TEXAS TECH UNIVERSITY

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Table of Content

Summary…………………………………………………………………………….…………………3

Introduction……………………………………………………………………………….3

Criteria……………………………………………………………………………………4

Problem Statement……………………………………………………………………...4

OR (Operations Research) Model (In Words) ……………………………..……………5

OR (Operation Research) Model (In Math Form) …………………………….………...6

Experiment……………………………………………………………………………….8

Plan Evaluation…………………………………………………………..…………8

Conclusion…………………………………………………………….………….**9**

References……………………………………………………………………………9

Summary

This report outlines a redistricting strategy for Iowa, utilizing the most recent census figures and advanced methods in operations research. The goal is to establish four districts, each with a population ranging from 793,605 to 801,580, while maintaining a maximum population variance of 1%. The primary emphasis is on reducing the number of divided boundaries, maintaining both compactness and contiguousness, in accordance with state and federal regulations.

Our strategy employs a comprehensive optimization model that merges demographic and geographic information to form districts that comply with legal standards and reflect community interests. The suggested districts are evenly populated, contiguous, and geographically consistent, ensuring effective political representation.

The accompanying report provides an in-depth explanation of our methodology, analysis, and the rationale for the suggested district lines, supported by both visual and numerical data. This carefully crafted plan strives to provide fair and representative districts for the varied communities across Iowa.

Introduction

The crucial process of redistricting in Iowa involves the challenge of organizing its 99 counties into four equitable districts. This critical task is performed every ten years, aligning with the release of new census data, and aims to ensure equal population distribution while maintaining the wholeness of communities.

Our initiative employs methods from operations research to delineate districts that are evenly populated, geographically compact, and connected. This methodical approach is designed to prevent partisan gerrymandering and promote equitable representation for all of Iowa's communities.

Our systematic plan divides the 99 counties into four well-proportioned districts, with a commitment to openness and integrity. Such efforts are crucial in upholding the principles of democracy in Iowa and guaranteeing proportionate representation throughout its political divisions.

Within the scope of this study on Iowa's redistricting, it's essential to recognize that although federal guidelines account for safeguarding racial and language minorities, this analysis does not delve into that element. Below is a synopsis of the criteria pertinent to this study.

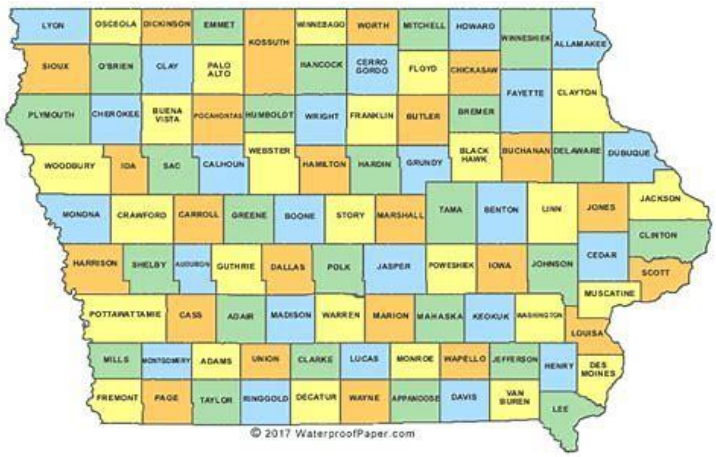


Figure showing Iowa counties.

<u>Criteria</u>

- ➢ Federal Guidelines
- Equal Population Distribution: This principle aims to guarantee nearly identical population counts in each district across Iowa, in compliance with federal statutes. This element is a cornerstone of the study, promoting equitable representation.

- ➢ State Guidelines:
- Geographical Solidity and Unity: The redistricting process in Iowa gives priority to creating districts that are geographically solid and connected, ensuring that one can travel within a district without entering another.
- Impartiality in Politics: Iowa's policy is structured to be nonpartisan, neither giving advantage to any political faction, incumbent, nor any group, upholding the neutrality of the redistricting endeavor.
- Keeping Political and Community Integrity: This project is particularly attentive to the geographic continuity and demographic balance during redistricting, while also considering the preservation of political subdivisions and community bonds.

