Are Cross Country Courses Getting Less Hilly?

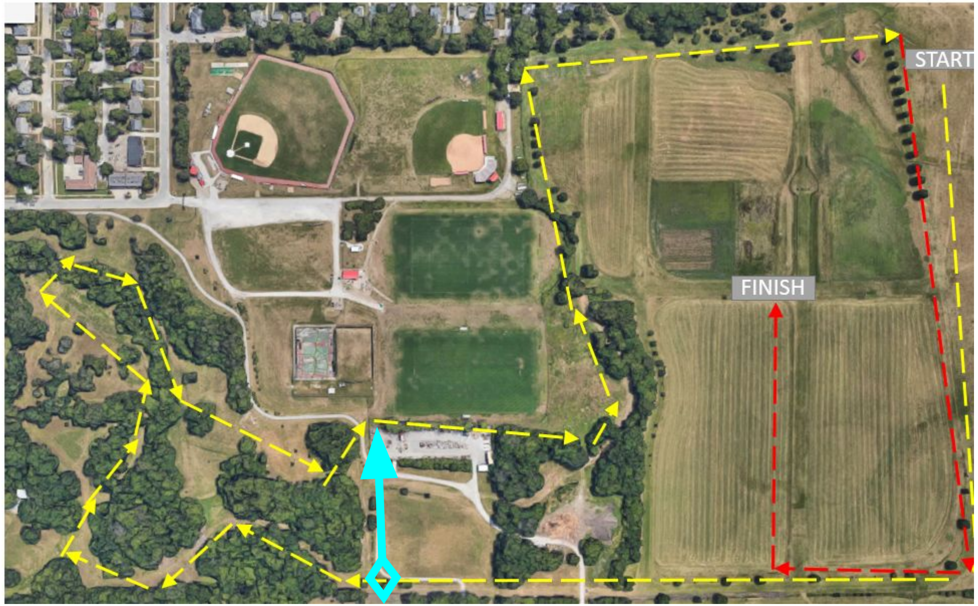
Team 37

Advisor/Client: Dr. Brian Hornbuckle

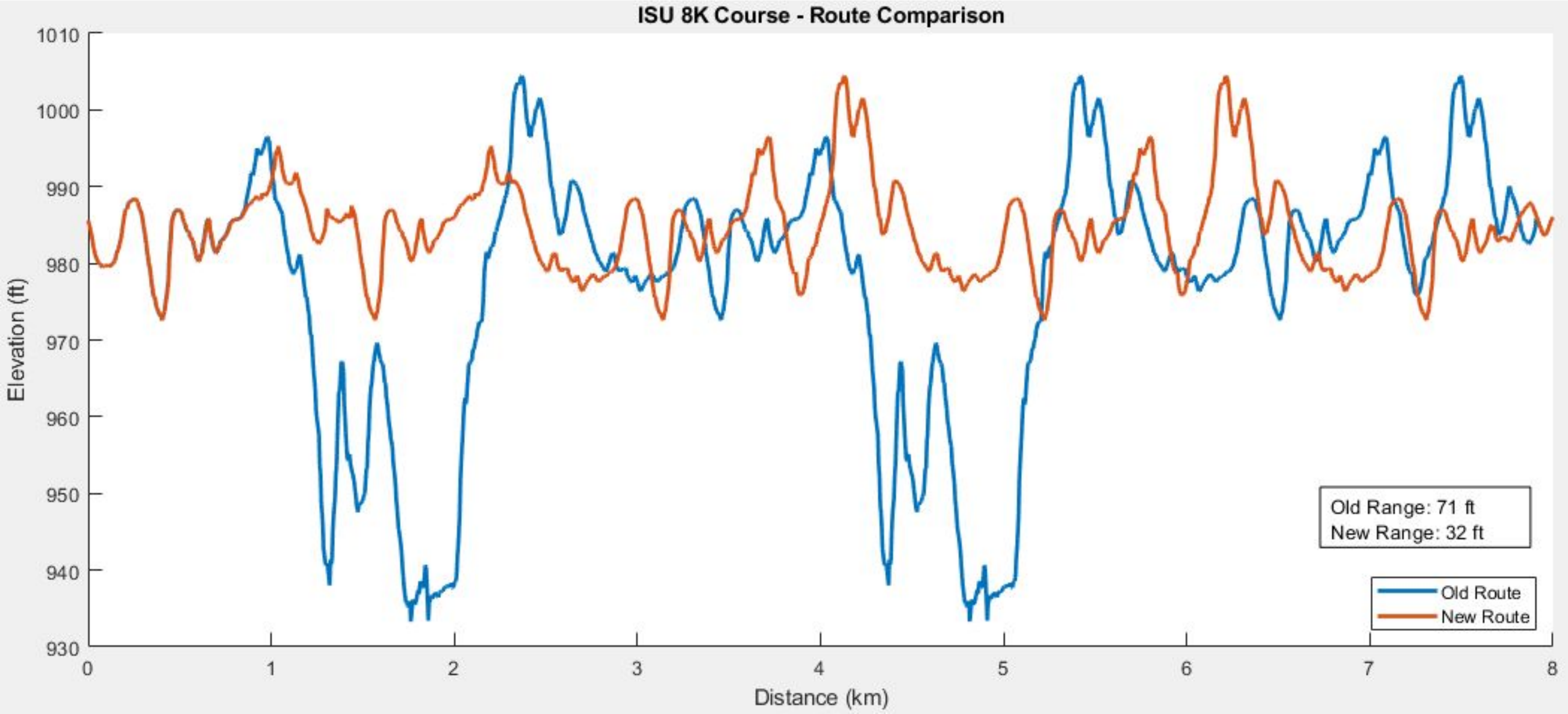
http://sdmay19-37.sd.ece.iastate.edu/

Problem Statement & Project Motivation

- Are cross-country courses getting less hilly?
  - Why is this a problem?
  - How can we test this?
- If they are getting less hilly, how can this trend be reversed?
  - Give course designers more insights into their courses



ISU XC Course - Route Comparisons


ISU 8K Course - Route Comparison
Elevation (ft)
1010
1000
990
980
970
960
950
940
930
Distance (km)
0
1
2
3
4
5
6
7
8
Old Range: 71 ft
New Range: 32 ft
Old Route
New Route

Project Objectives

- Determine the **best source of elevation data** for use in analyzing cross country course topography
- Evaluate our central hypothesis (courses getting less hilly) by finding maps of courses **before and after** their routes had changed
- Develop a website that allows for analysis of **any** cross country course
  - Generate a Course Rating on a 0-10 difficulty scale
  - Derive metrics from course elevation profiles
  - Targeted towards-
    - **Athletes** - to have better knowledge of race routes
    - **Coaches** - to better plan racing strategies for athletes
    - **Spectators** - to satisfy curiosities about how different courses compare to each other

What about all those other running apps?

- Strava, MapMyRun, etc. all calculate elevation profiles for routes
- Spent many hours researching existing methods of analyzing running routes but found two consistent issues
    1. Other apps use Google Maps elevation data combined with smartphone barometric altimeters
        a. We found these to be **unreliable** data sources in our surveys

    2. Other rating systems are **time-based, not topography-based**

Functional Requirements

- The initial ground truth validation studies need to provide definitive information regarding the accuracies and, subsequently, the viability of using topographic data sources available that are also feasible and scalable to a wider deployment.
- The web app tool needs to be able to use LIDAR files as its data source.
- The web app must easily allow users to provide the course XY data themselves.
- The web app must be able to run classification algorithms on the elevation profiles and classify hill-like topography in to subclassifications like big hills and rolling hills.
- The elevation profiles and their derived metrics must be presented in a visually appealing manner and in an easy-to-interpret format.

= met

= partially met

= not met

Non-Functional Requirements

- Server will match x, y coordinates in a course to elevation within 10 seconds.
- 90% of surveyed users must not report issues/confusion after using app
- Elevation data source must be consistently within 3 m of the USGS official elevation
- 90% of users report that they comprehend the meaning of the various metrics produced by the classification
- 90% of users report that the scorecards are presented in visually appealing and easily interpretable format
- Quantitative ratings of 0-10 course score must be within ±1.5 points of average trial runners' qualitative rankings of courses.

