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LABORATORY GUIDE

3 DOF Helicopter Experiment for LabVIEW™ Users

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PREFACE

Preparing laboratory experiments can be time-consuming. Quanser understands time constraints of teaching and research professors. That's why Quanser's control laboratory solutions come with proven practical exercises. The courseware is designed to save you time, give students a solid understanding of various control concepts and provide maximum value for your investment.

Quanser 3 DOF Helicopter courseware materials are supplied in a format of the Laboratory Guide. The Lab Guide contains lab assignments for students.

This courseware sample is prepared for users of National Instruments **LabVIEW™** software.

The following material provides an abbreviated example of in-lab procedures for the 3 DOF Helicopter experiment. Please note that the examples are not complete as they are intended to give you a brief overview of the structure and content of the courseware materials you will receive with the plant.

TABLE OF CONTENTS

1. Introduction to Quanser 3 DOF Helicopter Courseware Sample

Quanser courseware materials provide step-by-step pedagogy for a wide range of control challenges. Starting with the basic principles, students can progress to more advanced applications and cultivate a deep understanding of control theories. Quanser 3 DOF Helicopter courseware covers topics, such as:

- Derivation of simple dynamic model
- State space representation
- State feedback control
- LQR control design
- Control parameter tuning

2. Laboratory Guide Table of Contents

The full Table of Contents of the 3 DOF Helicopter Laboratory Guide is shown here:

3. BACKGROUND SECTION - SAMPLE

Dynamics

The free-body diagram of the 3 DOF Helicopter is illustrated in Figure 3.1 and accompanies the Maple worksheet named *3 DOF Helicopter Equations.mws* or its HTML equivalent *3 DOF Helicopter Equations.html*. The equations can be edited and re-calculated by executing the worksheet using Maple.

The 3 DOF Helicopter modeling conventions used are:

1. The helicopter is horizontal when the elevation angle equals $\epsilon = 0$
2. The travel angle increases positively, $\dot{\lambda}(t) > 0$, when the body rotates in the counter-clockwise (CCW) direction
3. The pitch angle is positive, $\rho(t) > 0$, when the front motor is higher than the back motor

The 3 DOF Helicopter model that is used in this laboratory is analogous to a tandem rotor helicopter such as the Boeing HC-1B Chinook illustrated in Figure 3.2. As described in the FBD shown in Figure 3.1, the pitch of the helicopter, ρ, is the rotation of the helicopter about a line perpendicular to the length of the body located at the centre of gravity. For example, the illustration in Figure 3.2 would have a positive pitch given that the nose of the helicopter is above the horizon. The elevation axis is defined as a line parallel to the length of the body, at the base coordinate frame. Therefore, a change in the elevation angle, ϵ, translates into a change in the ''altitude'' of the helicopter as it rotates about the base frame. For example, if the helicopter shown in Figure 3.2 were rotating about an imaginary elevation axis, it might have a slightly negative elevation since the base of the helicopter is visible. Finally, the travel axis is defined as a vertical line at the base coordinate frame perpendicular to the elevation axis. A change in the travel angle, λ, translates into forward flight about the travel axis. For example, if the helicopter shown in Figure 3.2 were attached to an imaginary travel axis limiting its mobility, forward flight would result in a circular trajectory about the base frame.

The worksheet goes through the kinematics of the system. Thus describing the front motor, back motor, helicopter body, and counterweight relative to the base coordinate system shown in Figure 3.1. These resulting equations are used to find the potential energy and translational kinetic energy of the front motor, back motor, and counterweight of the system. The thrust forces acting on the elevation, pitch, and travel axes from the front and back motors are defined and made relative to the quiescent voltage or operating point.

$$V_{op} = \frac{1}{2}\frac{g(L_\omega m_\omega - L_a m_f - L_a m_b)}{L_a K_f} \tag{3.1}$$

where the parameters are defined in [1].

