COVID-19: Tracking Bryan Center Congestion with Wi-Fi Data

Aston Yong, Angela Yoon, Sam Zhou, Hunter Klein, Mary Clair Thompson

1 Introduction

With Duke reopening amidst COVID-19, our team tracked the movement of foot traffic in Bryan Center by analyzing Wi-Fi log data from the center's wireless network users. We aim to provide Duke OIT and student related groups with visualizations indicating highly congested areas and frequented paths to suggest social distancing measures.

2 Data

29 csv files
2/1 - 2/29/2020
Wi-Fi log history

Connection time
Access point (AP)
Hashed user

Incomplete AP location map
List of all APs in building
Accounting floor maps

3 Access Point Mapping

3-1. Pixel Location Tool

Using a Tableau drawing tool, we recorded pixel coordinates of the AP locations from the incomplete ap map. We then utilized the below techniques to calculate the unknown AP locations. Coordinate pairs were then overlaid above the floor plan images to generate complete AP maps.

3-2. Markov Chain

Using the foot traffic data, we generated a Markov Chain outlining the probability that a user moves from one AP to another. We then created a list of the top 10 closest APs for each AP. This helps us get an idea of the location of the APs relative to each other.

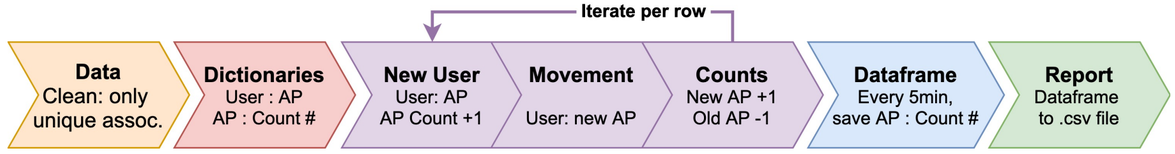
3-3. Coordinate Estimation Program

We have created a program that estimates the locations of the unmapped APs using the locations of the mapped APs and the Markov Chain. The program solves a system of equations where the coordinates of each unknown AP are a weighted average of all other AP coordinates.

4 Heatmap

4-1. Calculating User Count

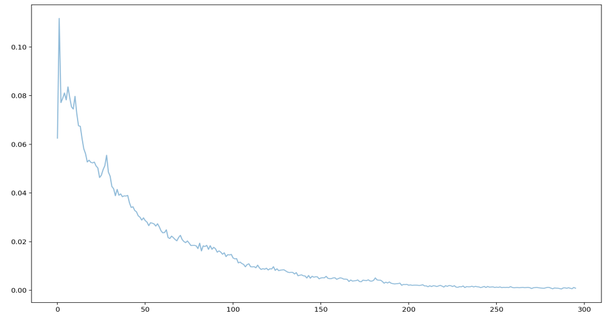
We developed code to track user movement and update AP user counts accordingly.



4-2. Solving the Buildup Problem

As no records are left after each user's last AP connection, the code cannot account for users leaving the building, causing an AP count buildup. To solve this problem, we generated a Kernel Density Estimation from users' first AP connection durations.

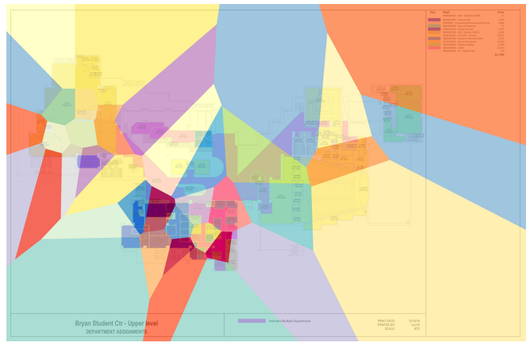
Assuming that devices behave similarly around exterior APs, we used this distribution to predict last AP connection durations. We computed the expected value of this distribution and the leaving user counts for each AP across the day, then decremented the original output csv data by values that adequately reflect these trends.



