Digitizing CSU's Campus into Esri's ArcGIS

Honors Thesis

Presented in Partial Fulfillment of the Requirements for the

University Honors Program

Colorado State University

By

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Spring Semester, 2025

Part 1: Planning the Project

Geographical Information Systems (GIS) offer unparalleled opportunities to organize, analyze, and display data. As a freshman in college, I was immediately inspired by introductory GIS classes to take on a minor in the field and further explore where it could take me. Skip forward a few semesters and suddenly it was time to decide on a final project for my honors thesis. The idea of using GIS software like ArcGIS to perform a larger study quickly came to mind, offering me the chance to practice what I've learned from multiple labs in an individual self-lead manner. This began my search for public data available online for project ideas. However, I also wanted to get experience in the process of collecting datasets in the field rather than solely working with information gathered from others. This meant my project would need to be focused somewhere nearby, and as I realized there was a lack of spatial data for campus, I decided to collect this data myself to create a map of Colorado State University in ArcGIS.

The process for creating a GIS map of CSU can be split into two main components, actively collecting data outside and working with this data online to create a functional and user-friendly map. But first, I needed to reign in the scope of how much data I would have time to gather. Colorado State University spans across a large area for just one person to accumulate detailed information with relatively limited resources, so an extent to the map was first established that included the main portions of campus used by students. This border was set for the area boxed in by W Laurel St, S Shields St, W Lake St, and S College Ave, excluding a couple buildings not owned by CSU. Additionally Aggie Village, Lake Street Garage, and the University for the Arts Center were included, setting up a decently sized portion of land to work with. I knew that core layers of data, such as roads, buildings, trash cans, trees, and sidewalks, were a must for the final map, but finalizing the total amount of layers and how much information within became a more difficult challenge than I expected.

An article written in 2022 stated that there were 9,562 trees across CSU's campus, yet the best data for these trees I could find came from the Geospatial Centroid which was clearly outdated. For example, 50+ trees are listed on the website to exist in the middle of Canvas Football stadium. This meant I needed to manually gather tree information myself. Over the summer of 2024 I set up a miniature experiment to see how long it would take me to collect every tree on campus and info on coordinates, scientific and common names, DBH, circumference, height, and lowest branch height. This experiment also allowed me to practice methods for organizing in the field and within excel sheets for other layers in the future. After extrapolating the time it took to measure 300 trees to the total number of trees on campus, I realized collecting this amount of information was way too ambitious for the time I had, forcing me to restructure my project goals.

Part 2: Collecting Everything on Campus

After my experience over the summer, I could better understand limits for the project scope and create strategies for efficient collection. Over the next semester I created a list of each layer of point data I wanted to gather along with specific information that could be detailed within a code word. These layers included trees, bike racks, trash cans, sidewalk intersections, benches + other outdoor seating, parking lots, bus stops, callboxes, facilities, monuments, signs, lampposts, building corners, and other miscellaneous objects. An example of a code word would be TCYYNNNS, which stands for trash can (TC), trash present (Y), recycling present (Y), compost no present (N), no covering for the trash (N), no cardboard (N), and a simple trash can oppose to a dumpster or collection of bins (S). The unique code for each point object and data about them was organized into a table that evolved over time to capture all the information I wanted to. This allowed me to gather all the data I wanted in one long sweep across campus.

Data on trees was limited to just location, height, and lowest branch height split into categories rather than using a rangefinder to collect specific measurements. The arboretum was also excluded since the number of trees there is incredibly dense. This helped reduce the time it would take to gather the tree layer, making it feasible. Another large change I made to the collection process was switching to printed black and white maps of campus rather than using the gps for every single point. The time it would take to wait for the GPS unit to center its location, lining it up with the points codes, and its inaccuracy for the density of points being collected made it a limiting factor. Instead, printed maps covering 62 separate pages to totally cover campus would be marked with points and later inserted into ArcGIS manually. This also allowed me to complete a somewhat second draft of point collection since I could complete one round of marking the points on paper with numbers, and a second round of checking the points and inserting the object codes into my phone. In turn making the data more accurate with two rounds of collection and eliminating GPS variability. However, this did add about 25 hours of creating point data in ArcGIS.

