

# Additional Information

Zhenghong Lieu

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  - Databases
    - SQL
    - Relational Algebra
    - Relational Design Theory
  - Computer architecture (NAND 2 Tetris I & II)
  - Linear Algebra
  - Multivariate Calculus
  - Machine Learning
  - Big Data Analysis in Scala and Spark
  - Functional Programming in Scala
6. Short snippet of Mathematical Analysis problem set
7. Short snippet of software project I developed

# Zhenghong Lieu

## (lieuzhenghong@gmail.com)

### Education

<b>Oct 2017 – present</b>	<b>University of Oxford</b> BA in Philosophy, Politics and Economics (PPE)
<b>Jun 2017 – present</b>	<b>Massive Open Online Courses (MOOCs) completed</b> Computer Science <ul style="list-style-type: none"><li>• Algorithms and Data Structures (Stanford)</li><li>• Databases (Stanford)</li><li>• Machine Learning (Stanford)</li><li>• From NAND to Tetris I &amp; II (computer architecture) (IDC Herzilya)</li><li>• Competitive Programmer's Core Skills (SPSU)</li></ul>
	Data Science <ul style="list-style-type: none"><li>• Functional Programming Principles in Scala (EPFL)</li><li>• Parallel Programming in Scala (EPFL)</li><li>• Big Data Analysis in Scala and Spark (EPFL)</li></ul>
	Mathematics <ul style="list-style-type: none"><li>• Linear Algebra (Imperial College London)</li><li>• Multivariate Calculus (Imperial College London)</li></ul>

### Experience

<b>Jun 2019 – Sep 2019</b>	<b>Data Scientist (Intern)</b> <i>Inzura AI</i> Increased monthly active users by > 20% by building a Bayesian SMS sender in Python and SQL, meeting a KPI which secured an important client contract Built deep learning model with Keras that reduces trip processing time from 7s to 0.05s, which made possible a new revenue vertical for the company Deployed distributed Apache Spark infrastructure and performed Big Data analysis with Scala on ~85 million data points used to assign users more accurate risk ratings
<b>Jun 2018 – Aug 2019</b>	<b>Blockchain Developer (Intern)</b> <i>Infocomm Media Development Authority of Singapore (IMDA)</i> Wrote a research paper on blockchain interop protocols and presented it to senior management Created a fully-automated blockchain demonstration of supply chain management: <ul style="list-style-type: none"><li>• Real-time blockchain visualisation using JavaScript and Canvas</li><li>• IoT sensor integration to update asset location data on Hyperledger blockchain</li><li>• QR-code based asset tracking with Node.js</li></ul>
<b>Jun 2017 – Aug 2017</b>	<b>Software Engineer</b> <i>Imcomp International</i> Greatly increased firm efficiency (75% less time taken to generate reports, 300 engineer hours saved per month) by developing bespoke building inspection software (Electron, Vue.js, JavaScript)

<b>Jan 2017 – May 2017</b>	<b>Venture Capital Analyst (Intern)</b> <i>iGlobe Partners</i>  Co-wrote 2 papers recommending investment; senior management accepted both recommendations and made Stage B investments
<b>May 2016 – Sep 2017</b>	<b>Python Programming Tutor (Volunteer)</b> <i>Ulu Pandan Stars</i>  Taught a team of underprivileged children Python and led them to win 3rd (amongst ~100 participating teams) in national hackathon CodeXtreme
<b>Feb 2015 – Dec 2016</b>	<b>Soldier (Conscript)</b> <i>Singapore Armed Forces (SAF), HQ Army Medical Service</i>  Developed the Army's first item tracker and SMS reminder service with React and Node.js: <ul style="list-style-type: none"> <li>• Won second prize in the Army Annual Innovation Competition</li> <li>• Won Best Soldier of the Month out of ~3000 soldiers</li> </ul>

## Working Papers

<b>2019</b>	“Accounting for Travel Times in Estimating Political Dislocation” <i>with Nicholas Eubank and Jonathan Rodden</i>
<b>2019</b>	“Using human geography to build a more meaningful compactness measure for automated districting algorithms”
<b>2019</b>	“Can freeform communication increase the rate of Pareto-efficient outcomes in repeated games?”

## Honors and Fellowships

<b>Oct 2019</b>	Postmaster <i>Major college scholarship awarded for sustained academic excellence</i>
<b>Aug 2019</b>	Raff Prize <i>Awarded for best second-year Economics performance in my college</i>
<b>Oct 2018</b>	Exhibitioner <i>Minor college scholarship awarded for good performance in the first year</i>
<b>Aug 2018</b>	Sam McNaughton Prize <i>Awarded for top score in Philosophy in the PPE first-year exams</i>
<b>June 2018</b>	Quantitative Political Essay Prize <i>Awarded to the best quantitative essay of my Oxford politics cohort (~300 students)</i>
<b>Dec 2017 – present</b>	Fowler Prize(s) <i>Awarded for First-class performance in termly exams, awarded 7/7 terms</i>
<b>Sep 2017</b>	National Infocomm Scholarship <i>Full-ride undergraduate scholarship awarded to promising Singaporean students by the Infocomm Media and Development Authority (IMDA), a Singaporean statutory board. Awarded on the basis of academic excellence, demonstrated interest in tech, and a will to serve the nation.</i>

# Accounting for Travel Times in Estimating Political Dislocation

Nicholas Eubank\*, Zhenghong Lieu† Jonathan Rodden‡

November 20, 2019

*Preliminary Draft*  
*PLEASE DO NOT CITE*  
Please click here for most recent version.