Kernel Density Estimation of first AP connection durations. x axis is time in seconds and y axis is the probability that user will stay connected for x seconds

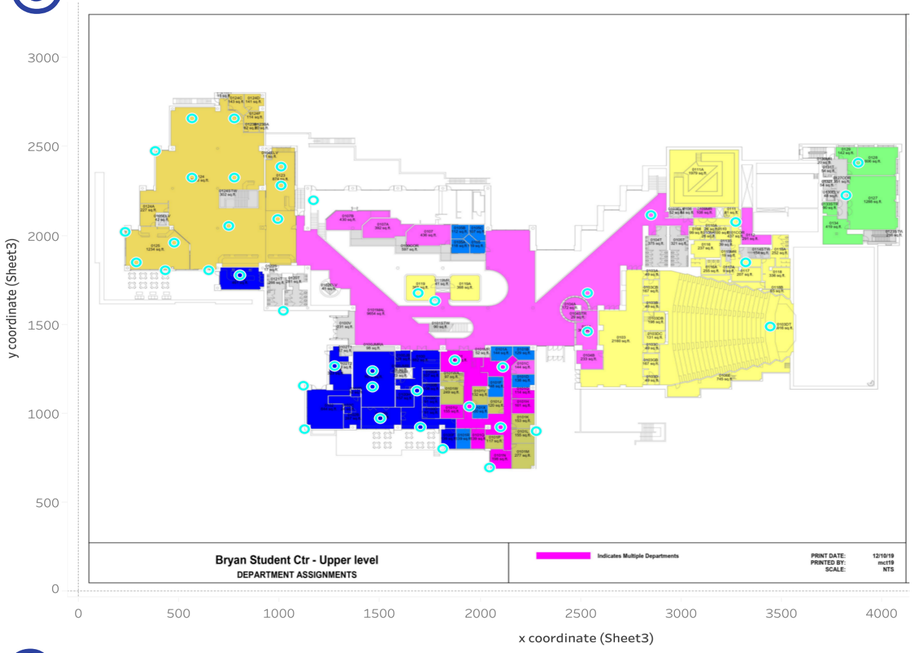
4-3. The Voronoi Diagram

To complete the Tableau polygon animation, we programmed a Voronoi diagram maker that generates polygons centered around data points. We coded the Voronoi diagram to the floor plan dimensions, and the diagram connects midpoints of our AP coordinates. We then overlaid the Voronoi diagrams over the floor plans and recorded the polygon coordinates using the pixel location tool.



Voronoi diagram of floor 3 overlaid on map

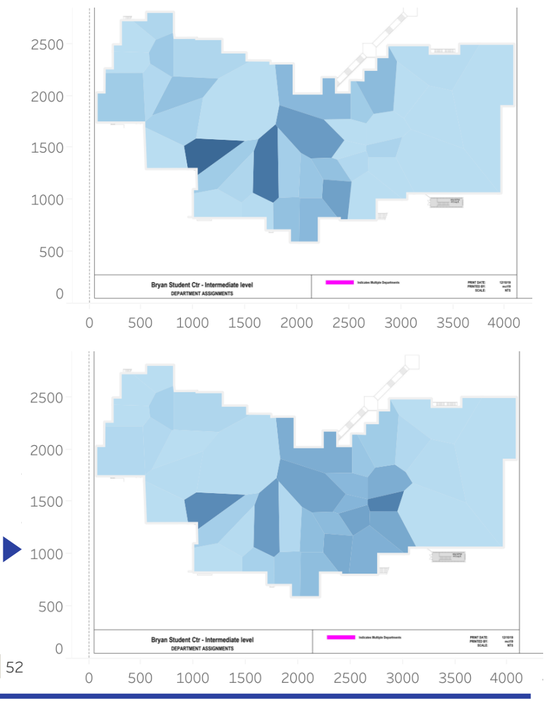
5 Results



AP map of floor 3

We created a new AP map based on the estimated coordinates for all three floors of the center. We also created a heatmap animation showing foot traffic movement on February 19th with 5 minute intervals.

Heatmap of floor 2 on Feb 19th, at 2:00 PM (top) and 3:15 PM (bottom)



6 Conclusions and Future Directions

From the heatmap, we were able to observe the general movement of foot traffic in the center across time as well as significant "hotspots" such as Griffith Theater, McDonalds, and certain hallways. By confirming estimated AP locations in person by visiting the center, generating animations for various time intervals and dates, and performing numerical analysis on the AP counts data, we will be able to increase the accuracy of our visualization and further make meaningful observations from it.

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