A lightweight beak-like sensing system for grasping tasks of flapping aerial robots

Daniel Feliu Talegón

RA-L paper with ICRA presentation

Robotic

Vision

Control

Universidad de Sevilla

Motivation

Flapping-wing robots are a very promising technology that deserves to be deeply explored. These robots outperform other aerial platforms in many aspects.

This technology suffers from a hard limitation in size and weight, mainly due to the lack of ultralight structures and its dependence on batteries. This fact impulses the development of lightweight sensor subsystems that require low computational load.

The hard challenge of adding functional limbs and sensing subsystems for flapping wing has not been explored yet.

GRIFFIN

Contribution

- Design and construction of a lightweight sensor prototype, inspired by the bird's beak to be mounted in flapping aerial robots thus allowing interaction with the environment and perform **grasping tasks.**

- A method to estimate when the beak impacts with an object, **the contact point distance** and **the exerted force in the contact point**. It is based on the information collected by two strain gauges, one located at the base of the link and other located at an intermediate point.

- Our sensor system outperforms other designs because it is **ultralight, cheap and need very low computational load**.

GRIFFIN

Related works

- The success of grasping tasks with this type of configuration, relies on a good estimate of the contact point with the beak, since it can be in anywhere, therefore it is crucial to know the exact location in order to exert a prescribed force.

- In most of applications where a robot exert a controlled force:

1) it is assumed that this location is perfectly known.
2) the contact is produced at the tip of the robot.
3) the contact location and the contact force is determinated with a complementary system e.g. using vision system (weight, complexity)

GRIFFIN

Related works

The estimation method proposed has the following features:

1) it estimates the impact instant, the contact point distance and the exerted force in the contact point in real time.

2) it does not require a small payload placed at the tip because it is based on a model with distributed mass along the beam.

3) the estimation considers the effect of gravity, which make the algorithm valid in our application.

4) the estimation is fast and reliable and with a very low computational load, which is another requirement in our applications.

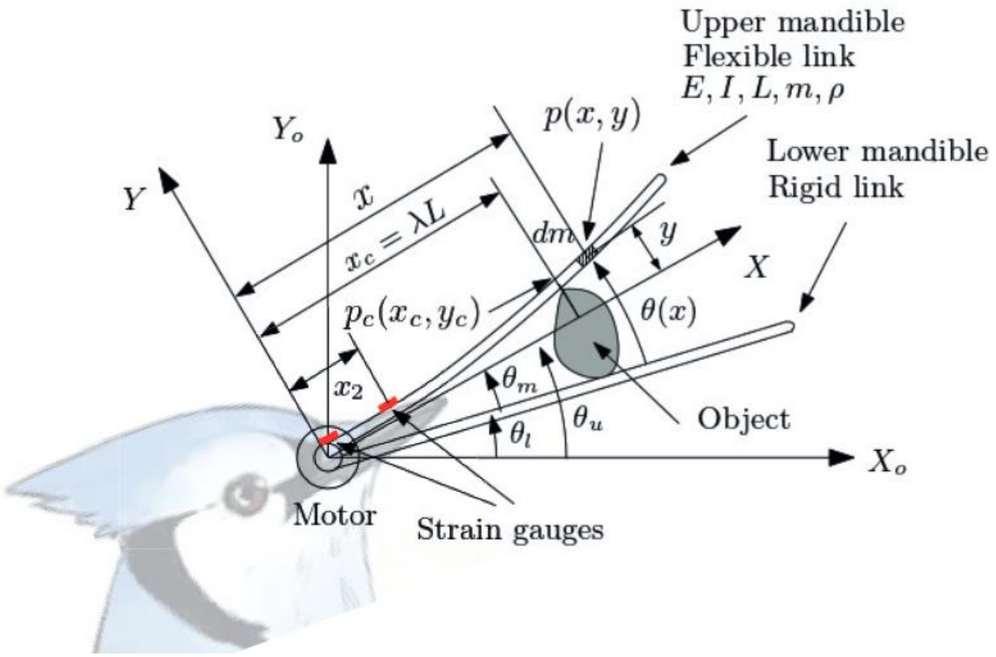
5) it does not require a force-torque sensor which makes it much lighter and minimizes its complexity.

GRIFFIN

Dynamic model of the bird's beak

The beak of the robotic bird is composed of two beam like parts.

The upper one is made of an elastic material. Then it can be modeled as a flexible link that deflects more or less in function of the location of the contact of the mandible with the grasped object and the force that the mandible exerts on it.



GRIFFIN

Dynamic model of the bird’s beak

The following assumptions are made about the beam that constitutes the upper mandible:

- The **deflection** of the beam is limited to **10%** of the total beam length in order to obtain a linear beam deflection.
- The upper mandible has been manufactured to have an **uniform cross section**.
- The contacted object does not move during sensing.
- **First mode** is much more **relevant** than the vibrations associated to other modes and that the gravitational force cannot be neglected neither in the movements nor in the contact condition.

GRIFFIN

Dynamic model of the bird's beak

The deflection of the upper mandible can be expressed as the addition of two components in the contact condition:

$$y(x,t) = y_t(x,t) + y_s(x)$$

transient response of all the points of the beam

the steady state component (permanent deflection of the beam assuming that the transient has vanished).

GRIFFIN

Methodology

1) The flexible beam is moved freely but servo controlled until it hits an object.

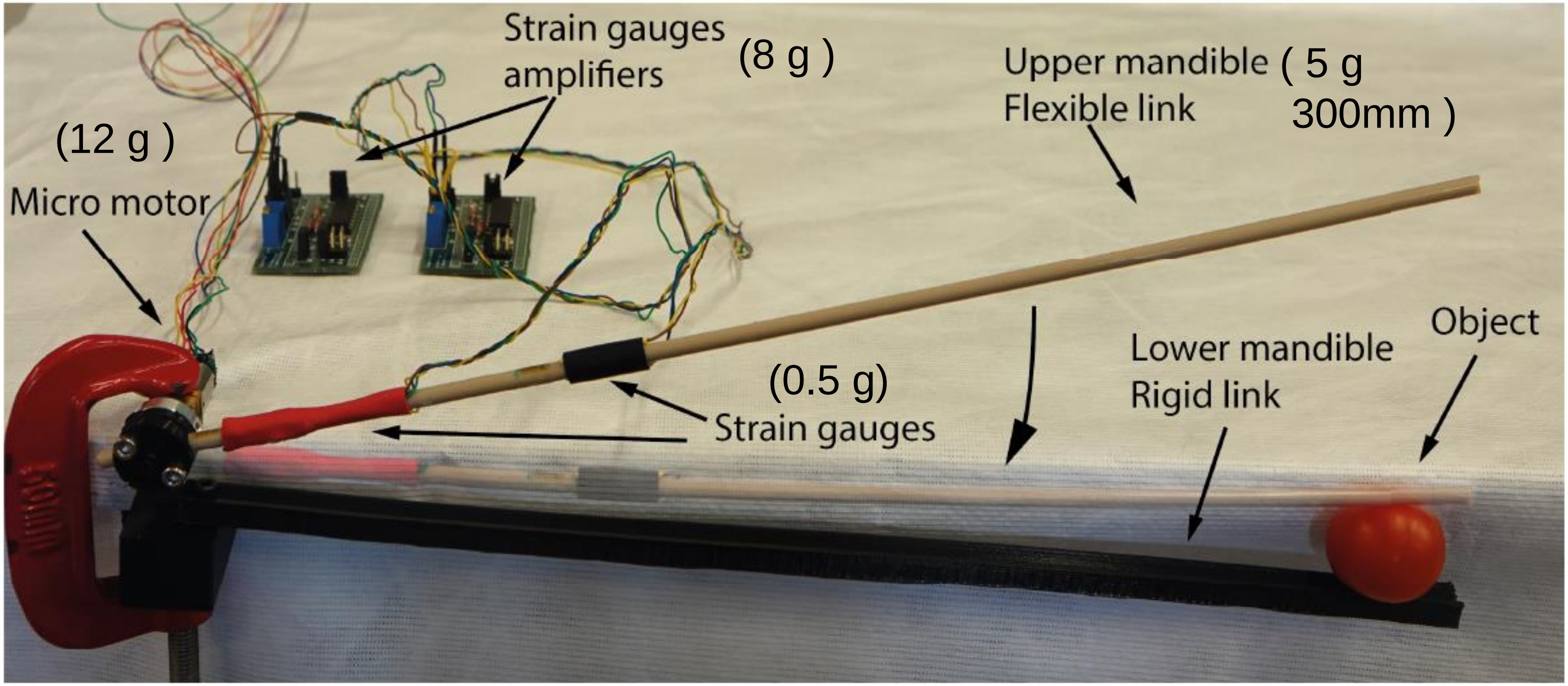
2) The flexible beam detects the instant of impact, t_c.

3) After contact has been made, the motor of the flexible link keeps pushing slightly the object to increase the contact force and prevent the sliding.

4) The estimator of the contact point and the exerted force is triggered based on the steady-state components. The torques signals used in the estimator are passed through a low-pass filter designed to attenuate the transient dynamics and to keep only the steady state components.

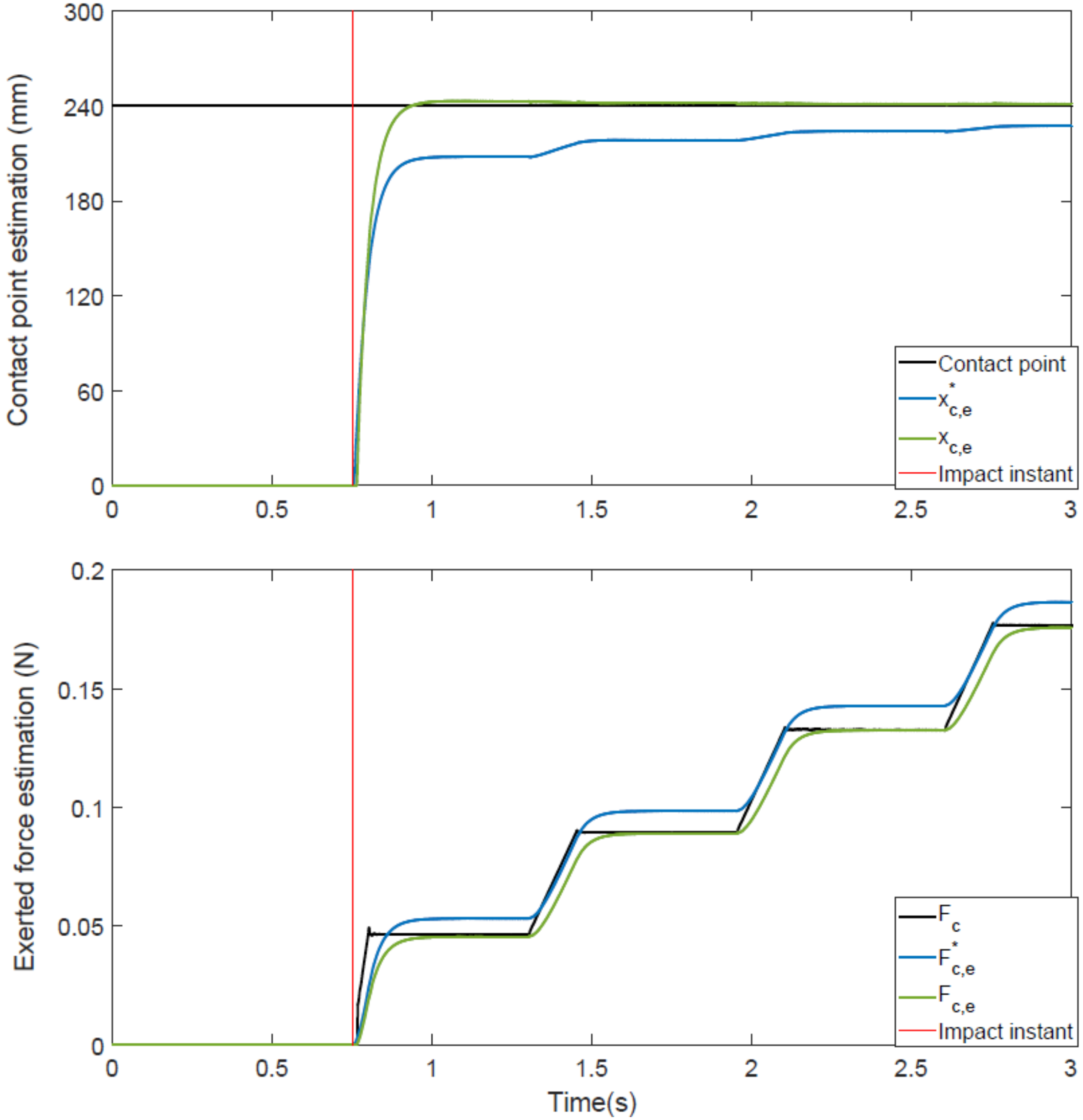
GRIFFIN

Experimental prototype

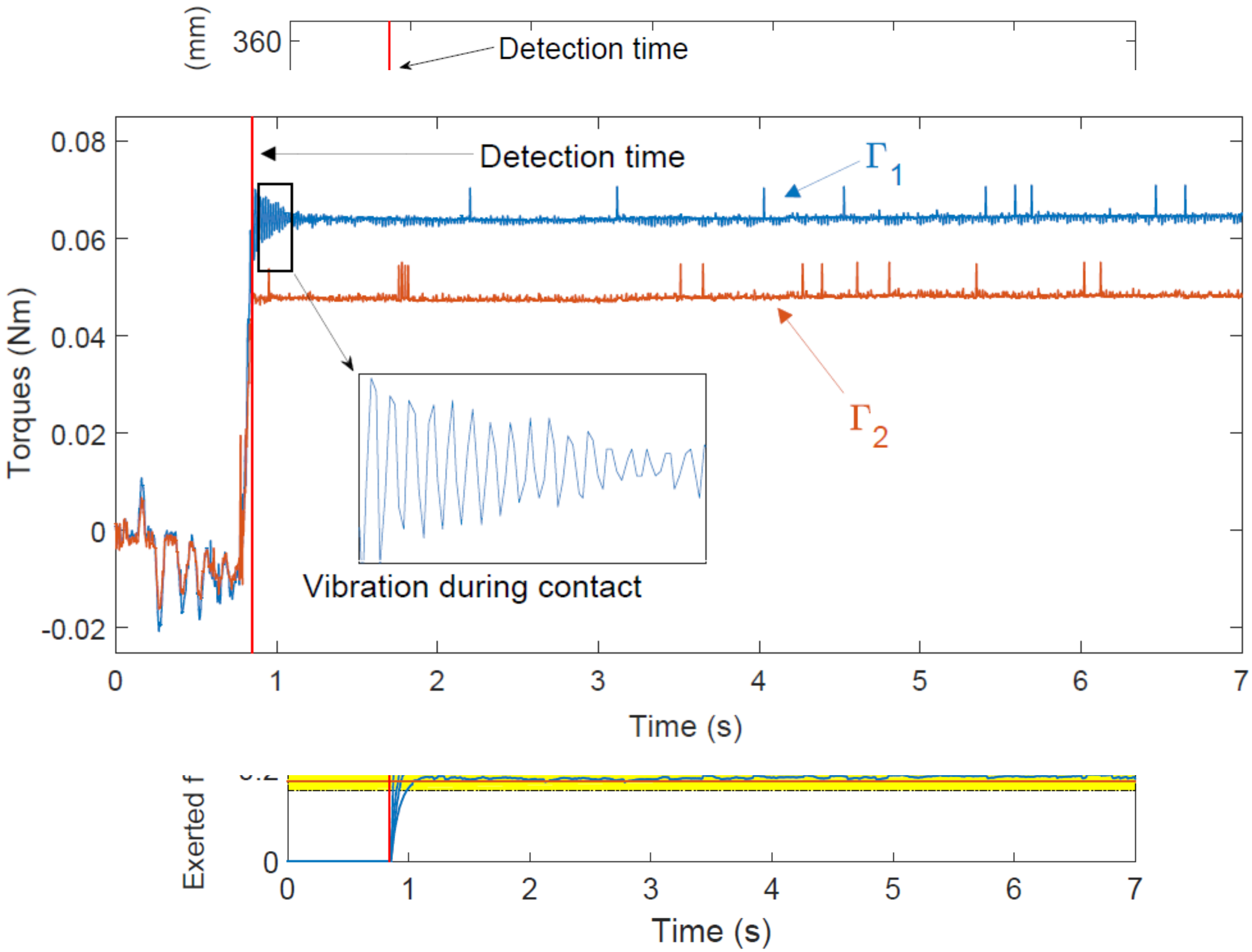


GRIFFIN

Simulated results (120 finite elements)



Experimental results



GRIFFIN

GRASPING EXPERIMENTS (I)

We show experiments where the beak–like sensing system grasps different objects at the tip

Conclusions

It has designed a very lightweight sensor system that emulates the bird's beak to allow flapping aerial robots perform manipulation and grasping tasks.

The estimation is performed sequentially, first detecting the impact of the beak and the object, and subsequently, the contact point distance and the exerted force. The proposed method has been validated through a finite element simulations and a experimental prototype.

The simulations demonstrate the high precision of the methodology and validate the assumptions made in the dynamic model. However, the experimental results show the effectiveness of the algorithm in real applications obtaining a maximum error in the contact point of 2.7% the length of the flexible beam and a 5% in the exerted force.

GRIFFIN

Thank you for your attention

Follow our latest advances on

http:// grvc.us.es

@grvc_us

Robotics, Vision and Control Group - GRVC

www.linkedin.com/company/grvcus