

# Programming projects

Victor Eijkhout, Susan Lindsey

Fall 2024

last formatted: November 12, 2024

# Introduction

# 1. Purpose

- Write a relatively serious C++/Fortran program
- Do a scientific simulation
- Write up your findings

## 2. What are we looking for?

- Pretend that this is a research article: explain the problem, how you go about solving it, what you find.  
Quality of the write-up is very important!
- Code quality: good naming, indentation, use of object-oriented techniques.

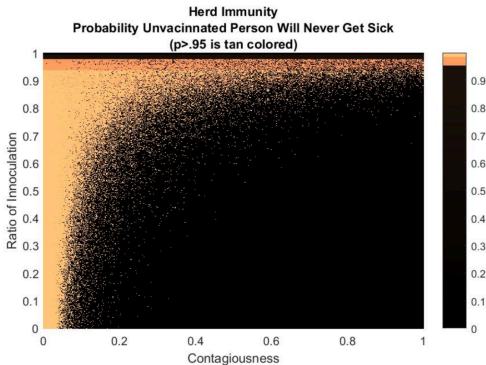
## **Project: infectious disease simulation**

### 3. What is it about?

- How does an infectious disease spread through the population?
- Does anyone escape being infected? How long does the disease run?

## 4. What can you do

- Investigate influence of parameters: chance of transmission, incubation period, how many people are vaccinated, ...Plot one thing against another.  
Don't forget to explain what it means!
- Sample graph:



## 5. Level of difficulty

- If this was your first semester you can do this on your own and be proud of having done a serious simulation.



## **Project: Amazon delivery trucks**

## 6. What is it about?

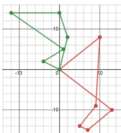
- How do you plan an optimal route for a delivery truck?
- How about if you have more than one truck?
- How about if you can spread over multiple days?

## 7. What can you do

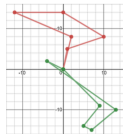
- Investigate heuristics for route planning.
- Discuss management and ethics issues.



(a) original route  
Total Dist = 195.954



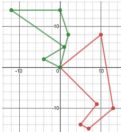
(b) opt2  
Total Dist = 115.372



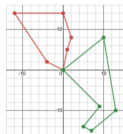
(c) greedy Opt2  
Total Dist = 116.184



(d) original route  
Total Dist = 195.954



(e) opt2 Robust  
Total Dist = 112.917



(f) greedy opt2 Robust  
Total Dist = 105.712

- Sample graph:

## 8. Level of difficulty

- This is tricky coding. Sophisticated use of object-oriented techniques will be a great help.
- You can do a lot of exploring.
- This is a two-person project.

## **Project: redistricting**

## 9. What is it about?

- Group census districts into congressional districts.
- Is it possible for a minority to gain the upper hand?

## 10. Level of difficulty

- This is *very* tricky programming.
- Even the naive approach is tricky; using dynamic programming takes it up a notch.
- If you tell you Amazon recruiter that you modeled gerrymandering by dynamic programming after your first semester they'll be impressed.

# Project: Google Pagerank

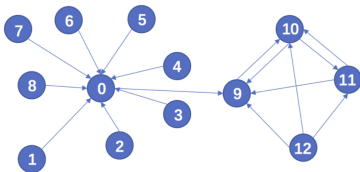


# 11. What is it about?

- Simulate the internet
- Which web pages are important?

## 12. What can you do

- Different techniques for modeling the problem.
- Dig into the mathematics of it: relation between graphs and sparse matrices.



**Figure 6:** Web with one page artificially made 'important'

- Sample graph:

## 13. Level of difficulty

- User of pointers in the simple model.
- Opportunity for thinking about computational efficiency.

# Project: High performance linear algebra

## 14. What is it about?

- In linear algebra the naive algorithms are often not efficient.
- Explore algorithms that take architecture into account.

# 15. What can you do

- Learn about architecture,
- ... and how to code for it.

## 16. Level of difficulty

- You get to use C++20 features. This is serious geekery.
- If you think programming correctly is hard, try programming efficiently ...

## **Project: Climate change**



## 17. What is it about?

- 'Climate has always changed, always will'.
- Make that statement testable, and test it with real data.
- Difficulty: not too hard, single person.

## 18. What can you do

- Handle multiple datasets through range algorithms.
- Explore numerical algorithms.

## 19. Level of difficulty

- Not too hard. Single person project.

# The Great Garbage Patch

## 20. What's it about?

In the ocean there are

- plastic particles
- turtles; they die when they ingest plastic
- ships; they sweep up the plastic

Simulate the interactions.

## 21. What can you do

- Data structures
- Algorithms
- Rudimentary graphics

Difficulty level: single person