Avian-Inspired Grasping for Quadrotor MAVs

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Motivation

- Prior research in aerial grasping only permitted slow, quasi-static motions [1, 2].
- We are interested in rapid acquisition of targets.
- Dynamic coupling between flight, grasping, and manipulation cannot be ignored.

Goals of Our Research

- Study the dynamics of aerial grasping
- Generate dynamically feasible trajectories to acquire or deploy small ground robots and sensors
- Develop vision-based control algorithms for dynamic acquisition of objects

Bio-Inspiration

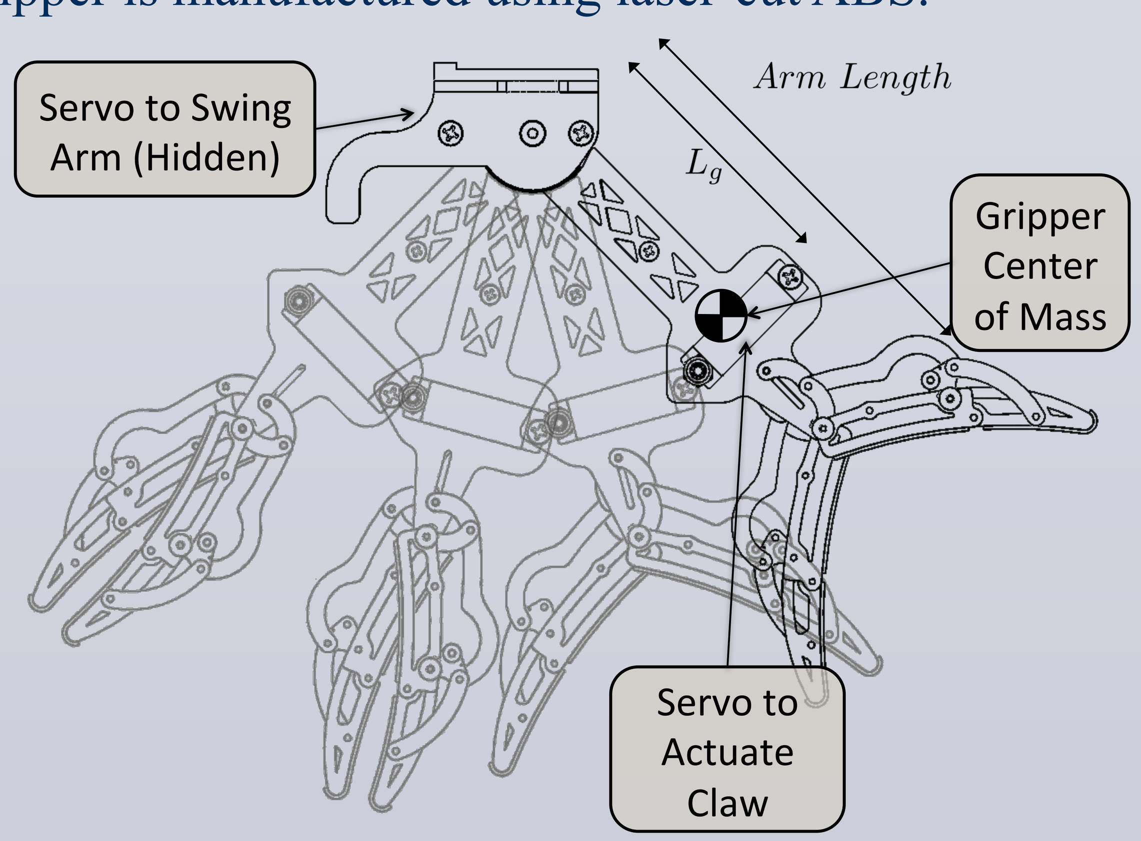
How does nature solve similar problems?

- We draw inspiration from nature, which already has examples of effective and efficient grasping.

Figure: Predatory birds such as the bald eagle are excellent at grasping prey while in motion [3].

