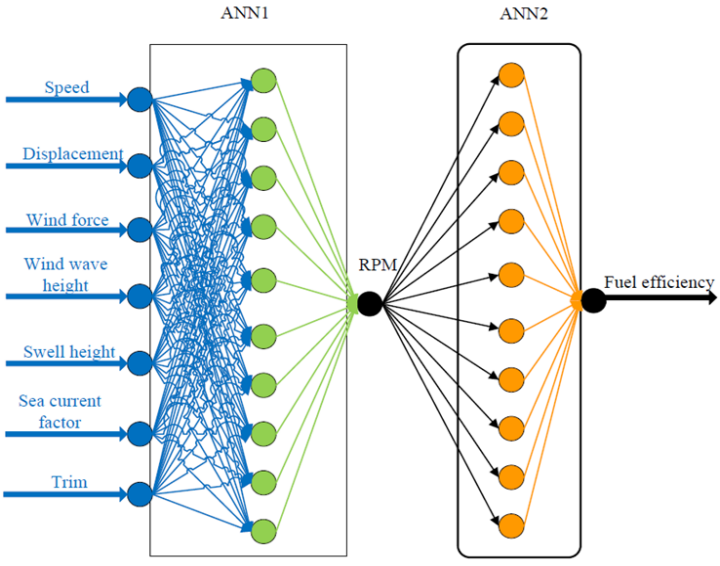

Figure 5. Model 2: ANN models are adopted in both steps

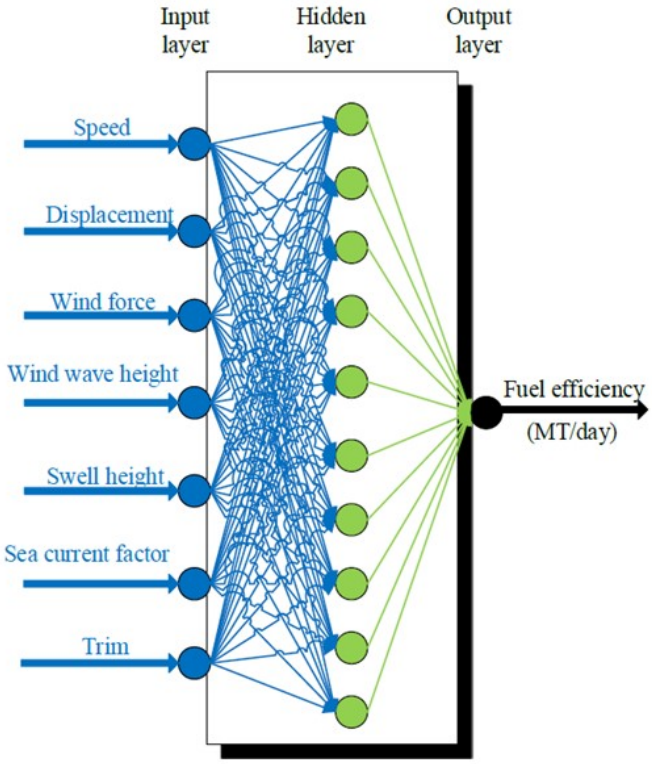

Figure 6. Model 3: combining two-steps into one

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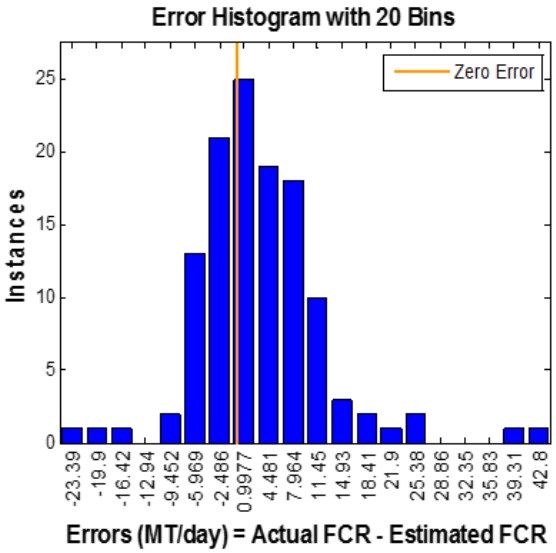
Fit Performance over Three 6600-TEU Containerships (C1, C2, C3)

- **Fit performance of Model 1: acceptable in step 1 but unacceptable as a whole**

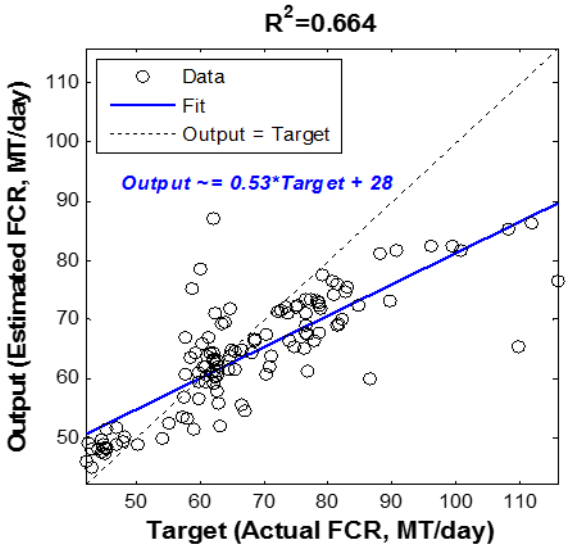
Table 1 Fitting performance of ANN in step 1 of Model 1

Ship		C1	C2	C3
# shipping log entries		121	160	153
R^2 [a]	Training set	0.92	0.95	0.95
	Test set	0.71	0.89	0.83
Error on training set (RPM)	All	-4.55~5.32	-3.22~6.85	-6.67~5.55
	85% percentile	-1.96~2.20	-1.63~1.55	-2.81~2.97
Error on test set (RPM)	All	-3.97~7.92	-4.45~5.53	-13.94~6.42
	85% percentile	-1.47~2.29	-2.35~2.39	-3.23~2.13
RMSE (RPM) [b]		1.91	1.62	2.15

Note. [a] R^2 value of the linear regression between actual RPM and estimated RPM. [b] Root mean squared error defined as $\sqrt{\sum_{i=1}^{N}\left(e^{(i)}\right)^2 / N}$.



