Envisioning an Accessible University: Campus Sidewalk Slope Analysis Utilizing LiDAR Data

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Introduction

The University of California, Riverside (UCR) campus, founded in 1954, is located three miles east of downtown Riverside at the base of the Box Springs Mountains. UCR currently has approximately 22,00 students with just over 6,500 faculty and staff. The campus covers just over 1,200 acres and is divided by the 60/215 freeways. The west campus is the relatively flat portion of campus and is primarily used for agricultural research. The east campus presents a greater variety of landforms, and this is the location of the majority of the administrative, academic, and campus housing facilities. The objective of this project was to determine if a high-resolution DTM of the campus could produce an accurate slope analysis of the sidewalk centerlines for the academic core of campus. The centerlines were divided into two-foot intervals which is the industry standard length of measurement used for assessing ADA compliance. The analysis focused on two specific areas of campus accessibility, from ADA designated parking spaces to facilities and overall accessibility from one facility to another in the academic core of UCR.

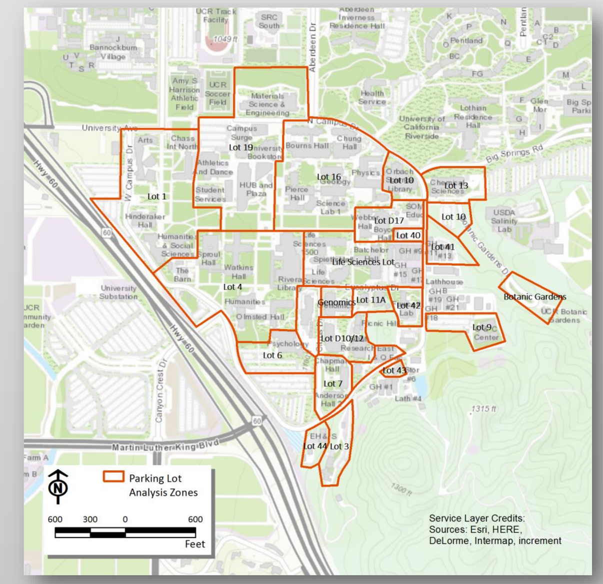

Figure 1. *UCR parking analysis zones*

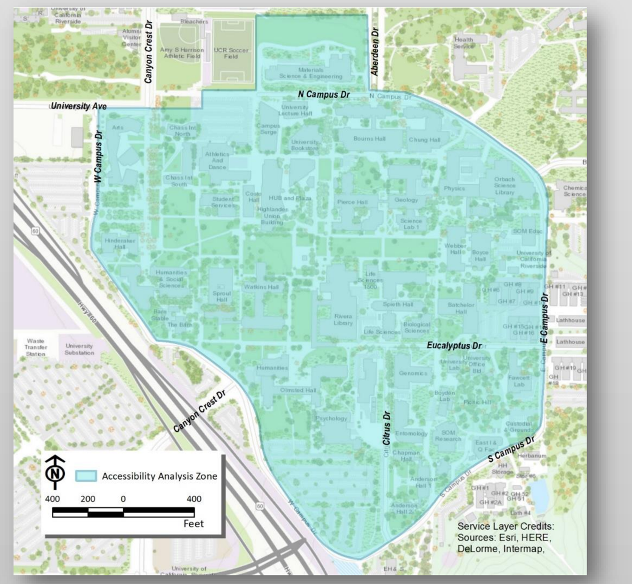

Figure 2. *UCR core analysis zone*

Data and Data Sources

The analysis conducted for this study used a combination of existing and newly created GIS feature classes along with DTMs of the campus. The base map data consists of 3-inch RGB aerial imagery along with 20 points per square meter LiDAR data and both were collected simultaneously in April of 2015 for UCR by Merrick and Company. The existing GIS data layers utilized included parking lots, buildings, and ADA designated parking spaces maintained by the UCR planning department. In addition to the existing GIS layers employed in the study, there were several new layers developed to complete the slope analysis for the campus.