By the end of spring break, 13,575 total points had been collected and stored with their codes and point locations in the Web Mercator Auxiliary Sphere projected coordinate system. Python was used to break apart the point codes into separated columns of data for each object type as well as fix typo mistakes. The 15th iteration of my written python code provided an adequate output that was then broken out into separate csv files for each of the 10 layers.

The polygon layers for buildings and parking lots were the next section of the project. While the city of Fort Collins has a publicly available building layer, once again the information was outdated and didn't show the amount of detail I wanted. Point codes were gathered before for building corners and data about parking lots across campus, which were used to help draw polygons in ArcGIS. A polygon layer for construction zones across campus was also created. For CSU building information, the CSU Building Floor Plan & Record Documentation Website was used to gather building numbers, name, address, year finished, gross square feet, floors which was recorded into another excel sheet to attach to the polygon layer in ArcGIS. The CSU 3D interactive map page provided info for the parking lots, including Lot number, pass requirements, spaces, and whether motorcycle spaces or EV chargers were present. These websites were also used to decide what counted as a parking lot or buildings. However, three buildings not listed on the website but existing within the boundaries for the map were added to the end. These include the Middel Realty building, a building near the CSU track, and the National Center for Genetic Resources Preservation.

The polyline layers for streets and sidewalks were created next and make up the final two layers of the map. Similar to before, publicly available data online was spotty and it ultimately made sense to manually create the layers using points collected from before, google street view and base maps online. The center point for roads and sidewalks were used to set the polylines, and only clearly defined and streets and paths were included in each. There are many sidewalks that are occasionally used as roads, but these were not included in the street layer. Designated crosswalks and bike lanes were also incorporated in the sidewalks layer to better gather info about the landscape of campus. Afterwards, a baseline version of the map was finished within ArcGIS that contains vast amounts of data across CSU inside the attribute tables of each layer.

Part 3: Experimenting with the Data

The next step of my project was to show the capabilities of this data using applications I've become familiar with during my undergraduate career. Firstly, multiple maps were created in ArcGIS to highlight general information like tree sizes across campus and locations of each type of outdoor seating. A heat map of bike rack availability was also created to show which areas offered the greatest amount of room for students and faculty cycling to CSU. These maps were stylized using symbology to be user friendly for anyone wanting to understand more about CSU. More in depth analysis tools can also be run on the data to obtain more nuanced information. The thiessen polygon tool was run on the CSU border polygon with the callbox point layer, showing the closest callbox to every point on campus. A map displaying this information could be incredibly useful for anyone needing to access a callbox in emergency situations or help staff decide locations where future callboxes should be installed.

An analysis I wanted to do from the very beginning was finding the optimal hammock locations across campus. Using the tree point layer, a near table between pairs of trees was created with a distance limit of 6 meters. Then distances below meters were deleted, leaving data on every pair of trees within the best hammock distance. Small bits of Python were then used in the calculate field tool to rank trees, buildings, and roads by their attributes. Taller trees with higher branches were given better rankings along with farther distances from nearby roads and buildings found through the near tool. This left each pair of trees with a ranking between 5 and 40, with higher scores representing best hammock spots. After the joining fields to gather point locations of trees, new layers were created to highlight the final trees and draw lines between pairs to act as hammocks. Ultimately, more secluded places with larger trees such as the Center for the Arts building or sherwood forest both had some of the best hammock spots on campus using this ranking system. However, the data I collected offers a lot of variability and personalization in how one might want to make hammock selections such as choosing to exclude locations based on sidewalk distance or use elevation maps to explore points with the best view of differing peaks to the west.

My experience using R Studio in multiple classes encouraged me to explore possibilities for displaying data in another program as well. After opening up csv within R, I first created a couple example graphs and pie charts with the ggplot package displaying the proportion of tree and seating varieties. I also created a bar chart for each trash can type that summarized the percentage of trash cans that were covered, including recycling options, cardboard waste, and compost. I then used ArcGIS to create a land cover raster of buildings, sidewalks, roads and the csu border which was downloaded as a tiff and opened up in R. This data allowed me to reclassify pixels based on the cost of moving through each land type, culminating in a resistance map that shows the easiest paths between two points on campus. Using a particularly busy day schedule I had a couple semesters ago, I created a points layer and printed a map that shows which sidewalks I should take along with where it makes sense to cut across grass sections to save time. I also asked one of my friends to send me his schedule for next fall and I provided him with a map to display how he should travel between his classes.

