フランスでの生活もすでに十ヶ月目を迎えました。この九ヶ月は今までの研究生活で最も充実した勉強と研究ができたと感じています。今回の報告書では、私のフランスでの研究生活について振り返り、今後の進路について報告します。

フランス生活

フランスでの私の生活は、研究以外の面で苦しいことが多かったと言えます。研究面で読む予定の教科書や論文が溜まっているため、フランス語の勉強に時間を費やすことが全くできず、百語程度の知っているフランス語で何とか生き延びる生活でした。シャンプーやボディソープを言葉を知らずに選ぶことは至難の業です。パッケージや内容物の粘性から中身を推定する逆問題（inverse problem）と言えます。リンスをシャンプーだと勘違いして買ったときは悲しい気持ちになりました。また、研究室内で使用される言語の割合はフランス語＞スペイン語＞イタリア語＞英語なので、雑談が英語で行われることがほぼありません。ストーリーを作って笑いをとろうとしている際に、横からフランス語で話を被せて持って行かれるときは、関西人として許せない気持ちになります。

そんな苦難はありつつも、研究面は今までで最も順調です。以前報告した通り、現在はフランス宇宙機構との共同研究で、将来フランスが打ち上げる望遠鏡に搭載する画像処理アルゴリズムを開発しています。この成果は、５月下旬にヘルシンキで行われたApplied Inverse Problems Conferenceにおいて発表することができ、二ヶ月中にまとめ上げ論文として出版する予定です。出版でき次第、報告書で詳しく内容を書きたいと思います。

このように研究が順調に進んでいることは、現在の指導教授が教育的であることに起因してると感じています。教授のアドバイスを受け、最近取り入れた研究スタイルが、自分の研究の記録（背景、理論、全ての実験結果 etc.）を一つのフォーマルなレポートとして、論文には書かないような内容まで全て残しておくことです。この方法は時間がかかるものの、自分の理解が確固たるものになり、間違いを正しやすいという利点があると感じています。また、一週間に一時間行う教授との議論では、このレポートを元にするため、お互いの理解の一致し議論が円滑になるという利点もあります。この議論では、一つの数式や画像などに対する彼の洞察にいつも驚かされます。

フランスに理系留学するという選択は日本人にとって稀有な例であり不安が大きかったですが、結果的に人生で最も飛躍できた年となったと感じています。

今後の進路

以前の報告書でお伝えしていた通り、MITに在籍していた当時の同僚がスタンフォード大学のファカルティポジションを獲得し、彼のグループに誘われていたのですが、渡仏が決まった後であったため、誘いを断ざるを得ないという経緯がありました。渡仏後も熱心に誘いを受けており、秋からの選択肢として残すため、スタンフォード大学を受験していました。彼のグループでは、彼の今までの研究の延長であるディスプレイやカメラの研究を進めています。その一方で、光遺伝学の創始者Karl Deisserothのグループや、超高解像度光学顕微鏡法の開発により

2014年度にノーベル賞を受賞したWilliam Moernerのグループと共に、新しい光学顕微鏡法の研究開発も行っています。私は留学当初から、アルゴリズムと光学系の相互デザインにより、今まで誰も観察したことがない生物現象を撮影できる光学顕微鏡を作りたいと考えていました。その一歩として、スペクトル分離アルゴリズムをMITにて開発しました（以前の報告書参照）。フランスでの研究環境には満足しており、今の指導教授と研究を続ければ、より深く画像に関連する応用数学を学べるだろうと感じています。また、フランスに残れば授業もなく残り三年でPh.D.を獲得できる一方で、スタンフォードでは授業によるストレスがある上に、Ph.D.獲得まで長く時間がかかってしまいます。しかし、以前から研究したいと思っていたトピックを最高の環境で研究できるという機会を逃すわけにはいかないと考え、スタンフォード大学に移ることを決意しました。長く苦しい期間になるだろうと予想していますが、楽しく実りのある研究生活にできるように邁進するつもりです。

参考

報告書の最後に、米国の大学院受験を考えている方の参考のために、受験の際に提出したStatement of Purposeを添付しておきます。このSoPを書いて以降のフランスでの経験を書き足せば更に良い出来になるだろうと思いますが、MITを受験した当時のSoPと比べると英語と内容に自分の成長を感じます。

Statement of Purpose

Applicant:
Hayato Ikoma
Choice of Program:
Electrical Engineering Ph.D. program,
Stanford University

My academic objective is to create mathematical tools for biologists, chemists, and physicists through my professional career. Particularly, I am interested in inverse problems of scientific imaging technologies such as telescopes, optical microscopes and electron microscopes. This objective requires the knowledge of physics, chemistry, biology, electrical engineering and applied mathematics, all of which I have acquired throughout my undergraduate and graduate studies. By combining knowledge of these diverse fields, I have developed a new technique for fluorescence spectral unmixing at the MIT Media Lab [1] and am currently developing wavefront estimation algorithm for telescopes at Centre de Mathématiques et Leurs Applications of École Normal Supérieure de Cachan (CMLA, ENS Cachan) in France.

