

# Discussion: limitations due to actuation and pose coupling

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Half-day Tutorial Session at ICUAS 2026 (09:00 – 13:00), 15<sup>th</sup> June 2026  
Room Calypso A – Divani Corfu Palace

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# Discussion: Why Position-Only Planning May Be Insufficient

Most communication-aware UAV optimization assumes

$$\max_{\mathbf{p}(t)} J(\mathbf{p}(t))$$

where only the UAV position is optimized.

However, many wireless communication metrics depend on both

$$J = J(\mathbf{p}(t), \Upsilon(t))$$

where

$$\Upsilon(t) = (\phi(t), \theta(t), \psi(t))$$

denotes the UAV orientation.

## Key Question

Can conventional multirotors independently optimize position and orientation?

# Underactuation in Conventional Multirotors

## Conventional quadrotors are underactuated

To move laterally, the vehicle must tilt:

$$F_x \neq 0 \implies \phi \neq 0$$

$$F_y \neq 0 \implies \theta \neq 0$$

Hence

Translation  $\iff$  Attitude Change

**Consequence:** orientation cannot be selected independently from motion.

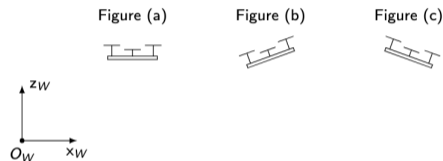


Figure: (a) u-MRAV hovering, (b) u-MRAV moving to the left, and (c) u-MRAV moving to the right.

# Why Is This a Problem for Communications?

Many communication systems are orientation-sensitive:

- Directional antennas
- Massive MIMO
- RIS-assisted communications
- THz communications
- Free-Space Optical (FSO) links

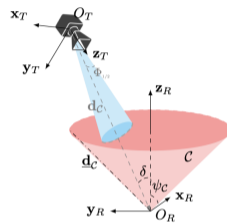
Communication quality depends on

$$\text{SNR} = f(\mathbf{p}, \Upsilon)$$

and not only on the UAV position.

## Challenge

Moving toward a better position may degrade beam alignment.



**Figure:** Transceiver geometry with idealized receiver cone. Misalignment angle  $\delta$  quantifies the deviation between beam direction  $z_T$  and receiver axis  $z_R$ .

Silano, Giuseppe, et al. "Free-Space Optical Communication-Driven NMPC Framework for Multi-Rotor Aerial Vehicles in Structured Inspection Scenarios", IEEE International Conference on Systems, Man, and Cybernetics (SMC), 2025.

# Example: Directional Antennas

Position-only planning seeks

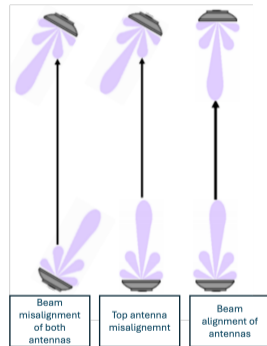
$$\mathbf{p}^* = \arg \max_{\mathbf{p}} G(\mathbf{p})$$

However, the actual antenna gain is

$$G(\mathbf{p}, \Upsilon)$$

Two UAVs at the same position may experience:

- Different antenna gains
- Different SINR values
- Different communication reliability



# From Position to Pose Optimization

## Position-only planning

$$\mathbf{p}(t) \in \mathbb{R}^3$$

Optimization variables:

$$(x, y, z)$$

Communication depends implicitly on orientation.

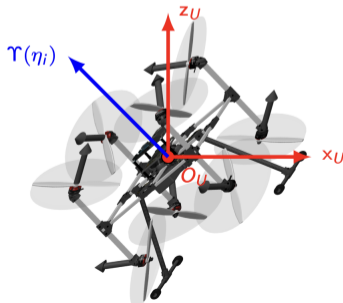
## Pose optimization

$$\mathbf{q}(t) = (\mathbf{p}(t), \Upsilon(t))$$

Optimization variables:

$$(x, y, z, \phi, \theta, \psi)$$

Communication becomes directly controllable.



# Towards Fully Actuated MRAVs

Conventional multirotors:

Position  $\iff$  Orientation

Fully actuated MRAVs:

Position  $\perp$  Orientation

They enable:

- Independent pose regulation
- Beam-aware trajectory planning
- Communication-aware control
- Joint optimization of mobility and connectivity

Position Optimization  $\implies$  Pose Optimization

# Thank you

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