QUANSER 3 DOF CRANE

The tower crane is one of the most widely deployed industrial platforms in the world today. It makes use of advanced controls to lower operating times and improve productivity. The Quanser 3 DOF Crane experiment helps teach students about the real-life control challenges involved in operating a tower crane.

A HANDS-ON WAY TO GRASP CRANE CONTROL CONCEPTS

Commonly used to build structures, tower cranes are designed to lift and move heavy objects over large distances safely. Operating them requires training and skills. The 3 DOF Crane experiment replicates much of the functionality of an actual tower crane and can be used to understand the dynamics and control challenges involved in everyday crane operations. For instance, the challenge of minimizing the motions of the load being carried introduces a great control problem for students.

HOW IT WORKS

The 3 DOF Crane has the same components as a real tower crane - the vertical tower or mast, the horizontal jib that sits on top of the tower, and the payload that moves up and down. The tower rotates in either direction using a high quality Maxon DC motor through a harmonic gearbox. This allows for high torques to be applied with minimal backlash. Two limit switches detect when the tower has reached its limits. If the tower surpasses either limit switch, two cut-off diodes stop the motor, ensuring safe operation of the experiment. The trolley suspended underneath the jib is fastened onto a linear guide and actuated using geared motor and lead-screw assembly. This allows the trolley to move along the jib smoothly and precisely. Two limit switches installed at each end of jib detect when the trolley has reached its end limits. The trolley has its own MICROMO DC motor that is fixed to pulley/spool system to move the payload vertically up and down. A limit switch underneath the trolley, where the steel wire is dispensed, detects when the payload has reached the top position.

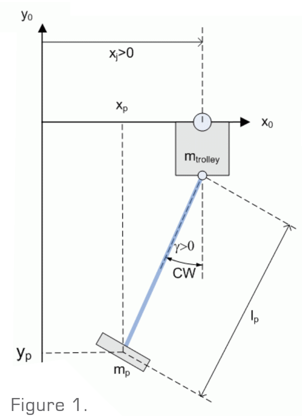


Figure 1.
Linear gantry challenge teaches how to minimize payload swings as the trolley move across the jib.

High-resolution encoders precisely measure positions of the rotary tower, the linear trolley, and the vertical payload. The deflection of the payload is also measured using encoders though an instrumented 2 DOF gimbal.

The 3 DOF Crane is comprised of three different subsystems, each with their own modeling and control challenges:

1. Rotary gantry is the tower crane coupled with the measured payload motions. As the tower rotates back and forth, students learn to use a state-feedback control to compensate for the motions of the payload.
2. Linear gantry is the trolley moving along the jib with the motions of the payload. As the trolley goes to a different position, students learn how to minimize the swinging payload.
3. Controlling the vertical position of the payload allows students to learn how to design a PID-based controller.

System specifications on reverse page.

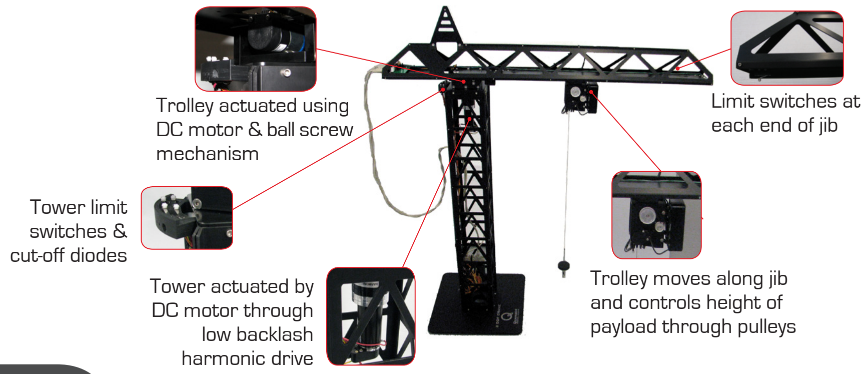
3 DOF CRANE WORKSTATION COMPONENTS

3 DOF Crane plant
Q8-USB or QPID/QPIDe data acquisition device
Quanser AMPAQ-L4 four-channel current power amplifier
QUARC Real-Time Control software for MATLAB®/Simulink®
User Manual provided on CD
Sample of pre-built controller and dynamic model

