# Kyle E. C. Booth

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### EDUCATION

### Ph.D., Industrial Engineering (Operations Research)

2021	University of Toronto, Ontario, Canada
	Department of Mechanical & Industrial Engineering
Thesis:	"Constraint Programming Approaches to Electric Vehicle and Robot
	Routing Problems"
Supervisor:	Prof. J. Christopher Beck

#### **B.A.Sc.**, Mechanical Engineering

2011	University of Toronto, Ontario, Canada
	Department of Mechanical & Industrial Engineering

### RESEARCH

Operations research, constraint programming, combinatorial optimization, quantum computing, vehicle routing, scheduling, hybrid algorithms.

### Journal Publications

- 7. Booth, K.E.C., O'Gorman, B., Marshall, J., Hadfield, S., & Rieffel, E., "Quantum-Accelerated Constraint Programming", *Quantum*, 5, 550, 2021.
- Booth, K.E.C., Piacentini, C., Bernardini, S., & Beck, J.C., "Target Search on Road Networks with Range-Constrained UAVs and Ground-Based Mobile Recharging Vehicles", *IEEE Robotics and Automation Letters*, 5(4), 6702-6709, 2020.
- Roshanaei, V., Booth, K.E.C., Aleman, D., Urbach, D., & Beck, J.C., "Branch-and-Check Approaches for Multi-Level Operating Room Planning and Scheduling", *International Journal of Production Economics*, 220, 107433, 2020.
- Booth, K.E.C., Chan, T.C.Y., & Shalaby, Yusuf, "A Mathematical Optimization Framework for Expansion Draft Decision Making and Analysis", *Journal of Quantitative Analysis in Sports*, 15(1), 27-40, 2019.
- Morin, M., Castro, M.P., Booth, K.E.C., Tran, T.T., Liu, C., & Beck, J.C., "Intruder Alert! Optimization Models for Solving the Mobile Robot Graph-Clear Problem", *Constraints*, 23(3), 335-354, 2018. Journal fast-track and winner of the Distinguished Paper Award at CPAIOR2018.

- 2. Booth, K.E.C., Mohamed, S.C., Rajaratnam, S., Nejat, G., & Beck, J.C., "Robots in Retirement Homes: Person Search and Task Planning for a Group of Residents by a Team of Assistive Robots", *IEEE Intelligent Systems*, 32(6), 14-21, 2017.
- 1. Booth, K.E.C., Tran, T.T., Nejat, G., & Beck, J.C., "Mixed-Integer and Constraint Programming Techniques for Mobile Robot Task Planning", *IEEE Robotics and Automation Letters*, 1(1), 500-507, 2016.

#### **Refereed Conference Publications**

- 8. Booth, K.E.C., "Constraint programming models for qubit allocation and SWAP-based routing", *Proceedings of the International Conference on Principles and Practice of Constraint Programming (CP2023)*, in press, 2023.
- Booth, K.E.C., O'Gorman, B., Marshall, J., Hadfield, S., & Rieffel, E., "Quantum-Accelerated Global Constraint Filtering", Proceedings of the International Conference on Principles and Practice of Constraint Programming (CP2020), 72-89, 2020.
- Bernal, D., Booth, K.E.C., Dridi, R., Alghassi, H., Tayur, S., & Venturelli, D., "Integer Programming Techniques for Minor-Embedding in Quantum Annealers", Proceedings of the International Conference on the Integration of Constraint Programming, Artificial Intelligence, and Operations Research (CPAIOR2020), in press, 2020.
- Senderovich, A., Booth, K.E.C., & Beck, J.C., "Learning Scheduling Models from Event Data", Proceedings of the Twenty-Ninth International Conference on Automated Planning and Scheduling (ICAPS2019), 401-409, 2019.
- Booth, K.E.C., & Beck, J.C., "A Constraint Programming Approach to Electric Vehicle Routing with Time Windows", Proceedings of the International Conference on the Integration of Constraint Programming, Artificial Intelligence, and Operations Research (CPAIOR2019), 129-145, 2019.
- Booth, K.E.C., Do, M., Beck, J.C., Rieffel, E., Venturelli, D., & Frank, J., "Comparing and Integrating Constraint Programming and Temporal Planning for Quantum Circuit Compilation", Proceedings of the Twenty-Eighth International Conference on Automated Planning and Scheduling (ICAPS2018), 366-374, 2018.
- Booth, K.E.C., Nejat, G., & Beck, J.C., "A Constraint Programming Approach to Multi-Robot Task Allocation and Scheduling in Retirement Homes", Proceedings of the International Conference on Principles and Practice of Constraint Programming, (CP2016), 539-555, 2016. Winner of the Distinguished Student Paper Award at CP2016.

