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Dynamic Balancing for Aerial Manipulation

Abstract

- The motion of a mobile robotic manipulator causes unwanted disturbances on its base, an Unmanned Aerial Vehicle (UAV)
- Reaction Forces and Torques caused by the displacement of the Centre of Mass, as well as actuation of the motors
- Utilise the concept of "Dynamic Balancing" to design a manipulator with minimal reaction forces and torques
- Application in grasping aerial manipulation tasks, with increased precision, dexterity and robustness

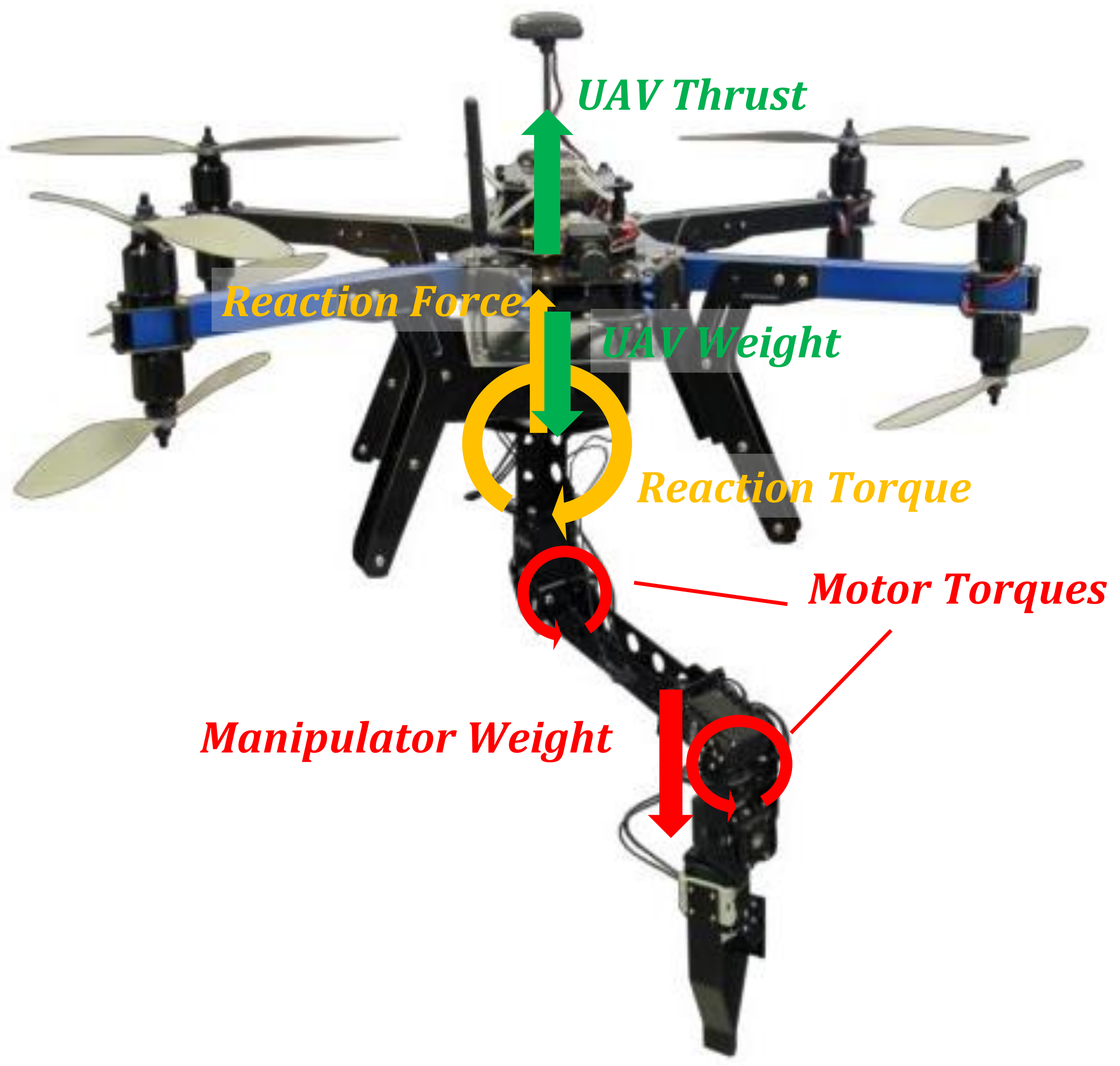

Figure 1: The interaction of forces and torques on a typical aerial manipulator system: UAV (Green), manipulator (Red) and reaction between both bodies (Yellow). Edited from [1].