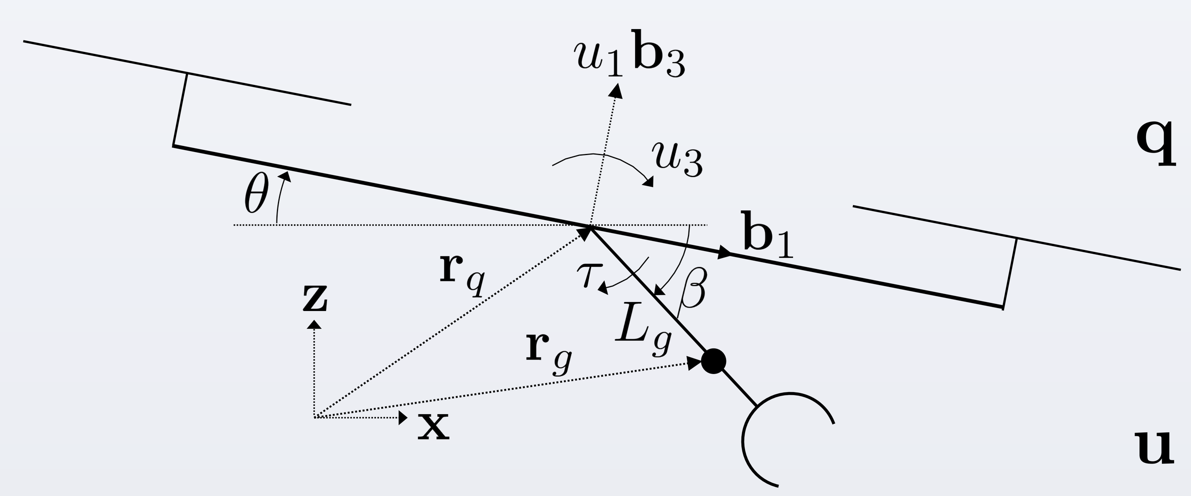
Gripper Design

- An underactuated gripper is attached to an articulated arm to reduce the relative velocity between the gripper and the target.
- The gripper is manufactured using laser-cut ABS.



Dynamic Model

- A dynamic model for a planar quadrotor with an articulated appendage is developed using the Euler-Lagrange equations.



$$\mathbf{q} = \begin{bmatrix} x_q \\ z_q \\ \theta \\ \beta \end{bmatrix} \qquad \mathbf{u} = \begin{bmatrix} u_1 \\ u_3 \\ \tau \end{bmatrix}$$

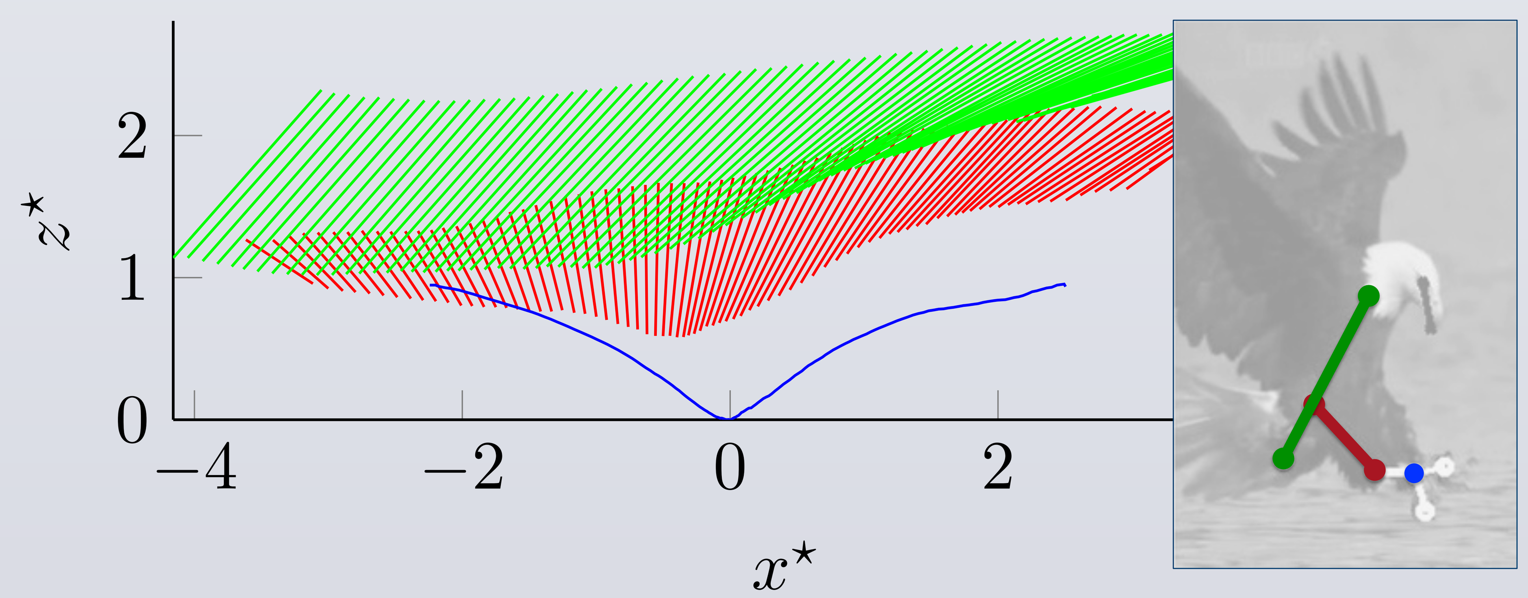
- The system is differentially flat with a set of flat outputs being