Table 1. *List of data and data sources used in the project*

Dataset	Source
3-inch Aerial Imagery & LiDAR Data	UCR Planning Department
ADA Parking	UCR Planning Department
ADA Parking	UCR Planning Department
Parking Lots	UCR Planning Department
Buildings	UCR Planning Department
Parking Analysis Zones	Personally Created
Accessible Building Entrances	Personally Created
Sidewalk Curb Cuts	Personally Created

Methodology

First, high-density LiDAR data was utilized to create a digital terrain model (DTM) of the campus in LASTools software. Once the DTM was created for the project study area, a sidewalk centerlines feature class was developed by digitizing sidewalk paths on top of the campus aerial imagery in ArcMap. These path segments extended from ADA identified parking spaces to each accessible entrance of core academic facilities. To accomplish this goal, parking zones were identified from each parking lot that contain multiple ADA parking spaces and that provide service to multiple buildings. A curb cut feature class was also created to identify issues with connecting one side of the crosswalk to another and could also be used to track curb cuts that are non-compliant. The slope data derived from the DTM for the study area was added to the sidewalk centerlines and potentially non-compliant walking path segments were identified. These potentially problematic slopes were then checked in the field to determine their true slope and assess the accuracy of the methodology.

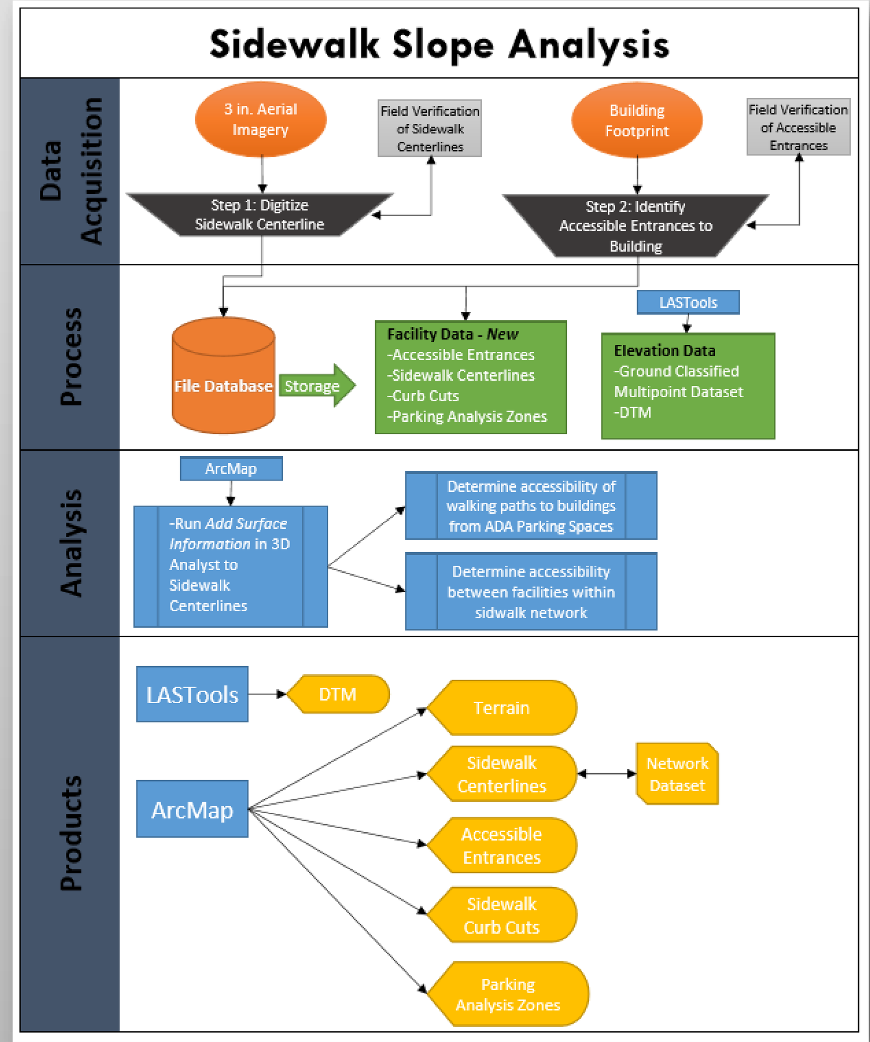

Figure 3. *Sidewalk slope analysis flowchart*

Timeline

The timeline I developed at the outset of this project proved to be overly optimistic and could not be successfully followed. A delay in obtaining LASTools and methodological issues extended the time spent on certain aspects of the project while other portions of the project were completed quickly and without issues.