(a) Fitting errors distribution



(b) Linear regression between actual FCR and the output of Model 1

Figure 7. Fitting errors distribution of Model 1 over training set (ship C1)

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- **Fit performance of Model 2: better but still practical unacceptable**

Table 2 Fitting performance of Model 2

Ship		C1	C2	C3
# Shipping log entries		121	160	153
R^2 [a]	Training set	0.90	0.79	0.90
	Test set	0.69	0.59	0.83
Error on training set (MT/day)	All	-10.91~17.51	-18.99~22.23	-22.99~27.27
	85% percentile	-8.28~8.75	-10.32~9.82	-8.23~7.46
Error on test set (MT/day)	All	-13.04~32.58	-27.51~18.14	-41.50~13.16
	85% percentile	-4.64~7.98	-10.94~9.46	-5.32~5.79
RMSE (MT/day) [b]		6.11	7.42	7.26

Note. [a] R^2 value of the linear regression between actual fuel consumption rates and estimated fuel consumption rates. [b] Root mean squared error defined as $\sqrt{\sum_{i=1}^{N}\left(e^{(i)}\right)^2 / N}$.

- **Fit performance of Model 3: practically acceptable**

Table 3 Fitting performance of Model 3

Ship		C1	C2	C3
# Shipping log entries		121	160	153
R^2 [a]	Training set	0.89	0.91	0.93
	Test set	0.89	0.75	0.89
Error on training set (MT/day)	All	-14.75~18.75	-14.85~18.18	-19.88~26.43
	85% percentile	-5.94~6.40	-4.42~6.01	-5.25~4.49
Error on test set (MT/day)	All	-11.76~9.26	-8.50~18.02	-9.32~23.20
	85% percentile	-5.12~5.94	-5.71~5.47	-7.61~6.08
RMSE (MT/day) [b]		5.26	5.13	6.36

Note. [a] R^2 value of the linear regression between actual fuel consumption rates and estimated fuel consumption rates. [b] Root mean squared error defined as $\sqrt{\sum_{i=1}^{N}\left(e^{(i)}\right)^2 / N}$.

The engine performance curve provided by the yard might not be trustable for ship fuel efficiency analysis in a shipping line's daily operations. This explains the bad performance of Model 1. Meanwhile, the pattern from shipping log data exhibits no functional relationship between engine power and RPM, which explains the advantage of Model 3 over Model 2. See Figure 8.

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Fit Performance over Three 6600-TEU Containerships (C1, C2, C3)

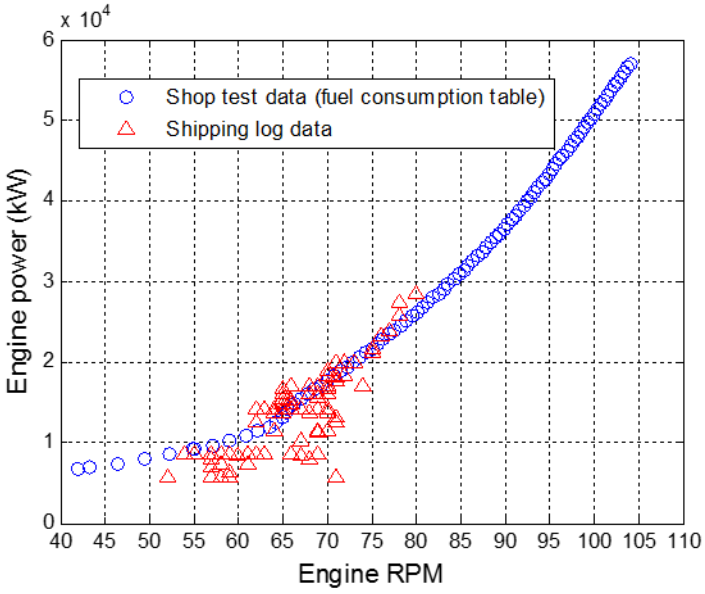

Figure 8. Different patterns of engine power against RPM shown by fuel consumption table and shipping logs

An In-Service Ship Fuel Consumption Management Scheme

Step 1. Calculate the control limits of FCRs for each sailing leg based on historical data

Table 4 Port rotation of a trans-Pacific liner service

Port Information	
Port	Code
Shanghai	SHA
Busan	P6H
Yokohama	YOK
San Pedro	SPQ
Oakland	OA8
Dutch Port	DUT
Naha	NAH
Qingdao	TSI

Leg No.	Origin	Destination	Distance (nm)
1	TSI	SHA	382
2	SHA	P6H	440
3	P6H	YOK	846
4	YOK	SPQ	4778
5	SPQ	OA8	363
6	OA8	DUT	2046
7	DUT	YOK	2544
8	YOK	P6H	875
9	P6H	NAH	543
10	NAH	TSI	726

- Mean and standard deviation of FCRs over leg l : μ_{FCR}^{l} , σ_{FCR}^{l}
- Based Lower and upper control limits (LCL, UCL): $[\mu_{FCR}^{l} - \sigma_{FCR}^{l}, \mu_{FCR}^{l} + \sigma_{FCR}^{l}]$, or $[\mu_{FCR}^{l} - 2\sigma_{FCR}^{l}, \mu_{FCR}^{l} + 2\sigma_{FCR}^{l}]$, $[\mu_{FCR}^{l} - 3\sigma_{FCR}^{l}, \mu_{FCR}^{l} + 3\sigma_{FCR}^{l}]$

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An In-Service Ship Fuel Consumption Management Scheme

Step 2. Detect the possible abnormality of FCRs for the current trip based in the control chart