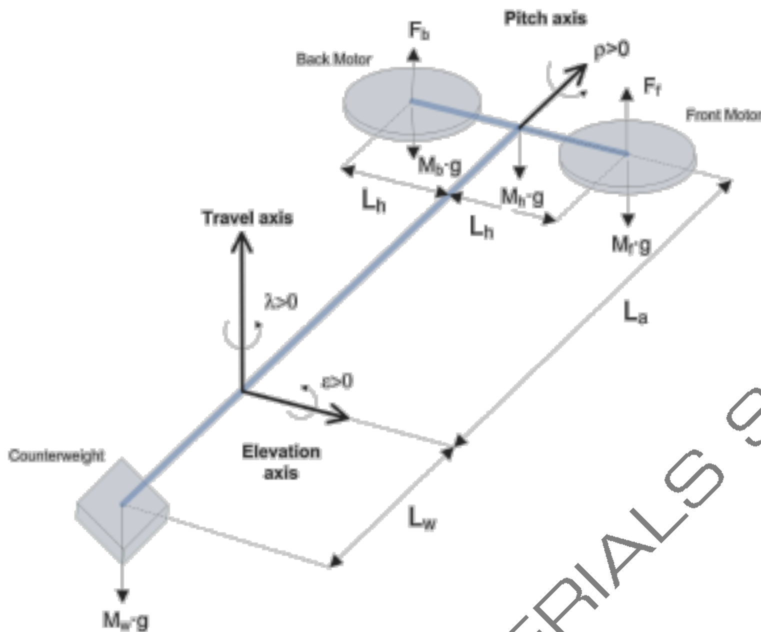

Figure 3.1: Free-body diagram of 3 DOF Helicopter .

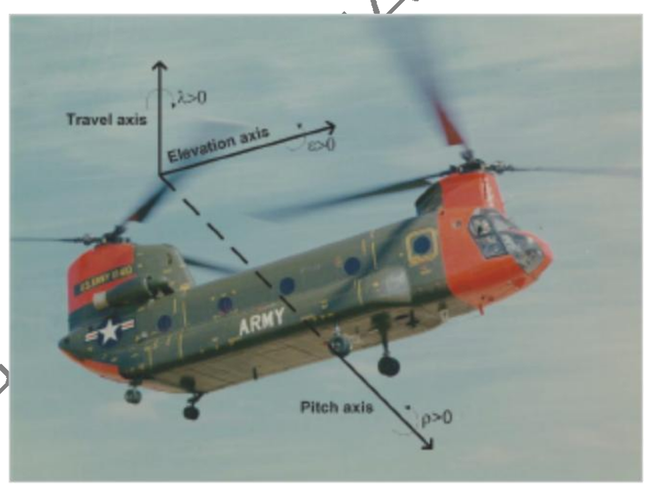

Figure 3.2: Translation of the free-body diagram onto a Boeing HC-1B Chinook.

4. Lab Experiments Section - Sample

Modeling, Control Design and Simulation

The following sections describe how to utilize LabVIEW™ and the Quanser Rapid Control Prototyping Toolkit® to develop the model, closed-loop controller, and simulation of the 3 DOF Helicopter experiment.

Objectives

- Generate a linear state-space model from the 3 DOF Helicopter system parameters
- Save the state-space model to a file that will be used for LQR control
- Design a LQR feedback controller to stabilize the 3 DOF Helicopter plant
- Simulate the performance of the LQR controller using the 3 DOF Helicopter nonlinear model

Modeling Procedure

Follow these steps to generate the state-space model of the 3 DOF Helicopter :

1. Load the LabVIEW™ software.
2. Open the LabVIEW project called 3*D HELI LAB.lvproj*, shown in Figure 5.2.

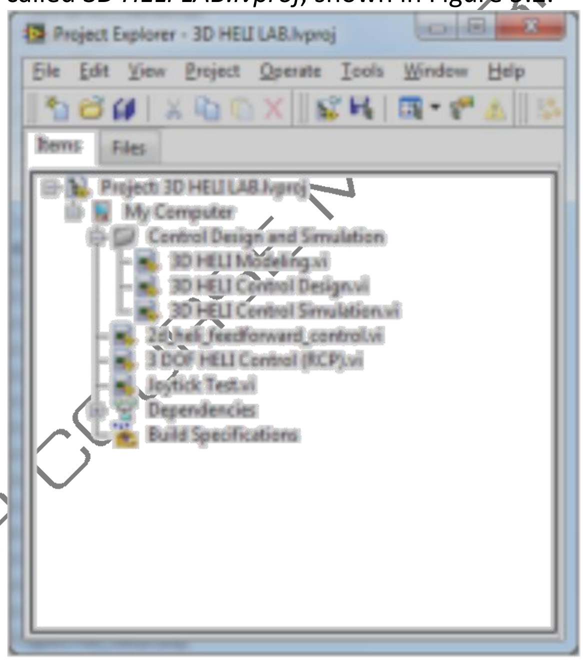

Figure 5.2: LabVIEW project used for the 3 DOF Helicopter system

3. Under the *Control Design and Simulation* directory in the project explorer, open the 3*D HELI Modeling* VI.
4. The front panel of the 3*D HELI Modeling* VI is shown in Figure 5.3.