Task	Activity	Start	Projected Completion	Actual Completion
1	Complete processing of LiDAR data to create both TIN and DEM of the study area.	5/13/17	6/1/17	7/15/17
2	Create analysis zones that will be used to analyze the sidewalk slopes from asscessible parking to facility entrances.	5/19/17	6/1/17	6/5/17
3	Digitize and compile sidewalk centerline data for study area and incorporating that data into the network dataset.	5/20/17	6/5/17	6/17/17
4	Test applying the sidewalk slope analysis to the sidewalk network dataset to ensure reliability of the slope analysis with the network system.	6/7/17	6/20/17	7/26/17
5	Conduct field work by ground-truthing portions of the sidewalks within the study area where the sidewalk centerline data is incomplete from the digitizing.	6/10/17	6/17/17	7/25/17
6	Final analysis and results.	6/10/17	7/1/17	8/4/17

Applied Project Timeline

Results

The analysis was ran on two and four-foot segments and also calculated based on each individual line segment. From this analysis several patterns were observed, for both the two and four-foot line segments, the slopes did not change in a gradual pattern of either sloping up or down in a single direction. The average slope percentage for both the two and four-foot intervals calculated would frequently change from being a compliant slope of five percent or below to a non-compliant slope of over five percent. Field verification revealed that most slopes identified as non-compliant by this analysis were not accurate compared to ground verified slopes as seen in Figures 5A and B below. While the goal of identifying accessible walkway slopes was not achieved, several useful new feature classes were generated from the efforts of this applied project and include accessible entrances, and curb cuts and within the study area.

A

B

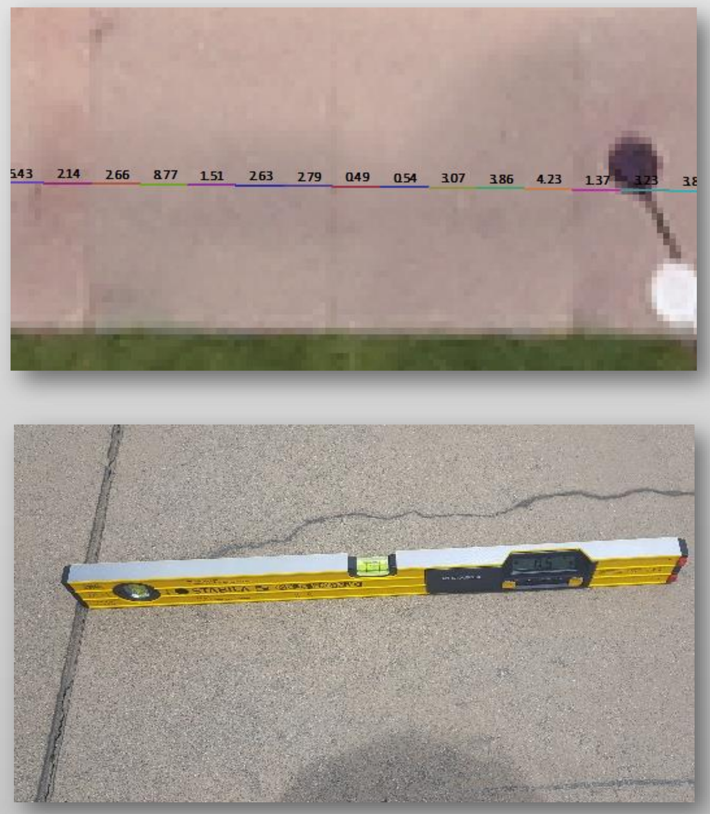

Figure 5A and B. *Comparison of slope calculated and field verified slope measured in same area*