## Abstract

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\*Assistant Research Professor, Social Science Research Institute, Duke University  
[nick@nickeubank.com](mailto:nick@nickeubank.com)

†Oxford University

‡Professor, Department of Political Science and Senior Fellow, Hoover Institution, Stanford University [jrodden@stanford.edu](mailto:jrodden@stanford.edu)

Fundamental to a political of single member districts is the idea that there is value in voters who live in the same area being represented by a single politician. Arguments for this are multifaceted — voters in the same area are likely to share political interests; voters in the same area are better able to communicate and coordinate with one another; politicians can better maintain connections with voters in the same area; voters in the same area are especially likely to belong to the same social communities — but all suggest the importance of voters being located in districts with their geographic peers. [need cites]

The idea that there is value in the constituents of a district being physically proximate to one another is present not only in political theory texts, but also in law. Many states, for example, explicitly state that geometric compactness is one of the desired attributes of electoral districts, and indeed compactness is often a metric used to evaluate the reasonableness of districts in legal cases around districting.

Yet historically, when evaluating whether districts accomplish their goal of creating districts composed of constituents who are “close” to one another, proximity is almost always evaluated on the basis of geographic district. But geographic distance often does not correspond to the human experience of proximity, as anyone who has tried to travel even a few miles across downtown at rush hour can attest. This reliance on purely geometric metrics is understandable given its tractability, but with the rise of ubiquitous data on travel patterns and the amount of time it actually takes for citizens to drive from one location to another, it is now possible to measure the distances between citizens not in feet or miles, but in actual travel times, reflecting for the first time the actual human geography of distance.

In this paper, we build on the work of Lieu (2019) – who develops a measure of district compactness built on a travel-time metric rather than a geographic-distance metric – to create a revised version of the *Political Dislocation* from Eubank and Rodden (2019) that takes into account travel times to more accurately estimate the characteristics of voters’ local neighborhoods.

*Political Dislocation* measures the degree to which a voter’s district is aligned with their immediate geographic neighbors. In particular, we examine the degree to which the *partisan composition* of a voter’s actual electoral district differs from the partisan composition of their local neighborhood. Where these measures differ dramatically — where, for example, a voter whose  $k$  nearest neighbors (where  $k$  is the number of people in the voter’s actual legislative district) are mostly Democrats, but despite this their district is mostly Republican — we term that voter *politically dislocated*. As shown in Eubank and Rodden (2019), not only is this measure of direct normative importance, it is also a very good measure of the degree to which an individual voter is the victim of packing or cracking, making it a valuable individual-level metric of abusive districting and gerrymandering.

In this paper, we take the *Political Dislocation* measure from Eubank and Rodden

(2019) and update it by identifying each voter’s  $k$  nearest neighbors not on the basis of geographic proximity, but on the basis of shortest travel times. As we will show, this not only provides an objective basis for identifying and guarding against abusive districting practices (like drawing districts that cross large impassable bodies of water), but it also offers a consistently different picture of the social context of suburban voters. As shown below, we find that our measure generally shows that suburban voters’ nearest neighbors tend to be more conservative when one uses travel times as a distance metric, likely because more geographically distant exurban (generally more conservative) voters are often closer on human-scales than voters on the other side of the city (who tend to be more liberal).

## 1 Data & Methodology

Following Eubank and Rodden (2018), estimation of the partisan composition of each voter’s neighborhood is accomplished through a three-step process. First, precinct-level election returns from the 2008 Presidential election are used to estimate the spatial distribution of voters in each state.<sup>1</sup> This is done by creating a number of representative voter points within each precinct, where points are positioned uniformly at random within each precinct’s catchment area, and the number of points in each precinct’s catchment area is proportional to the number of votes cast for each party.<sup>2</sup> While this down-sampling and placements of points randomly within precincts does introduce some noise, as discussed in Appendix A, the variability contributed to our dislocation measure is empirically very small. This analysis generates an estimate *for each representative-voter point* of the share of neighbors who are co-partisans.

Estimation of the partisan composition of the neighborhood around each of these representative-voter points is then calculated. In our naive nearest neighbor analysis (following Eubank and Rodden (2019)), for each representative-voter point  $v$  of a given party  $p \in \{D, R\}$ , the partisanship of the neighborhood around  $v$  is equal to the share of the  $k$  nearest points (as measured by geographic distance) who are democrats. The number of nearest neighbors considered –  $k$  – is set to ensure the included points

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<sup>1</sup>Before calculating these intervals, we apply a uniform swing to account for McCain / Obama vote shares in our 2008 Presidential two-party vote share data. In particular, as McCain’s two-party vote share was 46.31%, we apply a 3.69 percentage point uniform swing to all data, so that a Republican voter whose voter neighborhood is 46.31% co-partisan would be said to be in a perfect 50% co-partisan neighborhood. In Congressional races, Democratic victories have been quite rare in districts where McCain’s 2008 vote share was higher than 46.31 percent, and Republican victories have been quite rare in districts where Obama’s vote share was higher than 53.69 percent.

<sup>2</sup>In particular, the number of points we generate in each precinct for each party is determined by taking a binomial draw from the total number of actual voters. The binomial probability varies by state-chamber, but is equal to  $prob_k = \frac{\text{number of districts}}{\text{number of voters in state}} * k$ , where  $k=1,000$  for state legislative districts and 5,000 for US Congressional districts. This probability generates  $k$  voters per district in expectation. A larger number of points are used for US Congressional districts to adjust for the fact that the relatively small size of precincts with respect to US Congressional districts reduces the sampling probabilities in each precinct, increasing sampling variance for a given  $k$ .

# Using human geography to build a more meaningful compactness measure for districting algorithms

Zhenghong Lieu

14 November 2019

## Abstract

[This is a working title, and everything about this is very much a work-in-progress.]