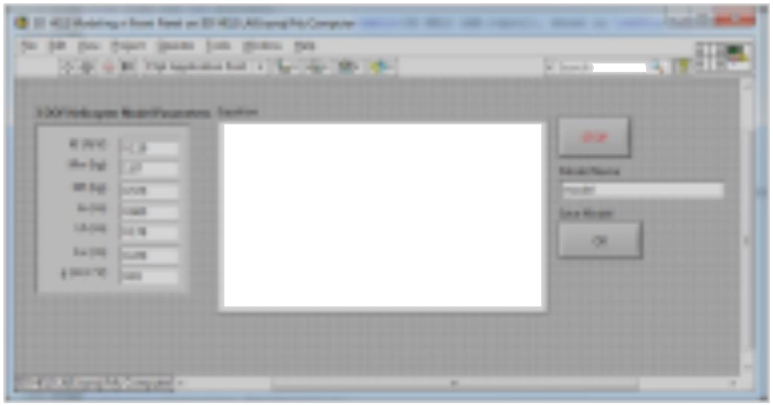

Figure 5.3: Model of the 3 DOF Helicopter.

5. Ensure all of the 3 DOF Helicopter model parameters are set in the VI list of parameters.
6. Run the VI. The resulting state-space model is shown in the Equation display on the front panel, as shown in Figure 5.4.

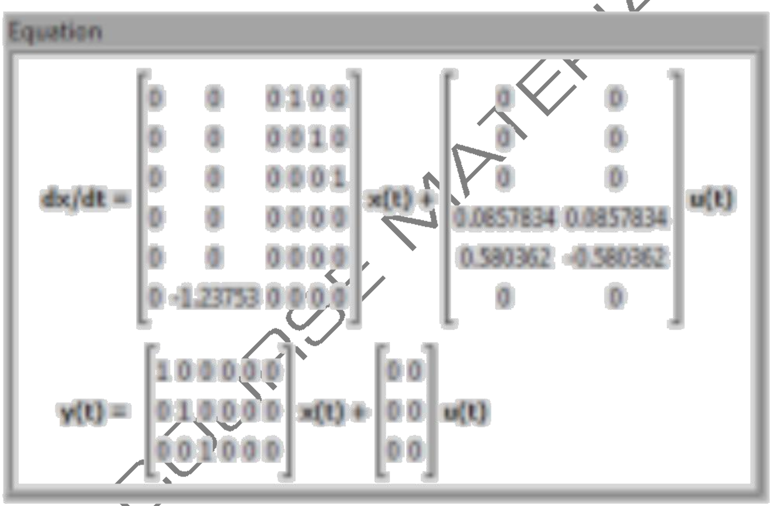

Figure 5.4: State-space model equations for the 3 DOF Helicopter

7. While the VI is running, click the OK button on the front panel to save the model to a file. This model file is used throughout the rest of the control design and simulation VIs.

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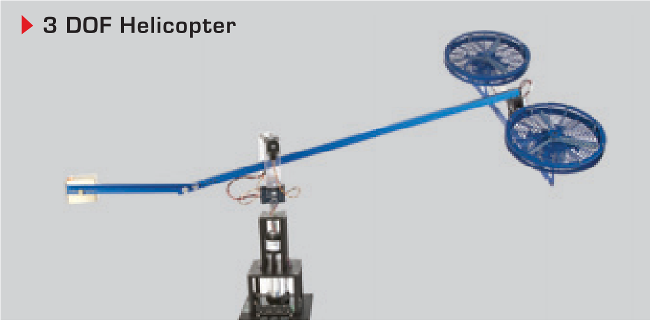

These plants are ideal for intermediate or advanced level teaching. They are also suitable for research relating to traditional or modern control applications of aerospace engineering. For more information please contact info@quanser.com.

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