Mechanical engineering students from Texas A & M University at Qatar use the 3 DOF Crane workstation in their lab to unserstand the dynamics and control challenges in everyday crane operation.
Image courtesy of Texas A & M University at Qatar

SYSTEM SPECIFICATIONS

3 DOF Crane



CURRICULUM TOPICS PROVIDED

- Derivation of simple dynamic model
- PID control design
- LQR control design
- State space representation (for Rotary and Linear gantry subsystems)
- Transfer function representation (for Payloads subsystems)
- State-feedback control
- Control parameter tuning

FEATURES

- Flexible operation and control design using MATLAB®/ Simulink® and QUARC software add-on
- Fully documented system parameters
- Precise, stiff and heavy-duty machined components
- Open architecture
- Limit switches to detect when the tower, trolley, and payload have reached their limits
- High-resolution optical encoders for precise position measurements
- Cut-off diodes disable the tower motor when its limits are reached
- Sample model and control design documented and derived in Maple™ worksheet
- Trolley and payload driven by high-quality MICROMO DC motors
- Tower actuated by high quality Maxon DC motor
- Low backlash harmonic drive used for tower
- Three degrees of freedom (3 DOF) jib rotates about tower, trolley travels along underside of the jib, and payload can be moved up/down.

DEVICE SPECIFICATIONS

SPECIFICATION	VALUE	UNITS
Device mass	16	kg
Height of tower (from base plate to top)	120	cm
Tower base dimensions – L x W x H	40.5 x 40.5 x 1.0	cm
Total length of jib (horizontal member)	121	cm
Available length of track for trolley		
Trolley lead screw pitch	1.27	cm/rev
Encoder count resolution (in quadrature)	4096	counts/rev
Effective tower angle resolution	8.79×10^{-4}	deg
Effective trolley linear position resolution	8.38×10^{-7}	m
Effective payload linear position resolution	7.83×10^{-7}	m
Effective payload gimbal deflection angle resolution	0.0879	deg
Tower angle range (approximate)	±155.0	deg

MOTOR	TOWER	TROLLEY	PAYLOAD	
Resistance	11.5	6.8	7.10	Ω
Current-torque constant	0.119	0.0396	0.0261	N-m/A
Output power	90	20.6	19	W
Max continuous current	0.962	0.79	0.72	A
Motor gearbox ratio	100	3.7	14	
Motor load to pulley ratio			2	

COMPLETE WORKSTATION COMPONENTS

Plant	3 DOF Crane
Control design environment	QUARC Real-time Control Design software add-on for Matlab®/Simulink®
Documentation	User Manual (includes modeling derivation summary, control design, hardware setup and specifications, and instruction on how to run the supplied controllers)
QUARC Targets	Microsoft Windows® and QNX® Momentics
Data acquisition devices	Quanser QPID/QPIDe or Q8-USB
Amplifier	Quanser AMPAQ-L4 multi-channel linear current amplifier

Complete dynamic model and a sample controller are supplied.

About Quanser:

Quanser is the world leader in education and research for real-time control design and implementation. We specialize in outfitting engineering control laboratories to help universities captivate the brightest minds, motivate them to success and produce graduates with industry-relevant skills. Universities worldwide implement Quanser's open architecture control solutions, industry-relevant curriculum and cutting-edge work stations to teach Introductory, Intermediate or Advanced controls to students in Electrical, Mechanical, Mechatronics, Robotics, Aerospace, Civil, and various other engineering disciplines. Quanser educational solutions are fully compatible with: