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Development of Virtual Environment for Swing-Up of Rotary Double Inverted Pendulum for Engineering Education

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The swing-up control of a Rotary Double Inverted Pendulum (RDIP) is considered one of the benchmark problems in teaching advanced control systems engineering. The RDIP is a 4th-order nonlinear underactuated system that involves many coupled forces affecting the system's stability. Fabrication of a reliable RDIP system requires precision machining and high-quality electronic sensors, and the few readily available products on the market are prohibitively expensive. With the current number of student enrollments in engineering faculties at state universities in Sri Lanka, multiple units of such systems are required to improve student interaction and hands-on experience. Therefore, a virtual environment for simulating and testing such systems could improve the current status of engineering education in Sri Lanka. In this study, a virtual environment has been developed for studying the swing-up behavior of the rotary double inverted pendulum. The developed virtual system is based on commonly available software in engineering education. The state-space mathematical model of the system was built using the Lagrangian method. Computer-Aided Design was used to demonstrate the dynamic system behavior visually, which was integrated with real-world conditions such as gravity, friction, and joint damping. The swing-up is achieved using multi-stage energy control. Energy is pumped into the system sequentially, considering the energy levels of the two links separately until the target energy level is achieved. Overall, this virtual environment allows multiple users to engage in individual learning of control systems engineering at once, even without depending on an internet connection. Furthermore, deploying a virtual RDIP will completely eliminate expensive hardware failures due to student mistakes.

Keywords: RDIP, Remote learning, Energy control, Engineering education, Swing-up control