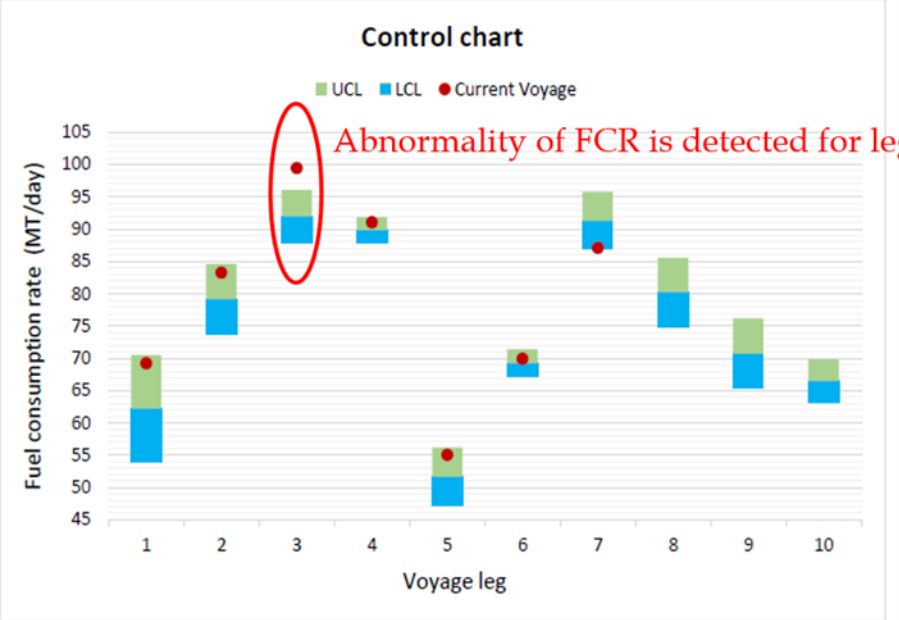

Figure 9. Ship fuel efficiency monitoring in a control chart

Step 3. Model 3 is trigged to conduct what-if analysis in order to identify (and even quantify) the possible reasons

If a single determinant had the average condition of the previous trips (on this leg), how would FCR change?

Table 5 What-if analysis on ship fuel efficiency over leg 3 based on Model 3

Determinants	Actual FCR	What-if FCR	Change	Within Control Limit?
Sea currents	99.46	97.45	-2.02%	
Trim	99.46	99.62	0.16%	
Displacement	99.46	97.96	-1.51%	
Speed	99.46	98.33	-1.14%	
Wind force	99.46	94.89	-4.59%	√
Wind waves	99.46	92.57	-6.93%	√
Swell	99.46	95.19	-4.29%	√

Bad conditions of local waves, wind, and swell are the major reasons for this abnormality of FCR!

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Conclusions

- The trend of shipping industry's evolution from eco-ships to eco-shipping highlights the roles of data analytics and managerial approaches in ship fuel efficiency management.
- To address the synergetic influence of sailing speed, displacement/draft, trim, and weather/sea conditions on ship fuel efficiency, three possible ANN-based ship fuel efficiency models complying with the fundamentals of ship propulsion are proposed.
- Based on the real shipping log data, we find that Model 3, with the simplest model structure, exhibits the best (surely practically acceptable) fit performance.
- Some insights into ship fuel efficiency modeling, with respect to model structures and data characteristics, are also provided.
- An in-service ship bunker fuel management scheme, which detects the abnormality of fuel efficiency in a control chart and triggers our proposed ANN model for what-if analysis, is innovatively designed.

Research Highlight 2: Obstacle-ship collision avoidance model for the Straits of Malacca and Singapore , by Ms. Lu Zhaoyang (Track Leader: Professor MENG Qiang)

Objective

During the simulation of ships passing through the Straits of Malacca and Singapore (SOMS), one of the most important sections is how to simulate the obstacle-ship collision avoidance behaviors. As Figure 1 is shown, when a ship meets an obstacle in the way of its direct route, the captain manipulates this ship to avoid a collision. In our recent research, we have studied how to model this obstacle-ship collision avoidance process and how to calibrate the relevant parameters.

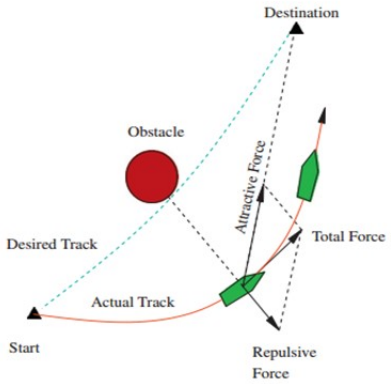

Figure 1: Illustration for obstacle-ship collision avoidance process

Theoretical Model Based Analysis

Theoretically, we propose the relevant mathematical models by the following four steps to describe obstacle-ship collision avoidance process. In addition, Figure 2 also draws the process two obstacle-ship avoidance scenarios.

- How to calculate the included angles between the obstacle and ships?
- When does the ship take actions?
- How do ships avoid collision?
- How do ships return back to courses?

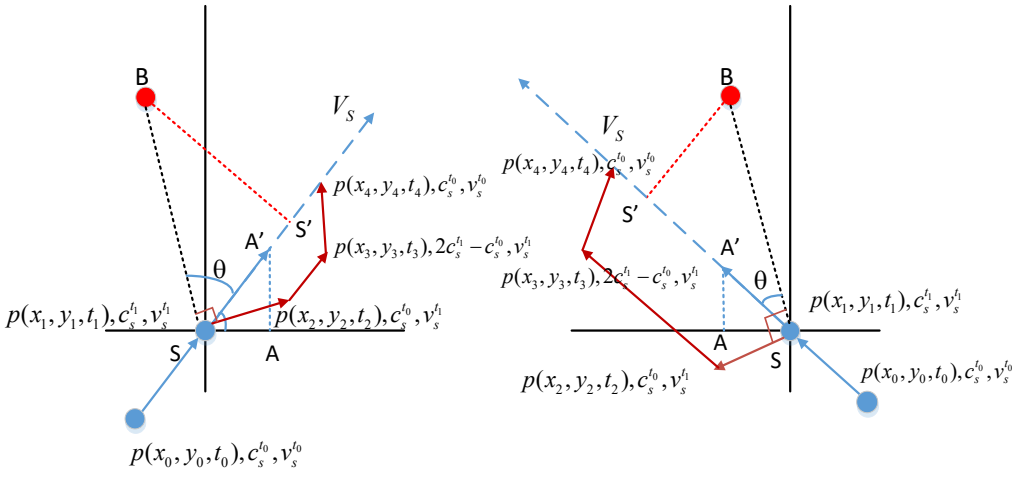

Figure.2. Process of accidence for obstacle avoidance scenarios

Research Highlight 2: Obstacle-ship collision avoidance model for the Straits of Malacca and Singapore , by Ms. Lu Zhaoyang (Track Leader: Professor MENG Qiang)

AIS Data Based Calibration Analysis

Based on the AIS data, the relevant parameters that needed in the above theoretical models will be derived.

- Firstly, some obstacles, such as the lighthouse, Racon, are illustrated in the following Table 1.
- Then based on these fixed points, the MMSI of ships travelling near these points can be found.
- Finally, the shortest distance, which is regard as DCPA, can be calculated from the position of ship route points (from AIS data) and obstacle points.

