Hierarchical and Distributed Building Temperature Control*

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Abstract

In this lab you are going to implement a hierarchical and distributed controller for the building temperature control problem. This lab is different from the previous ones in that here you are given the flexibility to implement *any* type of controller that you would like, but you must get the approval of what you will do from the instructor/TA before you do so. The focus of the lab is *both* on hierarchical/distributed control *and* the process of control system design and implementation.

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*Under the direction of K. Passino, this experiment was originally constructed by a group of undergraduates in an EE 682P design class, and it was later significantly improved by Todd Broceus and Tyson Rathburn (e.g., they added the power supply and greatly improved the flexible physical construction). Jorge Finke added the electrically controllable fans, interface cables, and implemented a controller in dSPACE.

1 Introduction

The basic requirement is that you confront the central challenges of coping with many plant inputs and outputs, for spatially distributed controller, but where there are interactions between the different subsystems, at least in some cases. You must define the structure (functional architecture) of the controller, the design methodology for the controller, the closed-loop specifications, and the manner in which you evaluate if you have met the closed-loop specifications. You will be graded both on the quality of the controller that you implement, and on the process that you use in the implementation.

2 Laboratory Procedures

2.1 Necessary Equipment

- 1 dSPACE software.
- 1 DS1104 interface card.
- Model building, 2 floors.

See the documentation on the web for how to connect the experiment.

2.2 Controller Development

The following provides some hints and broad guidelines for how to develop a controller:

1. Gain a good intuitive understanding of the plant. You may want to do this via experimentation (e.g., to study cross-coupling effects).
2. Gain a good understanding of the effects of disturbances (e.g., wind blowing in a window at a variable rate or the effect of nearby rooms).
3. Decide on the role/use of models for design and simulation. Justify your choices.
4. Pick a design methodology (e.g., a conventional one where you use a linear MIMO model that characterizes interactions between rooms or a systematic yet heuristic methodology). Clearly explain your approach.

2.3 Performance Objectives

Next, you must define your control objectives (closed-loop specifications):

1. Specify control objectives for the low-level control loops (e.g., the control of a single isolated room). These should include typical measures like rise-time, overshoot, settling time, and steady state error.

2. Specify control objectives between temperature zones (e.g., to keep the interaction to a minimum or to allow for some variations in one room if it is to be used to heat what you consider to be a more important area in the building).

3. Specify overall objectives (e.g., to reach steady state temperature in *all* rooms from a set condition within a certain amount of time).

4. You must include in your control objectives some specification to be able to do disturbance rejection, for a disturbance scenario that you define. This could be for single or multiple zone cases.

2.4 Control System Evaluation

Next, you must evaluate your control system:

1. If you developed a mathematical model use it to evaluate the closed-loop system (a part of the verification process). You can do this via either mathematical analysis (e.g., controllability, observability, stability) or via simulation. If you did not develop a mathematical model then clearly you will not be able to use simulations or mathematical analysis for verification and evaluation of the closed-loop system.

2. Define a *procedure* for evaluating the controller that you implemented. This procedure should be properly designed to be able to evaluate if the closed-loop specifications are met. Your procedure matters, be careful in creating an honest and thorough evaluation (if you do not feel it is entirely thorough then explain why).

3. Use your experimental evaluation procedure for your developed control system.

3 Post-Laboratory Exercises

1. Provide a detailed explanation of your controller development and performance objectives.

2. Provide a detailed explanation of your evaluation procedure and support your conclusions/evaluation with closed-loop responses taken in the laboratory.