While I have been determined to contribute to science and engineering since my childhood, my interest in imaging has increased as my academic career has progressed. It began when I was studying materials engineering as an undergraduate student at the University of Tokyo. During the course of my studies, I was deeply fascinated by the use of signal processing tools in transmission electron microscopy (TEM) for crystallography. Although raw TEM images and spectroscopic datasets reveal nothing on their own, the mathematical tool accurately estimates the atomic structures and components of crystals. My interest in imaging extended to optical microscopy during my Master's research at Kyoto University. There, I used the LC-PolScope to observe cell migration and was excited by this successful example of computational imaging. While conventional optical microscopy cannot reveal cytoskeletal structures in living cells without staining, the LC-PolScope achieves it by combining polarized light microscopy and computation.

My experience with these two computational imaging technologies has revealed to me that signal processing plays a vital role in imaging and is the gateway to discovery in a variety of academic fields. This has intensified my desire to work on mathematical modeling for scientific imaging, which was my focus at Professor Ramesh Raskar's group at MIT. With my previous research experience on optical microscopy, I have initiated a new project on fluorescence spectral unmixing for spectroscopy and microscopy. In this project, I proposed a method for a long-lasting problem in fluorescence analysis, where emitted fluorescence spectra are distorted by absorption and scattering by a sample itself. While simple mathematical techniques such as principal component analysis and linear decomposition have often been applied to fluorescence spectroscopy, I remodeled the forward model of fluorescence emission and developed an algorithm, called attenuation-corrected fluorescence unmixing, with the use of nonnegative matrix and tensor factorization [1]. This algorithm estimates the attenuation spectra and the components of fluorescence species from the perturbed spectra. In this research, I worked with a postdoc, Dr. Gordon Wetzstein, who is currently a professor at the Department of Electrical Engineering at Stanford University. I believe that this kind of approach was only possible with my deep understanding on optical microscopy, biology, and physical chemistry, and the collaboration with Professor Wetzstein, who is an expert of computational imaging. Through this project, I strongly felt that reinforcement of my mathematical skills would help me to pursue my objective.

To further explore this direction, I am currently affiliated with a graduate program of applied mathematics. This program is providing me intensive formal training in signal processing, optimization, and machine learning through courses such as sparse representation by Stéphane Mallat, optimization for imaging by Mila Nikolova, convex optimization by Alexandre d'Aspremont, and probabilistic graphical models by Francis Bach. In addition, here, I am working on optical wavefront estimation in satellite imaging with Professor Jean-Michel Morel at CMLA, ENS Cachan. In this ongoing project, I am starting with rigorous mathematical analysis on a traditional algorithm for wavefront estimation. While I have already had a clear idea to outperform the current state-of-the-art method, it has been good practice for me to be trained for various inverse problems ranging from probabilistic modeling to sparse regularization through the existing methods.

This exposure to various mathematical tools is inspiring me to keep exploring computational scientific imaging in my Ph.D. research. For this purpose, I believe that the Electrical Engineering Ph.D. program at Stanford University is the best possible place for me to pursue my vision. At Stanford University, I would like to mainly work with Professor Gordon Wetzstein. At the beginning of my Ph.D. study, I would like to collaborate with him on the application of my currently-developing algorithm for optical microscopy. While wavefront aberration has been a huge problem for deep-tissue imaging for neuroscience and cell biology, wavefront correction and estimation have not been explored extensively in the context of computational imaging. Later on, I would like to investigate other imaging modalities such as electron microscopy and MRI, and also collaborate with chemists and biologists. In this aspect, Stanford University would be the best environment in the world, because it has the state-of-the-art scientific equipment and world-leading experts in every field. Particularly, I am interested in the collaboration with the research group led by Professor Karl Deisseroth in the Department of Bioengineering. They are famous for the development of neurobiological sample preparation techniques such as optogenetics tools [2] and CLARITY [3]. While computational optical imaging is evolving through the co-design of optical system and signal processing algorithm, I believe that computational optical microscopy would evolve through the mutual development of optical system, signal processing algorithm, and biological sample preparation.

In addition to this excellent research environment, I am looking forward to the courses offered in the Department of Electrical Engineering. For example, I would like to take EE 364B: Convex Optimization II, EE373A: Adaptive Signal Processing, EE378A: Statistical Signal Processing, EE369C: Medical Image Reconstruction, and EE378B: Inference, Estimation, and Information Processing. Actually, the convex optimization class I am attending in my current graduate program is almost identical to EE 364A: Convex Optimization I. Its lecturer, Alexandre d'Aspremont, is a former student of Professor Stephene Boyd and is following the teaching method of EE 364A. Actually, I am impressed that his mere class report in EE 364B has been cited more than 50 times by top-journal papers. This fact convinced me that the lectures offered in Stanford University have potential to train students to follow the cutting-edge research topics. I hope that EE369C will be a good start for me to explore medical imaging systems.

To conclude, I firmly believe that gaining research experience and education at the the Electrical Engineering Ph.D. program of Stanford University will maximize my full research potential, expand the scope of my career, and allow me to contribute most effectively to the body of science and engineering.

References

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