

# Research Statement

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I am interested in the design of algorithms, optimization models and software tools for the planning and execution of complex service systems (such as logistics and health-care systems). More precisely, my work is centered around the following topics:

## (1) Metaheuristics for Large-Scale Planning and Scheduling

Meta-heuristics are generic algorithmic paradigms that generally work well on various problems. One major concern with meta-heuristics is the effort spent on tuning and configuration. I am interested developing an intelligent workbench that empowers designers to rapidly configure and hybridize heuristics. While it is generally believed that to build a completely general search method is impossible, my goal is to explore the boundaries between what is possible and what is not with respect to the automation of the heuristic design process.

## (2) Planning and Scheduling Under Uncertainty

There are increasing opportunities and needs for designing software systems that enable decision-makers to find solutions which are not only optimized but also *robust*, in a computationally efficient manner. In a supply chain system for example, decision support systems should help enterprises make resilient plans and schedules in the environment of business risks and unforeseen threats. My interest is to design efficient (heuristic) algorithms that tradeoff between optimality and robustness.

## (3) Multi-Agent Interaction in Planning and Scheduling

Often real-world decision making involves multiple decision-makers (agents) reaching agreement on a joint set of decisions, with no party taking full control over any single decision. My interest is to design algorithms and models that allow agents to reason cooperatively and/or strategically, and tools that produce solutions that comply with global objectives while maximizing individual payoffs.

In the following, I provide an annotated bibliography of three areas of my work within the last 10 years (2002-2011).

### (1) Metaheuristics for Planning and Scheduling

I have worked on efficient methods to solve a number of *real-world* logistics and supply chain problems with companies and government agencies. In most of them, systems that embed these methods have been developed and deployed. Examples are:

- (1) Convoy movement planning and scheduling (deployed in MINDEF's system)

R. Thangarajoo, L. Agussurja, H. C. Lau (2008). A Hybrid Approach to Convoy Movement Planning in an Urban City. In Proc. *Innovative Applications of Artificial Intelligence (IAAI)*, Chicago, USA.

(2) Spare parts inventory management (deployed, winner of Spring 2006 Star Award)

Y. Song and H. C. Lau (2004), A Periodic-Review Inventory Model with Application to the Continuous-Review Obsolescence Problem, *European J. Operational Research*, 159:1, 110-120.

H. C. Lau, H. Song, See and Cheng (2006). Evaluation of Time-Varying Availability in Multi-Echelon Spare Parts Systems with Passivation, *European J. Operational Research*. 170:1, 91-105.

H. C. Lau, J. Pan, and H. Song (2010). Periodic Resource Reallocation in Two-Echelon Repairable Item Inventory Systems, *IEEE Trans. Automation Science and Engineering*, 7:3, 474-485.

(3) Health-care personnel rostering (work with Tan Tock Seng Hospital Surgery Dept):

A. Gunawan and H. C. Lau (2012). Master Physician Scheduling Problem. *Journal of the Operational Research Society*, Forthcoming

I also worked on a variety of classical hard problems (on logistics and manufacturing):

H. C. Lau, Z. Liang (2002), Pickup and Delivery Problem with Time Windows, Algorithms and Test Case Generation. *International Journal on Artificial Intelligence Tools*, 11:3, 455-472.

H. C. Lau, M. Sim and K. M. Teo (2003). Vehicle Routing Problem with Time Windows and a Limited Number of Vehicles, *European J. Operational Research*, 148:3, 559-569.

H. C. Lau, T. H Ngo and B. N. Nguyen (2006). Finding a Length-Constrained Maximum-Sum or Maximum-Density Subtree and Its Application to Logistics, *Discrete Optimization*, 3:4.

G. Feng and H. C. Lau (2008). Efficient Algorithms for Machine Scheduling Problems with Earliness and Tardiness Penalties. *Annals of Operations Research* (Special Issue on Scheduling), 159, 83-95.

