Contact-Based Navigation and Mapping with Collision-Resilient UAVs

Aravind Adhith Pandian Saravanakumaran, Robotics and Autonomous Systems

Mentor : Wenlong Zhang, PhD, Associate Professor

Ira A. Fulton School of Engineering, Arizona State University

Research Question

Complex underground settings like caverns or dilapidated buildings show noteworthy challenges for military and first responders. This research provides a complementary system for UAVs to navigate such environments by sustaining collisions and synthesizing the environment map when vision system are less effective. It is almost the equivalent of blind person navigating around whilst the map of environment is also stored to be used by other autonomous systems.

Fig.1. Cavern Exploration from DARPA Subterranean Challenge

Design

- Arms can bend about the hinge point leveraging the torsional springs. Allowable maximum deflection of 40 Degrees
- Facilitates passive morphing and collision resilient characteristics to the drone
- Allows absorption of kinetic energy during collisions and maintain stable flight without any caged structures
- Modular and Versatile design allows for easy swapping and replacement of components on the go

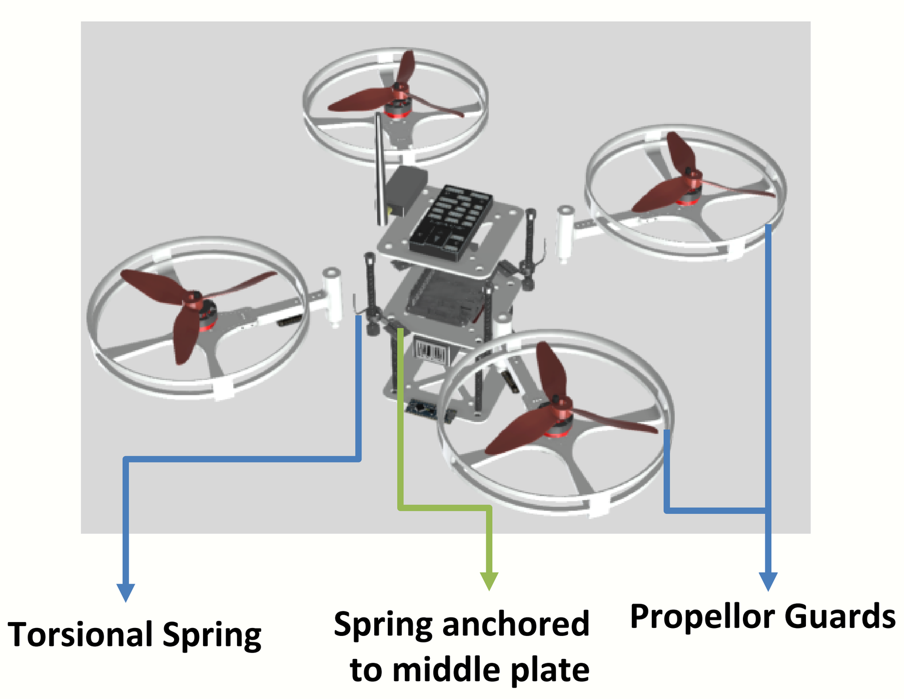

Fig.2. Quadrotor Design with a Passive Adaptive Morphology

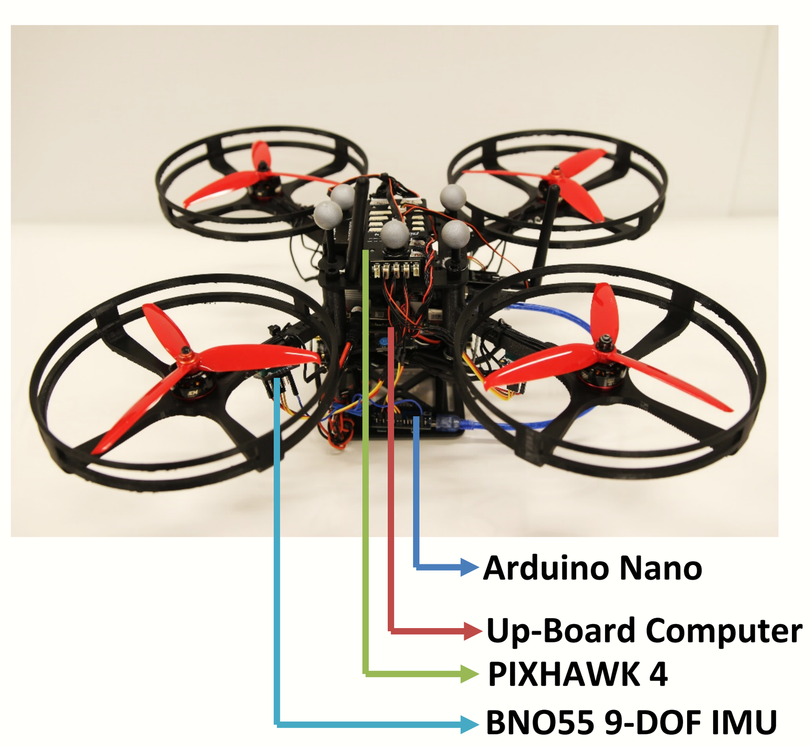

Fig.3. Overview of the Actual Quadrotor

System Architecture

- Four BNO055 9-DoF Inertial Measurement Sensors on each of the arm estimating arm bending angle using the Euler Angles
- Collision Detection and Localization by estimating the Wrench, utilizing the onboard IMUs
- Onboard computer and Motion Capture system and complementary computers on same network forming a Data Distribution System (DDS) via Robot Operating System 2 (ROS2)
- The DDS system enables point cloud data to be stored offsite enabling Big Data storage