Most existing districting approaches aim to optimise over geographical compactness measures like Polsby-Popper and Convex Hull. Compactness is important because compact districts better represent communities of interest and have been shown to improve democratic effectiveness. However, compactness measures are imperfect proxies for human interaction as they cannot account for human geography. For instance, a typical compactness measure would put two villages separated by a big mountain together, even if these villages have near-to-zero interaction. While the shortcomings of compactness measures are well-known in the literature, existing approaches to improve it have failed due to lack of data and computational intractability (NP-hardness). I develop a new metric (“human compactness”) based on travel times that is computationally feasible—yet still captures human geography—and calculate it for many US Congressional districts. Finally, I augment several districting algorithms with the metric, including the Metric Geometry and Gerrymandering Group (MGGG’s) Monte Carlo Markov Chain (MCMC) districting algorithm, and show that the plans drawn with my metric are superior in electoral competitiveness and media congruence, which directly translates to increased federal funding.

<b>Zheng Lieu</b> (mert3946), Merton Bachelor of Arts in Philosophy, Politics, and Economics  Logic Taught by <b>Simon Saunders</b> (lina0174)	XRNLI-2017-1323740  Organising Tutor: Simon Saunders , Emin Baysan , Karina Cendon boveda , Alistair Macaulay , Patricia Thornton , Bassel Tarbush  Personal Tutor: None Michaelmas 2017														
Total hours by Group Size <table> <thead> <tr> <th>Size</th><th>Hours</th></tr> </thead> <tbody> <tr><td>1</td><td>0.0</td></tr> <tr><td>2</td><td>0.0</td></tr> <tr><td>3</td><td>0.0</td></tr> <tr><td>11</td><td>12.0</td></tr> <tr><td>6</td><td>8.0</td></tr> <tr><td>0</td><td>0.0</td></tr> </tbody> </table>	Size	Hours	1	0.0	2	0.0	3	0.0	11	12.0	6	8.0	0	0.0	Lieu Zheng had a good presence in the class, a personality, with some interesting attitudes to philosophy. He is also extremely quick and able. He worked well and is on course to do very well in the subject. He has occasionally made poor choices in how to go about answering questions, and may yet mess up, but I predict a clear distinction.
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<i>of which</i> <table> <thead> <tr> <th><i>Hours missed</i></th><th><i>Hours to come</i></th></tr> </thead> <tbody> <tr><td>0.0</td><td>0.0</td></tr> </tbody> </table> Number of collections marked: 1.0	<i>Hours missed</i>	<i>Hours to come</i>	0.0	0.0											
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<i>Effort:</i> Excellent <i>Achievement:</i> Excellent <i>Estimate of Term's work:</i> 1	<i>Comments:</i>														
<i>Collection marks:</i> 66 <i>Vacation essay marks:</i>															
<i>Submitted on 10/01/2018</i>															
<i>Approved by Sergi Pardos-Prado on 04/03/2018</i>															

<b>Zheng Lieu</b> (mert3946), Merton Bachelor of Arts in Philosophy, Politics, and Economics  Macroeconomics Taught by <b>Matthias Qian</b> (shug3997)	XRNLI-2018-1402855  Organising Tutor: Simon Saunders , Emin Baysan , Karina Cendon boveda , Alistair Macaulay , Patricia Thornton , Bassel Tarbush  Personal Tutor: None Trinity 2018														
Total hours by Group Size <table> <thead> <tr> <th>Size</th><th>Hours</th></tr> </thead> <tbody> <tr><td>1</td><td>0.0</td></tr> <tr><td>2</td><td>0.0</td></tr> <tr><td>3</td><td>7.0</td></tr> <tr><td>0</td><td>0.0</td></tr> <tr><td>0</td><td>0.0</td></tr> <tr><td>0</td><td>0.0</td></tr> </tbody> </table>	Size	Hours	1	0.0	2	0.0	3	7.0	0	0.0	0	0.0	0	0.0	Zhenghong shows a great motivation to develop a deep and thorough understanding of Economics. Nearly all of his problem sets are written very beautifully and this answers show attention to detail. He is very proactive in the tutorials and is very energetic. He also has strong economic intuition - he already thinks like an Economist. I see great potential Zhenghong to obtain a First in the exams.
Size	Hours														
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3	7.0														
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<i>of which</i> <table> <thead> <tr> <th><i>Hours missed</i></th><th><i>Hours to come</i></th></tr> </thead> <tbody> <tr><td>0.0</td><td>0.0</td></tr> </tbody> </table> <p>Number of collections marked: 0.0</p>	<i>Hours missed</i>	<i>Hours to come</i>	0.0	0.0											
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<i>Effort:</i> <i>Achievement:</i> <i>Estimate of Term's work:</i>	<i>Comments:</i>    														
<i>Collection marks:</i> <i>Vacation essay marks:</i>															
<i>Submitted on 11/06/2018</i>															
<i>Approved by Sergi Pardos-Prado on 27/06/2018</i>															

