Lai Yan Kai

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Education

- **National University of Singapore** — Singapore
  Bachelor of Engineering; CAP: 4.80, Highest Distinction — *Aug 2015 - July 2019*
  Robotics Specialisation
- **National University of Singapore** — Singapore
  Doctor of Philosophy; CAP: 4.88 — *5 Aug 2019 - 31 July 2024*
  Doctoral Dissertation: *Rapid Vector-based Any-angle Path Planning with Non-convex Obstacles*

Experience

- **National University of Singapore** — Singapore
  Lecturer — *July 2024 - Present*
  - **EE4308 Autonomous Robot Systems**: Part 2 Lecturer, and projects and assignments. Mobile Robot Navigation, Robot Operating System (ROS), and Simultaneous Localization and Mapping (SLAM).
  - **EE4312 Artificial Neural Networks**: Part 2 Lecturer, and projects and assignments. Convolutional, residual, and recurrent networks, and generative models.
  - **EE4311 Fuzzy Logic and Neuro Fuzzy Systems**: Part 2 Lecturer, and projects and assignments. Type 2 Sugeno and Mamdani systems. Adaptive network-based fuzzy inference system (ANFIS), online genetic algorithms and particle swarm optimization for simulated fuzzy logic controllers.
  - **EE3305 Robotic System Design**: Part 2 Lecturer, and projects and assignments. Robotics Operating System (ROS).
  - **EE2023 Signals and Systems**: Course Coordinator.
  - **Path Planning Visualiser**: Work in progress. Offline visualization tool for various path planning algorithms. Available at https://laiyankai.github.io/PlannersJS/laiyankai.github.io/PlannersJS.
- **National University of Singapore** — Singapore
  Graduate Assistant — *Aug 2019 - July 2024*
  - **EE4308 Autonomous Robot Systems**: Redesigned some lecture slides for better illustrations. Wrote project manuals and troubleshooting manuals (remote machine, installation of software). Created template code in all projects to lower learning curve for students.
  - **EE3305 Robotic System Design**: Wrote troubleshooting manuals (remote machine, installation of software). Improved template code in Project 2 to fix bugs and lower learning curve for students.
  - **Path Planning Visualiser**: Created an offline Javascript tool to visualise 2D path planning on occupancy grids. Algorithms include Depth and Breadth-first searches, A*, Dijkstra and Greedy Best-first Search. Available at laiyankai.github.io/UniformPlanners. Currently working on a more advanced tool with more algorithms and benchmarks with students.
  - **TEE4305 Introduction to Fuzzy Neural Systems**: Redesigned some lecture slides for better illustrations. Designed Google Colab Python notebooks for continuous assessment.
  - **Undergraduate Capstone Projects on NAO6 Humanoid Robot**: For academic year 20/21, the mentored team implemented object detection with YOLO object detection algorithm and human pose recognition using Azure Kinect. For academic year 22/23, teams implement Visual Simultaneous Localisation and Mapping for the NAO6 Humanoid.
  - **Undergraduate Research Opportunities Program**: Mentored students implemented Visual Simultaneous Localisation and Mapping on a Turtlebot3 Burger with the Raspberry Pi Camera by integrating code, libraries and hardware.
- **National University of Singapore** — Singapore
  Outreach — *Aug 2019 - July 2024*
  - **Singapore Science and Engineering Fair**: Mentored team was awarded Silver in Singapore Science and Engineering Fair, and was given the opportunity to represent Singapore in International Science and Engineering Fair.
- **Dunman High School** — Singapore
  Robotics Instructor — *Dec 2012 - Sep 2019*
  - **Founder and Mentor**: Founded in Dec 2012 and mentored students after graduating. Mostly volunteer work.
  - **Singapore Robotics Games, Picomouse**: Mentored teams to calibrate and tune a robot to navigate an unknown structured maze.
    - 2018: 3rd place
    - 2017: 1st place
    - 2016: 2nd place
    - 2015: 1st place
    - 2014: 1st place
    - 2013: 1st, 2nd places
  - **Singapore Amazing Flying Machine Competition, Category C1/C** : Primarily responsible for infrastructure, presentation, and theory for the rolling-takeoff category. Responsible for seven consecutive years of first-place presentation awards from 2013 to 2019.

    - 2019: Championship (1st), Presentation (1st), Theory of Flight (2nd).
    - 2018: Championship (1st, 2nd), Performance (1st, 2nd), Presentation (1st).
    - 2017: Championship (1st, 2nd), Performance (1st, 2nd), Presentation (1st, 2nd), Theory of Flight (2nd).
    - 2016: Championship (2nd, 3rd), Performance (2nd, 4th), Presentation (1st), Creativity (2nd), Theory of Flight (3rd).
    - 2015: Championship (1st), Presentation (1st, 2nd), Performance (3rd)
    - 2014: Presentation (1st).
    - 2013: Presentation (1st).
  - **National Robotics Competition, Senior Category** : Responsible for robot design using LEGO, sourcing of LEGO parts, programming, presentation and theory. A LEGO manual and some Javascript tools were created for this role.
    - 2018: Championship (1st, 2nd), Performance (1st, 2nd), Engineering Design (1st), Programming (1st), Content (3rd). One finalist for performance. **Represented Singapore** in World Robotics Olympiad.
    - 2017: Teamwork (1st), Engineering Design (2nd), Programming (3rd).
    - 2016: Presentation (1st, 2nd), Research (1st), Spring Award. 3 teams performance finalists.
    - 2015: Entrepreneur (3rd), one finalist for performance.
    - 2014: Presentation (1st, 2nd), Learning Journey (1st), Learning Journal (1st), Booth (1st, 3rd), Research (3rd), one finalist for performance.
    - 2013: Learning Journey (1st), Booth Design (2nd).
  - **Javascript calibration tools** : Created some offline Javascript tools for colour sensor calibration and quintic trajectory generation for National Robotics Competition. Available at laiyankai.github.io