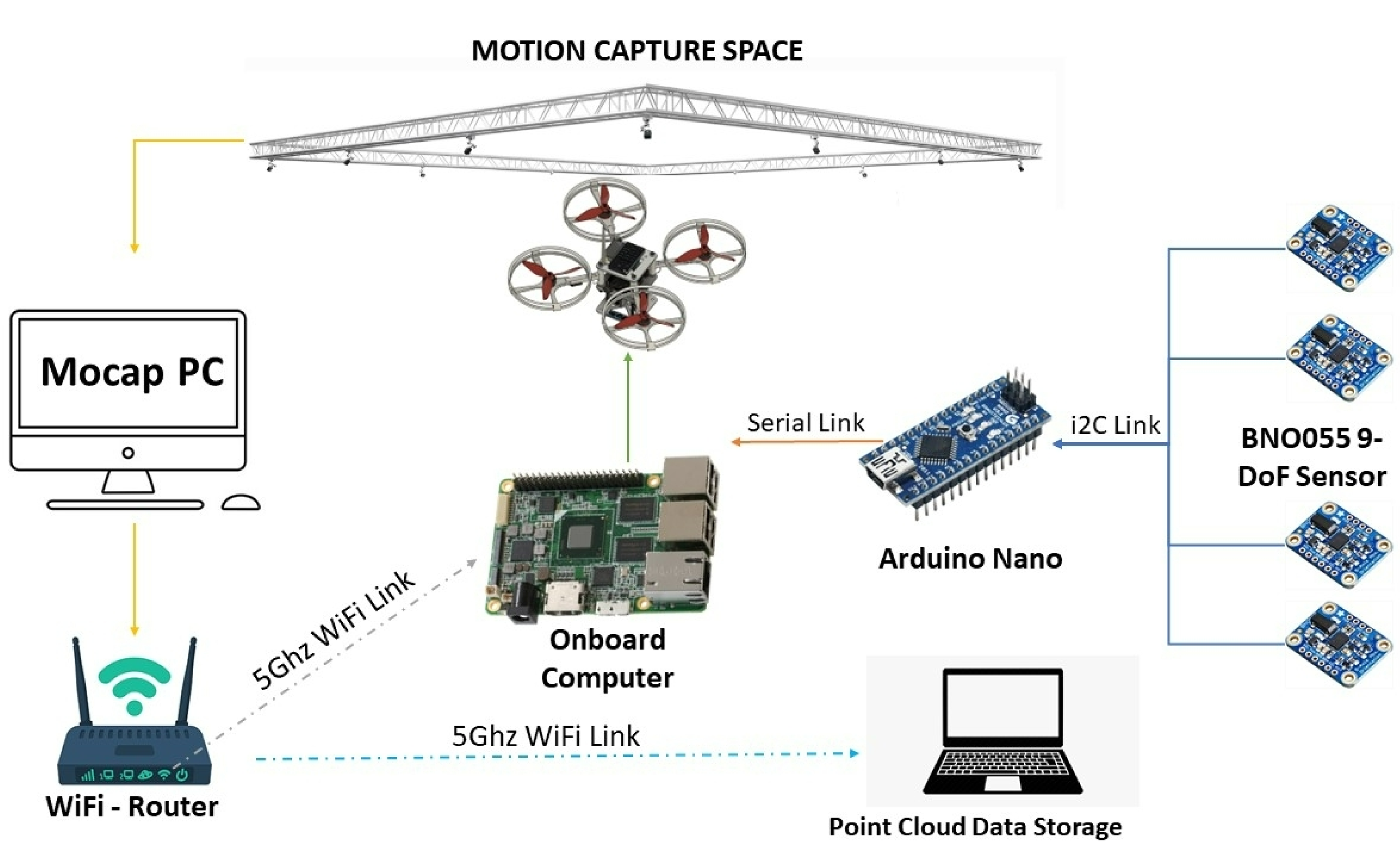

Fig.4. System Architecture

Navigation Algorithm

- The Navigation algorithm is devised as state machine model
- Trajectory planned in 2D plane confining the height to constant

