

# Self-aware drone swarm for transportation

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## 1 Motion planning (Estimation, control, and planning )/Path planning

**General definition** The fundamental problem of motion planning is obtaining a collision-free path from start to goal for a robot that moves in a static and totally known environment that consists of one or many obstacles Mohanan and Salgoankar (2018)[1]. Motion planning, also **path planning** (also known as the navigation problem or the piano mover's problem) is computational problem to find a sequence of valid configurations that moves the object from the source to destination <sup>1</sup>.

**Approaches in static environment** For wikipedia see <sup>2</sup> section Algorithms

**Sampling-based** The idea of the sampling-based planning is to random sample the configuration space  $C$  and classify the samples as free or non-free using collision detection. The free samples are stored in a roadmap and the nearest free samples are connected by edges. Then, the path in the roadmap corresponds to a motion in the workspace Spurny et al. (2019).

footnote <sup>3</sup>.

- **Probabilistic Roadmaps (PRM)**: LaValle (1998) which is used in Spurny et al. (2019)
- **Rapidly Exploring Random Trees (RRT)**: Kavraki et al. (1996) which is used in Spurny et al. (2019) The basic RRT builds a configuration tree  $T$  rooted at initial state  $q_{init}$  by sub-sequence adding of new reachable feasible configuration. In each iteration of the tree construction, a configuration  $q_{rand}$  is randomly sampled from the whole configuration space  $C$  and its nearest neighbor  $q_{near} \in T$  in the tree is found. The configuration  $q_{near}$  is then expanded using the motion model to obtain new configurations reachable from  $q_{near}$ . The new positions are obtained by applying control inputs to the motion model over time  $\Delta t$ . From these configurations, the nearest one towards  $q_{rand}$  is selected and added to

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<sup>1</sup>[https://en.wikipedia.org/wiki/Motion\\_planning](https://en.wikipedia.org/wiki/Motion_planning)

<sup>2</sup>[https://en.wikipedia.org/wiki/Motion\\_planning](https://en.wikipedia.org/wiki/Motion_planning)

<sup>3</sup><http://planning.cs.uiuc.edu/ch5.pdf>

the tree. The algorithm terminates if the goal configuration is approached within a given distance or if the maximum number of iterations is reached.

- Guided RRT: Vonasek et al. (2009) in which the guided path (a path that ) The guiding path can be computed as a simple geometric path, e.g. using **Voronoi diagram** or **Triangular-based** methods.
- Transition-based RRT Spurny et al. (2019)[19]

LaValle (1998) which is used by It also uses Spurny et al. (2019)[15][16][17][18][19]

**Approaches for dynamic environment** Dynamic environment means obstacles movements etc Mohanan and Salgoankar (2018) is a survey and the list of the approaches are taken out of it. Masehian and Katebi (2007)

**Artificial potential fields (APF)** Based on force field idea where the goal is the attractor and the obstacles are repulsive forces Mohanan and Salgoankar (2018); Baydoun et al. (2019).

**Accessibility graph (AG)**

**Configuration space (CS), state time space (STS)**

**Velocity based motion planning**

**A thousand more** see Mohanan and Salgoankar (2018)

**With a simple camera and an IMU** Loianno et al. (2017)

**Collision avoidance**

**In 3d environment** Wang et al. (2015)

## 1.1 Trajectory Tracking / tracking control

Tagliabue et al. (2017) has used Kamel et al. (2016) and Kamel et al. (2017). see footnote <sup>4</sup>

## Algorithms

**Using both a linear model predictive controller (MPC) and non-linear state feedback**

<sup>4</sup>[https://www.researchgate.net/publication/320913735\\_Trajectory\\_tracking\\_in\\_quadrotor\\_platform\\_by\\_using\\_PD\\_controller\\_and\\_LQR\\_control\\_approach](https://www.researchgate.net/publication/320913735_Trajectory_tracking_in_quadrotor_platform_by_using_PD_controller_and_LQR_control_approach)

**PID control for disturbance rejection** To make a drone follow its trajectory See footnote URL<https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8741829>

## 1.2 Disturbance rejection

**In trajectory tracking** See footnote <sup>5</sup>

## 1.3 Stability

**Position and altitude control** Nascimento and Saska (2019)

**Quadrotors** Quadrotors are underactuated systems by design, since they possess six degrees of freedom but only four actuating motors (lift-generating propellers). The system is categorized as inherently unstable in its open-loop operation due to the underactuated property but its stability can be achieved via closed-loop control<sup>6</sup>

## 1.4 State estimation

**Definition** to achieve state estimation and localization relative to a scene.

**Approches/Algorithms** It deals with techniques such as Kolman filter. See footnote <sup>7</sup>.

**UKF**

## Simultaneous Localization and Mapping (SLAM)

**Visual-inertial** Nikolic et al. (2014) Bloesch et al. (2015) See footnote <sup>8</sup>

## 1.5 General

Powers et al. (2015) Four forces of flight

- Thrust vs Drag (To move the drone forward)
- Lift vs Weight (To lift the drone up)

Six degrees of freedom

- **Pitch:** Orientation along the backward-forward axis

<sup>5</sup><https://journals.sagepub.com/doi/abs/10.1177/0142331220909003>

<sup>6</sup>[https://www.researchgate.net/post/Why\\_are\\_quadrotors\\_inherently\\_unstable](https://www.researchgate.net/post/Why_are_quadrotors_inherently_unstable)