<b>Zheng Lieu</b> (mert3946), Merton Bachelor of Arts in Philosophy, Politics, and Economics  Politics Prelims: Theory of Democracy Taught by <b>Patricia Thornton</b> (polf0211)	XRNLI-2018-1368547  Organising Tutor: Simon Saunders , Emin Baysan , Karina Cendon boveda , Alistair Macaulay , Patricia Thornton , Bassel Tarbush  Personal Tutor: None Trinity 2018														
<p style="text-align: center;">Total hours by Group Size</p> <table> <thead> <tr> <th>Size</th><th>Hours</th></tr> </thead> <tbody> <tr><td>1</td><td>0.0</td></tr> <tr><td>2</td><td>0.0</td></tr> <tr><td>3</td><td>0.0</td></tr> <tr><td>4</td><td>10.0</td></tr> <tr><td>0</td><td>0.0</td></tr> <tr><td>0</td><td>0.0</td></tr> </tbody> </table>	Size	Hours	1	0.0	2	0.0	3	0.0	4	10.0	0	0.0	0	0.0	<p>Zheng Hong is an extremely talented student who is driven to perform at a very high level. Several of his essays were very clear firsts-- he has an unusual ability to address directly and very clearly the key issues at hand, and demonstrates an unusual flair for political philosophy. He certainly turned in one of the best essays on civil society that I've seen. I very much enjoyed tutoring him, and I am very hopeful that he will continue on with Politics!</p>
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<p style="text-align: center;"><i>of which</i></p> <table> <thead> <tr> <th><i>Hours missed</i></th><th><i>Hours to come</i></th></tr> </thead> <tbody> <tr><td>0.0</td><td>0.0</td></tr> </tbody> </table> <p>Number of collections marked: 0.0</p>	<i>Hours missed</i>	<i>Hours to come</i>	0.0	0.0											
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<p><i>Effort:</i> Excellent  <i>Achievement:</i> Excellent  <i>Estimate of Term's work:</i> 1</p>	<p><i>Comments:</i></p>														
<p><i>Collection marks:</i>  <i>Vacation essay marks:</i></p>															
<i>Submitted on 17/07/2018</i> <span style="float: right;"><i>Approved by Ralf Bader on 30/07/2018</i></span>															

<p><b>Zheng Lieu</b> (mert3946), Merton Bachelor of Arts in Philosophy, Politics, and Economics  Analysis Taught by <b>Alexander Scott</b> (mert1909)</p>	<p>XRNLI-2019-1546252 Organising Tutor: Simon Saunders , Emin Baysan , Karina Cendon boveda , Alistair Macaulay , Patricia Thornton , Bassel Tarbush Personal Tutor: None Trinity 2019</p>														
<p>Total hours by Group Size</p> <table> <thead> <tr> <th>Size</th> <th>Hours</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>0.0</td> </tr> <tr> <td>2</td> <td>0.0</td> </tr> <tr> <td>3</td> <td>11.0</td> </tr> <tr> <td>0</td> <td>0.0</td> </tr> <tr> <td>0</td> <td>0.0</td> </tr> <tr> <td>0</td> <td>0.0</td> </tr> </tbody> </table>	Size	Hours	1	0.0	2	0.0	3	11.0	0	0.0	0	0.0	0	0.0	<p>This term we went through a significant part of the Prelims Analysis sequence. Zhenghong contributed well in tutorials, and produced some good written work. This was a very enjoyable group to teach!</p>
Size	Hours														
1	0.0														
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<p><i>of which</i></p> <table> <thead> <tr> <th><i>Hours missed</i></th> <th><i>Hours to come</i></th> </tr> </thead> <tbody> <tr> <td>0.0</td> <td>0.0</td> </tr> </tbody> </table> <p>Number of collections marked: 0.0</p>	<i>Hours missed</i>	<i>Hours to come</i>	0.0	0.0											
<i>Hours missed</i>	<i>Hours to come</i>														
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<p><i>Number of pieces of work set:</i> 0.0  <i>Work satisfactorily completed:</i> 0.0  <i>Work handed in late:</i> 0.0</p>															
<p><i>Effort:</i> Not specified  <i>Achievement:</i> Not specified  <i>Estimate of Term's work:</i> Not specified</p>	<p><i>Comments:</i></p>														
<p><i>Collection marks:</i>  <i>Vacation essay marks:</i></p>															
<p>Submitted on 01/07/2019</p>															
<p>Approved by Patricia Thornton on 01/07/2019</p>															

<b>Zheng Lieu</b> (mert3946), Merton Bachelor of Arts in Philosophy, Politics, and Economics  Core Macroeconomics Taught by <b>Michael Rousakis</b> (econ0431)	XRNLI-2019-1502598  Organising Tutor: Simon Saunders , Emin Baysan , Karina Cendon boveda , Alistair Macaulay , Patricia Thornton , Bassel Tarbush  Personal Tutor: None Hilary 2019																		
<p>Total hours by Group Size</p> <table> <thead> <tr> <th>Size</th><th>Hours</th></tr> </thead> <tbody> <tr><td>1</td><td>0.0</td></tr> <tr><td>2</td><td>0.0</td></tr> <tr><td>3</td><td>0.0</td></tr> <tr><td>4</td><td>12.5</td></tr> <tr><td>0</td><td>0.0</td></tr> <tr><td>0</td><td>0.0</td></tr> </tbody> </table> <p><i>of which</i></p> <table> <thead> <tr> <th><i>Hours missed</i></th><th><i>Hours to come</i></th></tr> </thead> <tbody> <tr><td>0.0</td><td>0.0</td></tr> </tbody> </table> <p>Number of collections marked: 0.0</p>	Size	Hours	1	0.0	2	0.0	3	0.0	4	12.5	0	0.0	0	0.0	<i>Hours missed</i>	<i>Hours to come</i>	0.0	0.0	Zheng Hong had a really good term. His essays were first class and his participation during the tutorials was extremely constructive. I have been very happy with Zheng Hong, and I expect him to get a first.
Size	Hours																		
1	0.0																		
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<p><i>Number of pieces of work set:</i> 7.0  <i>Work satisfactorily completed:</i> 7.0  <i>Work handed in late:</i> 0.0</p>																			
<i>Effort:</i> Excellent <i>Achievement:</i> Excellent <i>Estimate of Term's work:</i> 1	<i>Comments:</i>																		
<i>Collection marks:</i> <i>Vacation essay marks:</i>																			
<i>Submitted on 19/03/2019</i>																			
<i>Approved by Charlotte Pawley on 21/03/2019</i>																			

