DynaaDCP: Dynamic Navigation of Autonomous Agents for Distributed Capture Processing

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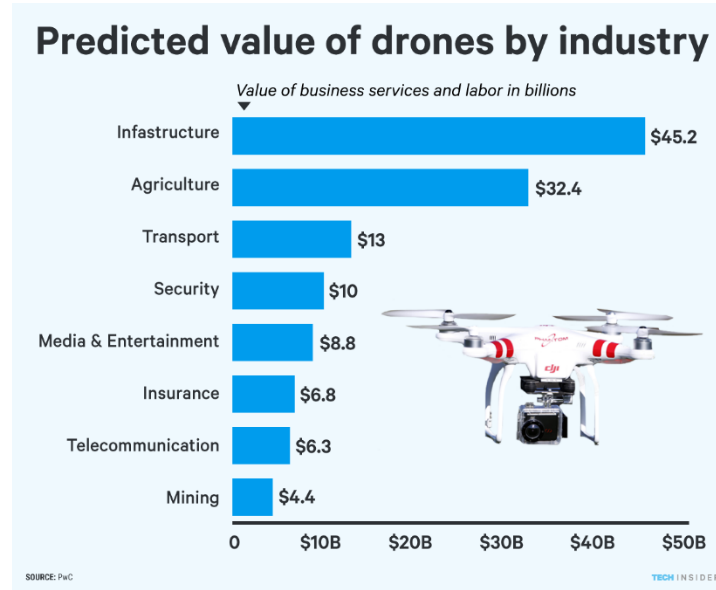
Motivation

- Commercial UAV industry will reach 805,000 in sales in 2021, a CAGR of 51%[1]
- Increasing use cases of UAVs from surveying land to emergency services and national security
- Communication between multiple UAV agents is increasingly becoming a bottleneck [2]
- Optimizing communication directly affects overall flight range and mission time
- Different physical form factors have different communication signatures



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Draganfly M600 (Photo: Draganfly)

DJI Matrice (Photo: DJI)

Orbital Scaneagle3 (Photo: Orbital)

MMCUAV Grifilon M8 VTOL (Photo: MMCUAV)

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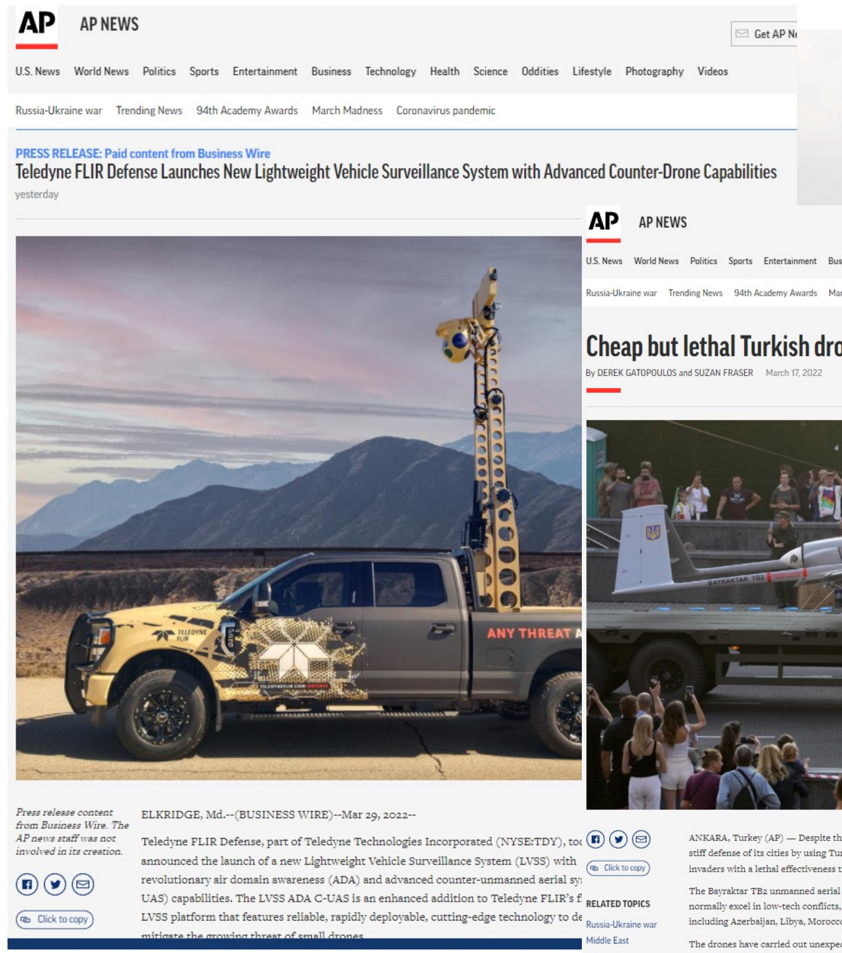
Applications of UAV Technology

- Aerial photography
- Agriculture
- Defense
- Emergency services
- Geographic mapping
- Personal hobby
- Search and rescue
- Shipping

and many more…



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PRESS RELEASE: Paid content from Business Wire

Teledyne FLIR Defense Launches New Lightweight Vehicle Surveillance System with Advanced Counter-Drone Capabilities

yesterday

Press release content from Business Wire. The AP news staff was not involved in its creation.