The aspects of racial and language minority rights, as stipulated by the Voting Rights Act within the federal guidelines, do not constitute the focus of this investigation. Instead, the study concentrates on ensuring demographic parity, geographic compactness, and nonpartisanship, in accordance with Iowa's redistricting principles and ensuring a fair and objective process.

Problem Statement

Our initiative utilizes methods from operations research to organize Iowa's 99 counties into four evenly populated congressional districts, adhering to the redistricting standards set by state and federal guidelines, which emphasize equal population, geographical compactness, and connectedness.

OR (Operations Research) Model (In Words)

Main Objective: The primary goal of our model is to minimize the number of "cut edges" to maintain district continuity.

Research Model Restrictions

- Exclusive Assignment Requirement: Every county is to be allocated to one and only one district.
- Population Parity: The population for each district should fall within a specified range [L, U].
- Adjacency Division Limitation: An edge is considered divided if two neighboring counties fall into separate districts.
- Proximity Limitation: Within any given district, the aggregate of the distances between any pair of counties, when multiplied by the corresponding binary assignment variables, must not exceed a predefined proximity threshold, which has been determined as 50 miles for each district.

Continuity Constraints

- Consumption of Flow Regulation: This guarantees that a county (vertex) i, when assigned to a district (center) j, uses up one unit of type j flow. If the county i isn't linked to center i, it does not utilize any type j flow.
- Reception of Flow Regulation: This stipulates that a county can only receive a specific type of flow if it is part of the associated district.
- Exclusion of Self-Provided Flow: A district center (node) is barred from receiving its own type of flow, which avoids self-connections.
- Positivity of Flow: This condition ensures that the flow value along any edge within the network remains positive.

OR (Operation Research) Model (In Math Form)

Sets and Indices

- i: Denotes the collection of Iowa counties, with i including values from 1 to 99.
- j: Denotes the group of districts to be established, with j comprising values 1 through 4.
- V: Symbolizes the complete set of nodes or vertices within the network.
- N(i): Represents the set of adjacent nodes or vertices to node i.
- u and v: These indices are utilized for iterating through sets of adjacent nodes in the model's constraints, where u and v denote individual adjacent counties or districts in the set N(i).

Parameters

- P_i: The population of county i, applicable for all i within the set I.
- L: The minimum population threshold for each district.
- U: The maximum population threshold for each district.
- d_{ij}: The distance between county i and county j, relevant for all distinct pairs i,j within the set I.
- k: The designated number of districts to be configured (k equals 4).

Decision Variables

- x_{ij}: A binary indicator that is set to 1 if county i is allocated to district j, and 0 otherwise.
- y_{ij}: A binary indicator that is set to 1 if the boundary between counties i and j is severed (indicating they belong to different districts), and 0 otherwise.

Objective of the Model

Aim to minimize the total ∑ over i in I of ∑ over j in J of y_{ij}.

Model Constraints

- Population Equilibrium: The sum of P_i multiplied by x_{ij} across all i in I should be within the range [L, U] for every j in J.

- Exclusive Allocation: The sum of x_{ij} across all j in J must equal 1 for each i in I.

- Boundary Division Limitation: For every i,k within I and each j within J, x_{ij} minus x_{kj} should be less or equal to y_{ik}.

- Proximity Constraint: Strive to minimize the total of d_{ij} multiplied by x_{ik} and x_{jk} across all i,j in I (where i is not equal to j) and for each k in J.