 Booth, K.E.C., Tran, T.T., & Beck, J.C., "Logic-Based Decomposition Methods for the Travelling Purchaser Problem", Proceedings of the International Conference on the Integration of Constraint Programming, Artificial Intelligence, and Operations Research, (CPAIOR2016), 55-64, 2016.

### **Refereed Workshop Papers**

- Venturelli, D., Do, M., O'Gorman, B., Frank, J., Rieffel, E., Booth, K.E.C., Nguyen, T., Narayan, P., & Nanda, S., "Quantum Circuit Compilation: An Emerging Application for Automated Reasoning", *Proceedings of the Scheduling and Planning Applications Workshop (SPARK2019)*, Berkeley, USA, July 2019.
- Booth, K.E.C., Tran, T.T., Nejat, G., & Beck, J.C., "Mixed-Integer and Constraint Programming Techniques for Mobile Robot Task Planning", *Proceedings of the* Workshop on Constraint Satisfaction Techniques for Planning and Scheduling (COPLAS2016), 1-4, London, UK, June 2016.

#### **Refereed Extended Abstracts**

- 3. Booth, K.E.C., "Constraint programming approaches to electric vehicle and robot routing problems", *Constraints*, in press, 2023.
- Morin, M., Castro, M.P., Booth, K.E.C., Tran, T.T., Liu, C., & Beck, J.C., "Intruder Alert! Optimization Models for Solving the Mobile Robot Graph-Clear Problem", Proceedings of the Fifteenth International Conference on the Integration of Constraint Programming, Artificial Intelligence, and Operations Research (CPAIOR2018), Front Matter, XXVII, 2018.
- Booth, K.E.C., Tran, T.T., Nejat, G., & Beck, J.C., "Mixed-Integer and Constraint Programming Techniques for Mobile Robot Task Planning", *Proceedings of the Twenty-Second International Conference on Principles and Practice of Constraint Programming (CP2016)*, Journal Track, 883, 2016.

### WORK EXPERIENCE

 Amazon Web Services, Inc.
 San Francisco, CA, USA

 Research Scientist
 March 2022– Present

• Amazon Quantum Solutions Lab (QSL) led by Dr. Helmut Katzgraber

Universities Space Research Association @ NASA Ames Associate Scientist Mountain View, CA, USA January 2020–March 2022

- Quantum Artificial Intelligence Laboratory (QuAIL) led by Dr. Eleanor Rieffel
- Planning and Scheduling Group led by Dr. Jeremy Frank
- USRA Research Institute for Advanced Computer Science (RIACS) led by Dr. Davide Venturelli

FundThrough Inc. Advisor, Data Science & Machine Learning	Toronto, ON, Canada June 2018–August 2019
Stinger Ghaffarian Technologies @ NASA Ames Research Intern	Mountain View, CA, USA $2017$
Toromont Industries Ltd. Manager, Product Support	Toronto, ON, Canada 2011–2014
TEACHING EXPERIENCE	
University of Waterloo Lecturer, MSCI 555: Scheduling: Theory & Practice Course evaluation: 88/100 (Faculty average: 68.2/100) Instructor evaluation: 93/100 (Faculty average: 72.9/100)	2019
University of Toronto <b>Teaching Assistant</b> , MIE562: <i>Scheduling</i>	2015-2018
University of Toronto <b>Teaching Assistant</b> , MIE465: Analytics in Action	2017-2019
University of Toronto Teaching Assistant, MIE262: Operations Research I - Determ	2016–2017 inistic OR