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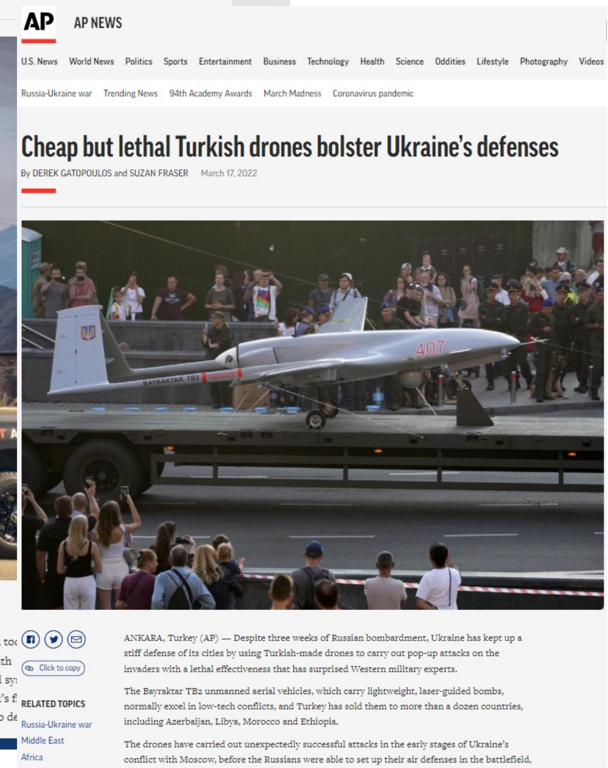
ELKRIDGE, Md.--(BUSINESS WIRE)--Mar 29, 2022--

Teledyne FLIR Defense, part of Teledyne Technologies Incorporated (NYSE:TDY), to announced the launch of a new Lightweight Vehicle Surveillance System (LVSS) with revolutionary air domain awareness (ADA) and advanced counter-unmanned aerial sy UAS) capabilities. The LVSS ADA C-UAS is an enhanced addition to Teledyne FLIR's f LVSS platform that features reliable, rapidly deployable, cutting-edge technology to de mitigate the growing threat of small drones.



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Cheap but lethal Turkish drones bolster Ukraine's defenses

By DEREK GATOPOULOS and SUZAN FRASER March 17, 2022

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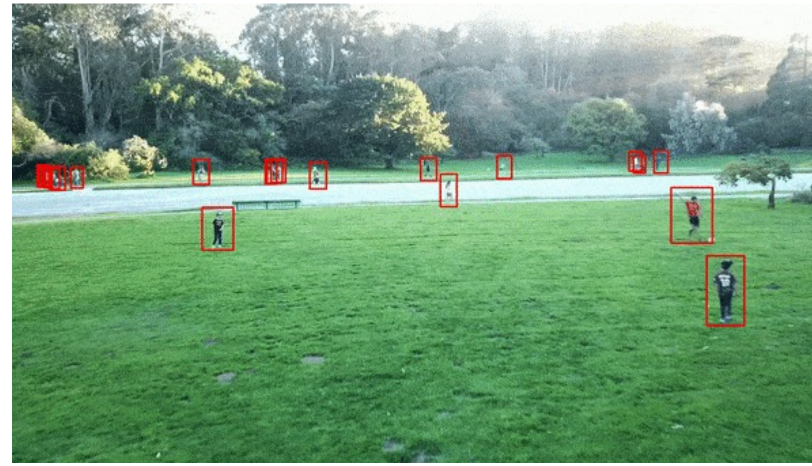
ANKARA, Turkey (AP) — Despite three weeks of Russian bombardment, Ukraine has kept up a stiff defense of its cities by using Turkish-made drones to carry out pop-up attacks on the invaders with a lethal effectiveness that has surprised Western military experts.

The Bayraktar TB2 unmanned aerial vehicles, which carry lightweight, laser-guided bombs, normally excel in low-tech conflicts, and Turkey has sold them to more than a dozen countries, including Azerbaijan, Libya, Morocco and Ethiopia.

The drones have carried out unexpectedly successful attacks in the early stages of Ukraine's conflict with Moscow, before the Russians were able to set up their air defenses in the battlefield,

