CPS: TTP Option: Medium: Multiobjective Control of Catoptric Systems

ROGER CHAMBERLAIN, CHANDLER AHRENS, CHRIS GILL
Dept. of Computer Science and Engineering, School of Engineering and Applied Science
College of Architecture, Sam Fox School of Design & Visual Arts
Washington University in St. Louis

Email: roger@wustl.edu

1. INTRODUCTION

FIXME: What are we doing?

FIXME: Where (if at all) should we define Open-Source Architecture (OSArc) as distinct from open-source software? How do the notions of OSArc integrate with what we are doing? (This is a Chandler question.) Is [18] a good citation (I just found it on wikipedia)? How about one or more things that Chandler has written?

FIXME: Articulate specific research questions below.

This research will investigate the following questions:

1. ***What are the qualitative and quantitative benefits that can be achieved for bulding daylighting and thermal management through the use of catoptric systems?***

   Issues within this question include FIXME: talk about multi-objective control in an MDP framework.

2. ***How do we provide for the safety, reliability, maintainability, and continued efficacy of these systems?***

3. ***Can we design abstractions that encapsulate sub-systems for effective reuse?*** Ultimately, we would like to generalize the above into abstractions that can be leveraged more broadly for arbitrary cyber-physical systems development.

FIXME: Brief description of who we are and what we've done.

2. BACKGROUND AND RELATED WORK

FIXME: Describe first two installations.

FIXME: Literature review [3, 5, 10, 13, 15].

FIXME: Describe MDP-based optimization and our history with it.

Markov Decision Processes (MDPs) [17] represent a general approach to modeling optimization problems and have been applied in a diverse set of application areas [21]. Examples include robotics [1], economics [4], experiment design [12], medical decisions [2], manufacturing [22], agriculture [14], and our own group's use in scheduling [11, 20] and wireless spectrum management [16].

In this proposal we adopt the definition used by Glaubius et al. [11] of a (discrete-time) Markov decision process as a 5-tuple $(\mathcal{X}, \mathcal{A}, T, R, \gamma)$, with ***states*** designated as $\chi \in \mathcal{X}$, ***actions*** designated as $a \in \mathcal{A}$, and a transition system, T, which gives the probability $P_T(\chi' \mid \chi, a)$ of transitioning from state χ to state χ' on action a. The reward function $R(\chi, a, \chi') \in \mathbb{R}_{\geq 0}$ describes the reward that accrues when transitioning from state χ to state χ' via action a, under a discount factor, γ, to ensure convergence of the long term reward.

3. RESEARCH DESCRIPTION

3.1. Intellectual Merit

The intellectual contributions of this project are FIXME: describe summary of intended intellectual merit [9].

4. EVALUATION/EXPERIMENTATION PLAN

5. PROJECT MANAGEMENT AND COLLABORATION PLAN

6. BROADER IMPACTS

FIXME: Describe broader impacts: environmental benefits of energy savings and quality of life benefits to building occupants.

At the undergraduate education level, this work is closely related to FIXME: describe CSE 132 connection.

At the graduate education level, this work will support 4 graduate students at Washington Univ. in St. Louis. FIXME: Expand, including REUs, multidisciplinary angle.

We will leverage a pair of existing university programs to help us attract students from traditionally underrepresented groups. The Olin Fellowship Program (for women) and the Chancellor's Fellowship Program (aimed at underrepresented minority students) have had a successful track record of enabling individuals to pursue graduate study. In our experience, the most effective method for attracting students from underrepresented groups is by personal contact with a suitable role model. To facilitate this, we regularly ask the appropriately qualified individuals in our group to be actively involved in the recruiting process. This cohort currently includes two minority graduate students (one African-American student and one hispanic student). FIXME: Can we strengthen the BPC story? Maybe somehow with 132 and maker spaces?

7. RESULTS FROM PRIOR NSF SUPPORT

CSR: Small: Concurrent Accelerated Data Integration (CNS-1527510, PI: R. Chamberlain), 10/2015–9/2019, $519,275.

Intellectual Merit – This project investigates the accelerated execution of data integration workflows, which increasingly are bottlenecks in data science. Execution platforms being targeted include both graphics engines and FPGAs. Publications resulting from this work include [7, 8, 16, 19].

Broader Impacts – This research project has supported 3 graduate students and 4 REU students. The applications investigated come from the fields of computational biology, astrophysics, and the Internet of Things, further expanding the scope of the students' experience. A benchmark suite of these workflows has been released as a community resource [6].

TBD - CyberMechProject (CNS-, PI: C. Gill), dates and dollars TBD.

Intellectual Merit – TBD

Broader Impacts – TBD

REFERENCES

[1] N. Achour and K. Braikia. An MDP-based approach oriented optimal policy for path planning. In *Proc. of International Conference on Machine and Web Intelligence*, pages 205–210, Oct. 2010.