According to our data analysis, for example, Figure 3 describes the shortest path between ships and the obstacle "Batu Berhanti Bn", and Figure 4 illustrates the physical positions of the obstacles.

Table 1. Examples of Some Obstacles in the SOMS

Position	Name	Longitude	Latitude
Leg 1E	One Fathom Bank Lighthouse	100°59.8E	02°53.3N
Leg 3E	Sepat Beacon	101°23.36E	02°33.87N
Leg 9E	Pulau Takong Kecil Lighthouse	103°43.13E	01°06.31N
Leg 11E1	Helen Mar Reef Racon (M)	103°46.52E	01°07.42N
Leg 11E2	Buffalo Rock Racon (K)	103°48.84E	01°09.44N
Leg 12E1	Batu Berhanti Bn.	103°52.51E	01°11.76N
Leg 12E2	Batu Berhanti Isolated Danger Buoy	103°52.99E	01°11.09N
Leg 15E	Horsburgh Lighthouse	104°24.32E	01°19.81N
Leg 5W	Raffile Lighthouse	103°44.45E	01°09.61N
Leg 7W	Tanjung Piai Light Beacon	103°30.57E	01°15.52N
Leg 10W	Bukit Segenting Lighthouse	102°53.4E	01°47.5N
…	…	…	…

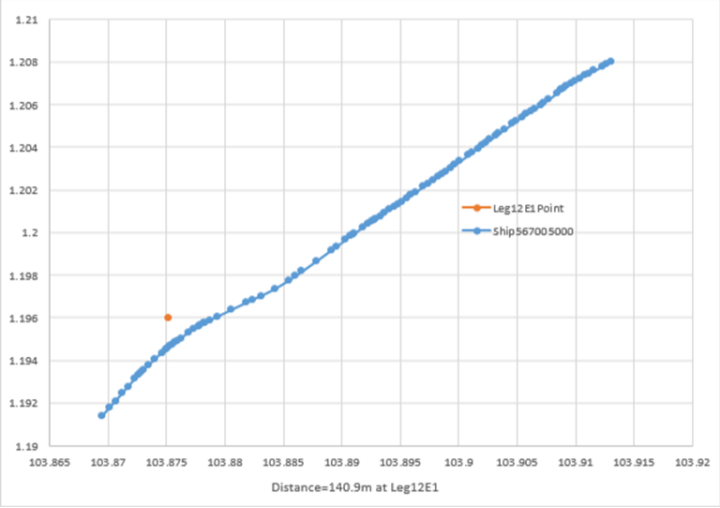

Figure 3. Shortest distance=140.9m at the obstacle of Leg12E1

Research Highlight 2: Obstacle-ship collision avoidance model for the Straits of Malacca and Singapore , by Ms. Lu Zhaoyang (Track Leader: Professor MENG Qiang)

AIS Data Based Calibration Analysis

Figure 4. The obstacle position of Leg12E1

Conclusion

In summary, we found that the shortest distance between travelling ships and obstacles will change with ship types and obstacle positions. Until now, we have finished the model building of obstacle-ship collision avoidance process, and the AIS-data based analysis for model calibration. In the following work, we plan to make a regression analysis for the shortest distance between travelling ships and obstacles by considering the effects of different ship types and obstacle positions.

Published Technical Papers (with Abstracts)

1. **H. Wang, B.W. Ang, Q.W. Wang, and P. Zhou (2017), Measuring energy performance with sectoral heterogeneity: A non-parametric frontier approach.** ***Energy Economics, Volume 62, Pages 70–78.***

Abstract:

Evaluating economy-wide energy performance is an integral part of assessing the effectiveness of a country's energy efficiency policy. Non-parametric frontier approach has been widely used by researchers for such a purpose. This paper proposes an extended non-parametric frontier approach to studying economy-wide energy efficiency and productivity performances by accounting for sectoral heterogeneity. Relevant techniques in index number theory are incorporated to quantify the driving forces behind changes in the economy-wide energy productivity index. The proposed approach facilitates flexible modelling of different sectors' production processes, and helps to examine sectors' impact on the aggregate energy performance. A case study of China's economy-wide energy efficiency and productivity performances in its 11th five-year plan period (2006–2010) is presented. It is found that sectoral heterogeneities in terms of energy performance are significant in China. Meanwhile, China's economy-wide energy productivity increased slightly during the study period, mainly driven by the technical efficiency improvement. A number of other findings have also been reported.

2. **Yuan Wang, Xinjia Jiang, Loo Hay Lee, Ek Peng Chew, and Kok Choon Tan (2017), Tree based searching approaches for integrated vehicle dispatching and container allocation in a transshipment hub.** ***Expert Systems with Applications, Volume 74, Pages 139–150.***

Abstract:

This study addresses the integration of Vehicle dispatching and container storage location problem with consideration of loading and unloading activities simultaneously. A MIP model is formulated to describe the interrelation between vehicle scheduling, yard crane scheduling and container storage location. A tree structure is used to represent the whole solution space. This representation has a good property as it captures the neighborhood structure and enhances the performance of local search and adaptive searching algorithms. Three variants of tree based searching approaches are developed, namely, the Nested Partitions method (NP), the Beam Search method (BS), and Stochastic Beam Search method (SBS). Extensive experiments show that these proposed methods can find a promising solution in matter of seconds for a practical problem and the Stochastic Beam Search method (SBS) method performs nearly as well as Nested Partitions method (NP) while gaining great computational efficiency. Due to this merit, SBS method is suggested to solve real time integrated vehicle dispatching problem in a relative large scale and may applied in other real time complex system scheduling.

3. **Jie Xu, Edward Huang, Liam Hsieh, Loo Hay Lee, Qing-Shan Jia, and Chun-Hung Chen (2016), Simulation optimization in the era of Industrial 4.0 and the Industrial Internet.** ***Journal of Simulation, Volume 10, Issue 4, Pages 310–320.***

Abstract:

Simulation is an established tool for predicting and evaluating the performance of complex stochastic systems that are analytically intractable. Recent research in simulation optimization and explosive growth in computing power have made it feasible to use simulations to optimize the design and operations of systems directly. Concurrently, ubiquitous sensing, pervasive computing, and unprecedented systems interconnectivity have ushered in a new era of industrialization (the so-called Industrial 4.0/Industrial Internet). In this article, we argue that simulation optimization is a decision-making tool that can be applied to many scenarios to tremendous effect. By capitalizing on an

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unprecedented integration of sensing, computing, and control, simulation optimization provides the "smart brain" required to drastically improve the efficiency of industrial systems. We explore the potential of simulation optimization and discuss how simulation optimization can be applied, with an emphasis on the recent development of multi-fidelity/multi-scale simulation optimization.

