PLANNING AND NAVIGATION (AR): SENSE AND AVOIDANCE SYSTEM, PATH PLANNING, AUTONOMOUS CONTROL, SWARMING.

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PLANNING AND NAVIGATION

Planning and navigation in aerial robotics encompasses the methods and systems that allow unmanned aerial vehicles (UAVs) to move from one point to another efficiently, safely, and autonomously. This involves real-time decision-making based on sensor data, mission objectives, environmental conditions, and inter-UAV coordination in swarms.

- Key pillars include:
  - Sense and Avoidance
  - Path Planning
  - Autonomous Control
  - Swarming Algorithms

CORE CONCEPTS

A. Sense and Avoidance (SAA)

- These systems detect obstacles (static or dynamic) and navigate around them. Techniques include:
  - Passive sensors: Cameras, stereo vision
  - Active sensors: LIDAR, radar, ultrasonic, infrared
  - Fusion algorithms: SLAM (Simultaneous Localization and Mapping), Kalman filters

B. Path Planning

- Involves calculating optimal routes based on:
  - Terrain and obstacle maps
  - Mission constraints (e.g., energy, time, threats)
  - Algorithms: A*, D*, RRT (Rapidly-exploring Random Tree), PRM (Probabilistic Roadmaps)

CORE CONCEPTS

C. Autonomous Control

Refers to onboard decision-making without human intervention using:

- **PID, LQR, MPC control strategies**
- **State estimation via IMU + GPS/GNSS fusion**
- **AI-enhanced feedback loops**

D. Swarming

Enables multiple UAVs to coordinate in tasks such as search and rescue, surveillance, or delivery:

- **Communication via mesh networks**
- **Behavioral models: Boids, potential fields**
- **Decentralized vs. centralized control**

DJI MATRICE 300 RTK

Sense and Avoidance:
- 6-directional obstacle sensing (visual + infrared)
- Redundant vision sensors with AI-enhanced flight safety

Path Planning:
- DJI Pilot 2 supports auto-grid missions and obstacle-aware pathing
- RTK for centimeter-level waypoint accuracy

Autonomous Control:
- Dual-IMU + barometer fusion for state estimation
- AI Spot Check feature uses machine learning for repeatable inspections

Swarming:
- Limited swarming; focus on single-unit precision missions

MQ-9 REAPER

Sense and Avoidance:

- Equipped with radar altimeter, Synthetic Aperture Radar (SAR), and forward-looking IR sensors
- Pilot-assisted deconfliction with layered airspace rules

Path Planning:

- Pre-programmed GPS flight plans with real-time dynamic rerouting
- Tactical control software supports terrain-following navigation

Autonomous Control:

- Semi-autonomous: requires human-in-the-loop for rules of engagement
- Autopilot handles altitude, heading, and waypoint transitions

Swarming:

- Not designed for swarming, but supports coordinated operations with other UAVs and manned aircraft

PARROT ANAFI AI

Sense and Avoidance:

- 48 MP sensor-based vision with embedded neural net for obstacle detection
- Real-time terrain and building modeling

Path Planning:

- AI-optimized photogrammetry paths
- Real-time waypoint editing through FreeFlight 7 and Pix4D

