Furuta Pendulum Control System - Requirements Documentation

1. Project Overview

The Furuta Pendulum Control System is a project for the MCT411 Hybrid Control course. The system must control a Furuta Pendulum (Rotary Pendulum) to maintain the pendulum in an upright position using LQR control techniques. The system will be implemented primarily in Simulink with Simscape for mechanical simulation.

2. System Requirements

2.1 Functional Requirements

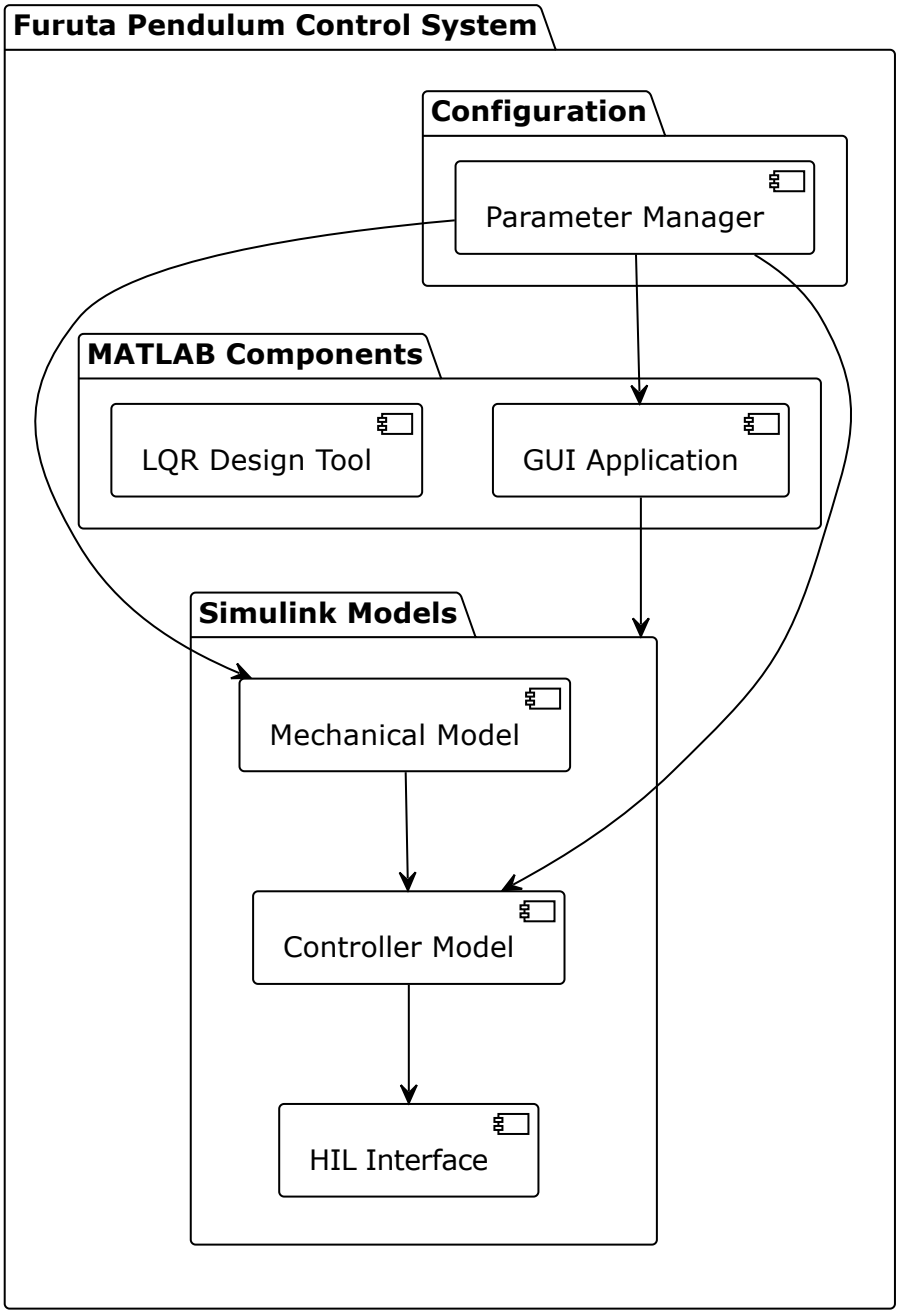
ID	Requirement	Description
FR-1	Pendulum Control	System shall control the pendulum angle theta1 to be zero, maintaining the pendulum in the upright position
FR-2	LQR Controller	System shall implement an LQR controller to regulate the pendulum in the upright position
FR-3	Swing-up Controller	System shall implement a swing-up controller to move the pendulum from hanging position to upright position
FR-4	Disturbance Rejection	System shall overcome disturbances and maintain the pendulum in the upright position
FR-5	GUI Display	System shall provide a GUI to display pendulum angle and actuator signal
FR-6	Simulation	System shall provide a Simulink simulation model of the Furuta Pendulum
FR-7	HIL Implementation	System shall implement Hardware-in-the-Loop using Simulink with Arduino support package