### **PROFESSIONAL ACTIVITIES**

#### Session Chair: INFORMS2019

Program Committee Member: AIQXQIA2023, ICAPS2022, ICAPS2021, IJCAI2020, ICAPS2019, AAAI2018, PlanSOpt2018, CP2016 Doctoral Program
Invited Journal Reviewer: IEEE Transactions on Quantum Engineering, IEEE Transactions on Medical Robotics and Bionics, IEEE Access, Computers & Operations Research, Journal of Applied Soft Computing, Journal of Intelligent Social Robotics
Invited Conference Reviewer: ICRA2019, SoCS2019, SoCS2018, CPAIOR2018, ICAPS2017

### **Research Presentations & Invited Talks**

- 18. Booth, K.E.C., "Constraint programming models for depth-optimal qubit assignment and SWAP-based routing", *Twenty-Ninth International Conference on Principles and Practice of Constraint Programming (CP2023)*, Toronto, Canada, August 2023.
- 17. Booth, K.E.C., "Constraint programming models for optimal qubit assignment and SWAP-based routing", *SIAM Conference on Optimization (OP23)*, Seattle, USA, June 2023.
- Booth, K.E.C., O'Gorman, B., Marshall, J., Hadfield, S., & Rieffel, E., "Quantum Computing for Constraint Programming", *American Physical Society - March Meeting* (APS2021), Online - Virutal Conference, March 2021.

- 15. Booth, K.E.C., O'Gorman, B., Wang, Z., Venturelli, D., & Rieffel, E., "Exact and Heuristic Approaches for Qubit Routing on QCCD Trapped-Ion Quantum Computers", *International Workshop on Quantum Compilation (IWQC2020)*, Online - Virtual Conference, September 2020.
- Booth, K.E.C., Piacentini, C., Bernardini, S., & Beck, J.C., "Target Search on Road Networks With Range-Constrained UAVs and Ground-Based Mobile Recharging Vehicles", Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS2020), Las Vegas, USA, October 2020.
- Booth, K.E.C., O'Gorman, B., Marshall, J., Hadfield, S., & Rieffel, E., "Quantumaccelerated global constraint filtering", *Twenty-Sixth International Conference on Principles and Practice of Constraint Programming (CP2020)*, Louvain-la-Neuve, Belgium, September 2020.
- 12. Booth, K.E.C., Nejat, G., & Beck, J.C., "The Social Robot Routing Problem", *IN*-FORMS Annual Meeting (INFORMS2019), Seattle, Washington, USA, October 2019.
- 11. Booth, K.E.C., & Beck, J.C., "A Constraint Programming Approach to Electric Vehicle Routing with Time Windows", Sixteenth International Conference on the Integration of Constraint Programming, Artificial Intelligence, and Operations Research (CPAIOR2019), Thessaloniki, Greece, June 2019.
- Booth, K.E.C., Do, M., Beck, J.C., Rieffel, E., Venturelli, D., & Frank, J., "Comparing and Integrating Constraint Programming and Temporal Planning for Quantum Circuit Compilation", *Twenty-Eighth International Conference on Automated Planning and Scheduling (ICAPS2018)*, Delft, Netherlands, June 2018.
- Booth, K.E.C., Mohamed, S.C., Rajaratnam, S., Nejat, G., & Beck, J.C., "Robots in Retirement Homes: Person Search and Task Planning for a Group of Residents by a Team of Assistive Robots", Twenty-Eighth International Conference on Automated Planning and Scheduling (ICAPS2018) - Journal Presentation Track, Delft, Netherlands, June 2018.
- Roshanaei, V., Booth, K.E.C., Aleman, D., Urbach, D., & Beck, J.C., "Decomposition Methods for Multi-Level Operating Room Planning and Scheduling", *IISE Annual Conference & Expo (IISE2017)*, Pittsburgh, Pennsylvania, United States, May 2017.
- Booth, K.E.C., Tran, T.T., G. Nejat, & Beck, J.C., "A Constraint Programming Approach to Multi-Robot Task Allocation and Scheduling in Retirement Homes", Twenty-Second International Conference on Principles and Practice of Constraint Programming (CP2016), Toulouse, France, September 2016.
- Booth, K.E.C., Tran, T.T., G. Nejat, & Beck, J.C., "Mixed-Integer and Constraint Programming Techniques for Mobile Robot Task Planning", Twenty-Second International Conference on Principles and Practice of Constraint Programming (CP2016) -Journal Presentation Track, Toulouse, France, September 2016.