= met

= partially met

= not met

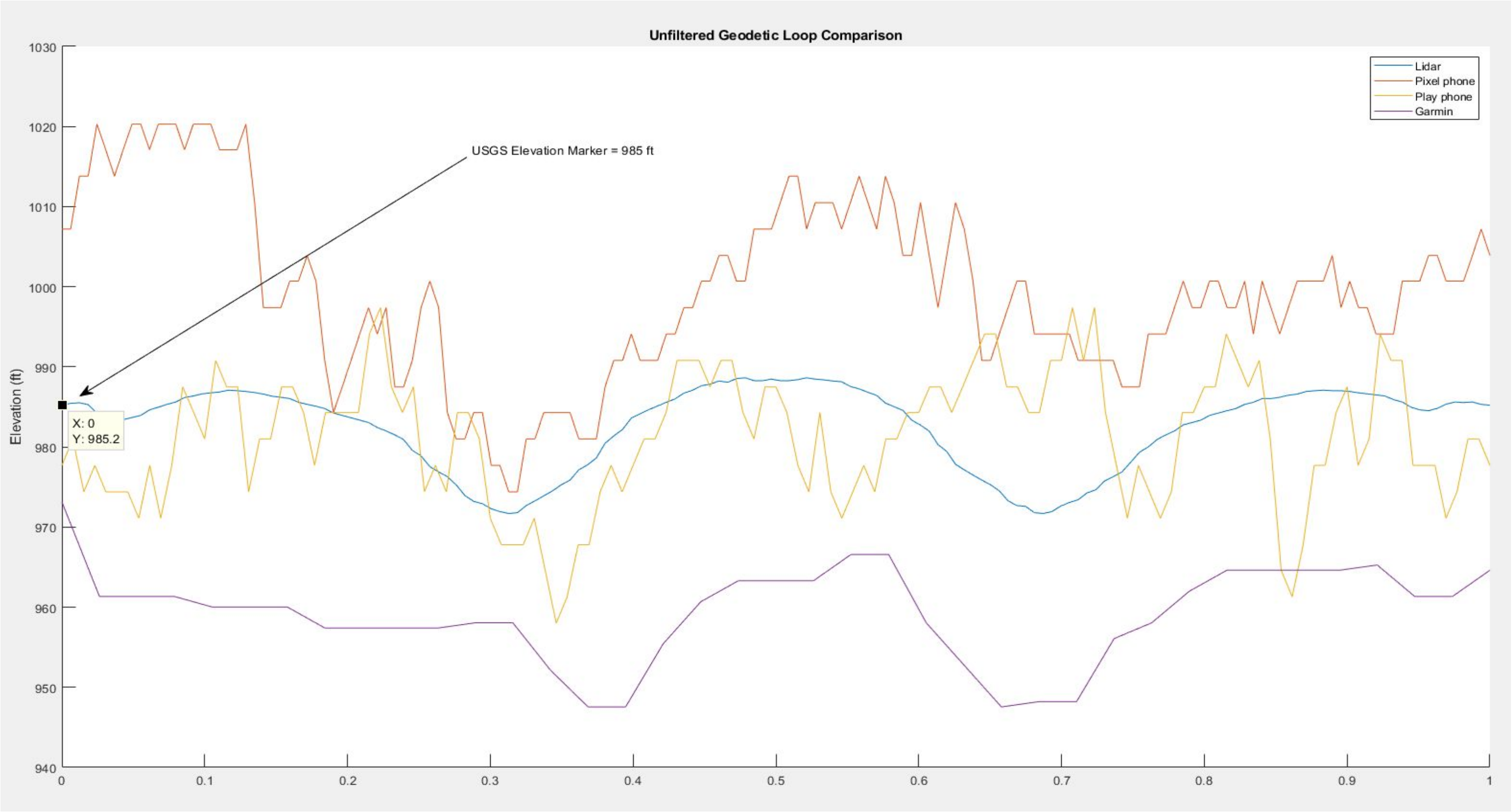
Use-Case Scenarios

1. Determine difficulty of a course
2. Determine more difficult parts of a course
3. Get information on the hills of a course
4. Replacement/alternative to walking a course to understand its layout

Design Plan - Ground Truth & Data Source Selection

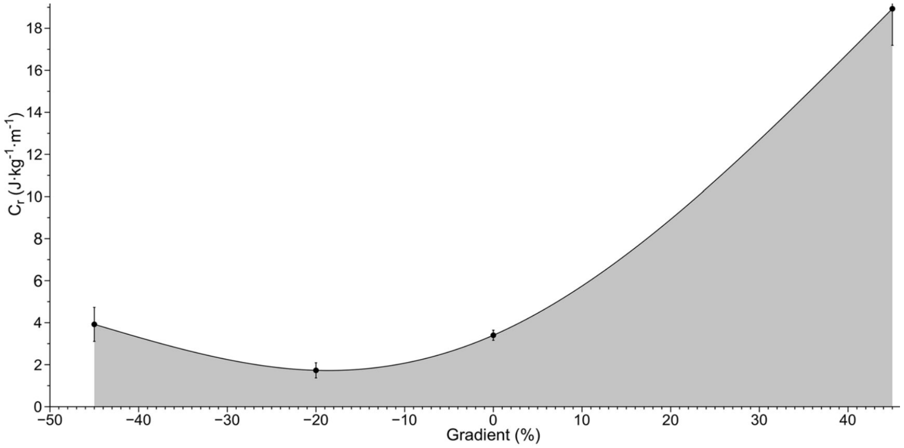
- Needed to confirm LIDAR was best data source
- Data Sources: LIDAR, smartphone, GPS, Google Maps
- Surveys:
  - ISU Course (featured woody areas, open flat areas, hills)
  - Geodetic Points (straight line) (reference next slide)
  - Test variety of cases
- Result: LIDAR is best for project
  - Covers entire state of Iowa
  - Matched geodetic points with accuracy of within 2 meters
- Further testing
  - Savitzky-Golay Filter with smartphones and GPS
  - While noise was reduced, subtle features weren't captured

Geodetic Survey



Design Plan - Rating System

- Energy Cost
- Fatigue Factor
- Hill Classification
  - Big Hills
  - Rolling Hills
- All of this factors into 0-10+ rating system
- 30 courses surveyed to establish baseline of rating system used

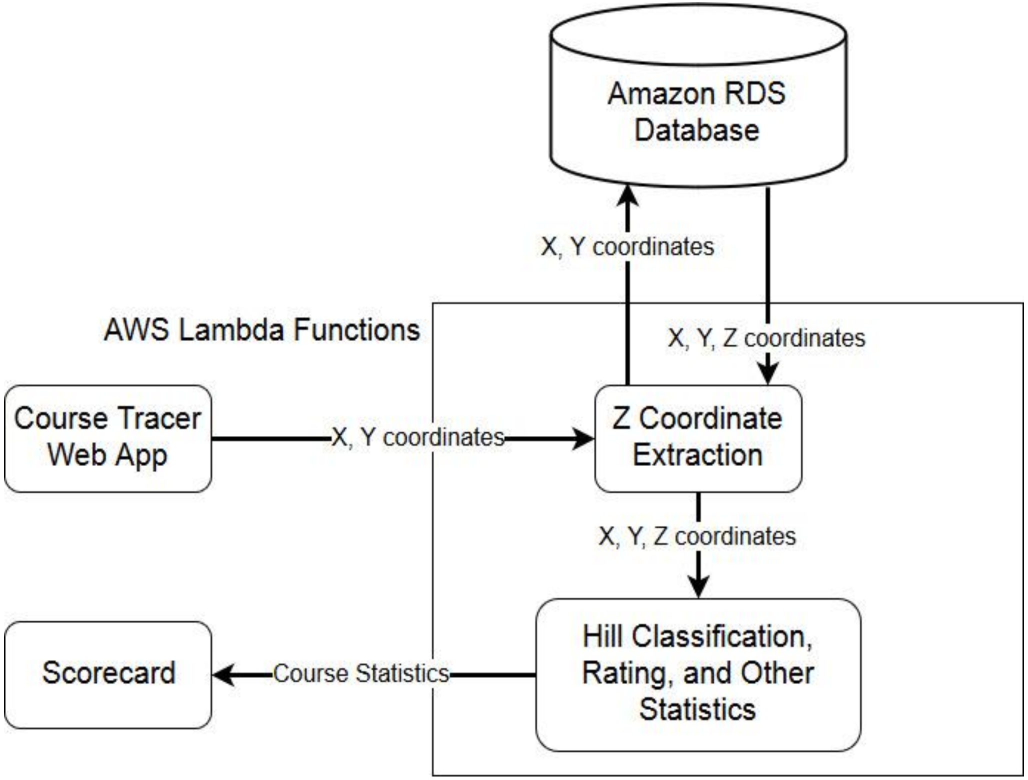


$$Cr = 155.4i^5 - 30.4i^4 - 43.3i^3 + 46.3i^2 + 19.5i + 3.6$$

Design Plan - Web Tool

- Angular Web App
  - David
  - Responsive
  - Easy to use
- AWS Lambda Back End
  - Andrew
  - Scalable
  - Fast
- AWS RDS
  - Jacob
  - Industry Standard
  - Widely Compatible

Project Architecture



System Constraints

- LIDAR data set is confined to Iowa
- Size of LIDAR data files
  - AWS RDS free tier
- Tech savviness of end users

Design Trade-Offs

- 3 meter resolution LIDAR files
- Web app and phone app
- Difficulty rating is only based on hilliness
- Research paper vs. web app

Implementation

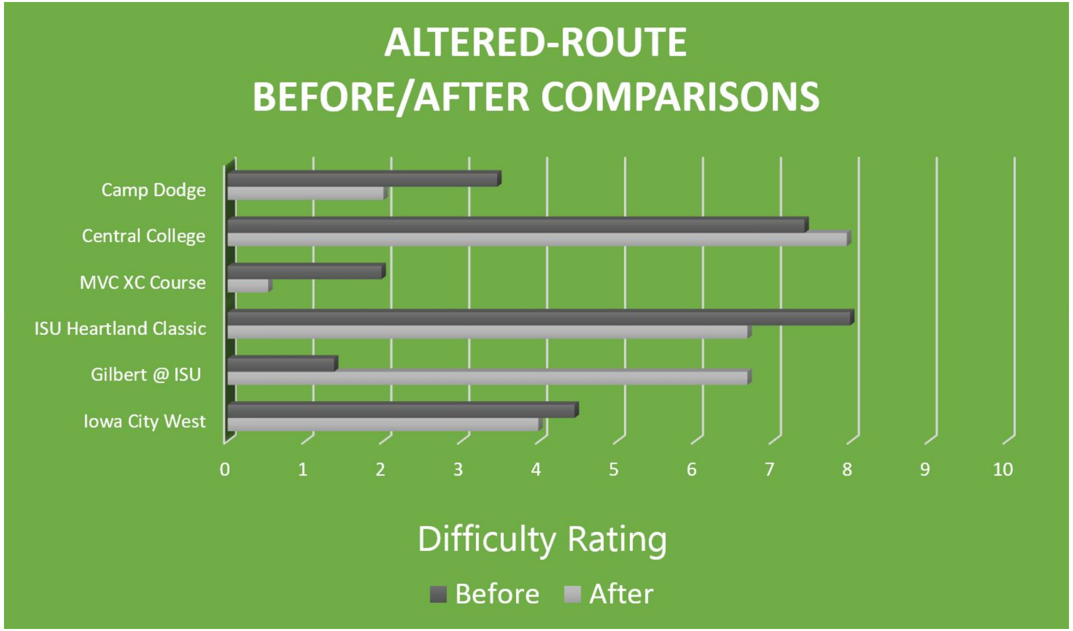
- Frontend
  - Angular 7
  - Webpack
  - Google Maps API
  - Languages: Typescript, JSON
- Backend
  - AWS Lambda
  - Amazon RDS - MySQL relational implementation
  - PyMySQL
  - Languages: Python

Testing Processes

- Scripts for three main components of elevation analysis as well as frontend, backend, and database all worked on concurrently and tested independently. Elevation analysis tested using saved courses from the LIDAR data while web app was in development.
- Three members working on elevation analysis compiled work in to one streamlined process in MATLAB, then converted to Python to be implemented in the backend.
- Tools were tested in Story County and then expanded to counties in other regions of the state.
- Tested with real high school courses, length verified.