General UAV Task Outline

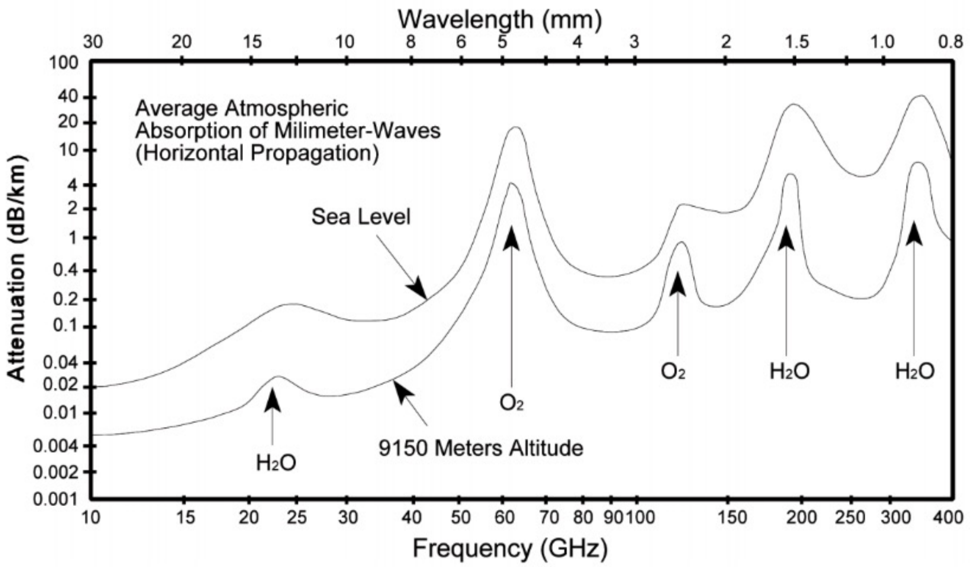
- Capture images
  - Various image sensors
  - Buffer video feed
- Run computations on images
  - 3D Reconstruction
  - Feature detection
  - Collision avoidance
- Communicate data and results
  - Distributed workload
  - Different communication technologies
  - Communicate tasks time vary significantly
- Dependencies exist between the tasks



DroneEye
(Photo: DSC IITP)

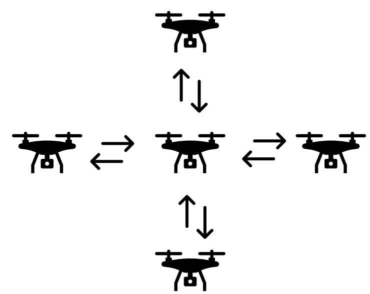
mmWave

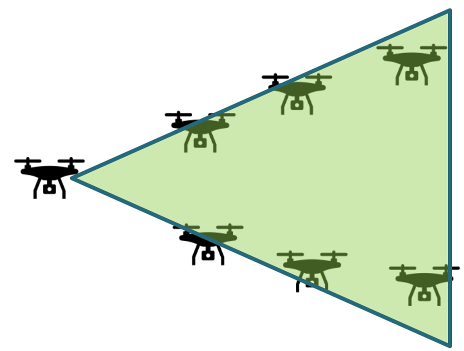
- Millimeter Wave (mmWave) spectrum between 30 GHz and 300 GHz
  - V band (60 GHz) set aside by FCC to be unlicensed
- High bandwidth
- Limited by short range
  - Due to oxygen absorption[6]
- *Bandwidth vs. Data Rate*
  - $C = B \log_2(1 + \frac{S}{N})$ [Shannon-Hartley Theorem]
  - Channel Capacity (C) is increased w/ higher bandwidth (B) keeping signal-to-noise ratio constant.

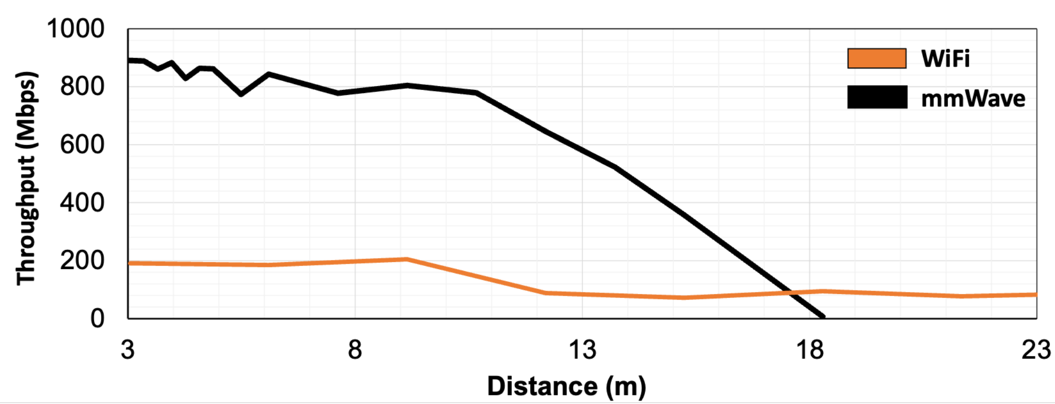


Utilizing mmWave for UAVs

- Two utility configurations
  - Star config
  - Cone config
- Two modes of operation
  - Wi-Fi
  - mmWave
- Wi-Fi for long range low throughput
- mmWave for short range high throughput
- Dynamically switch between the two modes on-the-fly
- But when should it switch? 🤔







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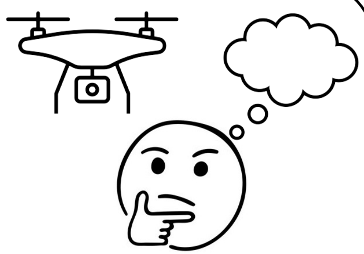
Our Domain



Making Location Schedule for Drones?