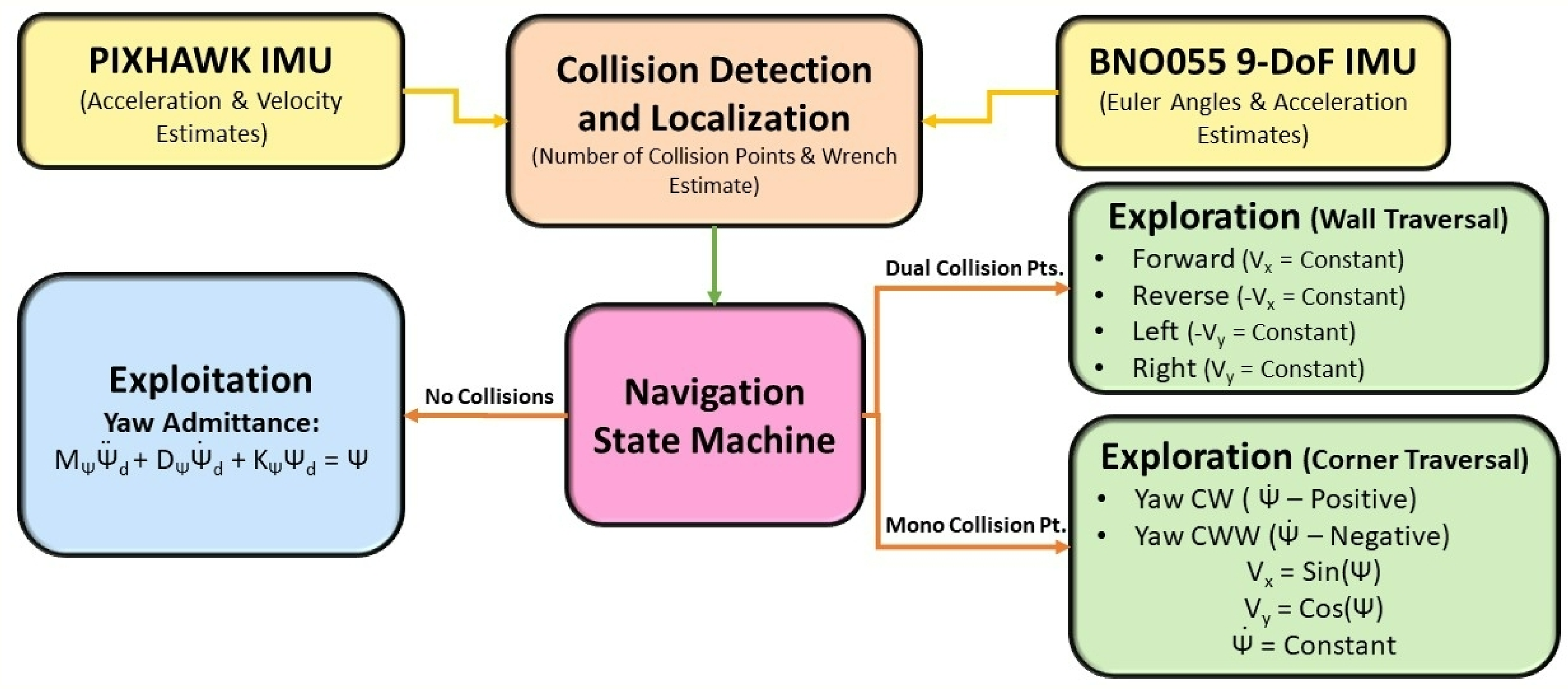

Fig.5. State Machine Model for Navigation

- The State machine outputs are broadly classified as **Exploratory** and **Exploitatory** states based on Collision Points
- **Exploration** categorized as Wall Traversal and Corner Traversal for Single and Double points of contact
- Corner Traversal is achieved by generating trajectory to yaw about the contact point and towards the obstacle
- **Exploitation** complies with external forces and allows to establish contact on two arms forming a contact plane
- Ψ_d – Desired Yaw is generated from **Yaw Admittance Controller** utilizing the Ψ – Current Yaw