Evaluation & Findings

- 30 high school courses traced in web app and scored with algorithm
- Subset of these courses contained rerouted courses
- Compared using t-statistic hypothesis testing
- No trend evident in our data to support our theory



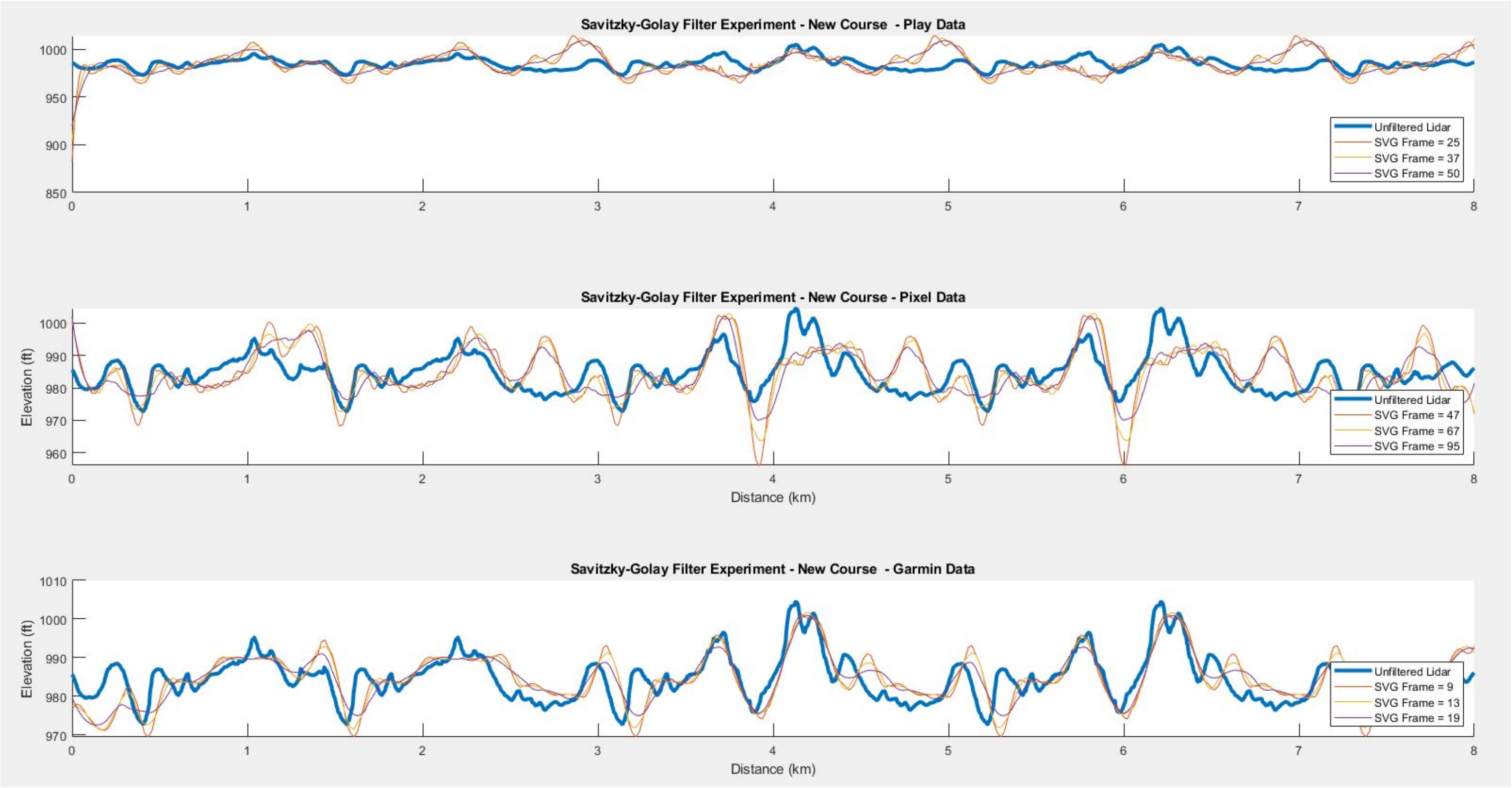
Lessons Learned

- Working on major tasks concurrently required a detailed schedule and taking ownership for one’s work.
- Troubleshooting problems, flexibility in our weekly work.
- Overcoming major technical problems/constraints, such as managing database size. Part of overcoming these problems involved team-wide discussions about different approaches without a decisive “best” option.
- Working with experts in another field and getting a working knowledge of a new subject.