Part 4: Final Touches and Future Usage

The final portion of my project was to add captions into the metadata of each layer and create a general base map that is user-friendly for others to use as well. This metadata explains what each column of the attribute table represents along with where the data came from if it was collected from an online source, allowing for users of the map to understand what the information means. Symbology for each layer was removed and organized to display the data all in one map frame. Within the zip file for the map, other folders with code and the original csv files were added to offer more resources for others to use or take inspiration from. A brief manual was also written which includes the captions for each layer along with basic information about the data available within the map.

While the map alone has plenty of data about CSU, it also can serve as a baseline for numerous other studies or projects. For example, future honors students could use this data to look at what may be impacting squirrel or rabbit distributions once data for these species have been collected. Another example, which I thought about doing but ended up not having time for, was collecting audio recordings of bats and comparing them to locations of lamps or buildings which give off light at night. The map also provides opportunities for further additions to make its data more conclusive. A professor wanting to get their students out in the field could assign sections of campus to different groups, have them collect a specific type of data such as tree information, and then have the students practice incorporating this info into the map. These are just a couple examples of how this project can become a resource for Colorado State University going forward.

Similar to how resources online for CSU trees or buildings were outdated, the project will slowly become less and less accurate as time goes on. Even while walking around campus over the past few weeks I've noticed new trees planted or portions of campus closed for construction. The changes I saw were incorporated into the map, however the campus will continue to evolve and require active documentations to keep any map fully accurate. Layers such as roads or buildings are more resistant to change, however smaller items like trash cans or signs are more likely to shift within shorter time periods. This means any future usage of the map should be cognitive of when the data was last updated and incorporate a level of possible error based on what layer is being used and how it might have changed since.

Part 5: Reflections and Looking Forward

The process of creating this map in ArcGIS allowed me to control each step of a larger project in a way I have never done before. Last summer I helped multiple graduate students with their own research projects and played a supportive role in collecting data or making important decisions. So as I transitioned beyond this supportive role and began leading this project on my own, although not as ambitious as graduate research, I found a lot of joy in problem solving through issues that came up and making plans to push forward. The most prominent example of this was constantly evolving the data collection process to make it as efficient yet still accurate as possible. Having to compare different methods for measuring trees or creating codes for campus objects were procedures absent from assignments in regular college classes with more limited scope and time. I believe this self-directive feeling will be the main aspect of this project I remember into the future, and it makes me excited for career opportunities for research that come up in the future.

Creating this map also incorporated a wide range of skill sets that I've used in college and will likely continue to use going forward. Coding in multiple languages, spending long periods in the field planning out data collection, using GIS software, and finding ways to best present results to others, are all important abilities that I hope to keep improving in the future. It was fun bringing together these skills and producing a piece of work I can truly call my own.

If I were to complete this project again, I would definitely spread the workload out more and try collecting more pieces of accurate data. When it comes to creating the map, points can always be even more precise or contain even more detail, meaning a line has to be drawn where the added benefit of more detail isn't worth the added effort. As an example, at first I wanted to collect width measurements of sidewalks as well to account for their varying sizes, but I quickly stopped recording this data after realizing the extra time it would take and the low chance anyone would ever find use in it. This dichotomy of there always being more info to gather but limited time to gather it can be an issue for people who are very perfectionist and want to keep things as precise as possible. While taking larger course loads in college and adding on other duties, I've had to train myself to give up on perfection a bit in order to have time for life outside school. However, there are still many aspects of campus that could be measured or incorporated with greater detail offering room to expand the map a lot more. Separating the campus into smaller bits and spending greater time and effort to record things with greater precision would be the main difference if I redid this project again.

When I finally got to use the data I collected this past month and began playing with the types of maps I could create, I was ultimately super happy with the amount of data I assembled in the limited time I had to do so. There are unlimited use cases for the information and possibilities for it helping a wide variety of other projects as well. As I walk around campus in these final few weeks before graduation, I’ve found myself constantly peering at trees, trash cans, or signs that I remember marking down before and wondering if things had been moved around or changed since. And if I come back to campus at some point later, it’ll also be interesting to see how much has changed knowing that I have a detailed map of what it was like when I lived here. Creating this map was a challenging but rewarding journey that will definitely be a core memory of my undergraduate experience.