

# Divyam Aggarwal

**Ph.D. Candidate**, Operations Research  
Department of Mechanical & Industrial Engineering (MIED)  
**Indian Institute of Technology (IIT) Roorkee**

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## RESEARCH INTERESTS

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Machine Learning in Optimization | Airlines Operations Research | Combinatorial & Discrete Optimization (Scheduling, Routing, Assignment, Resource-allocation Problems) | Mathematical Programming (Column generation, Mixed Integer Linear Programming) | Evolutionary Computation (Genetic Algorithm) | Search Heuristics

## EDUCATION

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**Indian Institute of Technology Roorkee**, Department of Mechanical & Industrial Engineering, India

**Ph.D. Candidate**, Operations Research

**Aug 2015 – July 2020 (expected)**

Dissertation: *Airline Crew Pairing Combinatorial Optimization for Large-scale & Complex Flight Networks*

Advisor(s): Dr. Dhish K. Saxena (IIT Roorkee, India) & Dr. Michael Emmerich (Leiden University, the Netherlands)

**B.Tech.**, Mechanical Engineering, *First Division* (83.2%)

**July 2011 – May 2015**

Thesis: *Optimization of Enhanced Aerodynamic Efficiency of Aircrafts With and Without Canard*

Advisor: Dr. Dhish K. Saxena (IIT Roorkee, India)

## PROFESSIONAL & RESEARCH EXPERIENCE

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**Project Associate | Ph.D. Candidate**, *Indo-Dutch Joint Research Project*

**July 2015 - Feb 2020 (expected)**

**Project:** *A Systems Approach towards Data Mining and Predictions in Airline Operations (SAPPAO)*

**Work Package:** *Airline Crew Pairing Optimization (CPO)*

**Consortium:** IIT Roorkee (India), Leiden University (the Netherlands), and General Electric (GE) Aviation (India & USA)

- Aim: To generate a set of *legal* flight sequences (*crew pairings*) for covering an airline's flight schedule at minimum-cost
- High commercial value (2<sup>nd</sup> largest cost for an airline) & scientific research value (NP-Hard Problem)
- Developed an *Airline Crew Pairing Optimization Framework (AirCROP)* [1, 5, 10]
  - Tested on large and complex flight data (multiple hub-and-spoke subnetworks and multiple crew bases) of US-based airlines
  - Validation Study: *AirCROP* generates better-cost crew schedules than the existing optimizer at GE Aviation
  - Technology Transfer to GE Aviation: *Ongoing (TRL 8-9: System Test, Launch & Operations)*
- Fundamental Contributions:
  - Developed a time-efficient constraint satisfaction approach for generation of "legal crew pairings" using customization of graph-traversal methods and its parallelization using multiprocessing [2]
  - Developed a time-efficient "initialization heuristic" for initializing large-scale airline CPOs (NP-Complete problem) [8, 11]
  - Customized search-heuristics & metaheuristic (HC, SA & GA) for solving small-scale yet complex problem [9]
  - Developed a Mathematical Programming-based Optimizer for large-scale and complex problems (integration of domain-knowledge in Column Generation to generate partial pricing networks from different regions of the search space) [7]
  - To assist the airline CPO for finding better-cost solutions in fewer iterations:
    - # Developed a "pairing archiving strategy" in which pairings are archived and re-used selectively in each CG-iteration. Such archiving strategy has been used for the first time in the paradigm of combinatorial optimization problems [6]
    - # Developed an *online-learning framework* based on Variational Graph Auto-Encoder for unsupervised learning of implicit combinatorial patterns from the optimization-data which are used 'on-the-fly' to generate better-quality pairings [4]

**Research Problem-** *Combinatorial Optimization of Composite Laminate Stacking Sequence*

**Ongoing**

**Collaborator:** *Dr. Somanath Nagendra (Principal Engineer, Pratt & Whitney, Hartford, Connecticut, USA)*

- To find the optimal stacking sequence of plies for designing composite laminates with maximum buckling strength and minimum thickness (high strength-to-weight ratio; to be used in light-weight structures such as aircraft wings, etc.)
- Involves huge number of complex function evaluations → binary decision trees used to capture linear approximations
- Customizing a GA by integrating ML techniques to learn higher-order interdependencies/design-rules from the Pareto-optimal solutions obtained during the GA-search which could be used "on-the-fly" for better and/or faster convergence

**Research Problem-** *Optimal Flight Scheduling for Aerial Surveys of US-based Locations*

**Oct 2019 - Jan 2020**

**Assisted:** *Mr. Zarif Aziz, an undergraduate student at the University of Sydney, and a research intern at Nearmap, Australia*