4. **Chenbo Zhu, Jie Xu, Chun-Hung Chen, Loo Hay Lee, and Jian-Qiang Hu (2016), Balancing search and estimation in random search based stochastic simulation optimization.** ***IEEE Transactions on Automatic Control, Volume 61, Issue 11, Pages 3593-3598.***

Abstract:

Stochastic simulation optimization involves two fundamental steps: 1) searching the solution space to generate candidate solutions for comparison and 2) estimating the performance of each candidate solution via multiple simulations and selecting a solution as the best solution found. Comparisons of solutions via simulation estimation are subject to error due to the stochastic noise in simulation output. While estimation errors can be reduced by increasing the number of simulation replications, it would in turn limit the number of candidate solutions that can be generated for comparison in a fixed computation budget. Under a random search framework, we derive an analytical formula to (approximately) optimally determine the number of candidate solutions generated in the search step and simulation replications in the estimation step to maximize the quality of the solution selected as the best by the random search algorithm. We then propose a practical method based on this formula and test the method on several common benchmark problems. Experiment results show that our method is quite effective and leads to significant improvement in the quality of the best solution found.

5. **Xinchang Wang and Qiang Meng (2017), Discrete intermodal freight transportation network design with route choice behavior of intermodal operators.** ***Transportation Research Part B: Methodological, Volume 95, Pages 76–104.***

Abstract:

We consider a discrete intermodal network design problem for freight transportation, in which the network planner needs to determine whether or not to build up or expand a link to minimize the total operating cost of carriers and hub operators under a general route choice model of intermodal operators. We formulate the problem as a mixed-integer nonlinear and non-convex program that involves congestion effects, piecewise linear cost functions, and a fixed-point constraint. We develop a series of relaxed and equivalent models to reduce the hardness of the problem and provide theoretical results to show the equivalences. We present two solution methods to solve the problem with one returning heuristic solutions and the other generating a globally optimal solution. We offer two numerical experiments to test the two solution algorithms and also shed light on their performance comparisons.

6. **Yiru Zhang, Qiang Meng, and Szu Hui Ng (2016), Shipping efficiency comparison between Northern Sea Route and the conventional Asia-Europe shipping route via Suez Canal. Journal of** ***Transport Geography, Volume 57, Pages 241–249.***

Abstract:

The continuous retreat of Arctic sea ice and seemingly appealing cost competitiveness of transarctic shipping routes are expected to boost shipping activities in the region. However, in reality, the number of Arctic transits remains meagre compared with major shipping routes. This study first develops a profit estimation model for containership sailing from an original port to a destination port with multiple port calls and a cost estimation model for

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oil tanker sailing from an origin port to a destination port. The authors then proceed to compare the shipping efficiency between the Northern Sea Route (NSR) and the Asia-Europe shipping route via Suez Canal by using the developed models and real shipping operational data. The results demonstrate that NSR shipping is not economically favored compared to traditional one in container shipping, but may be only appealing to small or medium-size tanker operators.

7. **Yuquan Du, Qiang Meng, and Shuaian Wang (2016), Mathematically calculating the transit time of cargo through a liner shipping network with various trans-shipment policies.** ***Maritime Policy and Management, Pages 1-23.***

Abstract:

This paper derives the mathematical expressions for the transit time of cargo through a liner shipping network. Main efforts are devoted to deriving the calculation expressions of the connection time of cargo during trans-shipment. For the forward and many-to-one trans-shipment policies, we conduct a minor correction towards the expressions in existing studies to improve the completeness. Meanwhile, we propose an alternative but more straightforward calculation method for connection time which bypasses the complicated inductive argument in existing studies. Then we introduce two new trans-shipment policies: backward trans-shipment and one-to-many trans-shipment, and mathematically calculate the corresponding connection times. Numerical experiments also deliver some managerial insights into the effectiveness of backward trans-shipment in transit time control.

8. **Jun Yuan, and Szu Hui Ng (2017), Emission reduction measures ranking under uncertainty.** ***Applied Energy, Volume 188, Pages 270–279.***

Abstract:

Shipping is a major contributor to global CO2 emissions. Various operational and technical measures have been proposed to reduce ship emissions. However, these emission reduction measures may not be all economically feasible to implement. Therefore, it is important to rank all these measures and select the most cost-effective measures for emissions reduction. Moreover, there are various uncertainties in evaluating emission reduction measures, such as uncertainties of implementation cost, fuel consumption, abatement potential and fuel price. These uncertainties may significantly influence the ranking of the emission reduction measures, which further result in an inappropriate selection of the measures for implementation. In this paper, a ranking algorithm with a new criterion is proposed to rank all the emission reduction measures by considering the preference between cost and abatement. Furthermore, a ranking under uncertainty method is developed which takes into account various uncertainties of the impact factors. This method can support policy makers in ranking and selecting emission reduction measures more appropriately by better quantifying and reflecting the uncertainties.

9. **G. Sollazzo, T.F. Fwa, and G. Bosurgic (2017), An ANN model to correlate roughness and structural performance in asphalt pavements.** ***Construction and Building Materials, Volume 134, Pages 684–693.***

Abstract:

In this paper, using a large database from the Long Term Pavement Performance program, the authors developed an Artificial Neural Network (ANN) to estimate the structural performance of asphalt pavements from roughness data. Considering advantages of modern high-performance survey devices in the acquisition of road pavement

Published Technical Papers (with Abstracts)

functional parameters, it would be of practical significance if the structural state of a pavement could be estimated from its functional conditions. To differentiate various road section conditions, several significant input parameters, related to traffic, weather, and structural aspects, have been included in the analysis. The results are very interesting and prove that the ANN represents an adequate model to evidence this relation. The papers shows the effectiveness of the adoption of a large database for the analysis of the correlation. ANN provides also better results in comparison with Linear Regression. Further, the authors trained three different ANNs to analyse the effects of modified datasets and different variables. The numerical outcomes confirm that, by using this approach, it is possible to correlate with good accuracy roughness and structural performance, allowing road agencies to actually reduce the deflection test frequency, since they are generally more costly, time consuming, and disruptive to traffic than functional surveys.