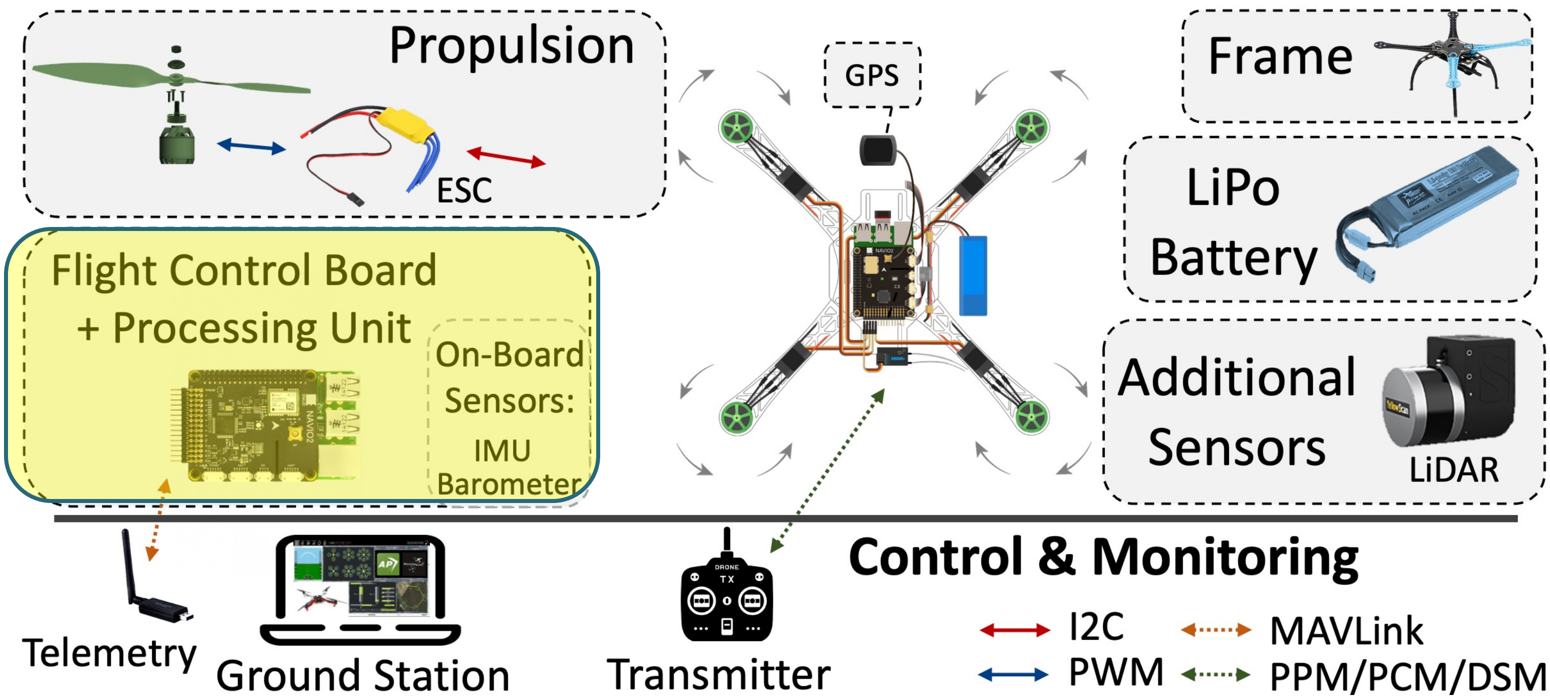
Should we
get the **drones closer** and use **high bandwidth communication** while incurring the **movement penalty**?

Or Should we
keep the **drones at distance** and **use low bandwidth communication** while incurring the **bandwidth penalty**?

Understanding these tradeoffs and their characteristics are critical to solve the correct set of problems

