# Gang Cao

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## Personal Summary

- PhD in Electrical Engineering, expertise in:
  - **Machine Learning**: deep learning, Bayesian learning, artificial neural network, reinforcement learning
  - **Computer Vision**: object recognition, classification, detection and tracking, image processing and analysis
  - **Advance and Intelligent Control**: model predictive control, adaptive control, optimal and robust control, system modelling, parameter identification, sensor fusion
  - **Numerical Optimization**: non-/convex optimization, stochastic optimization, evolutionary algorithm, dynamic programming
  - **Data Mining/Pattern Recognition**: data-driven modelling and prediction, un-/supervised learning, feature engineering, data engineering
- Academic publications, technical reports, open-source algorithm projects
- Strong mathematical skills in algorithm and optimization, linear and matrix algebra, multivariate calculus, probability and statistics, signal and system

## Qualification and Professional Development

- **Doctor of Philosophy (PhD)** in Electrical Engineering — January 2013 – March 2017
  School of Engineering and Advanced Technology
  Massey University, Auckland, New Zealand

  **Thesis Title: Gaussian Process based Model Predictive Control**

  **Summary**: With good learning and prediction abilities of machine learning, my PhD research developed a data-driven probabilistic model predictive control (MPC) approach to address the autonomous control issue of unknown dynamical systems. The proposed MPC algorithm is (1) ***safe*** by considering model uncertainties, (2) ***stability-guaranteed*** by using terminal constraints and sets, and (3) ***fast*** by proposing a computationally efficient optimization algorithm. The proposed machine learning based MPC is used in a hierarchical control strategy to solve the trajectory tracking problem of an unmanned quadrotor whose dynamical functions are not known. Seven international academic papers are published based on my PhD research.

- **Master of Engineering** in Control Theory & Engineering — September 2008 – April 2011
  Faculty of Automation and Information Engineering
  Xi'an University of Technology, Xi'an, China

  **Thesis Title: Research and Development of Ladle Refining Furnace Process Control System and Steel Mechanical Performance Prediction Model**

  **Summary**: This project developed a process control and data management system for the refining process in the steel-making industry. Through using AI and mathematical modelling algorithms, intelligent data-driven models are developed to predict molten steel temperature in the refining process, and final steel mechanical performance. The project won ***2012 Shaanxi Province Science and Technology Award*** and ***2012 Science and Technology Award of Higher Education of Shaanxi***. Three academic papers are published based on this project.

- **Bachelor of Engineering** in Electrical Engineering & Automation — September 2004 – June 2008
  School of Mechanical and Electrical Engineering
  Xi'an University of Architecture & Technology, Xi'an, China

## Career History

- December 2019 – Now **Applied Research Scientist** — BBC Technologies Ltd, Hamilton, New Zealand
  - AI Team Lead
  - Project and team management
  - Research and development of AI algorithms and solutions for optical sorting machines
  - Research and development of data-driven solution for packing house
  - Research resource and documentation management
  - Technical reports and presentations
  - Attending academic conference and presentation
- September 2019 – December 2019 **Research Scientist** — PlantTech Research Institute, Tauranga, New Zealand
  - Agritech technology research
- August 2017 – September 2019 **Artificial Intelligence Software Developer** — BBC Technologies Ltd, Hamilton, New Zealand
  - AI Research Lead
  - Research and development of AI algorithms and solutions for optical sorting machines
  - Research resource and documentation management
  - Technical reports and presentations
  - Attending academic conference and presentation
- March 2013 – November 2015 **Teaching Assistant** — School of Engineering and Advanced Technology, Massey University, New Zealand
  - Teaching second-year Signals & Systems and third-year Control Engineering
  - Assistant in control theory lab course (PID control of speed motor and pendulum)
- January 2009 – June 2012 **Research Assistant** — School of Automation and Information Engineering, Xi'an University of Technology, China
  - Research and development of process control and industrial automation system
  - Funding proposal, project documentation, academic publications and technical reports

## Research & Development Experience

- **AI algorithm and solution for optical sorting machine** August 2017 – Now
  - LUCAi AI Engine development, ***finalist of 2020 NZ Most Innovative Hi-Tech Agritech Solution***
  - deep learning computer vision algorithms for object recognition, detection, and segmentation
  - machine learning indirect measurement algorithms in optical sorting
  - autonomous learning and optimization algorithms for online model learning and parameter tuning
  - image process and camera calibration algorithms
  - AI and machine learning based tool development
- **AI ImageData Library development** August 2017 – Now
  - 500,000 single production images (RGB, IR, RGB-IR)
  - 100,000 hand-labeled samples
  - AI model based annotation tool development ***LabelImg+***, ***ClassifyImg***, ***SmarterSkin***
  - ImageData library pre-processing and management pipeline and tools
  - multi-spectral image fusion algorithms
- **Machine learning intelligent control** January 2013 – January 2017
  - Probabilistic data-driven modelling algorithm of unknown dynamical using machine learning
  - Fast and stability-guaranteed probabilistic intelligent control algorithm of unknown dynamical systems using machine learning and model predictive control