- Another combinatorial optimization problem, aimed at generating an optimal flight sequences for Nearmap's fleet of planes to perform aerial surveys of US-based locations at minimum operating cost
- Assisted him in developing a hierarchical optimization framework for solving an year-long scheduling problem in which:
  - a top-level optimizer decomposes the year-long schedule into fortnight schedules, and
  - each of these schedules are optimized using a customized GA, capable of handling a search space of up to a million-variables

- Developed optimizer has been validated to produce better-cost schedules than the current-practices at Nearmap

## B.Tech. Thesis

Aug 2014 - May 2015

**Title:** *Optimization for Enhanced Aerodynamic Efficiency of Aircrafts With and Without Canard*

**Test-case:** *Piaggio P-180 Avanti Italian Aircraft*

- Performed the analysis of an aircraft with-canard (a third lifting surface) for its aerodynamic superiority using ANSYS Fluent
- Carried out an iteration of shaped-design optimization for minimum drag coefficient during the cruise conditions by using wing's geometrical parameters as design variables and lift & trim flight conditions as constraints

## PATENTS/PUBLICATIONS [[GOOGLE SCHOLAR](#)] [[RESEARCH GATE](#)]

### Patent:

- [1] A patent application titled, "Airline Crew Pairing Optimization Framework for Complex Flight Networks Involving Multiple Crew Bases and Billion-Plus Variables", is being filed in Netherlands (to be filed by February 2020)

### Published:

- [2] **Aggarwal D.**, Saxena D.K., Emmerich M., Paulose S., "On Large-Scale Airline Crew Pairing Generation", *In: 2018 IEEE Symposium Series on Computational Intelligence (SSCI)*, pp. 593-600, Bengaluru, India (2018).
- [3] Mittal, S., **Aggarwal D.**, Saxena D.K., "Innovative Design of Hydraulic Actuation System for Operator Fatigue Reduction and its Optimization", *In Press, Proceedings of 2nd National Conference on Multidisciplinary Design, Analysis, and Optimization (NCMDAO)*, Bengaluru, India (2019).

### Manuscripts in Preparation/Pending Review:

- [4] **Aggarwal, D.**, Singh, Y.K., Saxena, D.K., "On Learning Combinatorial Patterns to Assist Large-Scale Airline Crew Pairing Optimization". (Manuscript under review in IJCAI 2020)
- [5] **Aggarwal D.**, Saxena D.K., Emmerich M., "AirCROP: Airline Crew Pairing Optimization Framework for Complex Flight Networks Involving Multiple Crew Bases and Billion-Plus Variables". (Abstract submitted to IFORS 2020)
- [6] **Aggarwal, D.**, Saxena, D.K., Emmerich, M., "On Exploiting Archived Variables to Assist Column Generation-based Large-Scale Airline Crew Pairing Combinatorial Optimization". (Manuscript to be submitted in Q1 2020)
- [7] **Aggarwal, D.**, Saxena, D.K., Bäck, T., Emmerich, M., "A Domain-Knowledge Inspired Column Generation Heuristic For Large-Scale Airline Crew Pairing Optimization". (Manuscript to be submitted in Q1 2020)
- [8] **Aggarwal, D.**, Saxena, D.K., Bäck, T., Emmerich, M., "On Initializing Airline Crew Pairing Optimization for Large-scale Complex Flight Networks". (Manuscript to be submitted in Q1 2020)
- [9] **Aggarwal, D.**, Saxena, D.K., Bäck, T., Emmerich, M., "Real-World Airline Crew Pairing Optimization Systems: Customized Genetic Algorithm Vs Column Generation Method". [Preprint](#). (Manuscript to be submitted in Q1 2020)

### Presentations:

- [10] 22<sup>nd</sup> IEEE Intelligent Transportation Systems Conference (ITSC) 2019, Auckland, New Zealand, Invited Talk, "Airline Crew Pairing Optimization Framework for Complex Flight Networks Involving Multiple Crew Bases and Billion Plus Variables"
- [11] 2<sup>nd</sup> National Conference on Multidisciplinary Design, Analysis, and Optimization (NCMDAO) 2019, Bengaluru, India, Abstract Presentation "Customized Initialization for Large-Scale Airline Crew Pairing Optimization Problems"
- [12] 21<sup>st</sup> World Conference of the Air Transport Research Society (ATRS) 2017, Antwerp, Belgium, Paper Presentation, "Interdependence and Integration among Components of the Airline Scheduling Process: A State-of-the-Art Review"