Introduction

- A robotic manipulator (such as an arm) typically moves to interact with the environment
- Causes reaction forces and torques which disturb the base it is mounted on → reduced precision
- Typically addressed through UAV flight controls → not responsive enough for precise and rapid manipulation tasks
- We address this through mechanical design of an arm that is Dynamically Balanced: for any motion, the forces and torques on the system cancel out

Research Objectives

- Design a dynamically balanced robot manipulator for fulfilling robotic grasping tasks
- Build a prototype with mechanical components and control algorithm integration
- Validate the prototype in real-world gripping tasks

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Methodology

- Explore different balanced linkage designs
- Compare and assess different concepts for feasibility
- Select a concept for detailed robotic manipulator design
- Build the robot arm from components, implement control algorithms, and integrate with a UAV
- Conduct live experiments to validate the manipulator

Concepts to Explore

- Based on Four-Bar Linkages, parallelogram and serial links using counter-weights to balance the mechanism
- Can synthesize these together to form a multiple degree of freedom robotic linkage mechanism
- Planar (2D) arrangement: stacked serially in a chain
- Spatial (3D) arrangement: parallel to each other to form legs

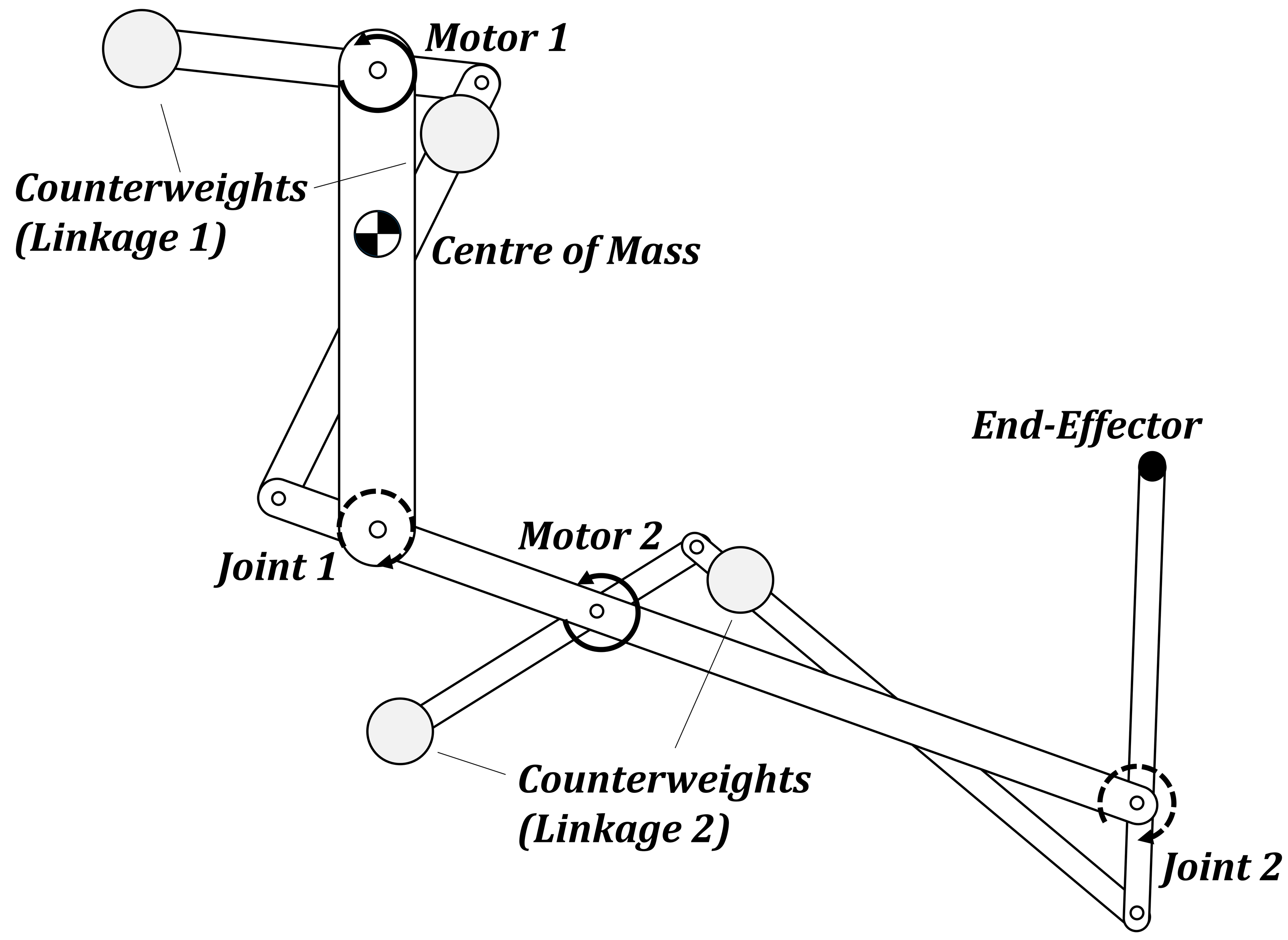

Figure 2: An example concept of a planar 2 joint manipulator synthesized from two four-bar linkages [2]. Through balancing with counterweights, the Centre of Mass does not move.

Next Steps

- Select the most promising high-level concepts to develop into detailed designs for comparison
- Compare these designs in terms of workspace, total mass, and reaction forces on the base for manipulation tasks

References

[1] R. Rossi & P. Rocco, "Trajectory Generation and Control for Aerial Manipulation", in *Automatica.IT 2016,* http://sidra2016.dia.uniroma3.it/trajectory-generation-control-aerial-manipulation/, Accessed 4 June 2022.
[2] C. M. Gosselin, F. Vollmer, G. Cote and Yangnian Wu, "Synthesis and design of reactionless three-degree-of-freedom parallel mechanisms," in *IEEE Transactions on Robotics and Automation*, vol. 20, no. 2, pp. 191-199, April 2004, doi: 10.1109/TRA.2004.824696.

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