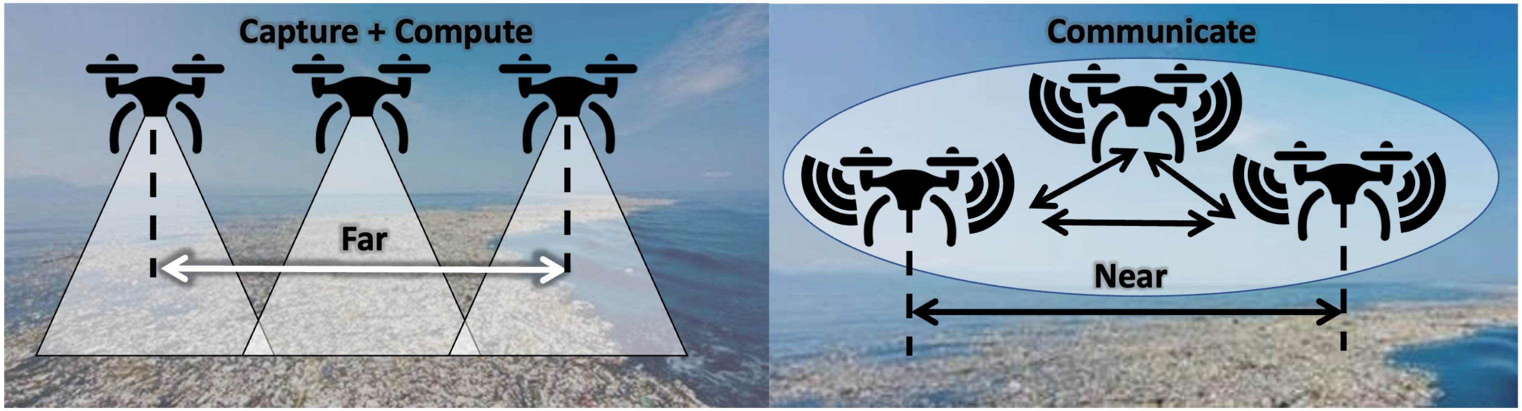
System Architecture & Design

- Envisioned Setting
- Overview
- Experiments



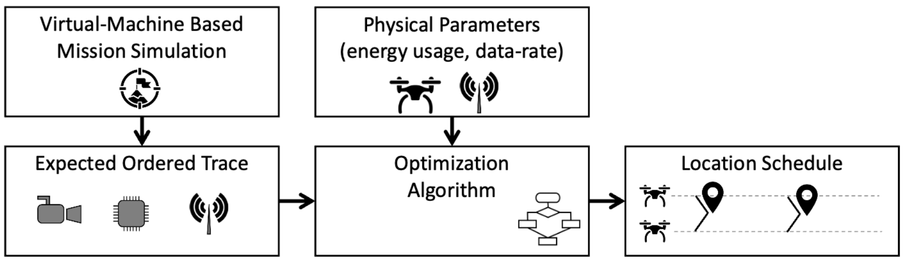
Envisioned Setting

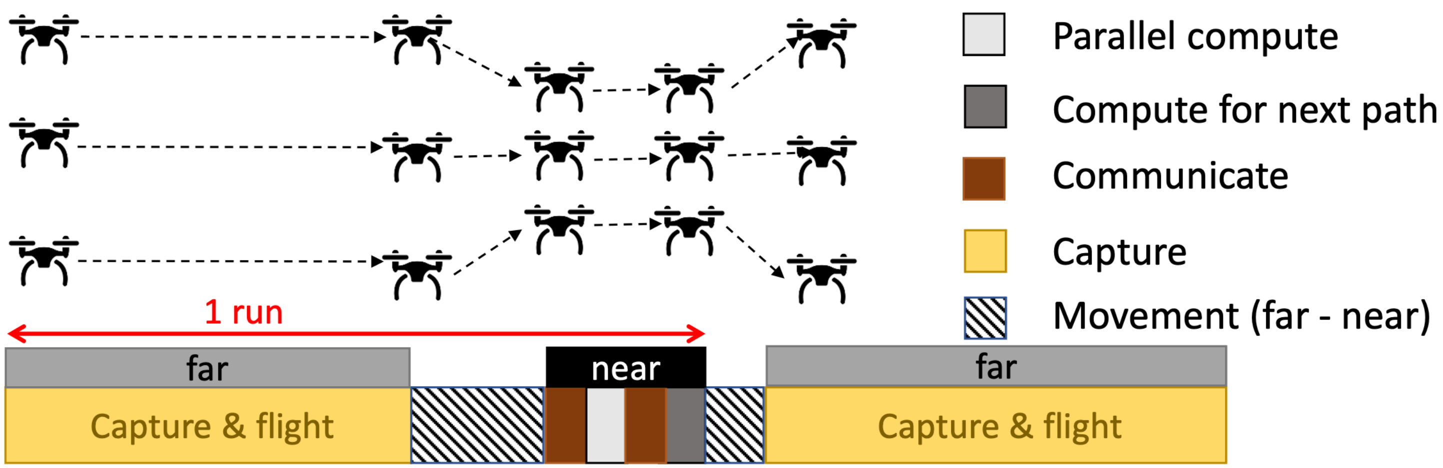
- Large scale forest fire
  - Objective is to quickly 3D map areas with immediate threat to human life & property
  - 3D Map to be used for SAR
  - High signal attenuation, cannot use base station
  - Area of interest is too large for a single UAV
  - Limited backhaul links
- Can be extended to any situation where backhaul and cloud links are not feasible
  - Ocean rescue, oil spill mapping, missions in mountain ranges etc.



Overview

- Near-Far movements
  - Drones halt capture
  - Come near to exchange data
  - Go back to their original position
  - Resume capture
- Contents of captured data do not affect the trace of the distributed algorithm
- No timed events



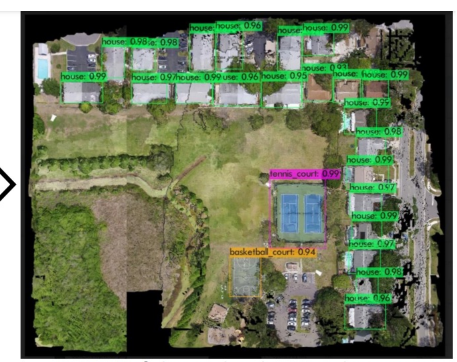


Experiment Setup

- Distributed CV Processing
  - Single node, Two/Four node Wi-Fi, Two/Four node mmWave
  - Compute model from Raspberry Pi 4 [7] and parameters configured
  - Parameters and knobs imported into VirtualBox[8] VMs
  - OpenDroneMap[4]
  - VMs configured for each run to simulate different mission characteristics
  - Network monitoring using Wireshark[5] and iperf3[3]