<b>Zheng Lieu</b> (mert3946), Merton Bachelor of Arts in Philosophy, Politics, and Economics  Core Microeconomics Taught by <b>Bassel Tarbush</b> (scat3580)	XRNLI-2018-1456794  Organising Tutor: Simon Saunders , Emin Baysan , Karina Cendon boveda , Alistair Macaulay , Patricia Thornton , Bassel Tarbush  Personal Tutor: None Michaelmas 2018														
<p style="text-align: center;">Total hours by Group Size</p> <table> <thead> <tr> <th>Size</th> <th>Hours</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>0.0</td> </tr> <tr> <td>2</td> <td>2.0</td> </tr> <tr> <td>3</td> <td>3.75</td> </tr> <tr> <td>4</td> <td>10.75</td> </tr> <tr> <td>0</td> <td>0.0</td> </tr> <tr> <td>0</td> <td>0.0</td> </tr> </tbody> </table>	Size	Hours	1	0.0	2	2.0	3	3.75	4	10.75	0	0.0	0	0.0	<p>Zheng Hong had a decent term. He was understandably very busy (preparing for his thesis in Pol. Soc.) and did not spend as much time on micro as I would have liked him to.</p> <p>That said, it was apparent in the tutes that he has a good grasp of most of the material. If he gives himself enough time to revise, he should do well. Just remember one thing: understanding the material is one thing. Knowing what is being asked and knowing how to respond to (exam) questions well is another. Please look at past exams and specimen papers. Practice on those. Get feedback from grad mentors.</p> <p>He is very creative on the essay writing front. That sometimes works really well, but it can also sometimes work against him if his approach happens to be too complicated (or possibly wrong). E.g. I'm thinking of the insurance market essay in which he attempted an analytical solution to the problem -- but it would have been much easier to approach it graphically.</p>
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<p style="text-align: center;"><i>of which</i></p> <table> <thead> <tr> <th><i>Hours missed</i></th> <th><i>Hours to come</i></th> </tr> </thead> <tbody> <tr> <td>0.0</td> <td>1.5</td> </tr> </tbody> </table> <p>Number of collections marked: 1.0</p>	<i>Hours missed</i>	<i>Hours to come</i>	0.0	1.5											
<i>Hours missed</i>	<i>Hours to come</i>														
0.0	1.5														
<p><i>Number of pieces of work set:</i> 0.0  <i>Work satisfactorily completed:</i> 0.0  <i>Work handed in late:</i> 0.0</p>															
<i>Effort:</i> <i>Achievement:</i> <i>Estimate of Term's work:</i>	<i>Comments:</i>														
<i>Collection marks:</i> <i>Vacation essay marks:</i>															
<i>Submitted on 13/12/2018</i>															
<i>Approved by Sergi Pardos-Prado on 18/12/2018</i>															

<b>Zheng Lieu</b> (mert3946), Merton Bachelor of Arts in Philosophy, Politics, and Economics  Political Sociology Taught by <b>Sergi Pardos-Prado</b> (nuff0797)	XRNLI-2018-1457065  Organising Tutor: Simon Saunders , Emin Baysan , Karina Cendon boveda , Alistair Macaulay , Patricia Thornton , Bassel Tarbush  Personal Tutor: None Michaelmas 2018														
Total hours by Group Size <table> <thead> <tr> <th>Size</th> <th>Hours</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>0.0</td> </tr> <tr> <td>2</td> <td>14.0</td> </tr> <tr> <td>3</td> <td>0.0</td> </tr> <tr> <td>0</td> <td>0.0</td> </tr> <tr> <td>0</td> <td>0.0</td> </tr> <tr> <td>0</td> <td>0.0</td> </tr> </tbody> </table>	Size	Hours	1	0.0	2	14.0	3	0.0	0	0.0	0	0.0	0	0.0	<p>ZhengHong has performed at the highest possible level in this module. His coverage and understanding of the materials, his committed attitude, his constant improvement on the econometric side of the paper, and the quality of his written work were First class. ZhengHong is planning to write a thesis on quantitative political science topic, so the effort he made in Pol Soc will be very helpful later on. Two things concern me, though, at this point. First, the level of nuance and sophistication that ZhengHong is able to show in his tutorial essays will be difficult to replicate in an exam setting. He will need to practice exam writing under timed conditions (at home and in Collections), and learn how to be more selective in his arguments and critical engagement with the literature. Second, I hear from Economics that the extra effort he put in Pol Soc came at the cost of investing in Microeconomics. ZhengHong should remember that all papers need to be mastered in order to get a First, and that, as he very well knows, technical papers are not necessarily always the most straightforward.</p>
Size	Hours														
1	0.0														
2	14.0														
3	0.0														
0	0.0														
0	0.0														
0	0.0														
<i>of which</i> <table> <thead> <tr> <th><i>Hours missed</i></th> <th><i>Hours to come</i></th> </tr> </thead> <tbody> <tr> <td>0.0</td> <td>0.0</td> </tr> </tbody> </table> <p>Number of collections marked: 1.0</p>	<i>Hours missed</i>	<i>Hours to come</i>	0.0	0.0											
<i>Hours missed</i>	<i>Hours to come</i>														
0.0	0.0														
<p><i>Number of pieces of work set:</i> 7.0  <i>Work satisfactorily completed:</i> 7.0  <i>Work handed in late:</i> 0.0</p>															
<i>Effort:</i> <i>Achievement:</i> <i>Estimate of Term's work:</i>	<i>Comments:</i>    														
<i>Collection marks:</i> <i>Vacation essay marks:</i>															
<i>Submitted on 18/12/2018</i>															
<i>Approved by Bassel Tarbush on 18/12/2018</i>															