[2] O. Alagoz, H. Hsu, A. J. Schaefer, and M. S. Roberts. Markov Decision Processes: A Tool for Sequential Decision Making Under Uncertainty. *Medical Decision Making*, 30(4):474–483, 2010.

[3] M. Alrubaih, M. Zain, M. Alghoul, N. Ibrahim, M. Shameri, and O. Elayeb. Research and development on aspects of daylighting fundamentals. *Renewable and Sustainable Energy Reviews*, 21:494–505, Feb. 2013.

[4] A. Briggs and M. Sculpher. An Introduction to Markov Modelling for Economic Evaluation. *PharmacoEconomics*, 13(4):397–409, 1998.

[5] B. Bueno, J. Wienold, A. Katsifaraki, and T. E. Kuhn. Fener: A radiance-based modelling approach to assess the thermal and daylighting performance of complex fenestration systems in office spaces. *Energy and Buildings*, 94:10–20, Feb. 2015.

[6] A. M. Cabrera, C. J. Faber, K. Cepeda, R. Derber, C. Epstein, J. Zheng, R. K. Cytron, and R. D. Chamberlain. Data Integration Benchmark Suite v1. DOI: `http://dx.doi.org/10.7936/K7NZ8715`, Apr. 2018.

[7] A. M. Cabrera, C. J. Faber, K. Cepeda, R. Derber, C. Epstein, J. Zheng, R. K. Cytron, and R. D. Chamberlain. DIBS: A data integration benchmark suite. In *Proc. of ACM/SPIE Int'l Conf. on Performance Engineering Companion*, pages 25–28, Apr. 2018.

[8] R. D. Chamberlain. Assessing user preferences in programming language design. In *Proc. ACM Int'l Symp. on New Ideas, New Paradigms, and Reflections on Programming and Software*, pages 18–29, Oct. 2017.

[9] R. D. Chamberlain, C. Ahrens, and C. Gill. Abstractions for cyber-physical systems development: An international opportunity. In *Visioning Workshop for International Networks to Advance CPS Research, Development, and Education Worldwide*, Apr. 2018. Available at `https://cps-vo.org/node/48624`.

[10] A. Galatioto and M. Beccali. Aspects and issues of daylighting assessment: A review study. *Renewable and Sustainable Energy Reviews*, 66:852–860, Sept. 2016.

[11] R. Glaubius, T. Tidwell, W. Smart, and C. Gill. Scheduling design and verification for open soft real-time systems. In *Proc. of Real-Time Systems Symposium*, pages 505–514, Nov. 2008.

[12] M. Kolonko and H. Benzing. The sequential design of Bernoulli experiments including switching costs. *Operations Research*, 33(2):412–426, Apr. 1985.

[13] M. Konstantoglou and A. Tsangrassoulis. Dynamic operation of daylighting and shading systems: A literature review. *Renewable and Sustainable Energy Reviews*, 60:268–283, Feb. 2016.

[14] A. R. Kristensen. A general software system for Markov decision processes in herd managment applications. *Computers and Electronics in Agriculture*, 38(3):199–215, Mar. 2003.

[15] R. Leslie. Capturing the daylight dividend in buildings: why and how? *Building and Environment*, 38:381–385, 2003.

[16] J. Meier, C. Gill, and R. D. Chamberlain. Combining admission and modulation decisions for wireless embedded systems. In *Proc. IEEE 19th Int'l Symp. Real-Time Distributed Computing*, pages 69–78, May 2016.

[17] M. L. Puterman. *Markov Decision Processes*. John Wiley & Sons, Inc., Hoboken, NJ, 1994.

[18] B. Schaban-Maurer. *Rise of the Citizen Practitioner: A Phronesis-Based Approach to Citizen Engagement and Social Policy*. Scholar's Press, 2013.

[19] J. A. Shidal. *Exploiting the Weak Generational Hypothesis for Write Reduction and Object Recycling*. PhD thesis, Dept. of Computer Science and Engineering, Washington University in St. Louis, May 2016.

[20] T. Tidwell, R. Glaubius, C. D. Gill, and W. D. Smart. Optimizing expected time utility in cyber-physical systems schedulers. In *Proc. of IEEE 31st Real-Time Systems Symposium*, pages 193–201, Dec. 2010.

[21] D. J. White. A Survey of Applications of Markov Decision Processes. *The Journal of the Operational Research Society*, 44(11):1073–1096, Nov. 1993.

[22] K. K. Yin, G. G. Yin, and H. Liu. Stochastic modeling for inventory and production planning in the paper industry. *AIChE Journal*, 50(11):2877–2890, Nov. 2004.