

Project Title: An Analysis of I-Cut-You-Freeze

Project Web Page: CutThePolitics.com

Project Description:

Researchers from many fields have examined how to reduce the negative effects of partisan Gerrymandering in the US. One proposed protocol by Pegden and Procaccia proposes an I-Cut-You-Freeze approach, whereby parties take turns apportioning the electoral map, and then choosing from the states apportioned by the other party on which district to “freeze.” Although the approach contains properties that suggest it may reduce phenomena such as minority packing and incumbent strongholds, the protocols guarantees are provided to an idealized and simplified model of the electoral process (e.g. many of the proofs assume the existence of one minority group) and open questions remain as to whether players using the protocols can efficiently produce optimal outcomes, and whether these outcomes are preferable in practice to the current system.

During the course of the project, I will work with Ariel Procaccia and Wesley Pegden to develop a website that allows users to face off with the protocols against both other users and AI, allowing us to gather data on what second order effects the protocols might produce in practice. By allowing users to simulate these protocols and facing off users of comparable skillsets against each other, we hope to observe if deleterious redistricting outcomes are possible in practice when faithfully following a few of the different redistricting protocols observed in this space. By facing users off against AI, we hope to develop an efficient algorithm to solve one or more of these protocols by potentially discovering of a reasonable heuristic that will allow the AI to perform well in competitive play. In addition to the benefits to observing users interact with a (hopefully) capable AI player, developing such an AI will hopefully allow us to define more rigorously some of the open problems related to the protocol and (hopefully) make justified claims about the effects of the protocols in practice. Thus, in working to develop a website that allows users to play around with these protocols and face AI opponents, we will gather data that will allow us to meaningfully assess the utility of these protocols in practice while simultaneously answering some theoretical questions that are crucial for the real-world implementation of such a protocol.

Regardless of the results of the data obtained, this work will create at least some meaningful contributions to the fields of computer science, political science, or computational game theory. If the above work shows no deleterious redistricting outcomes and we find either find an efficient algorithm to optimally play the redistricting game for the I-Cut-You-Freeze protocol, we will have found an optimal solution to redistricting that could positively impact the nation’s political discourse. If we gain traction on the website but the data indicate significant flaws in the redistricting outcomes produced by such a protocol, we will have produced a rich dataset that will allow us to refine such protocols to try to reduce these effects. Even if the website does not gain any popular traction, the development of an AI to play the I-Cut-You-Freeze redistricting protocol would allow us to make claims about the effectiveness of such an approach. Although in such a case we might not be able to answer some questions about the second-order effects of the protocols, the discovery of a heuristic or algorithm that such an AI requires would show that the protocol could be used in practice. Finally, in the case that we can disprove an efficient algorithm to finding an optimal solution exists (i.e. show the problem is NP-Hard), we will still have contributed meaningful work to the fields of computer science and computational game theory (and, who knows – perhaps the opacity of an NP-Hard problem would actually ease adoption to skeptical politicians, as either side would have no clear advantage!). In short, barring no progress on both a heuristic or website traction, research into this area would yield interesting results to at least one field of study.

Project Goals:

75%: Create a website that allows users to competitively play against each other for the following protocols: I-Cut-I-Freeze and I-Cut-You-Freeze (non-geometric case) on real data from at least one state from the 2010 Census. Generate an AI for the I-Cut-I-Freeze protocol based off of a heuristic

100% The above, except the incorporate at least one Independent agent protocol developed by either Landeu and Su or Landeu et al. Additionally, come up with an AI to play the I-Cut-You-Choose protocol with a reasonable heuristic or create an AI for the I-Cut-I-Freeze that plays provably optimally.

125% All of the work for 100%, plus the development an AI for the I-Cut-You-Choose protocol for either the geometric and non-geometric cases that plays provably optimally

And Beyond: It is important to note that due to the scope of the project, this goal only represents a portion of the research that can be done on this task. Other work that could be explored in future student projects includes what kind of efficient approximation algorithms may be developed for the various protocols, proof of optimality of certain solutions, and research into the many practical questions outside the scope of this initial project.