<b>Zheng Lieu</b> (mert3946), Merton Bachelor of Arts in Philosophy, Politics, and Economics  Quantitative Economics Taught by <b>Bassel Tarbush</b> (scat3580)	XRNLI-2019-1543918  Organising Tutor: Simon Saunders , Emin Baysan , Karina Cendon boveda , Alistair Macaulay , Patricia Thornton , Bassel Tarbush  Personal Tutor: None Trinity 2019														
Total hours by Group Size <table> <thead> <tr> <th>Size</th><th>Hours</th></tr> </thead> <tbody> <tr><td>1</td><td>2.0</td></tr> <tr><td>2</td><td>2.5</td></tr> <tr><td>3</td><td>9.0</td></tr> <tr><td>4</td><td>6.0</td></tr> <tr><td>8</td><td>2.0</td></tr> <tr><td>0</td><td>0.0</td></tr> </tbody> </table>	Size	Hours	1	2.0	2	2.5	3	9.0	4	6.0	8	2.0	0	0.0	Zheng Hong clearly enjoyed QE. He should spend some time solidifying his grasp of the material -- but he is on track to do very well in this paper. He submitted written work of high quality and he was an active participant in tutorials.
Size	Hours														
1	2.0														
2	2.5														
3	9.0														
4	6.0														
8	2.0														
0	0.0														
<i>of which</i> <table> <thead> <tr> <th><i>Hours missed</i></th><th><i>Hours to come</i></th></tr> </thead> <tbody> <tr><td>0.0</td><td>0.0</td></tr> </tbody> </table> Number of collections marked: 1.0	<i>Hours missed</i>	<i>Hours to come</i>	0.0	0.0											
<i>Hours missed</i>	<i>Hours to come</i>														
0.0	0.0														
<i>Number of pieces of work set:</i> 0.0 <i>Work satisfactorily completed:</i> 0.0 <i>Work handed in late:</i> 0.0															
<i>Effort:</i> Not specified <i>Achievement:</i> Not specified <i>Estimate of Term's work:</i> Not specified	<i>Comments:</i>														
<i>Collection marks:</i> <i>Vacation essay marks:</i>															
<i>Submitted on 01/07/2019</i>															
<i>Approved by Michael Rousakis on 01/07/2019</i>															

<b>Zheng Lieu</b> (mert3946), Merton Bachelor of Arts in Philosophy, Politics, and Economics  Theory of Politics Taught by <b>Collis Tahzib</b> (linc3311)	XRNLI-2019-1485729  Organising Tutor: Simon Saunders , Emin Baysan , Karina Cendon boveda , Alistair Macaulay , Patricia Thornton , Bassel Tarbush  Personal Tutor: None Hilary 2019														
Total hours by Group Size <table> <thead> <tr> <th>Size</th><th>Hours</th></tr> </thead> <tbody> <tr><td>1</td><td>0.0</td></tr> <tr><td>2</td><td>0.0</td></tr> <tr><td>3</td><td>12.0</td></tr> <tr><td>0</td><td>0.0</td></tr> <tr><td>0</td><td>0.0</td></tr> <tr><td>0</td><td>0.0</td></tr> </tbody> </table>	Size	Hours	1	0.0	2	0.0	3	12.0	0	0.0	0	0.0	0	0.0	Zhenghong has had a very good term. He is active in tutorial discussions and makes bright and thoughtful contributions. A few of his essays have been handed in late, but they are always well written and well argued.
Size	Hours														
1	0.0														
2	0.0														
3	12.0														
0	0.0														
0	0.0														
0	0.0														
<i>of which</i> <table> <thead> <tr> <th><i>Hours missed</i></th><th><i>Hours to come</i></th></tr> </thead> <tbody> <tr><td>0.0</td><td>0.0</td></tr> </tbody> </table> Number of collections marked: 0.0	<i>Hours missed</i>	<i>Hours to come</i>	0.0	0.0											
<i>Hours missed</i>	<i>Hours to come</i>														
0.0	0.0														
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<i>Effort:</i> Not specified <i>Achievement:</i> Not specified <i>Estimate of Term's work:</i> Not specified	<i>Comments:</i>														
<i>Collection marks:</i> <i>Vacation essay marks:</i>															
<i>Submitted on 01/03/2019</i>															
<i>Approved by Sergi Pardos-Prado on 14/03/2019</i>															

September 23, 2017

# Lieu Zheng Hong

has successfully completed a free online offering of

## Algorithms: Design and Analysis

This is an undergraduate level course on the design and analysis of algorithms. The main topics are: asymptotic analysis, divide and conquer algorithms, sorting and searching, basic randomized algorithms, graph search, shortest paths, heaps, search trees, and hash tables. In order to earn a Statement of Accomplishment, participants were required to score at least 70% on 6 problem sets, 6 programming assignments, and 1 final exam.



**Tim Roughgarden**  
Associate Professor of Computer Science  
Stanford University

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Authenticity can be verified at <https://verify.lagunita.stanford.edu/SOA/f06d4d781ad5466c85d65b279e2e2e63>



11/13/2019

# Zheng Hong Lieu

has successfully completed

## Big Data Analysis with Scala and Spark

an online non-credit course authorized by École Polytechnique Fédérale de Lausanne and offered through Coursera

Heather Miller  
École Polytechnique Fédérale de Lausanne

## COURSE CERTIFICATE



Verify at [coursera.org/verify/CSFJQZEQFBHD](https://coursera.org/verify/CSFJQZEQFBHD)

Coursera has confirmed the identity of this individual and their participation in the course.



