UAV Workload Characterization and Analysis

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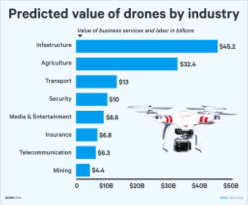
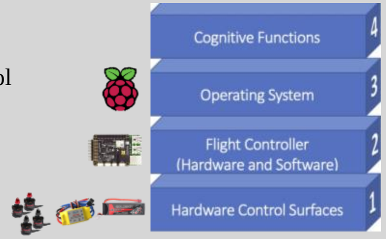
Motivation

- Increasing use cases of drones from surveying land to emergency services and national security
- Open-source flight stack to promote innovation through collaboration
- Characterizing underlying architecture and workloads to achieve high reliability, safety, and performance



UAV Systems

- Micro Air Vehicle Link (*MAVLink*)
- Data packet protocol for standardized communication between drones
- *DroneKit* API
- Python and C++ APIs to issue flight commands easily

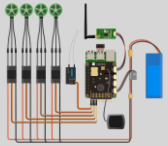


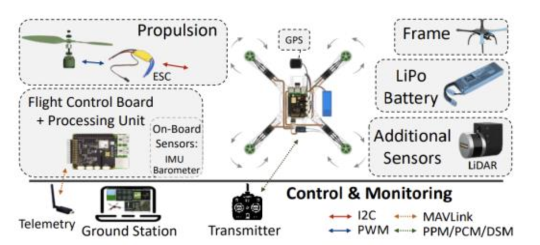
Flight Methodology

- Software in the Loop (SITL)
- Hardware in the Loop (HITL)
- Microsoft AirSim for HITL simulation
- Open-source
- Provides environment simulation (neighborhood, city)

UAV Control Mechanism

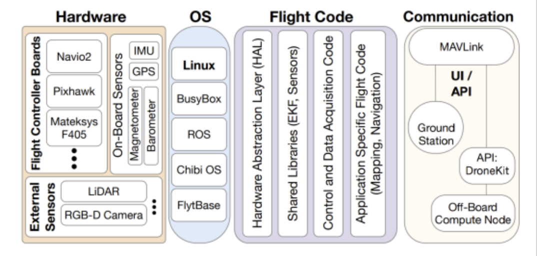
- Real Time Operating System (RTOS)
- Linux with PREEMPT_RT patch



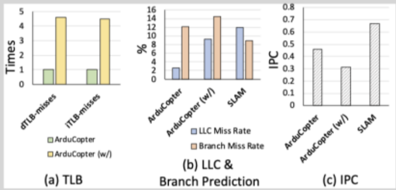


	Inner-Loop Control		Outer-Loop Control
Stabilization	Wind gusts Local disturbance Atmospheric turbulences In-door & close-to-object Propeller flapping	Set Target	Position target Attitude target Velocity target Navigation & trajectory Obstacle Detection* Planning
Control	Translational lift/thrust Absolute speed Weight imbalance Motor imperfection Angle of attack Flight time ESCs management	Applications	SLAM* LiDAR Mapping Sonar Mapping …

* Some implementations are across inner and outer loops

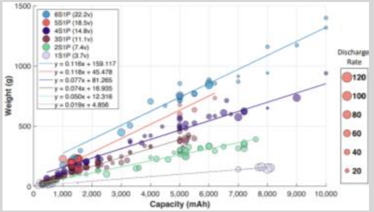


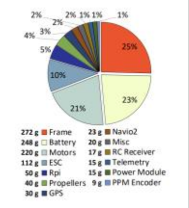
Performance Metric Measurements

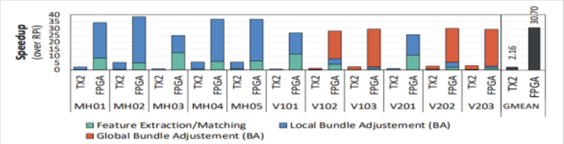


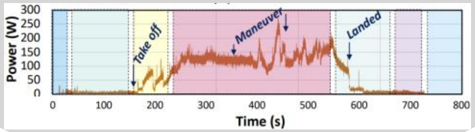
(a) ArduCopter with SLAM dTLBand iTLB misses normalized to only execute ArduCopter. (b) LLC and branch prediction miss rates for ArduCopter, ArduCopter with SLAM, and SLAM.(c) IPC for ArduCopter, ArduCopter with SLAM, and SLAM.

Platform		RPi	TX2	FPGA	ASIC
SLAM Speedup		1x	2.16x	30.70x	23.53x
Power Overhead (W)		2	10	0.417	0.024
Weight Overhead (g)		≈50	≈85	≈75	≈20
Integration Cost		Low	Low	Medium	High
Fabrication Cost		Low	Low	Medium	High
Gained Flight Time (min) †	Small Drones	0	≈-4	≈2−3	≈2.2−3.2
	Large Drones	0	≈-1.5	≈1	≈1





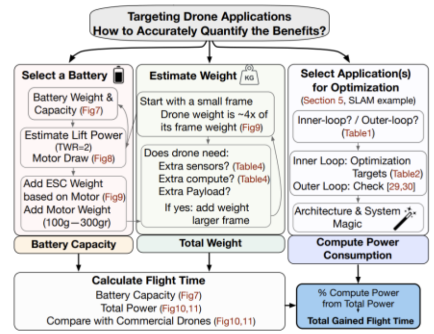




Workloads To Investigate

- Sensor Dependent
- Closed Feedback Loop
- Communication
- SAR
- Flight Planning
- ML and CV

Further characterization of these workloads can help better architect hardware to support these applications.



Future Work

- Simulations w/ Microsoft AirSim
- Offloading SLAM tasks to FPGA
- Sensor processing delay experiments
- Compute vs Communication Evaluation