Pacific Northwest NATIONAL LABORATORY

PNNL-29168

Optimal Control by Transfer-Learning

September 2019

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U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

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Abstract

Through the project, a transfer-learning based optimal control methodology was developed. This can significantly reduce the time and data required for model learning and increase operation robustness and resilience via data-driven controller optimization. Figure 1 illustrates an approach to transfer knowledge from a source task (S) to a target task (T). This methodology includes three major elements: 1) extraction of control knowledge or knowledge of tuning control parameter from a source feedback control task; 2) transferring of control knowledge from the source control task to a target control task (initialization of control parameters for the target control task); and 3) fast-adaptation of control parameters for the target task to achieve optimized performance.

Acknowledgments

This research was supported by the Energy and Environment Mission Seed under the Laboratory Directed Research and Development (LDRD) Program at Pacific Northwest National Laboratory (PNNL). PNNL is a multi-program national laboratory operated for the U.S. Department of Energy (DOE) by Battelle Memorial Institute under Contract No. DE-AC05-76RL01830.

1.0 Introduction and Project Description

The development of a control system has long been dependent on the transfer of knowledge, either in the form of previous experimental data or classical design principles. Transfer-learning has been developed to help facilitate and improve the process of knowledge-transfer from source task to the target task. In the past, it has been mainly applied to binary text classification and image classification, but limited applications in control system design. Notably, in building energy system, the current approach to transferring control knowledge is based on interpretation of control logic sequences into computer code, and human in the loop approach to tuning controller parameters. Advanced control algorithms such as model-based predictive control (MPC) have shown optimized performance with higher energy efficiency. MPC designs require significant effort and data to train the models that capture the system dynamics before optimizing the control decisions. The need for predictive models that have high accuracy is the main challenge for scalable deployment of MPC. Therefore, this project aims to integrate transfer-learning with feedback control design algorithms to reduce the computational time and data needed for controller development for a target task and apply it to building energy system domain.

2.0 Results and Accomplishments

In this project, three major tasks were accomplished and output three items: definition of transfer-learning scenarios in building control application, theoretical derivation of the transferability for the control system (linear and nonlinear system), and a case study in residential building for transfer-learning based control application.

Notably, in the theoretical analysis, we have investigated transfer learning in the context of the controller for dynamical systems. First, we have introduced a novel algorithm to design the transferable and non-transferable control components for linear systems. Secondly, we have derived the transferability conditions on the controller between two different nonlinear dynamical systems. Finally, we have numerically evaluated the performance of our transfer-learning based methods for exemplary linear and nonlinear dynamical systems (Figure 2).

In the case study, we applied the transfer-learning based controller for temperature control (optimal start) in residential building. Two identical single-family houses located in Alaska and in Hawaii were set as the source and target system for optimal start controller application. Preliminary result shows significant saving in computational time in the case with transfer-learning, comparing to the case without transfer-learning.

Figures/Tables

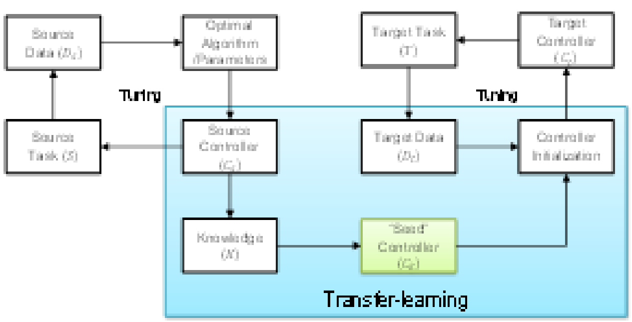

Figure 1 Control algorithm realized by transfer-learning.

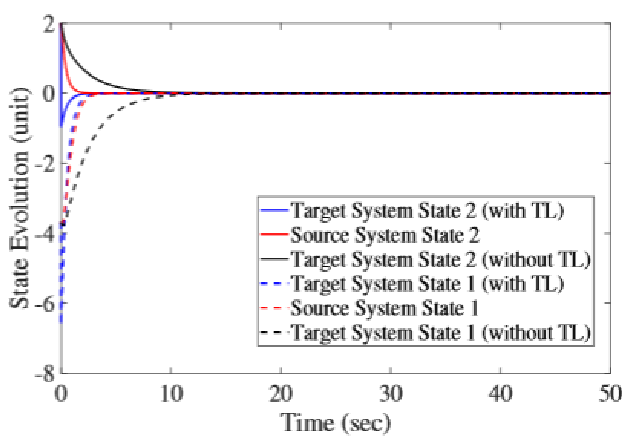

Figure 2 State evolution for Source and Target System, with and without Transfer Learning for the linear system example.

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