- **Contiguous Integrity**

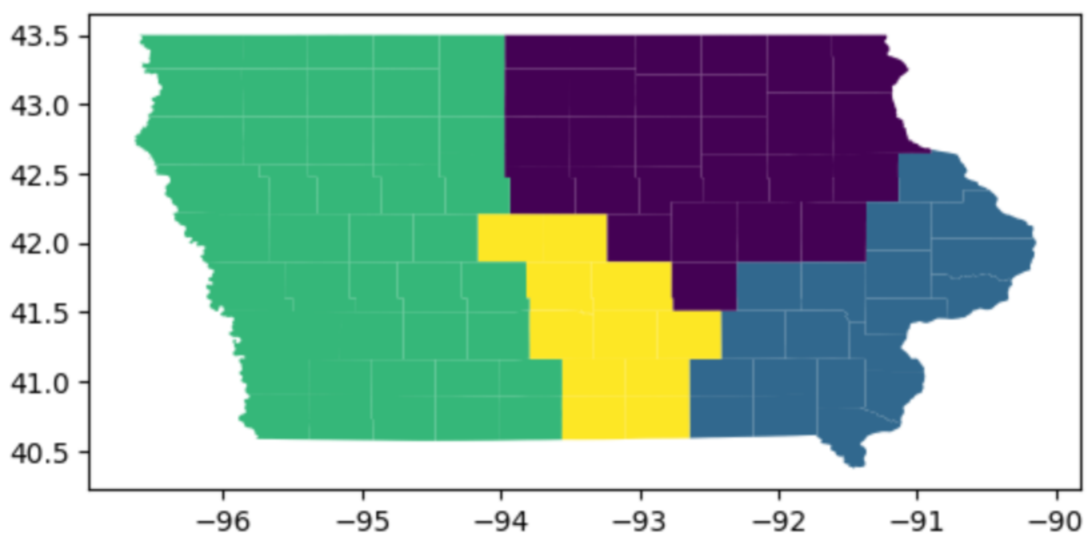
- Flow Consumption Rule: For each i in V excluding j, and every j in V, the sum of f_{ui}^j minus f_{iu}^j should equal x_{ij}.
- Flow Acceptance Rule: For each i in V excluding j, and every j in V, the sum of f_{ui}^j must be less than or equal to (n-1) times x_{ij}.
- Self-Connection Prohibition: For every j in V, the sum of f_{ui}^j where u is in N(j) must equal 0.
- Flow Positivity Requirement: The flow f_{ij}^v must be non-negative for every edge {i,j} in E and all v in V.

The study proceeded without incorporating the compactness feature due to limitations in the academic license. Therefore, the experiment was executed with the compactness aspect excluded from the coding process.

Experiment

The study was carried out on a machine powered by AMD Ryzen 5 7530U CPU with Radeon Graphics, instruction set [SSE2|AVX|AVX2], which has 6 physical cores and 12 logical processors. This setup was maximized by employing 12 threads. The Gurobi Optimizer model utilized was the 11.0.0 build v11.0.0rc2 (win64).

The optimal solution was ascertained with a high degree of accuracy, within a tolerance of 0.0001, achieving both the best objective and bound at 33, with no discernible gap. This result validates the model's optimal resolution, reflecting precision and computational efficacy.



Iowa districting from jupyter notebook code

Plan Evaluation

Overview of Suggested Redistricting Strategy

• Compliance with Standards: The strategy conforms to most established criteria.

• Population Equilibrium: Exhibits an exceptionally minor deviation of 0.08%, comfortably under the allowable 1% threshold.

• Spatial Efficiency & Connectivity: Districts are structured to be both spatially efficient and contiguous.

• Constraints: Accuracy in demarcating county boundaries could result in slight discrepancies.

In summary, the strategy satisfies the necessary standards, with notable success in ensuring population uniformity and district continuity, though it might display minor inconsistencies owing to the exact delineation of county borders.

Conclusion

Upon meticulous evaluation and compliance with necessary standards, our proposal indicates that segmenting Iowa into four separate districts with a nominal population variance of 0.08% is achievable. This recommended delineation strives for an equitable and balanced structure, ensuring uniform representation.

Github link - https://github.com/Haryokunle001HH/IOWA-Project

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