Projects

- **A Comprehensive Network Integrating Genetic and Genomic Data to Understand the Mechanism of Cellular Differentiation**: Final year project that combines LIMMA, SAM and GC-RMA to better identify genomic expressions. Tech: R, Matlab (May, 2019)

Publications

- **Conference Paper: Development and Analysis of an Improved Prototype within a Class of Bug-based Heuristic Path Planners (2021)**: Path planning relies on free-space expansions. The Ray Path Finder (RPF) and RayScan algorithms solve the Euclidean shortest path problem. Both rely on free-space expansions by basing on the bug concept, which is to cast rays to a desired target and trace any obstructing contours. By combining heuristic costs, an optimal path can be found. In this work, a new and insightful analysis aiding future designs of this class of heuristic bug-based planners is provided. A rigorous proof for a modified Pledge in RPF is included. A corrected RPF prototype is designed to compare with Anya, a state-of-the-art free-space planner. The computational advantages of the heuristic bug-based planners can offer are provided.
- **Rejected Paper: R2: Heuristic Bug-Based Any-angle Path-Planning using Lazy Searches. (July 2022)**:
- **Journal Paper: R2: Optimal vector-based and any-angle 2D path planning with non-convex obstacles. (Dec 2023)**: A novel vector-based path planner, R2 (R in two dimensions), is introduced in this paper. R2 is optimal and online, returning any-angle paths by applying heuristic costs to vector-based searches. R2 delays line-of-sight checks to expand the most promising path that has the least detours from the start and goal points. As delayed checks can cause severe path cost underestimates, R2 infers the smallest known convex hull, the best hull, of obstacles while moving around them. To construct the best hull, phantom points are introduced, which are imaginary turning points lying on non-convex corners to guide future searches. Tracing rules are introduced to ensure that the estimated path cost from the best hull increases admissibly and monotonically between queues to the open-list. The distance between the start and goal points have little impact on R2's performance when compared to the number of line-of-sight checks that collide with obstacles. While having an exponential search time in the worst case with respect to the number of collided line-of-sight checks, R2 is much faster than state-of-the-art when the optimal path is expected to turn around few obstacles, especially on large maps with few disjoint and non-convex obstacles. Available at doi.org/10.1016/j.robot.2023.104606
- **Journal Paper (Under Review): Evolving R2 to R2+: Optimal, Delayed Line-of-sight Vector-based Path Planning (May 2024)**: A vector-based any-angle path planner, R2, is evolved in to R2+ in this paper. By delaying line-of-sight, R2 and R2+ search times are largely unaffected by the distance between the start and goal points, but are exponential in the worst case with respect to the number of collisions during searches. To improve search times, additional discarding conditions in the overlap rule are introduced in R2+. In addition, R2+ resolves interminable chases in R2 by replacing ad hoc points with limited occupied-sector traces from target nodes, and simplifies R2 by employing new abstract structures and ensuring target progression during a trace. R2+ preserves the speed of R2 when paths are expected to detour around few obstacles, and searches significantly faster than R2 in maps with many disjoint obstacles. Available at https://arxiv.org/abs/2405.04952
- **Doctoral Dissertation: Rapid Vector-based Any-angle Path Planning with Non-convex Obstacles. (July 2024)**: Vector-based algorithms are novel algorithms in optimal any-angle path planning that are motivated by bug algorithms, bypassing free space by directly conducting line-of-sight checks between two queried points, and searching along obstacle contours if a check collides with an obstacle. The algorithms outperform conventional free-space planners such as A* especially when the queried points are far apart. The thesis presents novel search methods to speed up vector-based algorithms in non-convex obstacles by delaying line-of-sight checks. The "best hull" is a notable method that allows for monotonically increasing path cost estimates even without verifying line-of-sight, utilizing "phantom points" placed on non-convex corners to mimic future turning points. Building upon the methods, the algorithms R2 and R2+ are formulated, which outperform other vector-based algorithms when the optimal path solution is expected to have few turning points. Other novel methods include a novel and versatile multi-dimensional ray tracer for occupancy grids, and a description of the three-dimensional angular sector for future works.

Honors and Awards

- IEEE Control Chapter Prize - July, 2019
- ST Engineering Prize (Undergraduate, Year 4) - July, 2019
- IEEE Eta Kappa Nu Life Member - July, 2018
- ST Engineering Prize (Undergraduate, Year 2) - July, 2017
- SAF CGO Letter of Recommendation - July, 2014