CAP7003E Homework 2

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1 Doctoral journey, milestones

a

The milestones of my doctoral journey are:

- **Starting up**: Taking courses, ideas for project, agreement with advisor on interactions
- **Draft project** description: I establish the limits of knowledge in the subject, which triggers a research topic. I develop a strategy for how to expand the limits of knowledge.
- **Comprehensive exam**: Assessment of knowledge, Defense of the project proposal
- **Exploration**: Preliminary results and Adjustments
- **Diffusion**: Conferences, Publications
- **Maturing / Final developments**: Increasing originality, impact, autonomy
- **Finish line**: Creator of knowledge or technology, additional publications, thesis defense, next career steps

b

The finish line is the milestone that "stimulates" me the most. This is when I have the expertise to best contribute to the field while having already disseminated important work. I am in a good position to continue my career.

c

The comprehensive exam is the milestone that I "fear" the most since I find written exams tend to be stressful to prepare for.

2 Comprehensive examination

It is used to identify knowledge gaps of the field and in the specific research subject so that they can be corrected early in the program. It also is used to determine the level of originality of the proposed research.

3 Research proposal

Background

Silicon photonics have proven to be an effective tool in the advancement of computation hardware, boasting improvements in faster data transfer over long distances, low power and high throughput[1]. Its importance reaches to application in lidar, computation, and quantum information processing while providing advantages in volume production scalability as well as improved stability and reliability over time[2,3,4]. Despite this, increasingly complex applications have led to the requirement of increasing complex designs. To this end, there has been much literature dedicated to finding limits on optical response in order to gauge the optimality of current devices and search for improvements. The field of inverse design in nanophotonics has presented effective results for treating this problem[5]. However this usually comes at the detriment of computational cost and slow algorithms, making them impractical for designs with many degrees of freedom[6].

Objectives

The context of design for silicon on-chip photonics requires computating wave scattering of electromagnetic radiation. For linear potentials, it is possible to view many of these optimization problems in the design of these devices as quadratically constrained quadratic programs (QCQPs)[7,8,9]. It is therefore the objective of this research to find computational methods that solve these problems in a way that is practical for the number of degrees of freedom present in these applications.

Approach

The approach to creating this inverse design method will use Lagrange Duality in tandem with an iterative strategy that improves bounds on the solution for these QCQPs. This has the effect of guaranteeing that discovered solutions are either optimal or optimal to within some tolerance[5,7]. Current literature has little to say about the conditions under which convex relaxation techniques can be used to solve a given QCQP[10,11]. It is therefore of vital importance to therefore determine such conditions. In addition to this, Sion's Minimax Theorem for QCQPs[12] can be leveraged in order to determine whether Lagrange Duality holds. Even if strong duality is violated, consequences of this theorem would then reveal the degree to which is the solution optimal. This can then potentially be used to modify the objective in order to obtain a strong dual and the globally optimal solution[12]. This project will firstly comprise of the theoretical task of determining the conditions outlined above in addition to the algorithm which uses them. Following this, a program implementation of the algorithm will be created and assessed according to its optimality of solutions (using the methods outlined above) and by the computational resources it uses.

Significance

Ultimately speaking, the goal of this project is to develop an this algorithm for the purpose of developing on-chip silicon photonics with a higher degree of optimality while utilizing less resources than what is currently available. The original addition comes in the integration of the simultaneous computing of a solution and bounds using Sion's Minimax Theorem for QCQPs. However, it should be noted that the applicability of this inverse design method extends far beyond. There are many problems in applied photonics, acoustics, and quantum mechanics that can be stated as a compact QCQP optimization. Such problems in all these domain can use Lagrange Duality and Sion's Minimax Theorem for QCQPs in order to simultaneously find an optimal structure while computing bounds[12].

References

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4 Publications

a

Possible difficulties might include merging writing styles with collaborators and choosing which journal to publish in.

b

In photonics the three scientific journals (ranked according to fame and desire to publish) would be Nature Reviews Physics, New Journal of Physics, and Physical Review Journals.

5 Competencies (skills) required at Polytechnique (Graduate studies)

The competencies are used for education and evaluation purposes so that students may identify the hard skills, soft skills and knowledge they need. In addition, after being evaluated according to these criteria the student is better able to develop these competencies. Doctorate students should be able to:

- Autonomously and expertly lead a scientific research project that makes an original contribution to knowledge or development in the areas of science and technology.
- Identify, manage and analyze information and resource materials relevant to one's field of research.
- Clearly communicate, across a wide range of situations, findings from scientific research or knowledge on one's subject area.
- Respect standards, rules of ethics and airness, as well as best practices for research.
- Commit to a process of lifelong learning and improvement.

One thing that holds my attention is the inclusion of some of the soft skills in the evaluation. The concepts are subjective in nature and as a result to not lend themselves well to objective quantification. In addition there seem to be some competencies that are simply not verifiable or irrelevant to the scientific process such as the "Practice of self-reflection". This is likely just a semantics issue, but overall the criteria seem like very reasonable characteristics that would be sufficient for producing a doctorate student that can effectively research, collaborate, use, and disseminate information in their field.