Teaching Statement

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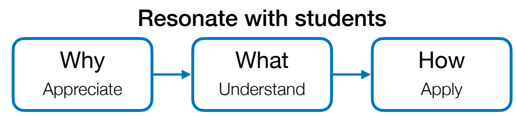
Born in a family where both my parents are high-school teachers, I had a front-seat view of how much they enjoyed teaching and helping students grow, as well as how much that paid back when the students realized their dreams. I am very excited to become an educator. In the following, I describe my teaching philosophy, teaching and mentoring experiences, and teaching interests in the future.

Teaching philosophy. I believe that *a good teacher always tries to step into the shoes of the students.* Teaching should resonate more with the students than with the teacher. I want to divide the teaching process into three phases, *i.e.,* teaching the *why*, *what*, and *how* of a subject, and detail how I plan to resonate with the students. I will draw a few examples from robotics, computer vision, and optimization to illustrate my thoughts.



- ***Why***. This phase aims to motivate the students so that they can *appreciate* the importance and impact of a subject. I believe that a student who sees the motivation behind the subject will learn much better than one who does not feel excited. However, the challenge here is, students may come from drastically different backgrounds and thus have different tastes. Therefore, I think it is beneficial to do a pre-course questionnaire to survey the background of the students and learn about their expectations. For example, in teaching a computer vision class, students with a robotics background may be fascinated by how computer vision can help detect objects in autonomous driving, but students with an architecture background may be more interested in using vision for augmented and virtual reality applications. Understanding students' tastes and providing a broad range of examples can help motivate students from different backgrounds.
- ***What***. This phase aims to teach the core knowledge so that students can *understand* the subject. I believe that *understanding the knowledge is much more than memorizing concepts.* In order to help students develop a deep understanding, it is important to help them *organize and connect the knowledge to things they already know* [1]. The following strategies are useful. (i) *Teaching a historical perspective helps students understand why pioneers studied the subject.* For example, in simultaneous localization and mapping (SLAM), the historical perspective helps students understand how the field has evolved and what are the challenges and new opportunities along the path. (ii) *Starting from simple insights and having students derive the knowledge on their own helps them connect the new knowledge with their existing knowledge base.* For example, when teaching epipolar geometry in computer vision, instead of just telling the governing equations of epipolar geometry, the instructor can guide the students to derive the equations from a basic pinhole camera model. (iii) *Creating tailored examples and exercises helps students connect the knowledge back to their motivations.* An excellent example is the book *convex optimization* [2], which contains a diverse set of examples and exercises from engineering, science, finance, etc. (iv) *Asking questions during class and asking feedback after class encourage students to share their own perspectives.* In doing so, students will feel engaged and further motivated, while instructors will gain richer experience to teach future versions of a course.
- ***How***. This phase aims to teach the students how to *apply* the subject. I advocate for *active learning*, and *learning by doing* in this phase. For a robotics class, I will encourage students to play with different robotic platforms, simulated or real, and apply the knowledge they have learned to create intelligent behavior. For an optimization class, I will encourage students to try different optimization algorithms for problems in their own fields. The best practice for applying a subject is perhaps a research-oriented *final project.* However, as an instructor, I think it is of paramount importance to guide the students (especially junior students) through the open research challenge, by setting up regular checkpoints, milestones, and meetings.

Finally, I will strive to create an *inclusive climate* without *stereotypes* [3], where each student can equally excel.

Teaching experiences. I gained teaching experience via teaching assistantship, guest lectures, and tutorials.

- *Teaching assistantship.* I was a teaching assistant for the MIT graduate course *Visual Navigation for Autonomous Vehicles* during fall 2020 (about 40 students). I gave a recitation on mathematical preliminaries, held office hours, designed problem sets, and graded student submissions.

- *Guest lectures.* I gave a guest lecture at the University of Michigan graduate course *Visual Navigation for Autonomous Aerial Vehicles* in April 2021; and another guest lecture at the MIT undergraduate course *Robotics: Science and Systems* in May 2021. Both lectures were about *certifiable outlier-robust geometric perception.*
- *Tutorials.* I gave a *Hands-on Tutorial on Global Optimization in Matlab* at ICCV 2019 "Global Optimization for Geometric Understanding with Provable Guarantees"; and a tutorial on *Certifiably Robust Geometric Perception with Outliers* at RSS 2020 "Certifiable Robot Perception: from Global Optimization to Safer Robots".