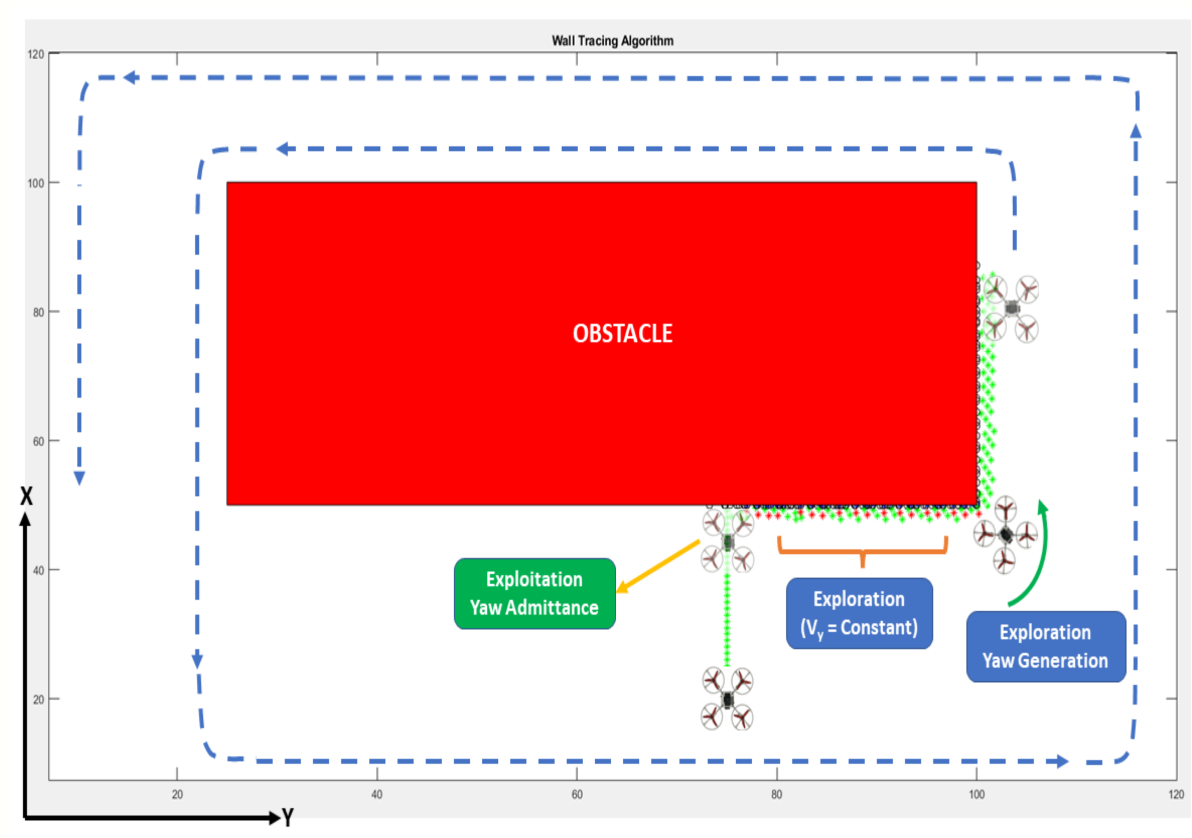

Fig.6. Simulation of the Algorithm

Fig.7. Top view of Wall Traversal

Mapping Strategy

- Generation of Point Cloud Data of the Drone
- Geometric Model of the Drone used to generate Point Cloud Data
- Precise Geometric model generated from the CAD data of the Drone
- The Odometry Data and Arm bending angles are utilized to form the Geometric Model

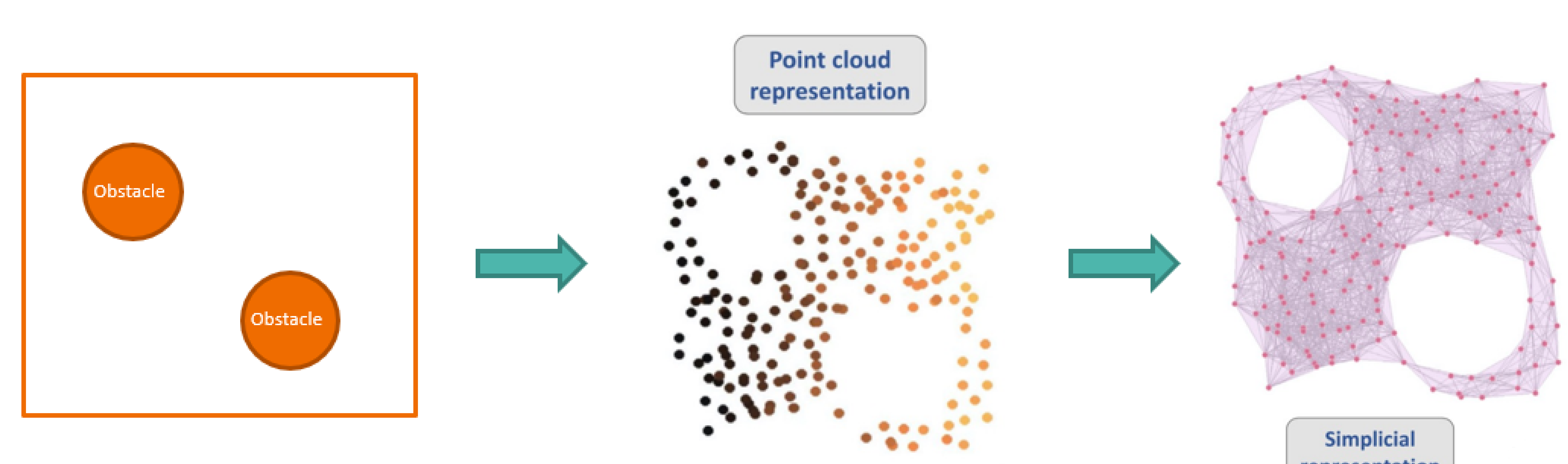

Fig.8. Map Generation Methodology

Acknowledgement and References

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[1] K. Patnaik, S. Mishra, S. M. R. Sorkhabadi and W. Zhang, "Design and Control of SQUEEZE: A Spring-augmented QUadrotor for intEractions with the Environment to squeezE-and-fly," 2020 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2020, pp. 1364-1370, doi: 10.1109/IROS45743.2020.9341730.