$$\mathbf{y} = \begin{bmatrix} x_q & z_q & \beta \end{bmatrix}^T$$

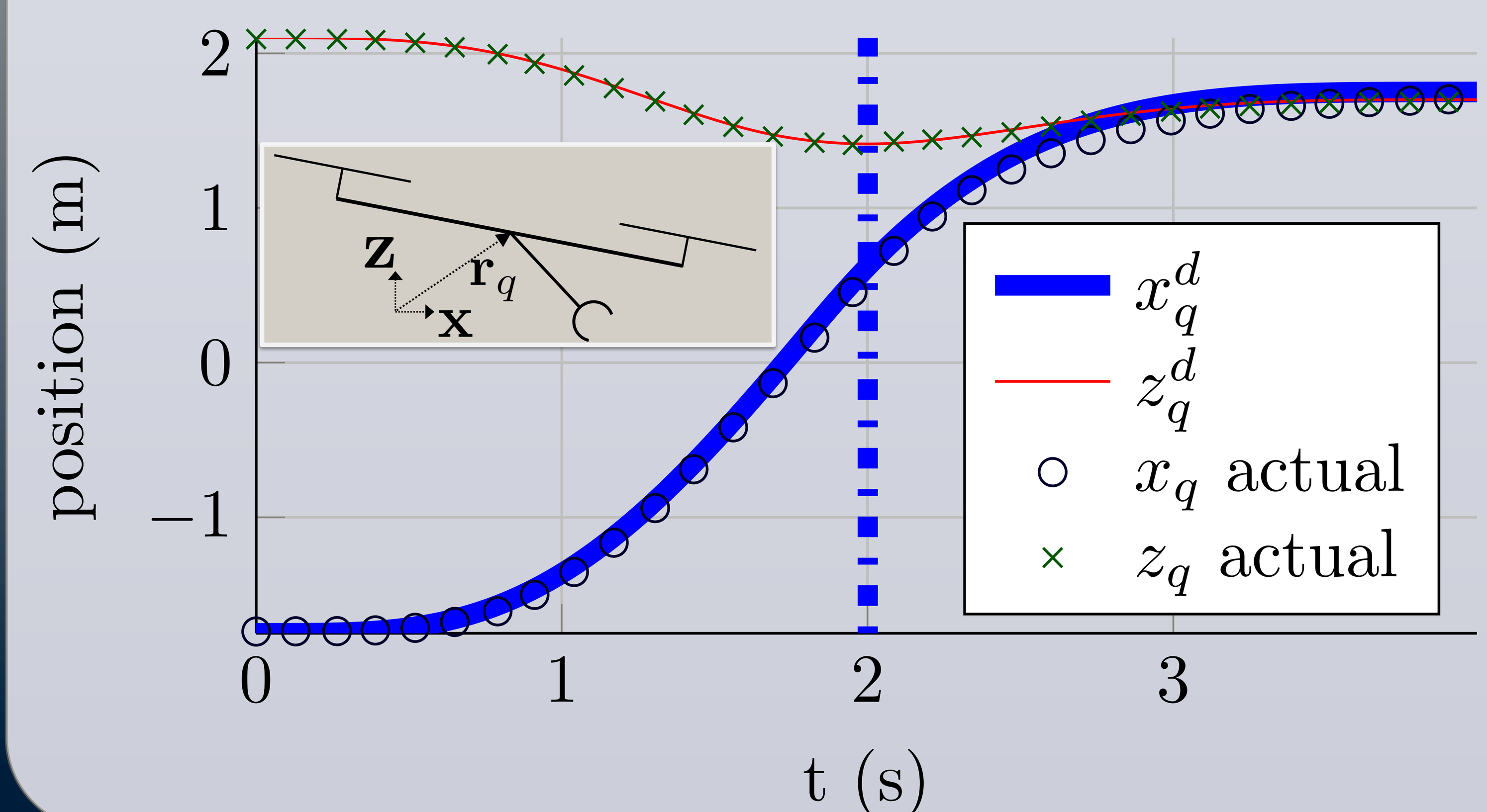
- Dynamically feasible trajectories can be planned in the flat space and mapped to the full state space of the coupled system.