09/10/2018

# Zheng Hong Lieu

has successfully completed

## Competitive Programmer's Core Skills

an online non-credit course authorized by Saint Petersburg State University and offered through Coursera

*Alexander S. Kulikov  
Alexander Logunov*

*Kirill Simonov*

Alexander S. Kulikov, Alexander Logunov, Kirill Simonov

## COURSE CERTIFICATE



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Coursera has confirmed the identity of this individual and their participation in the course.

June 26, 2019

# Lieu Zheng Hong

has successfully completed a free online offering of

## Relational Algebra

with **Statement of Accomplishment**.



Jennifer Widom  
Professor in Computer Science  
Stanford University

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Authenticity can be verified at <https://verify.lagunita.stanford.edu/SOA/129872c52c734402a73bfd3098992146>

July 25, 2019

# Lieu Zheng Hong

has successfully completed a free online offering of

## Relational Design Theory

with **Statement of Accomplishment**.



Jennifer Widom  
Professor in Computer Science  
Stanford University

**PLEASE NOTE:** SOME ONLINE COURSES MAY DRAW ON MATERIAL FROM COURSES TAUGHT ON-CAMPUS BUT THEY ARE NOT EQUIVALENT TO ON-CAMPUS COURSES. THIS STATEMENT DOES NOT AFFIRM THAT THIS PARTICIPANT WAS ENROLLED AS A STUDENT AT STANFORD UNIVERSITY IN ANY WAY. IT DOES NOT CONFER A STANFORD UNIVERSITY GRADE, COURSE CREDIT OR DEGREE, AND IT DOES NOT VERIFY THE IDENTITY OF THE PARTICIPANT.

Authenticity can be verified at <https://verify.lagunita.stanford.edu/SOA/56aea8ef39b248c784c0d00f6c714034>

July 23, 2019

# Lieu Zheng Hong

has successfully completed a free online offering of

## SQL

with **Statement of Accomplishment**.



Jennifer Widom,  
Ph.D  
Professor in Computer Science  
Stanford University

**PLEASE NOTE:** SOME ONLINE COURSES MAY DRAW ON MATERIAL FROM COURSES TAUGHT ON-CAMPUS BUT THEY ARE NOT EQUIVALENT TO ON-CAMPUS COURSES. THIS STATEMENT DOES NOT AFFIRM THAT THIS PARTICIPANT WAS ENROLLED AS A STUDENT AT STANFORD UNIVERSITY IN ANY WAY. IT DOES NOT CONFER A STANFORD UNIVERSITY GRADE, COURSE CREDIT OR DEGREE, AND IT DOES NOT VERIFY THE IDENTITY OF THE PARTICIPANT.

Authenticity can be verified at <https://verify.lagunita.stanford.edu/SOA/4ab3b5eca8c541c2824e9be512d1abfb>



11/13/2019

# Zheng Hong Lieu

has successfully completed

## Functional Programming Principles in Scala

an online non-credit course authorized by École Polytechnique Fédérale de Lausanne and offered through Coursera

MARTIN ODERSKY  
PROFESSOR OF COMPUTER SCIENCE  
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

## COURSE CERTIFICATE



Verify at [coursera.org/verify/M9QXY6C62MKX](https://coursera.org/verify/M9QXY6C62MKX)

Coursera has confirmed the identity of this individual and their participation in the course.



07/25/2019

# Zheng Hong Lieu

has successfully completed

## Mathematics for Machine Learning: Linear Algebra

an online non-credit course authorized by Imperial College London and offered through Coursera

Two handwritten signatures in black ink. The first signature on the left appears to read "David Dye". The second signature on the right appears to read "Samuel J. Cooper".

David Dye and Samuel J. Cooper

## COURSE CERTIFICATE



Verify at [coursera.org/verify/R5MYEW9MU2J](https://coursera.org/verify/R5MYEW9MU2J)

Coursera has confirmed the identity of this individual and their participation in the course.

# Stanford | ONLINE

04/30/2017

## Zheng Hong Lieu

has successfully completed

### Machine Learning

an online non-credit course authorized by Stanford University and offered through  
Coursera



Associate Professor Andrew Ng  
Computer Science Department  
Stanford University

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## COURSE CERTIFICATE



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Coursera has confirmed the identity of this individual and  
their participation in the course.



11/18/2019

# Zheng Hong Lieu

has successfully completed

Mathematics for Machine Learning: Multivariate  
Calculus

an online non-credit course authorized by Imperial College London and offered through  
Coursera

Two handwritten signatures in black ink. The first signature on the left appears to be "David Dye". The second signature on the right appears to be "Samuel J. Cooper".

David Dye and Samuel J. Cooper

## COURSE CERTIFICATE



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Coursera has confirmed the identity of this individual and  
their participation in the course.



08/28/2017

# Zheng Hong Lieu

has successfully completed

Build a Modern Computer from First Principles:  
From Nand to Tetris (Project-Centered Course)

an online non-credit course authorized by Hebrew University of Jerusalem and offered  
through Coursera

Shimon Schocken  
Associate Professor  
Computer Science

Professor Noam Nisan  
School of Computer Science and Engineering  
The Hebrew University of Jerusalem

## COURSE CERTIFICATE



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Coursera has confirmed the identity of this individual and  
their participation in the course.



12/24/2017

# Zheng Hong Lieu

has successfully completed

Build a Modern Computer from First Principles:  
Nand to Tetris Part II (project-centered course)

an online non-credit course authorized by Hebrew University of Jerusalem and offered  
through Coursera

Shimon Schocken  
Associate Professor  
Computer Science

## COURSE CERTIFICATE



Verify at [coursera.org/verify/9AC7ZV3ZZWQW](https://coursera.org/verify/9AC7ZV3ZZWQW)  
Coursera has confirmed the identity of this individual and  
their participation in the course.