- Autonomous control of quadrotors using machine learning and probabilistic MPC
- Fast linear and nonlinear optimization algorithms
- Stochastic optimization algorithms using swarm intelligence
- Trajectory tracking control of quadrotors using machine learning and probabilistic MPC
- 7 international peer-reviewed publications
- Matlab toolbox "**gpmpc**":Gaussian Process Model Predictive Control
- Matlab toolbox "**cgps**": Convolved Gaussian Processes

- **Ladle furnace (LF) process control system** January 2010 – September 2012
  - ***2012 Shaanxi Provincial Science and Technology Award***
  - ***2012 Science and Technology Award of Higher Education of Shaanxi***
  - LF process control and data management system
  - Data acquisition tool using Siemens OPC server
  - Mechanical performance prediction model using artificial intelligence algorithms
  - Molten steel temperature prediction model using artificial intelligence algorithms
  - Alloy addition prediction model using mathematical modelling algorithm
  - 3 peer-reviewed publications
- **Monocrystalline refining process control system** August 2009 – December 2009
- **Tunnel boring machine (TBM) PLC control system upgrade** July 2008 – October 2008

## Computer Skill

- PyTorch, TensorFlow, Darknet, OpenCV, Keras, TFLearn, Scikit-learn, SciPy, CUDA
- Python, Matlab, C, C++, Shell, SQL; Linux; Git, SVN; VS Code, Qt, Vim; LaTeX

## Selected Awards

- Finalist of 2020 NZ Hi-Tech Award in Most Innovative Hi-Tech Agritech Solution (LUCAi project)
- 2018 Tomra Value In Practice (VIP) Award
- 2012 Shaanxi Provincial Science and Technology Award
- 2012 Science and Technology Award of Higher Education of Shaanxi

## Peer Review Activity

- Information Sciences (Since 2019)
- Electronics Letters (Since 2019)
- IET Image Processing (Since 2019)
- IET Computer Vision (Since 2019)
- IET Control Theory and Application (Since 2018)
- Journal of Intelligent and Robotic Systems (Since 2017)
- International Journal of Intelligent Systems Technologies and Applications (Since 2016)

## Hobbies and Interests

- Cycling and Running
- Drone and DonkeyCar

## Selected Publications

- **Gang Cao**, "Gaussian Process based Model Predictive Control," Ph.D. dissertation, Massey University, New Zealand, 2017
- **Gang Cao**, "LF Refining Process Control System and Forecasting Model Research of Steel Mechanical Property," Master dissertation, Xi'an University of Technology, China, 2011 [in Chinese]

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- **Gang Cao**, Edmund M-K Lai, and Fakhrul Alam, "Enhanced particle swarm optimization algorithms for multiple-input multiple-output system modelling using convolved Gaussian process models," *International Journal of Intelligent Systems Technologies and Applications*, Vol. 17, No. 3, 2018 [published online]
- **Gang Cao**, Edmund M-K Lai, and Fakhrul Alam, "Gaussian process model predictive control of unmanned quadrotor helicopter," *Journal of Intelligent and Robotic Systems* Vol. 88, No. 1, 2017, pp. 147-162
- **Gang Cao**, Edmund M-K Lai, and Fakhrul Alam, "Gaussian process model predictive control of unknown nonlinear systems," *IET Control Theory & Applications* Vol. 11, No. 5, 2017, pp. 703-713
- Qiang Li, **Gang Cao**, Jiang Li, and Ning Wang, "Process estimated temperature model of molten steel in LF based on BP neural network combined with expert system," *Applied Mechanics and Materials*, vol.48, 2011, pp. 853–857.
- Qiang Li, **Gang Cao**, and Zhi-Feng Gou, "Research and implementation of Level 2 process control system for LF," *Gongye Jiare*, vol.40, 2011, pp.34–37 [in Chinese]
- Qiang Li and **Gang Cao**, "Forecasting model for the molten steel temperature in refining furnace based on artificial neural network and expert system," *Heavy Machinery*, vol.6, 2010,pp.22–25 [in Chinese]