Conference Papers (with Abstracts)

1. **Nugroho A Pujowidianto, Loo Hay Lee, Giulia Pedrielli, Chun-Hung Chen, and Haobin Li (2016), Constrained optimizaton for hospital bed allocation via discrete event simulation with Nested Partitions.** ***In proceeding of Winter Simulation Conference, 11-14 December 2016, Washington, D.C..***

Abstract:

This paper aims to further motivate the use of simulation of complex systems in optimizing healthcare operations under uncertainty. One argument to use optimization only such as mathematical programming instead of simulation optimization in making decisions is the ability of the former to account for constraints and to consider a large number of alternatives. However, current state-of-the art of simulation optimization has opened the possibilities of using both simulation and optimization in the case of multiple performance measures. We consider the case of hospital bed allocation and give an example on how a stochastically constrained optimization via simulation can be applied. Nested Partitions are used for the search algorithm and combined with OCBA-CO, an efficient simulation budget allocation, as simulation is time-consuming.

2. **Haobin Li, Giulia Pedrielli, Min Chen, Loo Hay Lee, Ek Peng Chew, Chun-Hung Chen (2016), V-shaped sampling based on Kendall-Distance to enhance optimization with ranks.** ***In proceeding of Winter Simulation Conference, 11-14 December 2016, Washington, D.C..***

Abstract:

In the area of discrete optimization via simulation (DOvS), optimization over rank values has been of concern in computer science and, more recently, in multi-fidelity simulation optimization. Specifically, Chen et al. (2015) proposes the concept of Ordinal Transformation to translate multi-dimensional discrete optimization problems into single-dimensional problems which are simpler, and the transformed solution space is referred as ordinal space. In this paper, we build on the idea of ordinal transformation and its properties in order to derive an efficient sampling algorithm for identifying the solution with the best rank in the setting of multi-fidelity optimization. We refer to this algorithm as V-shaped and we use the concept of Kendall distance adopted in the machine learning theory, in order to characterize solutions in the OT space. The algorithm is presented for the first time and preliminary performance results are provided comparing the algorithm with the sampling proposed in Chen et al. (2015).

3. **Giulia Pedrielli, Yinchao Zhu, Loo Hay Lee, and Haobin Li (2016), Empirical analysis of the performance of variance estimators in sequential single-run Ranking & Selection: The case of Time Dilation algorithm.** ***In proceeding of Winter Simulation Conference, 11-14 December 2016, Washington, D.C..***

Abstract:

Ranking and Selection has acquired an important role in the Simulation-Optimization field, where the different alternatives can be evaluated by discrete event simulation (DES). Black box approaches have dominated the literature by interpreting the DES as an oracle providing i.i.d. observations. Another relevant family of algorithms, instead, runs each simulator once and observes time series. This paper focuses on such a method, Time Dilation with Optimal Computing Budget Allocation (TD-OCBA), recently developed by the authors. One critical aspect of TD-OCBA is estimating the response given correlated observations. In this paper, we are specifically concerned with the estimator of the variance of the response which plays a crucial role in simulation budget allocation. We propose an empirical analysis over the performance impact on TD-OCBA of several variance estimators involved in resource allocation. Their performances are discussed in the typical probability of correct selection (PCS) framework.

Conference Papers (with Abstracts)

4. **Russell Cheng, Charles Macal, Barry Nelson, Markus Rabe, Christine Currie, John Fowler, and Loo Hay Lee (2016), Simulation: The past 10 years and the next 10 years.** ***In proceeding of Winter Simulation Conference, 11-14 December 2016, Washington, D.C..***

Abstract:

The Journal of Simulation is celebrating its tenth anniversary. The journal is published by The Operational Research Society of the United Kingdom. The society is the world's oldest-established learned society catering to the Operational Research profession, and one of the largest in the world, with 2,700 members in 66 countries. This panel session brings together four leaders of the simulation community to discuss significant advances in simulation over the last ten years, major simulation issues that still need to be addressed, and what can be accomplished during the next ten years. The first four authors of this paper are the panelists and the other three are editors of the Journal of Simulation.

5. **Giulia Pedrielli, Albert Vinsensius, Ek Peng Chew, Loo Hay Lee, Alessandro Duri, and Haobin Li (2016), Hybrid order picking strategies for fashion E-commerce warehouse systems.** ***In proceeding of Winter Simulation Conference, 11-14 December 2016, Washington, D.C..***

Abstract:

E-commerce has become an increasingly relevant business in Southeast Asia. Effective warehouse management in terms of order picking is a key competitive advantage in this industry. Fashion products are particularly difficult to efficiently manage in a warehouse as they have high demand variability, with a short shelf-life and very little replenishment. In this work, after a detailed analysis of demand and physical layout of the warehouse, we propose: (1) a new pick list generation algorithm considering aspects such as work balancing and picking time minimization, and (2) a family of picking strategies accounting for possible order configurations and warehouse layout. The main contribution of this work is in the development of hybrid order picking strategies: a combination of zone-based and order-based picking with batching. Simulation is used to assess the performance of these strategies. We have found that these hybrid strategies outperform FIFO order picking often employed in industry.

6. **Giulia Pedrielli, Szu Hui Ng (2016), G-STAR: A new Kriging-based trust region method for global optimization.** ***In proceeding of Winter Simulation Conference, 11-14 December 2016, Washington, D.C..***

Abstract:

Trust region methods are an efficient technique to identify good solutions when the sampling effort needs to be controlled due to the cost of running simulation. Meta-model based applications of trust region methods have already been proposed and their convergence has been characterized. Nevertheless, these approaches keep the strongly local characteristic of the original trust region method. This is not desirable in that information generated at local level are “lost” as the search progresses. A first consequence is that the search technique cannot guarantee global convergence. We propose a global version of the trust region method, the Global Stochastic Trust Augmented Region (G-STAR). The trust region is used to focus the simulation effort and balance between exploration and exploitation. Such an algorithm focuses the sampling effort in trust regions sequentially generated by adopting an extended Expected Improvement criterion. This paper presents the algorithm and the preliminary numerical results.