Attn : Prof Allen Scott .

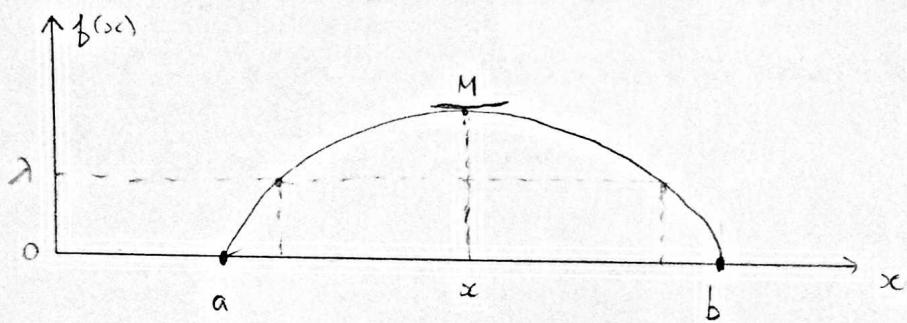
Real Analysis

TTW8



3.  $f: [a, b] \rightarrow \mathbb{R}$  has the property that  $f(x) > 0$  for  $a \leq x \leq b$  and  $f(a) = 0, f(b) = 0$ . If for each  $x \in [a, b]$  there exists exactly one distinct  $y \in [a, b]$  such that  $f(x) = f(y)$ , prove that  $f$  cannot be continuous on  $[a, b]$ .

We prove by contradiction.



If  $f$  is continuous on  $[a, b]$ , it must obtain a maximum on the interval  $[a, b]$ .

Let this maximum  $M$  be reached at point  $x$ .

Now consider the function on the intervals  $[a, x]$  and  $[x, b]$ . Of course,  $f$  must be continuous on both intervals, and go from  $[0, M]$  from  $[a, x]$  and  $[M, 0]$  from  $x$  to  $b$ .

Consider the value  $\lambda$  <sup>pick me!</sup> that lies between  $0$  and  $M$ .

By the Intermediate Value Theorem, we can find a  $\xi_1$  between  $a$  and  $x$  such that  $\lambda = f(\xi_1)$ .

But similarly, we can also find a  $\xi_2$  between  $x$  and  $b$  such that  $\lambda = f(\xi_2)$ .

But this contradicts our distinctness assumption, as  $\xi_2 > \xi_1$  and yet  $f(\xi_2) = f(\xi_1)$ . Hence  $f$  cannot be continuous on  $[a, b]$ .

5. Suppose  $a < c < d < b$  and  $f(a, b) \rightarrow \mathbb{R}$   
 is differentiable on  $(a, b)$ . If  $f'(c) > 0$   
 and  $f'(d) < 0$ , prove there exists  $\{\xi(c, d)\}$ ,  
 such that  $f'(\xi) = 0$ .

Consider the interval  $(c, d)$ .

As  $(c, d)$  is contained within  $(a, b)$

$f(c, d) \rightarrow \mathbb{R}$  is differentiable on the interval

It follows that it is continuous.

Consider the closed interval  $[c, d]$ . By continuity, it must have a maximum  $M$ .

Claim:

$f(c)$  and  $f(d)$  are not maximum  $M$ .

Proof:

$$\text{Let } \lim_{x \rightarrow c} \frac{f(x) - f(c)}{x - c} = \delta > 0. \quad \checkmark \quad f(c) > 0.$$

$$\left| \frac{f(x) - f(c)}{x - c} - \delta \right| < \frac{\delta}{2}. \quad \text{This implies that}$$

$$\Rightarrow \frac{f(x) - f(c)}{x - c} > \frac{\delta}{2}. \quad \text{As } x > c,$$

$$\Rightarrow f(x) - f(c) > \frac{\delta}{2}(x - c) > 0. \quad \text{Therefore, } f(c) \text{ cannot be a maximum.}$$

Similarly,

$$\lim_{x \rightarrow d} \frac{f(x) - f(d)}{x - d} < 0, \quad \Rightarrow \quad \frac{f(d) - f(x)}{x - d} > 0.$$

By a similar argument

$$f(d) - f(x) < \frac{\delta}{2}(x - d) < 0; \quad f(d) \text{ cannot be a max.}$$

$\Rightarrow$  Since  $f(a)$  and  $f(b)$  are not maximum, this implies that there exists  $\exists \{c, d\} \text{ s.t. } f(\{c, d\}) = M$ .

But if  $\exists \{c, d\} \text{ s.t. } f(\{c, d\}) = M$ , then this implies (by Theorem 11.2) that  $f'(\{c, d\}) = 0$ .  $\square$  ✓

Deduce that the image of  $(a, b)$  under  $f'$  is an interval.

6. Let  $f: \mathbb{R} \rightarrow \mathbb{R}$  be differentiable at every point and satisfy  $f'(x) > 0$  for all values of  $x$ . Prove that the equation  $f(x) = 0$  can have at most one solution.

We prove by contradiction. Suppose that there were exactly two solutions of  $f(x) = 0$ , call them  $a$  and  $b$ . Then, by Rolle's Theorem, there must exist a stationary point  $\xi \in (a, b)$  s.t.  $f'(\xi) = 0$ . But this gives us a contradiction as  $f'(x) > 0 \quad \forall x$ . With any number of solutions greater or equal to two (e.g.  $f(a) = f(b) = f(c) = 0$ ), applying Rolle's Theorem to any pair gives us a contradiction. Hence, it can have at most one soln. ✓

If  $f''(x) > 0 \quad \forall x$  show  $f(x) = 0$  can have at most two solutions.