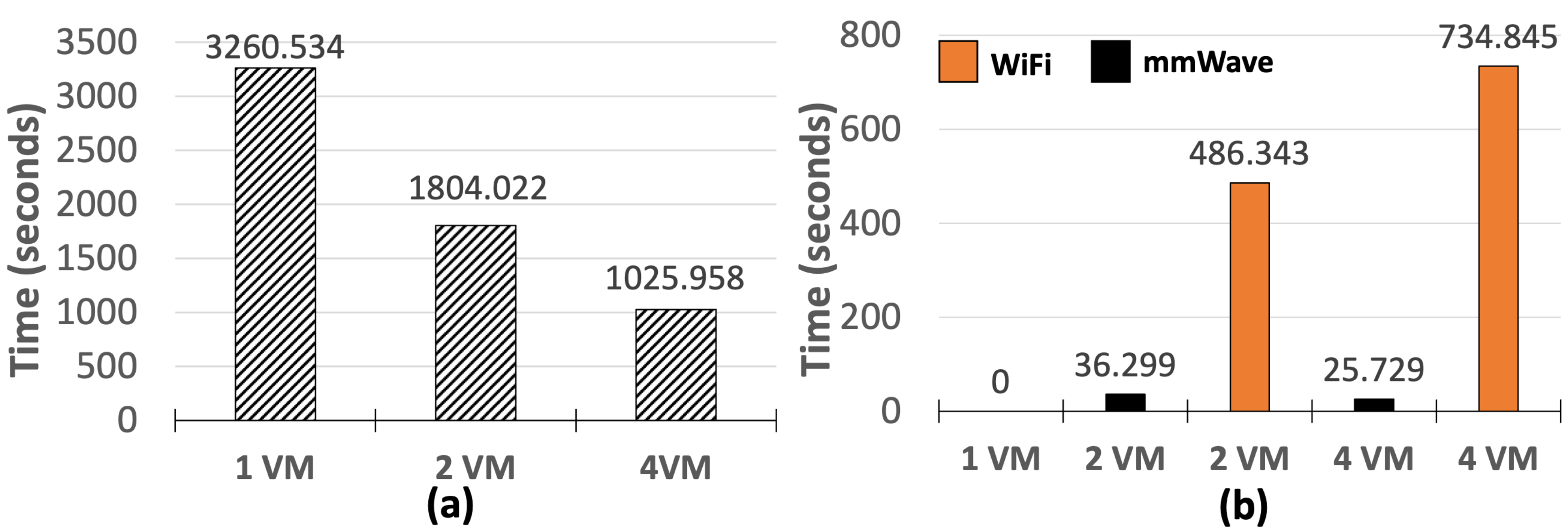
Feature Extraction
(Photo: Seabee)

Sample input images captured from different angle by drones.



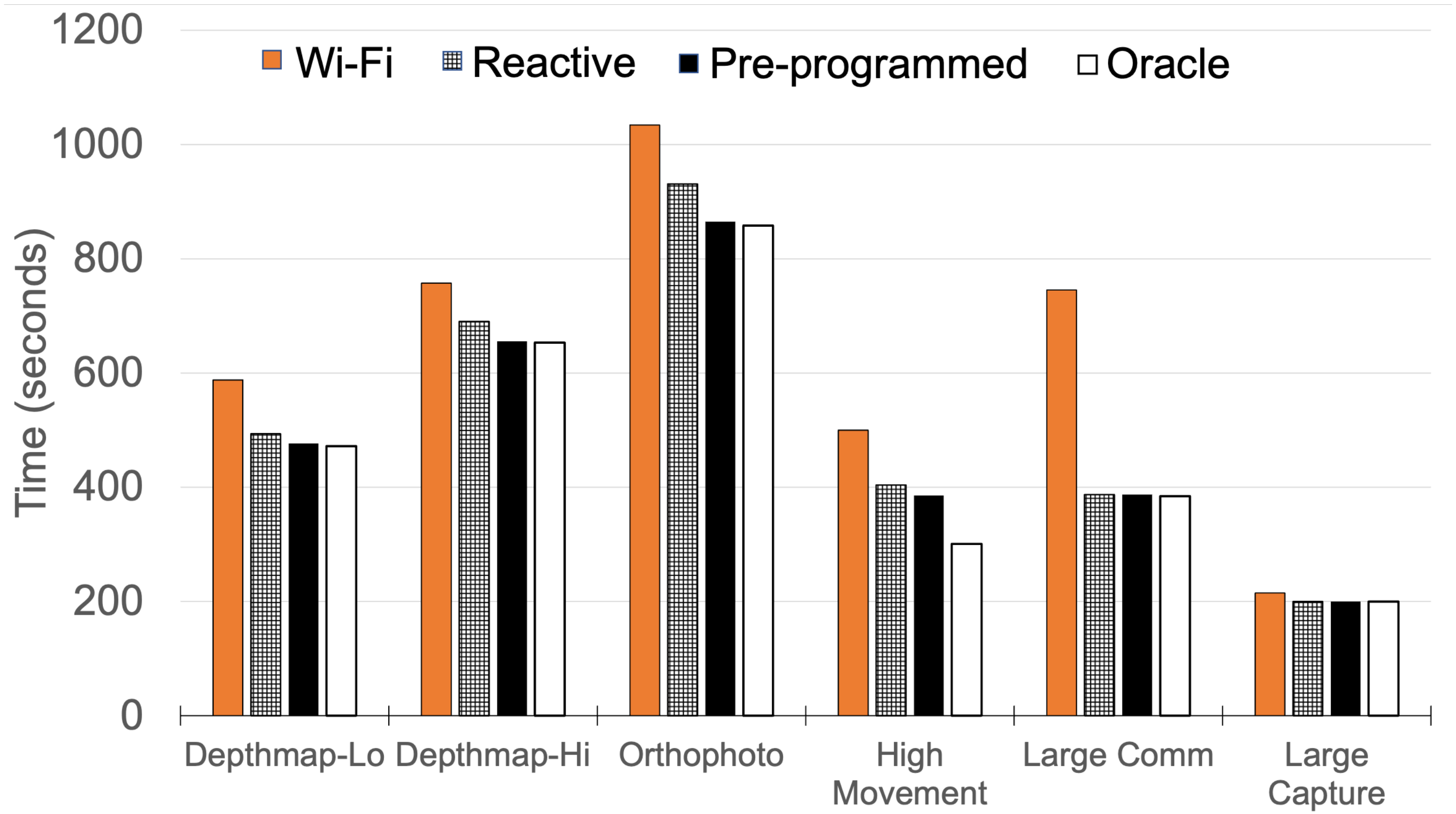
Output of the Orthophoto and YOLOv4 object detection.