Results

- Nondimensionalized kinematic analysis of an eagle's motion provides boundary conditions for the motion planner.



- We demonstrated successful acquisition of a target while moving at 2 and 3 m/s with feedback from a motion capture system.



Results (continued)

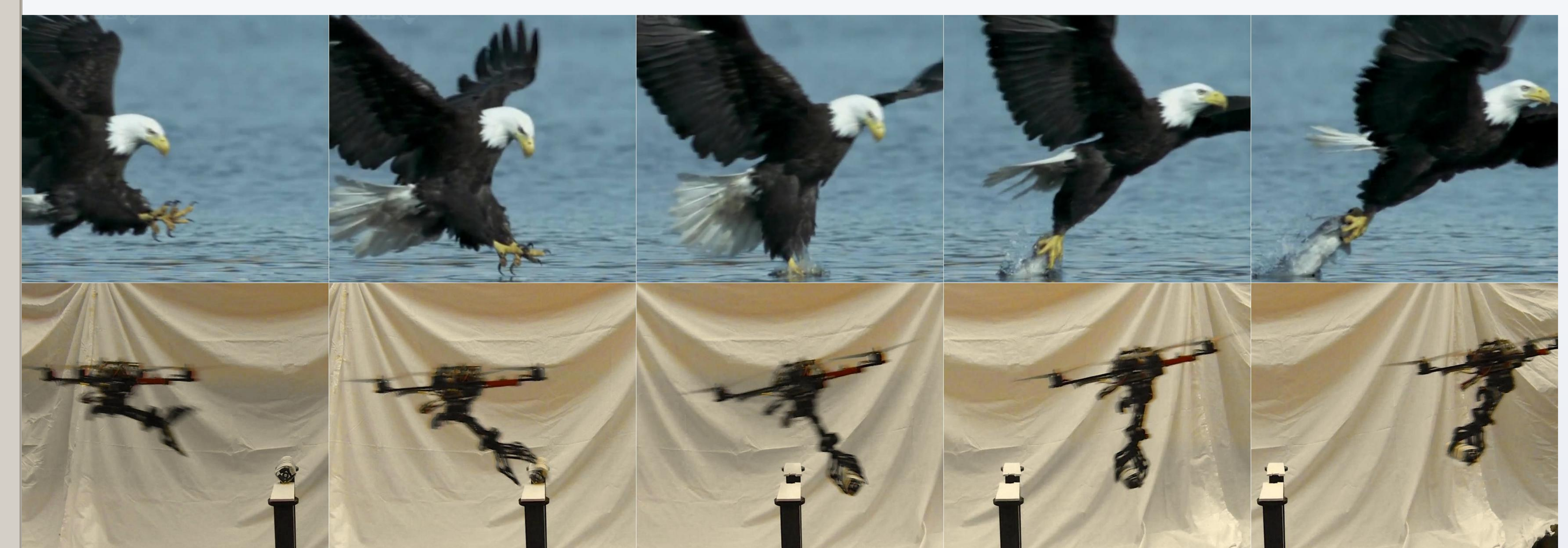
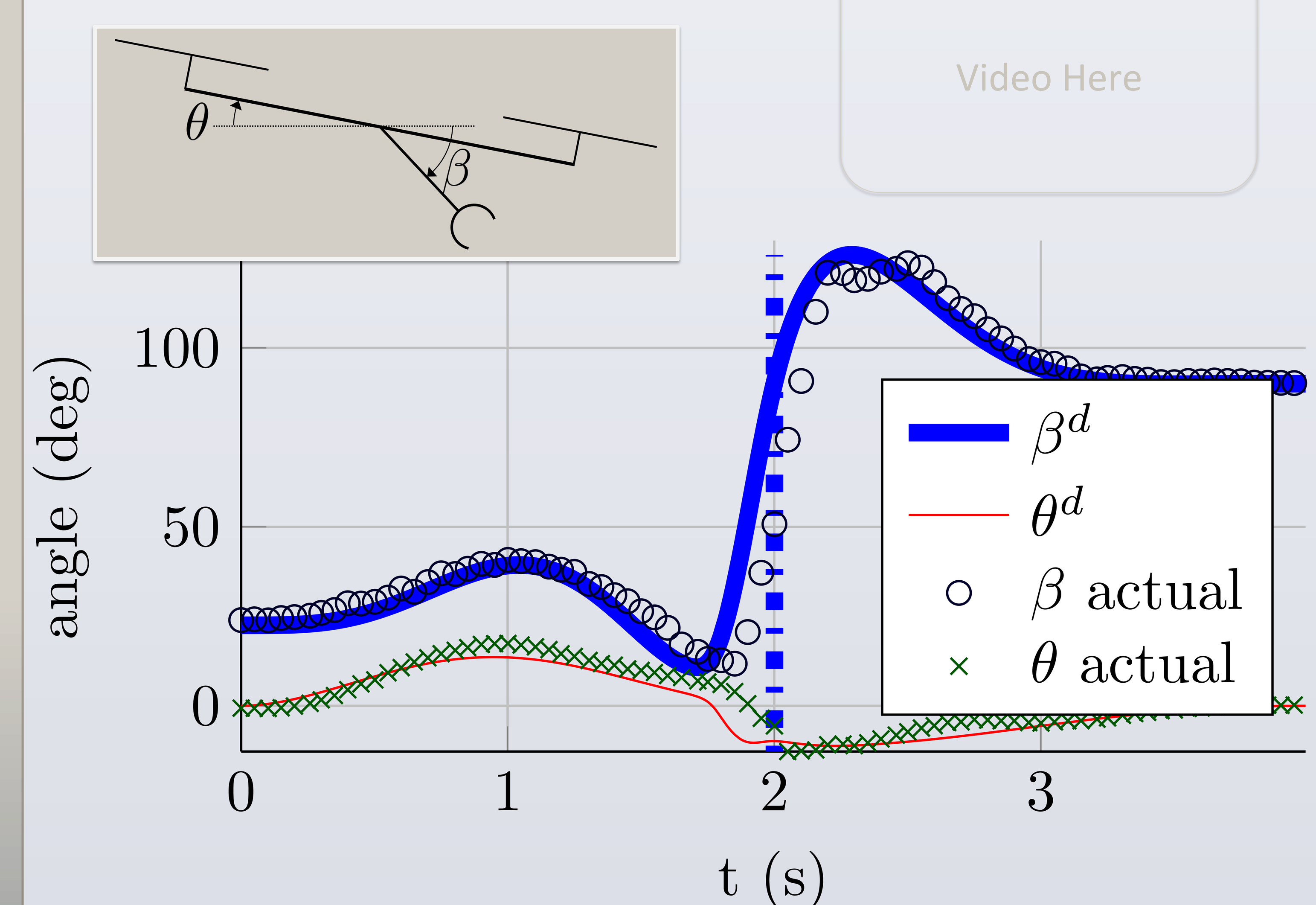


Figure: A still image comparison of a bald eagle and the robot grasping targets. For more details, see [4].

Video Here



Current and Future Work

- Formulate grasping as a visual-servoing problem
- Develop image-based control algorithms with feedback from image features
- Perform onboard blob detection using a Gumstix at 60 Hz
- Extend dynamic model and differential flatness to the 3-D case
- Extend the visual-servoing to the 3-D case by considering image moments for orientation estimation of the cylinder in the image

References

[1] Q. Lindsey, D. Mellinger, and V. Kumar, "Construction of Cubic Structures with Quadrotor Teams," in Robotics: Science and Systems, 2011.

[2] D. Mellinger, M. Shomin, and V. Kumar, "Control of Quadrotors for Robust Perching and Landing," in International Powered Lift Conference, 2010.

[3] K. Bass, B. Leith, J. Anderson, P. Bassett, J. Stevens, H. Pearson, and J. Turner, Nature's Most Amazing Events. 2009.

[4] J. Thomas, J. Polin, K. Sreenath, and V. Kumar, "Avian-Inspired Grasping for Quadrotor Micro UAVs," to appear IDETC/CIE, 2013.