PAUL J. GOULART

Q. How did your education and early career lead to your initial and continuing interest in the control field?

Paul: I did my first degree in aeronautics and really didn't take many control courses beyond the basic ones. I don't think I understood at the time what control was really about. I then worked for several years in the flight operations center for the Chandra Observatory, which is a large space-based X-ray telescope operated by NASA. I started there about a year before launch and ended up writing a lot of software for things like orientation estimation and maneuver planning, which are really filtering and control problems. After the launch, I did a lot of work on schedule optimization for the observatory, where we tried to find ways of producing orderings for the observations that didn't waste too much time maneuvering, while simultaneously trying to avoid the need to dump momentum with the vehicle thrusters. In retrospect, that was the first model predictive control application I worked on, although I didn't think about it in those terms at the time. After performing this work for a few years, I decided I really wanted to learn more about optimization and control, so ended up pursuing my Ph.D. in those areas.

Paul Goulart

Q. What are some of your research interests?

Paul: I did my Ph.D. on applications of robust optimization in predictive control, and since then I've continued to work somewhere in the middle ground between the two. I have been working a lot recently on developing open-source software for convex problems using operator-splitting methods, and our group released a software package called OSQP this year for solving quadratic programing problems on embedded systems. We're also working on similar methods and software for solving semidefinite programing (SDP) problems. For those problems, there are many nice modeling tricks for decomposing large problems by exploiting sparsity and other internal problem structures.

I became interested in solving large-scale SDPs after collaborating with some colleagues at Imperial College on the stability analysis of fluid flows. It turns out that one can determine whether a given flow is guaranteed to be laminar by solving a robust sum-of-squares problem. We obtained some nice results that showed how this could be accomplished and that it was a real improvement over classical methods. However, we didn't get very far initially because the problems can be really large, with many tens of millions of variables. At the moment, I guess I'm interested in knowing how large of an SDP I can realistically solve. Once that's answered, I'll see what other doors that opens.

I am also interested in more modeling-focused questions in optimization, specifically how to address uncertainty in optimal control problems. We've made some good progress on distributionally robust optimization in the last few years, where the uncertainty itself is only imperfectly understood (for example, only partial moment information is available). That work wasn't specific to control applications, so I'm now trying to bring it back to the control side and see how it can be used to handle uncertain predictive control problems with things like chance constraints or bounds on the frequency of extreme outliers.

Finally, I really like learning about new application areas and seeing how to use optimization-based control in them. That applies to the fluid work I mentioned, and I've also worked on applications in road traffic control (for which we won the Hugo Schuck

Paul Goulart with his daughters Clara (right) and Mabel.

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Profile of Paul J. Goulart

- *Current position:* associate professor, Department of Engineering Science, Oxford University; tutorial fellow, St. Edmund Hall, Oxford, United Kingdom.
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- *Notable awards:* Gates Cambridge Scholar (2003–2006); O. Hugo Schuck Award (2018).

Award), power electronics (for which we won an IEEE Power Electronics Best Paper Award), aircraft maneuvering planning, atomic force microscopy, and building control.

Q. What courses do you teach relating to control? Do you have a favorite course? How would you describe your teaching style?

Paul: I teach the introductory control course in engineering at Oxford, which is compulsory for all undergraduates and covers all of the basics that everyone with a general engineering degree should know. I also teach some optional courses later in the program on convex optimization and networked systems.

A large difference with the system at Oxford is that, aside from lectures, we do a lot teaching in groups of two or three within our constituent colleges. This means that, in addition to teaching the control courses, I also work through tutorial problems with students on a wide range of topics across our curriculum. I don't know that I have a particular style when I do this, but I try to get the students to see that a lot of the concepts they are learning in different subjects are really just the same thing appearing in different contexts. In other words, if you can solve a linear system, compute eigenvalues, and linearize a function, you can go pretty far with an engineering degree.

Q. What are some of the most promising opportunities you see in the control field?

Paul: Data-driven optimization and machine learning are growing very rapidly, and I think there are many opportunities there. It can sometimes seem like people in those areas reinvent the wheel and try to apply somewhat ad hoc methods to things that are considered classical control problems. We shouldn't view that as competition but instead as a large opportunity to get into the conversation. It's an opening for us to use some of the methods that we've built over recent decades, to identify the machine-learning approaches that are the most suitable for different applications and generally bring more rigor into the design process.

Q. What are some of your interests and activities outside of your professional career?

Paul: My wife and I have two young daughters, and we are slowly exploring Oxford with them. I also like to make stuff with my kids, and we do everything from bake cakes to drill holes in the wall (and occasionally fix them). We also build circuits, construct little machines, and perform chemistry experiments and things like that together.

Q. Thank you for your comments.

Paul: Many thanks for the opportunity.

» TECHNICAL ACTIVITIES *(continued from p. 15)*

Yutaka Hori (substituting for Douglas Densmore, who was unable to travel to the conference).

As part of the involvement in the IEEE Life Science Community, of which the CSS was one of the cofounders, the TC has cosponsored a new IEEE annual conference in life sciences. The first conference was held December 13–15, 2017 in Sydney, Australia (https://lsc.ieee.org/2017/), and the second was held October 28–30, 2018 in Montreal, Canada (https://lsc.ieee.org/2018/). TC members are also actively involved in the International Conference on Foundations of Systems Biology in Engineering (FOSBE). The last FOSBE conference was held in Chicago in August 2018 and was chaired by Juergen Hahn.

In 2019, Steffen Waldherr from KU Leuven takes over as TC chair, replacing Bayu Jayawardhana, who has served as chair since 2015. If you are interested in participating in our activities as a member of TC, we warmly welcome your participation. You can contact us by e-mail: b.jayawardhana@rug.nl or steffen.waldherr@kuleuven.be for further information and updates.

Bayu Jayawardhana
Steffen Waldherr