Results



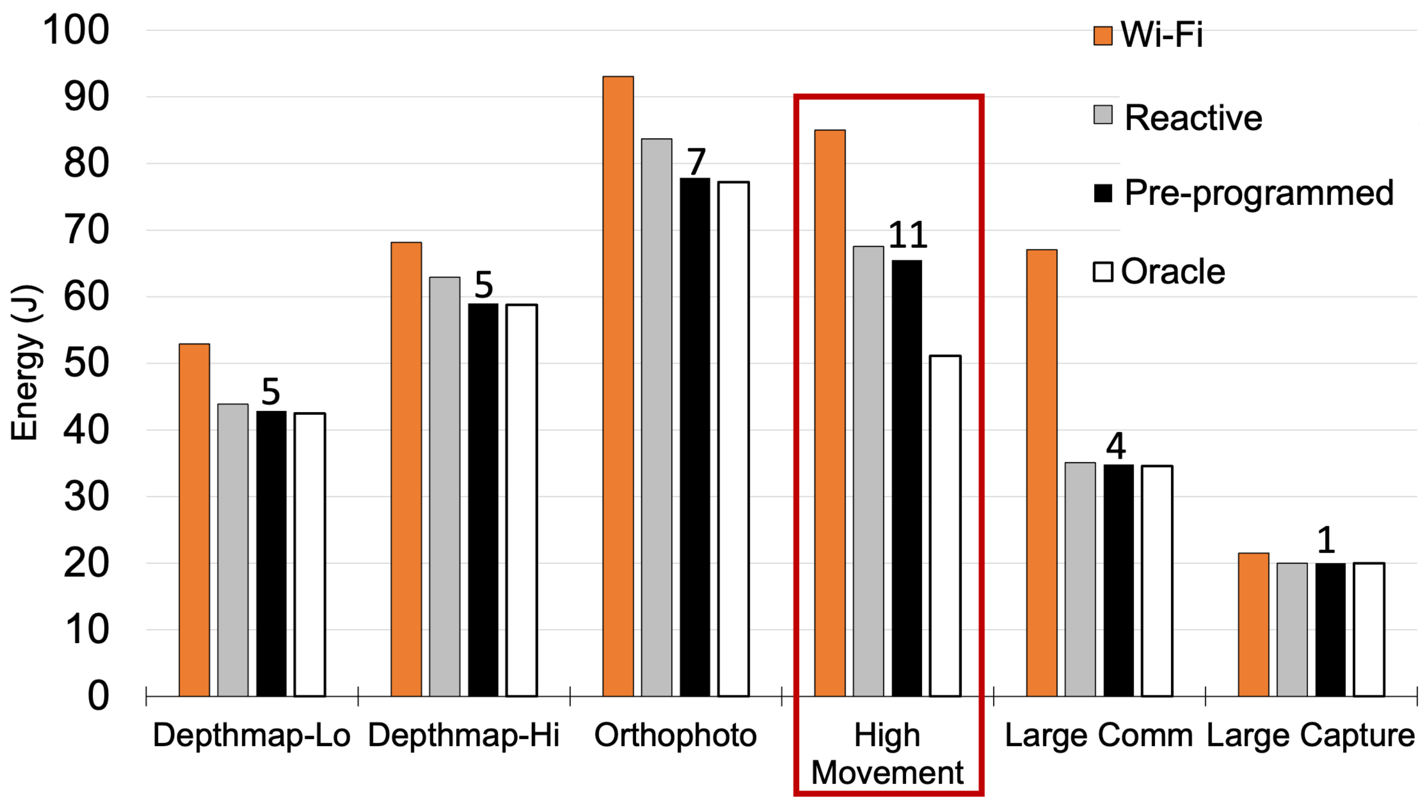
Distributed Computer Vision Processing on VMs: (a) Compute Benchmarks, (b) Communication Benchmarks.