<sup>7</sup><https://www.mdpi.com/2504-446X/3/1/19>

<sup>8</sup><https://www.sciencedirect.com/science/article/pii/S2405896317302859>

- **Roll:** Orientation along the left-right axis
- **Yaw:** Orientation along the up-down axis

Components of a drone

- **Telemetry module:** to receive back information from the drone

## 2 Auto pilot

**Companies** Such as Pixhawk auto pilot <sup>9</sup>

## 3 Sensors

**Altitude meter** <http://downloads.hindawi.com/journals/mpe/2013/587098.pdf> [https://www.researchgate.net/publication/309486306\\_Altitude\\_Control\\_of\\_a\\_Quadcopter](https://www.researchgate.net/publication/309486306_Altitude_Control_of_a_Quadcopter)

**For obstacle detection the such sensor may contribute** <https://www.dronezon.com/learn-about-drones-quadcopters/top-drones-with-obstacle-detection-collision-av>

**Exteroceptive sensors**

- **Stereo Vision:**
- **Time-of-Flight:** [https://en.wikipedia.org/wiki/Time-of-flight\\_camera](https://en.wikipedia.org/wiki/Time-of-flight_camera)
- **Lidar:**
- **Infra-red:**
- **ultra-sound(Sonar):**
- **Monocular Vision:**

**Proprioceptive sensors** <https://3dinsider.com/drone-sensors/>

**Accelerometer** : Measures acceleration in all 3 axis

**Gyroscope** : Measure angular rate in all 3 axis

**Compass** : Determines heading

**GPS** : Determines position based on GPS/GLONASS satellites

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<sup>9</sup><https://pixhawk.org/>

**Power module** : Power supply to flight controller

**mmWave sensor**

**IMU** : Inertial measurement unit [https://en.wikipedia.org/wiki/Inertial\\_measurement\\_unit](https://en.wikipedia.org/wiki/Inertial_measurement_unit)

**MEMS inertial sensors** See footnote for their application<sup>10</sup>

**Force sensors** : Such as this company <sup>11</sup> Always consider sensor fusions

## 4 Social

**People** Follow the url [https://scholar.google.it/citations?view\\_op=search\\_authors&hl=en&mauthors=label:mavs](https://scholar.google.it/citations?view_op=search_authors&hl=en&mauthors=label:mavs) to see people interested in MAV.

**giuseppe-loianno** <https://engineering.nyu.edu/faculty/giuseppe-loianno> with thousands of citations in this field and he also is an expert in sensor fusion.

**Byung Joon Lee** [https://scholar.google.it/citations?hl=en&user=aH-8urcAAAAJ&view\\_op=list\\_works&citft=1&citft=2&citft=3&email\\_for\\_op=mohammad.rahmani.xyz%40gmail.com&gmla=AJsN-F44tTmgP\\_9kMnERit5P20t03MYngw\\_9qmDB904GX0B07sXFFGoUhMC6yh8sDwCgsw4oinKq2ljx02YbwB2aCBCteHQ1iy9XzFBNYCV3Sns-MylEhG\\_BAr8GXXGWZ5-sY2\\_1Lla6jboK51H\\_6qvayyc9RJCa-kMYAsFVkWwL20AsBpJwH8LRJ00gzcQ0T96WiKX5IV4iufgari.ZHz5-pVDhfhYAYfYbTN01axLY12wXx0-2Q1nhWKmm\\_i14YH3C9J\\_UwhicmXuQun-3MJHG5EH3QJI5EsJWUz7\\_cB7gyf0kK5kTc-9fAw0SW7XCG85Kgabtza1v8VAX1PrdUUpHy5gimBhXA](https://scholar.google.it/citations?hl=en&user=aH-8urcAAAAJ&view_op=list_works&citft=1&citft=2&citft=3&email_for_op=mohammad.rahmani.xyz%40gmail.com&gmla=AJsN-F44tTmgP_9kMnERit5P20t03MYngw_9qmDB904GX0B07sXFFGoUhMC6yh8sDwCgsw4oinKq2ljx02YbwB2aCBCteHQ1iy9XzFBNYCV3Sns-MylEhG_BAr8GXXGWZ5-sY2_1Lla6jboK51H_6qvayyc9RJCa-kMYAsFVkWwL20AsBpJwH8LRJ00gzcQ0T96WiKX5IV4iufgari.ZHz5-pVDhfhYAYfYbTN01axLY12wXx0-2Q1nhWKmm_i14YH3C9J_UwhicmXuQun-3MJHG5EH3QJI5EsJWUz7_cB7gyf0kK5kTc-9fAw0SW7XCG85Kgabtza1v8VAX1PrdUUpHy5gimBhXA)

**Vijay kumar** Scholar [https://scholar.google.com/citations?hl=en&user=FU0EBDUAAAAJ&view\\_op=list\\_works&sortby=pubdate](https://scholar.google.com/citations?hl=en&user=FU0EBDUAAAAJ&view_op=list_works&sortby=pubdate)

**Daniel Mellinger** <https://scholar.google.com/citations?user=hI8nho4AAAAJ&hl=en>

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<sup>10</sup><https://ieeexplore.ieee.org/document/4610859>

<sup>11</sup><https://www.tekscan.com/products-solutions/embedded-force-sensors>

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