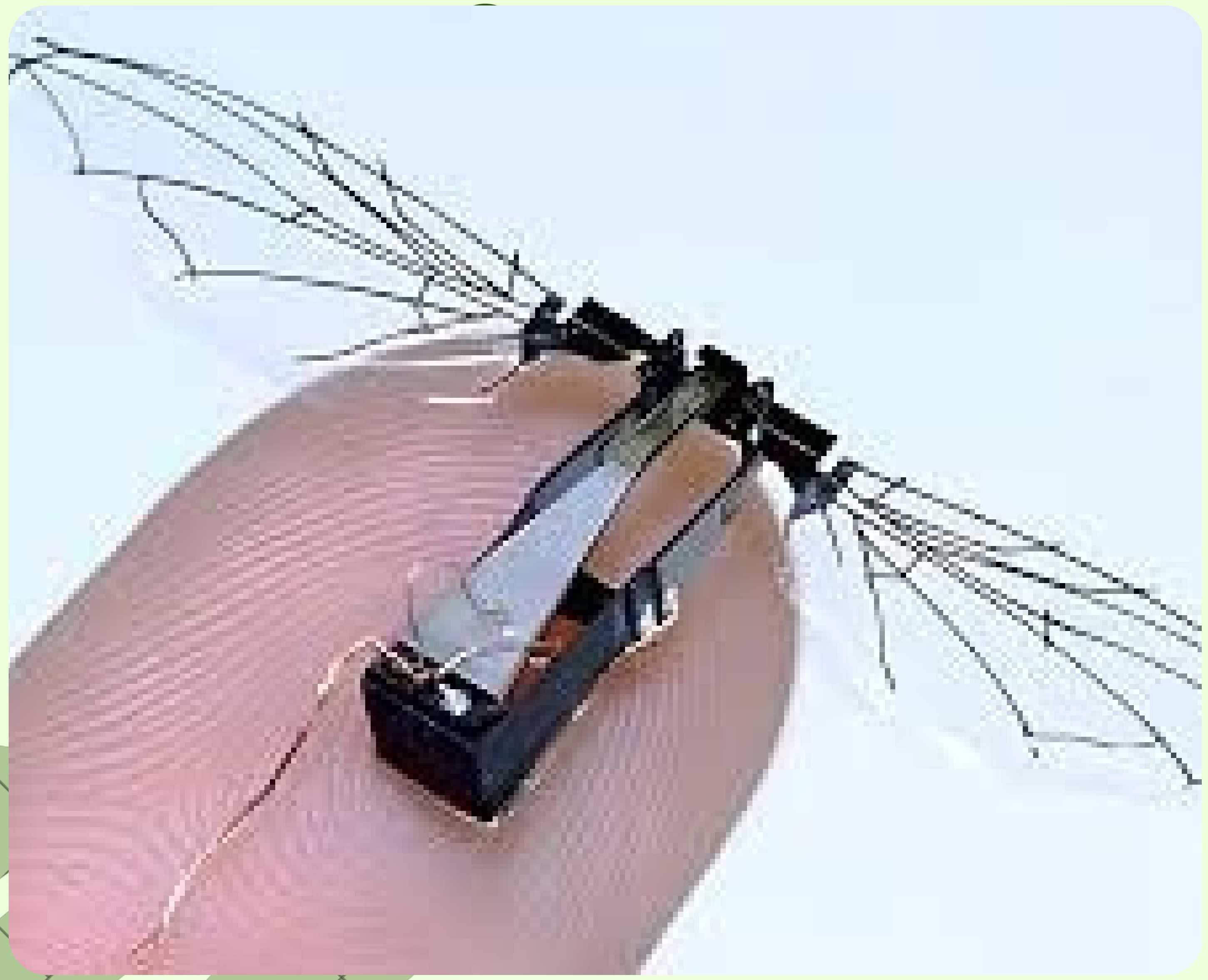
Autonomous Control:

- Onboard AI SoC (System on Chip) enables smart tracking and scene recognition
- Adaptive flight behavior based on visual cues

Swarming:

- Limited to sequential tasking; cloud-enabled for multi-drone flight control

ROBOBEE (HARVARD)



Sense and Avoidance:

- Minimal onboard sensors; vision-assisted lab tracking
- External motion capture systems provide position feedback

Path Planning:

- Predefined motion sequences tested in controlled environments
- Experiments with adaptive flapping patterns for spatial changes

Autonomous Control:

- Extremely lightweight control with off-board processing
- Inertial control stabilized via tethered command loops

Swarming:

- Lab-level swarm behavior using optical beacons and centralized coordination

WINGCOPTER 198

Sense and Avoidance:

- LIDAR and ultrasonic modules for delivery landing zones
- Computer vision assists in safe drop-zone identification

Path Planning:

- AI-generated routes factoring in no-fly zones, wind, and battery life
- Supports mid-mission rerouting and fail-safe reruns

Autonomous Control:

- Fully autonomous take-off, cruise, landing
- Tilt-rotor stabilization managed via proprietary autopilot firmware

Swarming:

- Multi-drone fleet operations enabled via cloud software
- Centralized swarm scheduling for logistics missions

CONCLUSION

Navigation and planning are critical to aerial robot autonomy. High-end UAVs like the MQ-9 Reaper integrate powerful sensors and military-grade control for precise mission execution, while commercial platforms like the Wingcopter 198 and Anafi AI use onboard AI to enhance real-time adaptation. Experimental robots like RoboBee challenge the miniaturization of navigation technologies. As aerial swarming becomes more viable, system-level integration of planning, control, and communication will define the next frontier in AR development.

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THANK YOU