## FELLOWSHIPS / AWARDS / ACADEMIC ACHIEVEMENTS

- Silver medal (top 22<sup>nd</sup> out of 1,620 teams) in Kaggle's Santa's Workshop Tour 2019 optimization competition (found global-optimal solution)
- IEEE- Intelligent Transportation Systems Society (ITSS) Young Professionals Travelling Fellowship (USD 1400) to deliver talk at 22<sup>nd</sup> IEEE Intelligent Transportation Systems Conference (ITSC), held in Auckland, New Zealand, in October 2019
- Institute Assistantship as Senior Research Fellow (SRF) (from MHRD, Govt. of India) from June 2019 to Date
- Project Associate Fellowship (jointly from MEITY, Govt. of India and GE Aviation) from Aug 2015 to May 2019
- 2<sup>nd</sup> Prize in CAE Award Category, given by ANSYS INC., for the best structural analysis of an All-Terrain Vehicle in BAJA SAEINDIA 2013, a national-level ATV racing competition
- All India Rank 1800 (480,000+ registered students) in Indian Institute of Technology Joint Entrance Examination (IIT-JEE) 2011 with a success rate of 2.8%

## TEACHING ASSISTANTSHIP / ACADEMIC ACTIVITIES

- Teaching Assistant (TA) in a-
  - Masters-level course titled, "Product and Process Optimization" in Spring Semester, 2020 (25+ students)
  - UG-level course titled, "Kinematics of Machines" in Autumn Semester, 2019 (60+ students)
- Mentored 10+ undergraduate students in their internal course projects/B.Tech. final year thesis
- Assisted Mr. Zarif Aziz, an undergraduate student at the University of Sydney, Australia, in his B.E. Hons. Thesis
- Reviewer of reputed international conferences-

- 99<sup>th</sup> Annual Meeting of Transportation Research Board (TRB) 2020
- 22<sup>nd</sup> IEEE Intelligent Transportation Systems Conference (ITSC) 2019
- 10<sup>th</sup> International Conference Series on Evolutionary Multi-criterion Optimization (EMO) 2019
- Coordinated and participated in a Short-course (“Pragmatic Optimization for Practical Problem Solving”) and a Workshop (“Computational Intelligence & Its Applications”) organized jointly by IIT Roorkee & IISc Bangalore (India), and Michigan State University (USA) in Nov. 2019

## TECHNICAL SKILLS

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<i>Programming Languages</i>	C++ (Basic)   Python (Advanced)   LaTeX
<i>Python Packages</i>	NetworkX   Multiprocessing   NumPy   SciPy   Pandas   Matplotlib   TensorFlow
<i>OR Solvers</i>	Gurobi   IBM CPLEX   PuLP (Coin-OR)   SciPy.optimize.linprog
<i>OR Techniques</i>	Mathematical Programming (Column Generation, MILP, Interior-point method)   Graph-search Methods   Metaheuristics for Single- & Multi-Objective Optimization (Genetic Algorithms, GA, NSGA-II & III)   Search Heuristics (Hill Climber, HC, & Simulated Annealing, SA)
<i>ML Techniques</i>	Regression   Clustering   Bagging & Boosting   Graph Neural Networks   Auto-encoders

## RELEVANT COURSEWORK

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Operations Research | Product & Process Optimization | Modeling and Simulation | Soft Computing | Introduction to Machine Learning | Computer Systems & Programming | Lab I (Programming Lab) | Fractals and Application

## OTHERS

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<i>Languages</i>	English (fluent), French (beginner), Hindi (native speaker)
<i>Extra-Curricular</i>	Hockey   Football   Cycling   Robotics
<i>Citizenship</i>	India

## REFERENCES

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### Academia:

- *Dr. Dhish Kumar Saxena*, Associate Professor, Department of Mechanical & Industrial Engineering, IIT Roorkee, India  
Contact Info.: +91 821 861 2326; [dhishfme@iitr.ac.in](mailto:dhishfme@iitr.ac.in)
- *Dr. Michael Emmerich*, Associate Professor, Leiden Institute of Advanced Computer Science, Leiden University, Netherlands  
Contact Info.: +31 62 650 1797; [m.t.m.emmerich@liacs.leidenuniv.nl](mailto:m.t.m.emmerich@liacs.leidenuniv.nl)
- *Prof. Dr. Thomas Bäck*, Full Professor, Leiden Institute of Advanced Computer Science, Leiden University, Netherlands  
Contact Info.: +31 71 527 7108; [t.h.w.baeck@liacs.leidenuniv.nl](mailto:t.h.w.baeck@liacs.leidenuniv.nl)

### Industry:

- *Dr. Saaju Paulose*, Senior Manager, Digital Solutions, GE Aviation, Dallas/Fort Worth, Texas, USA  
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