Conference Papers (with Abstracts)

7. **B. Hartono, N. Indarti, K. H. Chai, and S. R. Sulistyo (2016), Knowledge management maturity and firm's performance: Firm's size as a moderating variable.** ***In proceeding of IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), 4-7 December 2016, Singapore.***

Abstract:

This follow-up study provides a conceptual refinement on the possible linkage between `knowledge management maturity' (KMM) and `organizational performance' within the setting of Indonesia construction firms. A moderating variable of `size of organization' is introduced into the analysis. An empirical study was carried out by means of a cross-sectional survey. Out of 486 questionnaires distributed, 117 were returned and deemed usable. The study found compelling evidence to support the conjecture that company size serves as a moderating variable between the two key variables. Further analysis shows a variety of contribution levels of KMM sub-dimensions towards performance. The study could benefit Indonesia construction firms by providing convincing empirical evidence on the differing efficacy of KMM across different company sizes. The practical insights could assist development of KMM strategy for respective organizations.

8. **D. Jin, X. Mo, A. M. Subramanian, K. H. Chai, and C. C. Hang (2016), Key management processes to technology transfer success.** ***In proceeding of IEEE International Conference on Management of Innovation and Technology (ICMIT), 19-22 September 2016, Bangkok, Thailand.***

Abstract:

The success rate of technology transfer from government laboratories is quite low. This paper combines findings from academic research to provide valuable managerial insights. We conclude that technology transfer factors identified so far actually relate to four management processes: project management, strategy management, innovation management, and relationship management.

9. **Shukai Chen, Min Xu, and Qiang Meng (2017), A public transit driver scheduling problem with practical meal time windows.** ***In proceeding of the 96th Annual Meeting of Transportation Research Board, 8-12 January 2017, Washington D.C..***

Abstract:

The public transit operators have to arrange the necessary meal time for drivers operating the vehicles (buses). In practice, the drivers have meal during a specific time window instead of any time slots assumed in the literature. Thus, this paper proposes a public transit driver scheduling problem with practical meal time windows (PTDSP-PMTW) by simultaneously taking the duty working rules into account. It proceeds to develop an integer linear programming model for the PTDSP-PMTW. A sequential heuristic method is also designed by decomposing a large-scale problem into two sub-problems. These two sub-problems are solved separately and combined afterwards. Finally, the case studies with various problem sizes, based on the real bus route data in Jinan city of China, are carried out to demonstrate the effectiveness of proposed model and solution method. It can be seen that the proposed integer linear programming model can provide the optimal solutions for the small-size problems, while the heuristic method is able to find a better solution with the increase of problem size.

10. **Bojian Zhou, Min Xu, and Qiang Meng (2017), A discrete day-to-day route flow dynamic model for the mixed equilibrium behavior.** ***In proceeding of the 96th Annual Meeting of Transportation***

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Research Board, 8-12 January 2017, Washington D.C..

Abstract:

This study investigates a travelers' day-to-day route flow dynamic model under a predefined market penetration of advanced traveler information system (ATIS). It is assumed that some travelers equipped with ATIS will follow the deterministic user equilibrium route choice behavior due to the complete traffic information provided by ATIS, while the other travelers unequipped with ATIS will follow the stochastic user equilibrium route choice behavior. The interaction between the two groups of travelers will result in a mixed equilibrium state. In this paper, we propose a discrete day-to-day route flow adjustment process for this mixed equilibrium behavior by specifying the travelers' route adjustment principle and adjustment ratio. The convergence of proposed day-to-day flow dynamic model to the mixed equilibrium state is rigorously demonstrated under certain assumptions on route adjustment principle and adjustment ratio. In addition, without affecting the convergence of proposed day-to-day flow dynamic model, the assumption on the adjustment ratio is further relaxed, thus making the proposed model more appealing in practice. Finally, numerical experiments are conducted to illustrate the performance of proposed day-to-day flow dynamic model.

11. Yadong Wang and Qiang Meng (2016), Slot booking data based liner container shipping demand forecasting for intercontinental shipping services. ***In proceeding of the 96th Annual Meeting of Transportation Research Board, 8-12 January 2017, Washington D.C..***

Abstract:

Liner shipping links trades between different continents in the international logistic system. This paper investigates how to forecast the realized container shipping demand before each ship voyage for the long haul leg of intercontinental shipping service based on currently arrived container slot booking data during booking period. As container shipping demand across the long haul leg significantly affects profitability of the whole service, it is a very important input for tactical and operational shipping service planning. In this paper, a novel integrated forecasting model with a self-adaptive weight average method is developed. This model is able to combine the predictions from different forecasting models such as piecewise liner regression model, autoregressive model and artificial neural network model by assigning weights to these models and work in a rolling horizon manner by dynamically adjusting their weights to reflect new trend for container shipping demand. Test results on real container slot booking data from several intercontinental services shows high forecasting precision of this model. Some applications of this demand forecasting in intercontinental service planning are also briefly introduced.

12. Qing Liu, Debabrota Basu, Talel Abdessalem, and Stéphane Bressan (2016), Top-k queries over uncertain scores. ***In proceeding of the OTM Confederated International Conferences" On the Move to Meaningful Internet Systems", 24-28 October 2016, Greece.***

Abstract:

Modern recommendation systems leverage some forms of collaborative user or crowd sourced collection of information. For instance, services like TripAdvisor, Airbnb and HungyGoWhere rely on user-generated content to describe and classify hotels, vacation rentals and restaurants. By nature of such independent collection of information, the multiplicity, diversity and varying quality of the information collected result in uncertainty. Objects, such as the services offered by hotels, vacation rentals and restaurants, have uncertain scores for their various features.

Conference Papers (with Abstracts)

In this context, ranking of uncertain data becomes a crucial issue. Several data models for uncertain data and several semantics for probabilistic top-k queries have been proposed in the literature. We consider here a model of objects with uncertain scores given as probability distributions and the semantics proposed by the state of the art reference work of Soliman, Hyas and Ben-David.

In this paper, we explore the design space of Metropolis-Hastings Markov chain Monte Carlo algorithms for answering probabilistic top-k queries over a database of objects with uncertain scores. We are able to devise several algorithms that yield better performance than the reference algorithm. We empirically and comparatively prove the effectiveness and efficiency of these new algorithms.