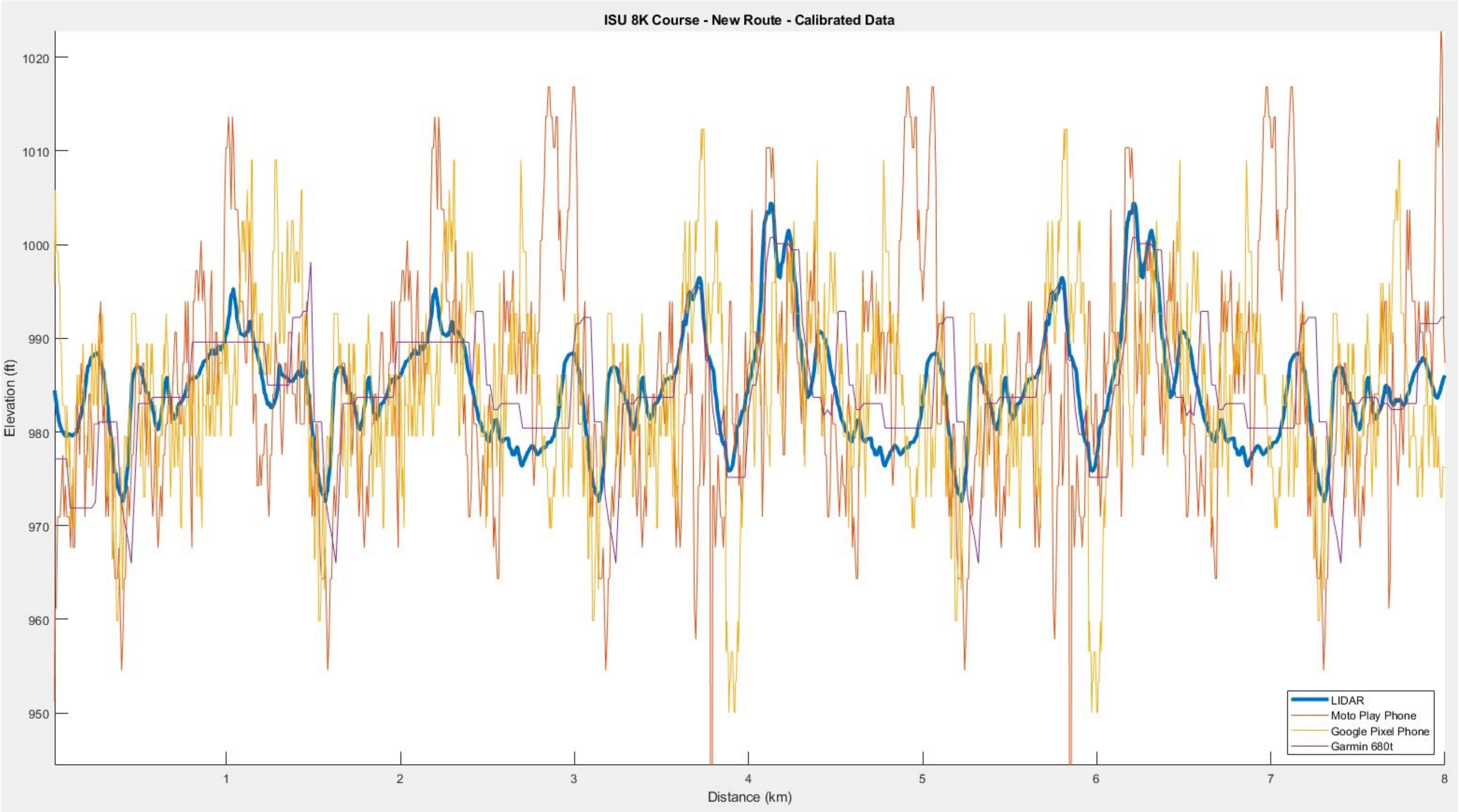
Thank you!

Questions?

Savitzky-Golay Filtering Testing



Unsmoothed Raw Elevation Data



Smoothed Elevation Data