2.2 Non-Functional Requirements

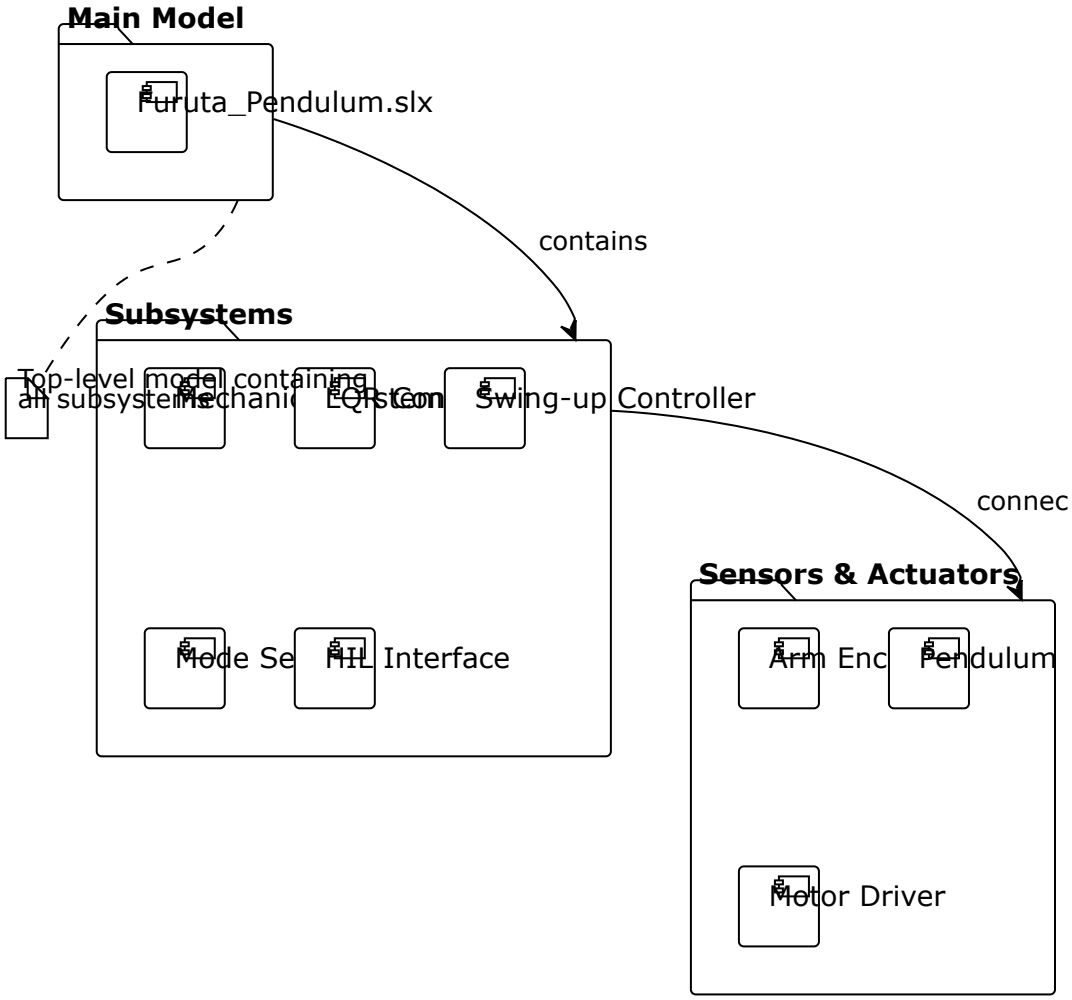
ID	Requirement	Description
NFR-1	Robustness	System shall maintain pendulum stability despite external disturbances
NFR-2	Real-time Performance	System shall update control signals in real-time
NFR-3	Parameter Configurability	System shall allow configuration of physical and control parameters

ID	Requirement	Description
NFR-4	Modularity	System shall have modular architecture for easy maintenance and extension

3. System Architecture



4. Simulink Model Structure



5. Component Responsibilities

5.1 Mechanical Model

- Implements the physical Furuta Pendulum dynamics using Simscape Multibody
- Includes pendulum rod, arm, joints, and physical properties
- Provides sensor outputs (angles and angular velocities)

5.2 LQR Controller

- Implements Linear Quadratic Regulator for pendulum stabilization
- Maintains pendulum in upright position (theta1 ≈ 0)
- Uses state feedback with pre-computed gain matrix

5.3 Swing-up Controller

- Implements energy-based swing-up algorithm
- Moves pendulum from hanging position to upright position

5.4 Mode Selector

- Manages transitions between swing-up and regulation modes
- Automatically switches based on pendulum position

5.5 HIL Interface

- Provides interface between Simulink and Arduino hardware
- Reads encoder values from hardware
- Sends control signals to motor driver

5.6 Parameter Manager

- Loads configuration from JSON file
- Provides parameters to all Simulink blocks
- Enables easy tuning of system parameters

6. Constraints

- Must be implemented primarily in Simulink
- Mechanical system must use Simscape Multibody
- Must use LQR technique (not PID)
- Must implement HIL using Simulink Arduino support package
- Must support both simulation and hardware operation
- GUI must display pendulum angle and actuator signal