# Feeling: a measurable quantity?

As a part of the project on the 'Design and development of an autonomous mini-helicopter', we have designed and constructed several test rigs for calibration of sensors, servo actuators, measurement of rotor loads and control law evaluation. Figure 1 *a* shows a three-axis test rig specifically designed to have three rotations, denoted as pitch, roll and yaw motions, which can be independently locked or set free in any or all of the axes. This test rig comprises of two wooden frames and a circular metal plate made of aluminium. The centre metal plate is mounted on a bearing having yaw (rotation about a vertical axis) motion. The hinge at the middle of the outer frame provides the pitch motion (rotation about a horizontal axis) and the hinge at the middle of the inner frame provides the roll motion. Essentially, this test set-up provides three-axis rotation to any structure mounted on the metal plate. Figure 1 *b* shows the mounting of the model helicopter on the three-axis test rig.

The idea behind designing this experimental set-up was to test the control algorithms developed for autonomous flight control of the vehicle. As a by-product, using this three-axis test rig, a new technique was developed to experimentally determine the complete inertia tensor of a rigid body. (This technique has been patented; patent no. 2365/DEL/2007.)

The development of the control algorithm was undertaken in a step-by-step manner. Initially rpm control of the main rotor system was implemented. This control algorithm can be used to set the operating rpm of the rotor at any predefined value. In the vehicle control experiments, the rpm of the rotor was set at 1100 rpm.

As a first step, the experiment on pitch control of the helicopter was undertaken. During this experiment, roll and yaw motions were locked in the test rig. It may be noted that the centre of mass of the helicopter is much above the hinge, thereby making the system highly unstable in pitch. This kind of system is similar to balancing an inverted pendulum; the only difference is that the control force (or moment) is provided through the rotor system. The tilt sensor and the rate sensor mounted on the helicopter provide the tilt angle (measured from the vertical) and the angular rate of the helicopter in pitch respectively.

In the closed loop control, the feedback to the rotor control was initially given only using tilt angle and the angular rate. It was found that for a wide range of gain values, it is not possible to stabilize the system. The helicopter tilted

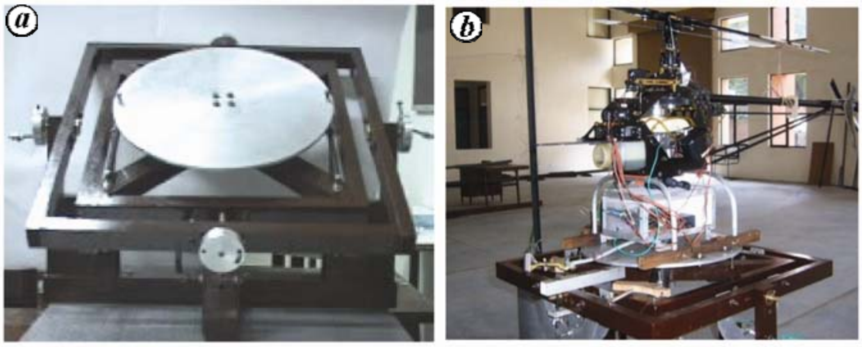

**Figure 1.** *a*, Three-axis test rig. *b*, Model helicopter mounted on the three-axis test rig.

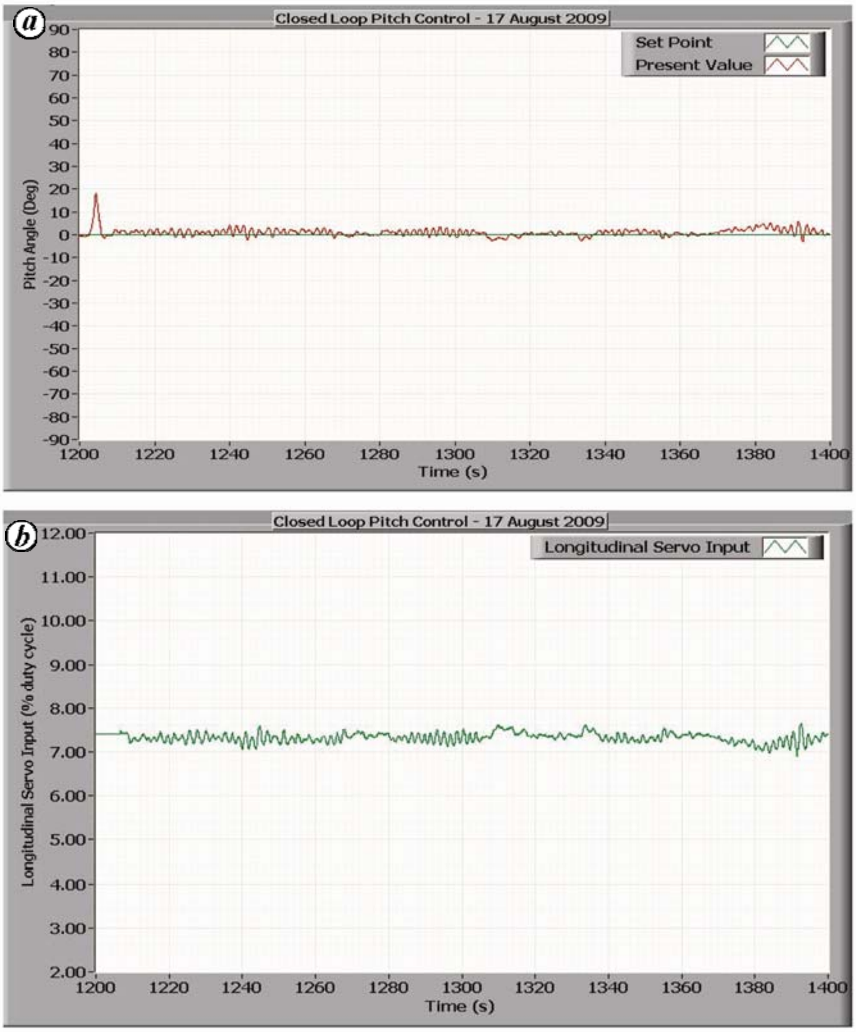


**Figure 2.** *a*, Pitch angle response of the mini helicopter with closed loop control. *b*, Control input during pitch stabilization of the mini helicopter.

(pitched) back and forth violently. This observation and the measured data did not provide any clue with regard to achieving stability of the vehicle in pitch. This led to a thought process about how a person balances a stick in his palm. There is no calculation done in the brain to balance the stick. Even a kid, after observation, learns to balance the stick in his palm. How is it done.

After a lot of contemplation, it led to a realization that we balance the stick in our palm by feeling. So how does one measure the feeling and use it in feedback control for stability? It became clear that human beings cannot feel position or velocity, but can feel acceleration which is the second-order time derivative of position. We cannot feel zeroth order or first-order derivative (velocity) of position. The *least* order of derivative we can feel is the second-order derivative of position. Maybe that is the reason, Newton's law relates force to acceleration (second-order time derivative of position, which is a feeling). (Then naturally a more fundamental question arises immediately: Could there be a more general relation having higher-order derivatives? May be possible!)

**Figure 3.** Attitude control of a mini helicopter under tethered hover flight.

On realizing the influence of feeling, the acceleration quantity (in the present case angular acceleration or pitch acceleration, evaluated by simple finite difference scheme using angular rate data at two time instances) was included in the feedback loop, and it was possible to stabilize the vehicle without any problem. It was experimentally observed that we could stabilize the vehicle even with zero rate feedback, despite the fact that the rate quantity represents damping. Figure 2 *a* and *b* shows the stabilized time response of the pitch motion and the corresponding control input respectively. The pitch angle was maintained at zero value, which refers to the vertical position of the helicopter. It is clear that the highly unstable pitch motion is made stable using acceleration (i.e. the quantity of feeling) feedback.

Incorporating acceleration feedback in the control loop, the attitude (pitch–roll–yaw degrees of freedom) control of the model helicopter under tethered hover flight was tested. The helicopter showed excellent attitude control. Figure 3 shows a snapshot of the helicopter in tethered hover flight. The effectiveness of acceleration feedback has also been reported recently[1,2].

This simple experiment and observation has raised an interesting point whether the events in nature (related motion) happen based on feeling, which can be a combination of several higher-order time derivatives of position. We plan to test this concept while we conduct future experiments on autonomous flights of the helicopter model.

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2. He, Y. Q. and Han, J. D., *J. Guidance, Control, Dyn.*, 2010, **33**(4), 1236–1250.

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# Melissopalynological studies on mangrove honeys from Sunderbans (Bangladesh) and Little Andaman (India)

A diverse spectrum of 27 pollen types belonging to 19 families was recovered from 12 honey samples, collected from the Sunderbans (Bangladesh) and Little Andaman (India). Melissopalynology, the study of honey with respect to its pollen composition, is an effective tool for studying the interaction between honey bees and vegetation, and is important in establishing apiculture-based honey industries. Pollen analysis of honey is used to determine its type, quality and origin, and indicate the floral nectar sources utilized by bees to produce honey[1–6]. In the growth and development of honey bees, nectar is the source of carbohydrates, whereas proteins are provided by the pollen[7]. The honey bees frequently make use of the resources available close to the site of the hives and analysing the proportional representation of different pollen types allows the characterization of honey from different regions, in terms of flora and vegetation.

Pollen analytical studies of Indian honeys are mostly fragmentary, although the honey and pollen load samples from different parts of India have been palynologically studied by several workers[8–11]. The importance of mangroves in honey industry has also been stressed[12–14]. However, melissopalynological studies from the Sunderbans (Bangladesh) are limited[15], whereas no such work has been undertaken from Little Andaman (India). Thus, the present study is aimed to understand the composition of vegetation around the bee hives and identify the major, medium and minor pollen plants through analysis of pollen content of regional honeys of the respective areas, and also to establish a basis for differentiation between honey samples procured from Katka, the Sunderbans, Bangladesh and from Dugong Creek and Jackson Creek, Little Andaman, India (Figure 1 and Table 1).

The Sunderbans is the largest single block of tidal halophytic mangrove forests in the world that lies at the mouth of the rivers Brahmaputra and the Ganga,