Evaluation (1)



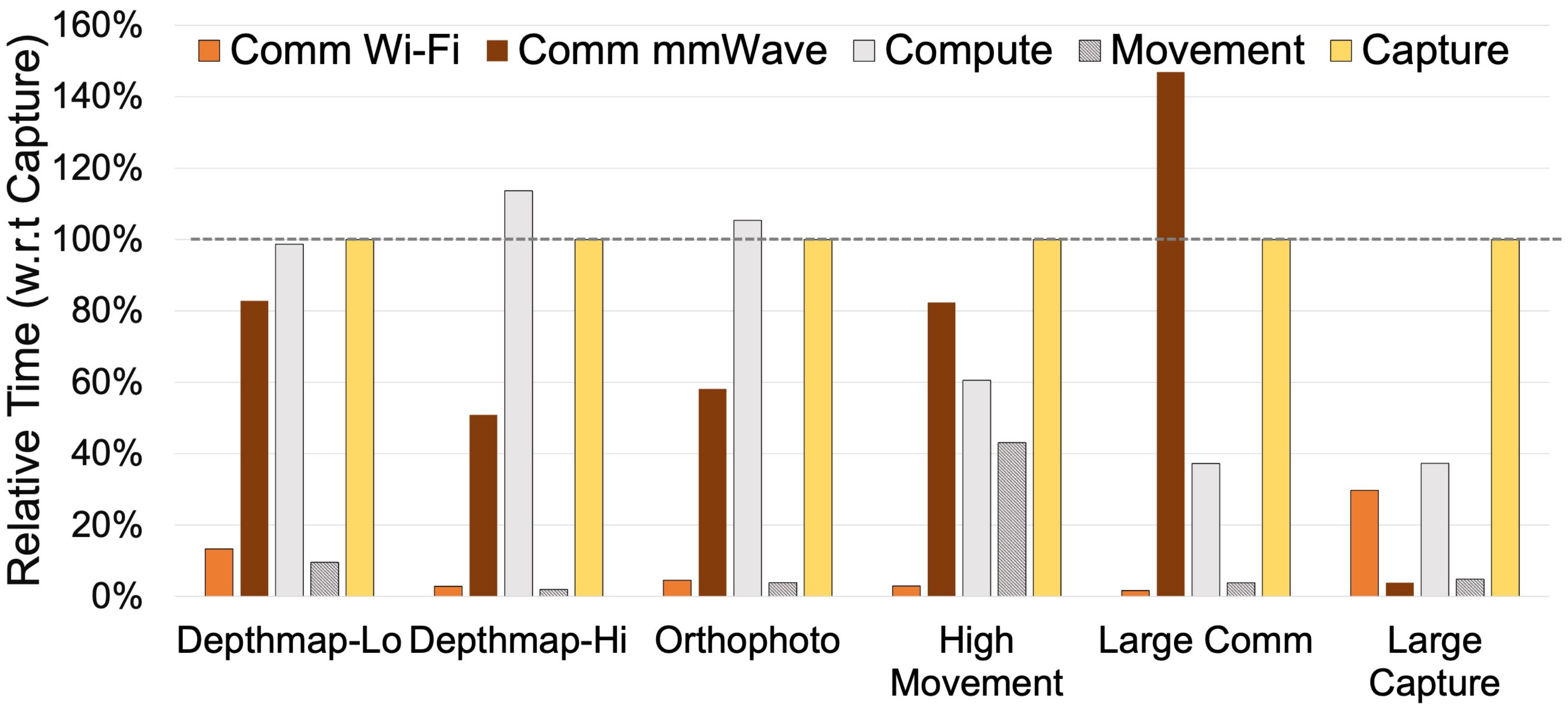
DynaaDCP reduces the total flight time required to complete the mission, can comes close to the hypothetical least time required (Oracle).

Evaluation (2)



Despite multiple near ↔ far transits (numbers on graphs), total energy consumption reduces due to shorter flight times.

Evaluation (3)



Time spent on each subtask (normalized to capture); mmWave's contribution to communication in DynaaDCP.

Key Contributions & Future Directions

- The key contributions of our work as summarized
  - A novel approach to run distributed algorithms on autonomous agents where control of proximity improves efficiency.
  - A movement scheduling algorithm that incorporates goals of compute, communicate, and capture of data.
  - Example use-cases that demonstrate the proposed scheduling algorithm’s benefits to various distributed application scenarios.

- Future Directions
  - End-to-end System Implementation
  - Variations in Compute Tasks
  - Real-time Decision making
  - Scalability analysis

Thank you

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References

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