I summarize a few strategies that I put into practice in the teaching experiences. (i) *Know the audience.* Before teaching, I try to understand the background of the audience so that I can know their expectations. For example, lecturing undergraduates should be different from lecturing graduates: the former audience may need more motivation (*e.g.,* fascinating applications and videos), while the latter audience may be interested in the technical aspects and how they can apply the techniques (*e.g.,* mathematical foundations). (ii) *Visualization, Visualization, Visualization.* Even if the contents can be quite abstract, pictures and drawings can greatly help students understand the intuition. (iii) *Be interactive.* I typically design a few interesting questions in the middle of the lecture to engage the audience. These questions are not difficult, but they serve as a tool to refresh students' energy and encourage critical thinking. (iv) *Be patient and generous.* When I was a teaching assistant and interacting with students, I found that *students can have completely different starting points.* Therefore, I realized that I should make as few assumptions as possible on the students' prior knowledge, and more importantly, be patient when teaching things that may look quite obvious to myself. (v) *Continual learning.* I believe that one of the goals of teaching is to *encourage and enable students to continue the learning process after class.* For example, I try to give them references to interesting papers, open-source implementations, and online tutorials, so that they can explore even more on their own.

Mentoring experiences. I have mentored an MIT undergraduate from the *Undergraduate Research Opportunities Program* (UROP); mentored an MIT master student on a research project originated from the graduate course *Visual Navigation for Autonomous Vehicles* (the project was presented at the Rendezvous & Proximity Operations symposium of the 2021 AAS/AIAA Astrodynamics Specialist Conference); and mentored/collaborated with an MIT master student (now a PhD student) at the MIT SPARK Lab (the project has led to 3 papers published at TRO 2020, ICRA 2021, and RSS 2021). My general philosophy for mentoring is that *I should help the students as much as possible when they get lost, but I should also leave most of the intellectual fun in doing research untouched.* I believe the goal of mentoring is to help the students become independent researchers, and the joy of mentoring is to see them grow. I was very glad to see a student wrote "thanks to Hank [Heng] Yang for the unwavering support throughout the process of implementing his work and applying it to a new perception problem" in a published paper.

Teaching interests. Given my interdisciplinary background in robotics, computer vision, and optimization, I am very excited to teach existing courses and develop new courses.

- **Existing courses**. (i) *Robotics*, at both the introductory (undergraduate) level and the advanced (graduate) level. (ii) *Computer vision*, both geometric vision (*e.g.,* multi-view geometry, robot perception) and recent learning-based frontiers (*e.g.,* feature learning, neural scene representation). (iii) *Optimization*, both the modeling and analysis perspective, and the algorithmic and computational perspective.
- **New courses**. (i) *Optimization Methods in Robotics.* Optimization (*e.g.,* convex optimization, nonlinear programming, global optimization) has played a critical role in designing all modules of a robotic system (*e.g.,* perception, planning, control, learning). I want to create a course at the intersection of optimization and robotics, which aims to introduce key problems in robotics and how optimization has been used to solve them. The course will also encourage students to develop and apply new optimization techniques to solve fundamental robotics problems. (ii) *Theory and Computation for Safe Autonomy.* Safe autonomy is a grand challenge for robotics, and this course aims to teach and explore the theoretical and computational machinery that are promising for enabling safe robotics, *e.g.,* Lyapunov and contraction analysis, control barrier functions, global optimality in state estimation, and convex and semidefinite relaxations.

References

[1] Ambrose, S.A., Bridges, M.W., DiPietro, M., Lovett, M.C., Norman, M.K.: How learning works: Seven research-based principles for smart teaching. John Wiley & Sons (2010)
[2] Boyd, S., Vandenberghe, L.: Convex optimization. Cambridge university press (2004)
[3] Glenn, W.S., Taylor, E.M.V., Drennan, C.L.: What every teacher and mentor should know