Automated Project-based Assessment in a Predictive Control Course

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***Abstract*—Written assessments, such as book problems and exams, have customarily been used in control courses to measure student progress, but usually only gauge their knowledge of the theoretical concepts. More complicated control methods, such as predictive control, benefit from gauging student progress through implementation projects. We present a set of automatically marked project-based assessments that test student knowledge on concepts ranging from the derivation of physics models to the creation of a closed-loop predictive controller. We present a simulation framework that allows for the students to utilize any predictive control concepts that they decide to use in their implementation. The framework then automatically tests the student solutions against multiple constraint sets and conditions to provide quantitative data for marking the assessment.**

I. Extended Abstract

Assessing student progress in control courses has customarily been done using written assessments, such as exams and book problems. These assessments may not accurately reflect the student understanding of the material, since they focus on problems that can be completed in a short time frame and usually have many simplifications. In more complex control topics, such as Predictive Control, the controller design cannot be easily assessed using the standard written means. Instead, these assessments may focus on more theoretical aspects, such as stability theory and matrix formulations, rather than the application of the controller to a real system.

We present a series of automated assessments that can be used to determine student understanding of predictive control through its implementation. These assessments utilize a laboratory-scale gantry crane made by INTECO [1], but can be adapted to other physical systems. The students submit these assessments through the online tool Cody Coursework, developed by MathWorks [2]. This tool provides an on-line platform for students to submit MATLAB functions/scripts, and for instructors to define an automated test suite to check the correctness of the submitted code. This provides an objective marking scheme that provides fast results to students.

In the first assessment, the students derive a continuous-time mathematical model of the crane, and then create a linear discretization. In the following assessments, the students create MATLAB functions that construct the linear predictive control formulation and create a controller implementation. These functions are marked automatically by passing in different physical systems, horizon lengths and physical parameters. In addition to the on-line submission, students are provided laboratory time to use these functions on the actual crane.

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In the final assessment, the students are asked to design a complete closed-loop control system for the gantry crane. The objective is to move the crane from a starting point to a target point, while both the cart and the payload mass remain inside a specified region in the xy plane. This region can be arbitrary, but we limited this to two shapes: a rectangle, and an elbow with a 90° bend. The students are not given exact coordinates defining the shape at design time — instead they must design a controller that accepts them at run-time.

For marking, the student controller is run using multiple variations of the shapes; such as with decreasing widths or with the target point moving closer to the boundary. On each run, the computational time of the controller, the settling time of the system and any constraint violations are recorded. These provide metrics to determine the performance of the student's design and can be used to gauge their understanding of how more complex concepts in MPC (e.g. soft constraints or disturbance rejection) can improve their design.

The students are provided with a framework in MATLAB/Simulink where they write four functions: a setup function, a target generator, a state estimator, and the controller. A simulation script runs the setup function first, which allows the student to construct any matrices or define any controller parameters for use inside the three other functions. The three other functions are automatically placed inside a Simulink diagram that contains a nonlinear SimScape model of the gantry crane. The students are provided complete freedom in their design choices, as long as it fits within the framework.

We had to overcome some limitations with the current version of Cody Coursework. First, students are only allowed to submit one file, so we developed tools to extract the multiple functions from the single file. Additionally, the nonlinear Simulink model could not run in the Cody Coursework system due to software limitations. Instead, only syntax checking and a linear simulation were run online to verify the code; with the actual marking performed using scripts on a local machine.

Though there was some initial time investment with configuring the Cody Coursework assignments and creating the framework, we have now developed a system that should be transportable to other courses and reusable from year to year.

References

[1] INTECO, "3D Crane." [Online]. Available: http://www.inteco.com.pl/products/3d-crane/

[2] MathWorks, "Cody Coursework." [Online]. Available: https://uk.mathworks.com/academia/cody-coursework.html