Z. Zhao, S. Ge and H. C. Lau (2009). Integrated Resource Allocation and Scheduling in Bidirectional Flow Shop with Multi-Machine and COS Constraints. *IEEE Trans. Systems, Man, Cybernetics (Part C)*. 39:2, 190-200.

For problems involving uncertainty (stochasticity), my focus has been to extend search procedures for a deterministic problem to solve the variant under uncertainty effectively and efficiently.

H. C. Lau, T. Ou and M. Sim (2005), Robust Temporal Constraint Networks. Proc. *17th IEEE Conf. on Tools with Artificial Intelligence (ICTAI)* (Special Track on AI in Logistics and Supply Chain Management), 82-88, Hong Kong.

H. C. Lau, J. Li, and R. Yap (2006). Robust Controllability in Temporal Constraint Networks under Uncertainty. Proc. *18th IEEE Conf. on Tools with Artificial Intelligence (ICTAI)* Washington D.C.

N. Fu, F. Xiao and H. C. Lau (2008), Generating Robust Schedules Subject to Resource and Duration Uncertainties. In Proc. *International Conf. on Automated Planning and Scheduling (ICAPS)*, Sydney, Australia.

A. Liang, X. Wu, H. C. Lau (2009), Optimizing Service Systems based on Application-Level QoS. *IEEE Trans. Service Computing*, 2:2, 108-121.

N. Fu, H. C. Lau, P. Varakandham, and F. Xiao (2012). Robust Local Search for Solving RCPSP/max with Durational Uncertainty. *Journal of Artificial Intelligence Research*, 43, 43-86.

## (2) Platform for Supporting/Automating Heuristics Design

One major challenge of heuristic (and meta-heuristic) algorithm designers is the tedious and often adhoc task of configuring their algorithms to solve a given specific problem well. I am interested in “engineering” algorithm design, i.e. through a systematic process of *hybridization*, *visualization* and *automation*, I am interested to develop a generic decision support workbench to help algorithm designers rapidly and systematically configure algorithms. More precisely, I apply statistical and datamining methods to automatically learn the behavior of search algorithms, which in turn provide prediction of algorithm performance against different algorithm configurations.

### On hybridization:

H. C. Lau, A. Lim, and Q. Z. Liu (2000). Solving a Supply Chain Optimization Problem Collaboratively. Proc. 17th *National Conf. on Artificial Intelligence (AAAI)*, 780-785, Texas, USA.

H. C. Lau, H. Ono, and Q. Z. Liu (2002). Integrating Local Search and Network Flow to Solve the Inventory Routing Problem. Proc. 18th *National Conf. on Artificial Intelligence (AAAI)*, 9-14, Edmonton, Canada.

H. C. Lau, K. M. Ng, and X. Wu (2004). Transport Logistics Planning with Service-Level Constraints, Proc. 19th *National Conf. on Artificial Intelligence (AAAI)*, San Jose, USA, 519-524.

H. C. Lau et al. (2007). A Software Framework for Rapid Hybridization of Meta-Heuristics. *International Trans. Operations Research (IFORS 2005 Special Issue)*, 14:2.

### On Visualization:

S. Halim and H. C. Lau (2005). Visual Diagnostics for Parameter Tuning in Meta-Heuristics. In *Metaheuristics – Progress in Complex Systems Optimization (MIC 05 post-conference volume)*. Springer Operations Research / Computer Science Interfaces Book Series. 365-388, 2007.

S. Halim, R. Yap and H. C. Lau (2006). Explaining Local Search Behavior Using Viz: The Local Search Visual Analysis Suite. Proc. 19<sup>th</sup> *Annual ACM Symposium on User Interface Software and Technology (UIST)*. Montreux, Switzerland. October 2006.

S. Halim, R. Yap and H. C. Lau (2007). An Integrated White+Black Box Approach for Designing and Tuning Stochastic Local Search. Proc. 13th *International Conf. on Principles & Practice of Constraint Programming (CP)*, Rhode Island, USA.