13. André V Moreira, Tien F Fwa, Joel RM Oliveira, and Lino Costa (2017), Coordination of user and agency costs using two-level approach for pavement management optimization. ***In proceeding of Transportation Research Board 96th Annual Meeting, 8 - 12 January 2017, Washington, D.C..***

Abstract:

Pavement maintenance and rehabilitation programming requires the consideration of conflicting objectives in order to optimize its life-cycle costs. While there are several approaches to solve multi-objective problems for pavement management systems, when user costs or environmental impacts are considered, the optimal solutions are often unpractical to be accepted by road agencies, given the dominating share of user costs in the total life-cycle costs. This paper presents a two-stage optimization methodology that considers maximization of pavement quality and minimization of agency costs as the objectives to be optimized at the pavement section level, while at the network level, the objectives are to minimize agency and user costs. The main goal of this approach is to provide decision-makers with a range of optimal solutions from which a practically implementable could be selected by the agency concerned. A sensitivity analysis and some trade-off graphics illustrate the importance in balancing all the objectives in order to obtain reasonable solutions for highway agencies. The multi-objective optimization problems at both levels are solved using genetic algorithms. The results of a case study indicate the applicability of the methodology.

CMS Research Seminars

1. Impact Analysis of Public Transport Services on the HDB Resale House Prices in Singapore, by Researcher Mr. Lu Zhaoyang (Track leader: Professor Meng Qiang)

Seminar Abstract:

The high interrelationships between public transport services and land use and development for large Asian cities including Singapore and Hong Kong is well recognized by researchers and the public because public transport is the main daily travel mode in these large cities; for example, most daily travels in Hong Kong and Singapore are made using various public transport modes (over 90% and over 55%, respectively). Such an interrelationship can be reflected by the relationship between the public transport service accessibility and property house values. This paper hence deals with the relationship between the public transport – Mass Rapid Transit (MRT), bus, Light Rail Transit (LRT), and the property house value based on the using available Housing and Development Board (HDB) flat resale data in in Singapore. It first develops the hedonic pricing models incorporating public transport services. Based on these models, this paper quantitatively shows positive impact of the public transport service on HDB re-sale house prices, which also lend the empirical support to common belief that the public transport service has a significant influence on the property house value in large Asian cities. Through the comparison of different towns in Singapore, the special characters between Singaporean property house values and public transport services are analyzed.

2. Discrete Choice Models (3)- Model Calibration and Discussions , by Researcher Ms. Zhang Yiru (Track leader: Professor Meng Qiang)

Seminar Abstract:

The viability of the Northern Sea Route (NSR) can be understood from navigation and commercial perspectives. Based on existing studies, researchers expected the NSR to become an attractive alternative to existing shipping routes. However, the real ship traffic at NSR demonstrates a different picture. In our project, the impact of opening of the NSR on the port of Singapore would be analyzed by quantifying the shift in shipping market share from traditional shipping routes to transarctic routes. The changes in shipping market share can be estimated by using discrete choice models. We believe that it is important to understand shipping companies' perspectives in order to have accurate model calibration. In this seminar, we will go through the calibration results and present our findings.

3. Towards Resilience in Water Transport Systems: A lesson Learned from Eastern Star, by Researcher Mr. Wei Xiaoyang (Track leader: Professor Meng Qiang)

Seminar Abstract:

The cruiser Eastern Star accident is a catastrophic accident in water transportation industry. The accident has originated from both natural and human-induced causes. This type of complex causation constitutes a pervasive threat to a broader range of human activities rather than the single case of Eastern Star. The present paper offers an in-depth reflection on the Eastern Star accident through analysis by conventional methods. A first objective is to identify issues in the water transport system. A comparative study is performed to find how the different methods can help to improve safety in unexpected or unknown disruptions for the water transport system, steering towards the concept of resilience as more pertinent from the perspective of safety engineering. Difficulties and challenges in the current paradigms of risk and resilience are delineated at both the operational and theoretical levels, with respect to the specificities of water transport. To articulate the relationship between resilience and risk assessment, this paper proposes a resilience-modulated risk model for integration in the practical sense.

CMS Research Seminars

4. Intelligent Control Algorithm Development for Ship Tracking in Uncertain Ocean Environments, by Researcher Dr. Yang Jiasheng (Track Leader: Associate Professor Tan Woei Wan)

Seminar Abstract:

Control algorithms with the application of intelligent technologies have been widely studied to improve the performance of ship maneuvering. In this topic, we present intelligent controller development for ship tracking control in uncertain ocean environments. First, we introduce the motivation and objective of intelligent control for ship tracking. Furthermore, we illustrate its theoretical development integrated with intelligent technologies and control theories. Finally, we make case studies to illustrate the effectiveness of intelligent controller for ship tracking. It is expected that this presentation would be useful for those researchers to contribute in ship autonomous control.

5. Intelligent systems for dynamic control in manufacturing, by Guest Speaker Dr. Wei Weng (Invited by: Associate Professor Stéphane Bressan)

Seminar Abstract:

Intelligent systems such as multi-agent systems and distributed systems are being applied to industrial engineering for the purpose of control and manufacturing. One advantage of such systems is that they are able to deal with dynamic problems such as new job arrival and unexpected machine breakdown. Another is that their online working mechanism makes it possible to solve large-size problems in real-time. This presentation introduces some of our research on such systems, the objective including achieving lower inventories, tardiness, and energy consumption in manufacturing processes. We design the multi-agent systems by dividing a complex manufacturing system into multiple independent local parts and assigning an agent to each local part. We show how the agents work interactively for achieving a common goal and what differences there might be when applying the systems to different manufacturing processes.

6. Analysis of Spatial Traffic Distribution and Ship Characteristics in the Singapore Strait, by Researcher Dr. Xie Yajuan (Track Leader: Professor Meng Qiang)

Seminar Abstract:

Spatial ship traffic distribution and ship characteristics are vital for the ship traffic management of Singapore Strait especially for those legs with high ship traffic flow. The aim of this study is to investigate spatial ship traffic distribution and large-ship characteristics in the Strait by using one-month AIS (Automatic Identification System) data with 18 billion records and ship characteristics database with 70,160 vessels. Our analyses exhibit those vessels with length more than 300m account for 5.8%, vessels between 200m and 300m 6.8%, between 100m and 200m 27.2%, and less than 100m 50.2%. The analyses of ship traffic spatial distribution show that ships passing through the legs 3W, 4W, 12E, and 13E of the Strait constitute the 42.2% of the total traffic flow. More efforts for the ship traffic management and monitoring on these four legs can be invested although the current ship traffic on these four legs are managed and monitored well.