1st Technical Milestone: Establish the groundwork for a website to simulate these protocols. This includes completing a literature review of the work done in the past on this project and building out the architecture of the website. Upon completion of this task, I should be able to test locally that I have a React client server working with a Node.JS backend. Some sort of third party service should be used for authenticating the connection and then passing the client a session key to access the backend server. If I am ambitious, I can also incorporate in a database or do some of the UI/UX work on the client server.

15-400 Milestones:

January 31st:

- Migrate the frontend server and the backend server from local host to either AWS or Heroku
- Complete the UI/UX of the frontend server so that protocol simulations can be dropped in when ready
- Come up with a solidified UI/UX plan for the simulation of first protocol
- Finish database integration
- Identify which state from the 2010 census should be targeted for the initial redistricting simulation

February 14th:

- Become familiarized with a web game engine that will provide the basic functionality for the simulation. Create some toy examples that mimic likely UI/UX interactions to prove competency
- Create a solidified UI/UX plan for the remaining protocols to be implemented, using the first protocol as a template

February 28th: Implement the I-Cut-You-Freeze (non-geometric) protocol for competitive play

March 21st: Using the I-Cut-You-Freeze (non-geometric) protocol as a template, implement the I-Cut-You-Freeze (geometric) and I-Cut-I-Freeze protocols for competitive play

April 4th:

- Test the protocols on a few fellow students to see if they are sticky.
- Begin attempting to raise awareness about the site through platforms like Hacker News, Reddit Dzone and Tech Ladder
- Begin work on developing heuristics for the protocols that would allow for competitive AI paly
- Write up results justifying the heuristic of the I-Cut-You-Freeze protocol

April 18th: Implement an AI that plays the I-Cut-You-Freeze protocol

May 2nd: Gather results and perform data analysis. Answer the following questions if the site had a good amount of users:

- Did users come up with strategies that showed a weakness in the protocols B-Target Property? If not, were there any other observable deleterious redistricting outcomes that emerged from strong competitive play?
- How did the users fair against the AI? Did the AI's play against the users lead to any deleterious outcomes?
- Were there any interesting trends in user play? What strategies were used?

If the site did not gain a significant number of users, instead focus analysis on the heuristic developed for the AI.

Literature Search:

I believe that the following sources will be useful in my work over the next few semesters (listed in order of perceived importance from the abstracts):

1. **A Partisan Redistricting Protocol with Provably Non-Partisan Outcomes (working paper by Pegden and Procaccia)**
2. Unfair Partisan Gerrymanders in Politics and Law: A Diagnostic Applied to Six Cases (by McDonald and Best)
3. Fair Division: From Cake-Cutting to Dispute Resolution (Brams and Taylor)
4. **Fair Division and Redistricting (Landau and Edwards)**
5. Redistricting: Drawing the Line (by Bangia et al.)
6. Three Tests for Practical Evaluation of Partisan Gerrymandering (Wang)
7. **Assessing Significance in a Markov Chain Without Mixing (by Chikina et al.)**
8. Cake Cutting: Not Just Child's Play (by Procaccia)
9. The Effect of Redistricting Commissions on Electoral Competitiveness in US House Elections (by Lindgrin and Southwell)
10. Quantifying Gerrymandering (by Vaughn et al.)

Of the above works, I have read the bolded ones, and I hope to read a few more as part of my milestone achievement. In addition to these papers, I am seeking out additional papers that analyze this problem from an algorithmic or mathematical approach. From my search on Google Scholar, the work above represents much of the work in this area, but I hope to find additional papers that tackle this problem by proposing additional novel protocols.

Resources Needed:

I do not anticipate needing to use any non-free framework or software in developing this study, although I might need a non-trivial amount of resources for Heroku or AWS hosting/data storage costs in order to obtain a good dataset on how people play this game competitively.

Fortunately, I do not anticipate finding the costs of hosting to be large issue, as the number of users necessary to proceed to the next phase of the project is relatively small compared to the funding available. If hosting costs become too much, it is a signal of the project's popularity to a larger scale than I anticipated, which would mean that more resources would likely become available or user donations could support the site at that point.

One potential cost that might be large is the need to hire a designer to complete the UI elements in the event that the ones that I create are not sticky enough.