- Booth, K.E.C., Tran, T.T., G. Nejat, & Beck, J.C., "Mixed-Integer and Constraint Programming Techniques for Mobile Robot Task Planning", *Constraint Satisfaction Techniques for Planning and Scheduling*, (COPLAS2016), London, England, June 2016.
- Booth, K.E.C., "Optimization Approaches to Multi-Robot Planning and Scheduling", *Twenty-Sixth International Conference on Automated Planning and Scheduling* (ICAPS 2016) - Doctoral Consortium, London, England, June 2016.
- Booth, K.E.C., Roshanaei, V., Aleman, D., Urbach, D., & Beck, J.C., "Optimal Operating Room Allocation to Multiple Surgical Specialties Using Decomposition Methods", *Canadian Operations Research Society Annual Conference*, (CORS2016), Banff, Alberta, Canada, May 2016.
- Booth, K.E.C., Tran, T.T., & Beck, J.C., "Logic-Based Decomposition Methods for the Travelling Purchaser Problem", *Thirteenth International Conference on the Integration of Constraint Programming, Artificial Intelligence, and Operations Research* (CPAIOR2016), Banff, Alberta, Canada, May 2016.
- Booth, K.E.C., Tran, T.T., & Beck, J.C., "Decomposition Methods for the Travelling Purchaser Problem: A Computational Study", *International Symposium on Artificial Intelligence and Mathematics*, (ISAIM2016), Fort Lauderdale, USA, January 2016.

### Mentoring

All students were co-advised with Professor J. Christopher Beck.

#### Undergraduate Thesis Students (Full year)

1. Mengli Duan, Division of Engineering Science 2018–2019 Thesis: "Task Allocation Strategies for Robotic Mobile Fulfillment Systems".

#### Research Project Students (Single semester)

- 2. Kejie Zhao, Division of Engineering Science Summer 2017 Project: "Online Task Allocation Strategies for Autonomous Order Fulfillment".
- 1. Alice Nuz, Division of Engineering Science Summer 2016 Project: "Variable State Independent Decaying Sum in Logic-based Benders Decomposition".

### Honors & Awards

• Featured in UofT Engineering "Grads to Watch"	2021
• Ontario Graduate Scholarship	2019 - 2020
• Journal presentation track, ICAPS	2019
• Ontario Graduate Scholarship	2018 - 2019
• APSC Graduate Student Endowment Fund Award	2018
• Journal fast-track and Distinguished Paper Award, CPAIOR	2018
• Journal presentation track, ICAPS	2018

<ul> <li>Edmond G. Odette Scholarship</li> <li>Mart Liinve Graduate Scholarship</li> <li>Journal presentation track, CP</li> <li>Distinguished Student Paper Award, CP</li> </ul>	$17-2018 \\ 16-2017 \\ 2016 \\ 2016$
LEADERSHIP	
The Operations Research Challenge (TORCH)Toronto, Ontario,President (2018, 2019), Chief Information Officer (2017)Toronto, Ontario,	Canada .6–2019
University of Toronto Operations Research Group (UTORG)Toronto, Ontario,Co-President (2016-2017), Webmaster (2015-2017)20	Canada 15–2017
Other Attended Events	
<ol> <li>Quantum Computing Short Course, Air Force Institute of Technology (AFIT) Dayton, Ohio, USA</li> </ol>	2020
5. Summer School on Cognitive Robotics, Massachusetts Institute of Technology Cambridge, Massachusetts, USA	2017
4. Summer School on Planning and Scheduling, <i>ICAPS, King's College London</i> London, United Kingdom	2016
3. Doctoral Consortium, ICAPS, King's College London London, United Kingdom	2016
2. Master Class on Decomposition Methods, <i>CPAIOR</i> Banff, Alberta, Canada	2016
1. Summer School on Constraint Programming, ACP, University of Toronto Toronto, Ontario, Canada	2015
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## TECHNICAL SKILLS

Programming	C, C++, Python, MATLAB/Octave, R, PHP, Javascript
Scientific	Pandas, NumPy, Jupyter/Anaconda
Databases	MySQL, SQL, MongoDB, Amazon Redshift
Optimization	$\operatorname{CPLEX},$ CP Optimizer, Gurobi, SCIP, OR-Tools, MiniZinc
Inference	Scikit-learn, XGBoost, PyTorch, TensorFlow
Environments	Linux, Windows