### On Automation:

H. C. Lau and F. Xiao (2009). Enhancing the Speed and Accuracy of Automated Parameter Tuning in Heuristic Design. In Proc. 8th *Metaheuristics International Conference (MIC)*, Hamburg, Germany.

Lindawati, H. C. Lau and D. Lo (2011). Instance-based Parameter Tuning via Search Trajectory

Similarity Clustering. In Proc. *Learning and Intelligent OptimizatiON Conference (LION5)*, LNCS volume 6683, Rome, Italy.

A. Gunawan, H. C. Lau and Lindawati (2011). Fine-Tuning Algorithm Parameters using the Design of Experiments. In Proc. *Learning and Intelligent OptimizatiON Conference (LION5)*, LNCS volume 6683, Rome, Italy.

### (3) Multi-agent Planning and Scheduling

My interest is on distributed task/resource allocation and scheduling, particularly in a real-time environment in cooperative settings. For example, an armed force can be seen as a network of fighting units, where commanders at different echelons make coordinated decisions in a decentralized fashion based on situations developing in the theatre of operations but consistently with the higher HQ's intent.

H. C. Lau and L. Zhang (2003). Task Allocation via Multi-Agent Coalition Formation: Taxonomy, Algorithms and Complexity. Proc. 15th *IEEE Conf. on Tools with Artificial Intelligence (ICTAI)*, Sacramento, USA. 346-350.

H. C. Lau, G. L. Soh and W. C. Wan (2006). Dynamic Multi-Linked Negotiations in Multi-Echelon Production Scheduling Networks. Proc. *IEEE/WIC/ACM Int'l Conf. on Intelligent Agent Technology (IAT)*, Hong Kong, 498-505.

H. C. Lau, L. Agussurja and R. Thangarajoo (2008). Real-Time Supply Chain Control via Multi-Agent Adjustable Autonomy. *Computers & Operations Research* (Special Issue on Real-time Supply Chain Management), 35, 3452–3464.

D. T. Nguyen, W. Yeoh, and H. C. Lau (2012). Stochastic Dominance in Stochastic DCOPs for Risk Sensitive Applications. In Proc. *11th International Conference on Autonomous Agents and Multiagent Systems (AAMAS)*, Valencia, Spain. To appear.

I am also interested in mechanisms for resource allocation and scheduling among self-interested agents. A pilot system has been developed for a port operator in Singapore using the methods I developed.

H. C. Lau, S. F. Cheng, T. Y. Leong, J. H. Park and Z Zhao (2007). Multi-Period Combinatorial Auction Mechanism for Distributed Resource Allocation and Scheduling. Proc. *IEEE/WIC/ACM International Conference on Intelligent Agent Technology (IAT)*, San Jose, USA.

L. Agussurja and H. C. Lau (2009). The Price of Stability in Selfish Scheduling Games. *Web Intelligence and Agent Systems: An International Journal*, 9:4.

H. C. Lau, Z. Zhao, S. Ge, T. H. Lee (2011). Allocating resources in multi-agent flowshops with adaptive auctions. *IEEE Trans. Automation Science and Engineering*, 8:4, 732-743.

S. F. Cheng, J. Tajan, H. C. Lau (2011). Robust distributed scheduling via time period aggregation, *Web Intelligence and Agent Systems: An International Journal*. Forthcoming.

## Future research

I am interested to work on the following research themes:

- (1) A computationally efficient and readily deployable decision support workbench that empowers algorithm designers to configure and visualize algorithm designs to solve complex optimization problems. This work combines data mining, machine learning and algorithm design.
- (2) An emerging topic of interest is the business of moving *people* (rather than objects) in logistics. Unlike objects, people are typically motivated by self-interest, so the challenge is to coordinate flows in an uncertain environment, and to provide the right kind/level of information/incentives for people to move towards some form of system optimality. While most game theories that stem from classical economics are descriptive in nature and assume availability of unlimited computational resources, there is scope for developing methods to solve large-scale games where people are themselves the agents. Applications can be found in theme park crowd guidance, emergency response, and intelligent transportation.