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- **Gang Cao**, Edmund M-K Lai, and Fakhrul Alam, "Gaussian process model predictive control of unmanned quadrotors," in *International Conference on Control, Automation and Robotics (ICCAR)*, IEEE, 28-30 April 2016, pp. 200-206
- **Gang Cao**, Edmund M-K Lai, and Fakhrul Alam, "Gaussian process based model predictive control for linear time varying systems," in *International Workshop on Advanced Motion Control (AMC Workshop)*, IEEE, 22-24 April 2016, pp. 251-256
- **Gang Cao**, Edmund M-K Lai, and Fakhrul Alam, "Particle swarm optimization for convolved Gaussian process models," in *International Joint Conference on Neural Networks (IJCNN)*, IEEE, 6-11 July 2014, pp.1573–1578
- **Gang Cao** and Edmund M-K Lai, "Dependent Gaussian process models for MIMO nonlinear dynamical systems using PSO," in *Proceedings of 20th Electronics New Zealand Conference*, 5-6 September 2013, pp.3–7

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- **Gang Cao**, "Technical report: Comparative Analysis of PatchDehydration Performance using High-Resolution and Low-Resolution Images," Tomra Fresh Food, Hamilton, New Zealand, *Tech. Rep.*, 2021
- **Gang Cao**, "Technical report: PatchDehydration: From PatchDehydration Model to SmarterSkin Model," Tomra Fresh Food, Hamilton, New Zealand, *Tech. Rep.*, 2021
- **Gang Cao**, "Technical report: PatchDehydration: artificial intelligence dehydrated blueberry detection model using deep learning and an edge-detection-guided maximal-rectangle boundingbox proposal algorithm," BBC Technologies Ltd, Hamilton, New Zealand, *Tech. Rep.*, 2020
- **Gang Cao**, "Technical report: Artificial Intelligence Blueberry's Calyx Recognition and Detection Model using YOLO," BBC Technologies Ltd, Hamilton, New Zealand, *Tech. Rep.*, 2018
- **Gang Cao**, "Technical report: How to use the YOLO based calyx recognition and detection network," BBC Technologies Ltd, Hamilton, New Zealand, *Tech. Rep.*, 2018
- **Gang Cao**, "Technical report: Blueberry's calyx recognition and detection using Faster R-CNN deep learning neural networks," BBC Technologies Ltd, Hamilton, New Zealand, *Tech. Rep.*, 2017
- **Gang Cao**, "Technical report: Deep convolutional neural networks based blueberry calyx recognition and detection," BBC Technologies Ltd, Hamilton, New Zealand, *Tech. Rep.*, 2017

- **Gang Cao**, "Technical report: Modelling and Control of Unmanned Quadrotor Helicopters," Massey University, Auckland, New Zealand, *Tech. Rep.*, 2015

## Selected Presentations and Talks

- **AI based Fruit Counting and Tracking**, Tomra AI meeting, Tomra Fresh Food, Hamilton, 2021
- **TOMRA Fresh Food AI Research**, Tomra AI meeting, Tomra Fresh Food, Hamilton, 2021
- **BBC Technologies AI Leadership Introduction**, Tomra AI meeting, BBC Technologies, Hamilton, 2020
- **Dehydrated Blueberry Recognition using Deep Learning Computer Vision**, Neural Network Compac Meeting, BBC Technologies Ltd, Hamilton, 2018
- **Artificial Intelligence for Blueberry Sorting – An Update of AI Research at BBC Technologies Ltd**, RnD Meeting Presentation, BBC Technologies Ltd, Hamilton, 2018
- **Artificial Intelligence for Fruit Sorting – A Demonstration of AI Projects at BBC Technologies Ltd**, BBC AI Demonstration Presentation, BBC Technologies Ltd, Hamilton, 2018
- **Artificial Intelligence for Sorting and Grading**, Sales Meeting Presentation, BBC Technologies Ltd, Hamilton, 2018
- **Blueberry's Calyx Recognition and Detection Using Artificial Intelligence**, RnD Meeting Presentation, BBC Technologies Ltd, Hamilton, 2017
- **Gaussian Process Model Predictive Control of Unmanned Quadrotors**, The 2nd International Conference on Control, Automation and Robotics, Hong Kong, 2016
- **Gaussian Process based Model Predictive Control for Linear Time Varying Systems**, IEEE International Workshop on Advanced Motion Control, Auckland, 2016
- **Enhanced PSO Algorithms for CGP Model Learning**, Massey University Post Graduate Seminar, Palmerston North, 2015
- **Particle Swarm Optimization for Convolved Gaussian Process Models**, IEEE World Congress on Computational Intelligence, Beijing, 2014
- **Dependent Gaussian Process Models for MIMO Nonlinear Dynamical Systems using PSO**, NZ Electronics Conference (ENZCon), Auckland, 2013
- **LF Process Control System**, XAUT Research Seminar, Xi'an University of Technology, Xi'an, 2012