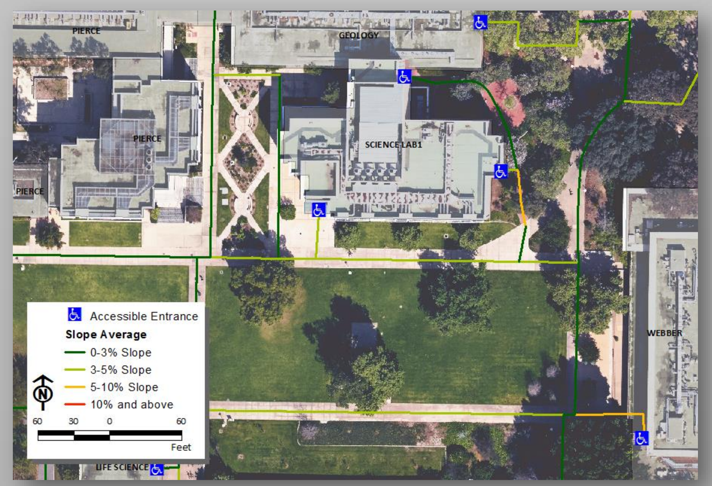

Figure 6. *A map illustrating the slope average on longer segments of the sidewalk centerlines and problematic areas identified in shades of orange and red*

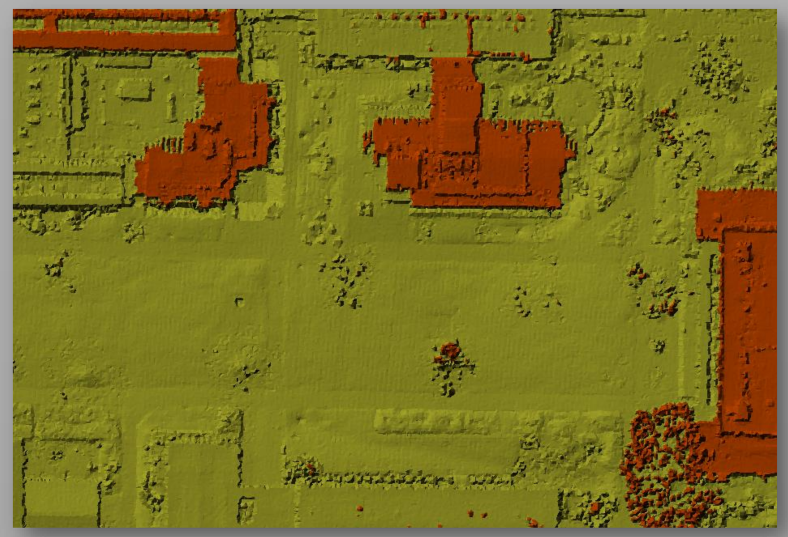

Figure 7. *Ground classified terrain using "last returns" LiDAR*

Discussion

The slope percent values for each two-foot segment actually vary up and down from being a relatively flat slope of 1.25 percent (a compliant slope) to over 5.43 percent (a non-compliant slope) and then back down to 2.14 percent all within a distance of just 16 feet. The wide variation was not just observed in walkways that are known to have high slopes, but also in areas that are relatively flat like pedestrian malls within the study area. With the discrepancies observed the analysis was expanded to calculating the slopes every four-feet. Unfortunately, expanding this analysis did not improve the results of the slope analysis. The same overall patterns were observed in the four-foot segment analysis but the results were even more inaccurate than the result of the two-foot segment analysis. With the refinement of the methodology a more trustworthy outcome could be produced and be used by departments to categorize problem slope and prioritize repairs saving the campus money.

A

B

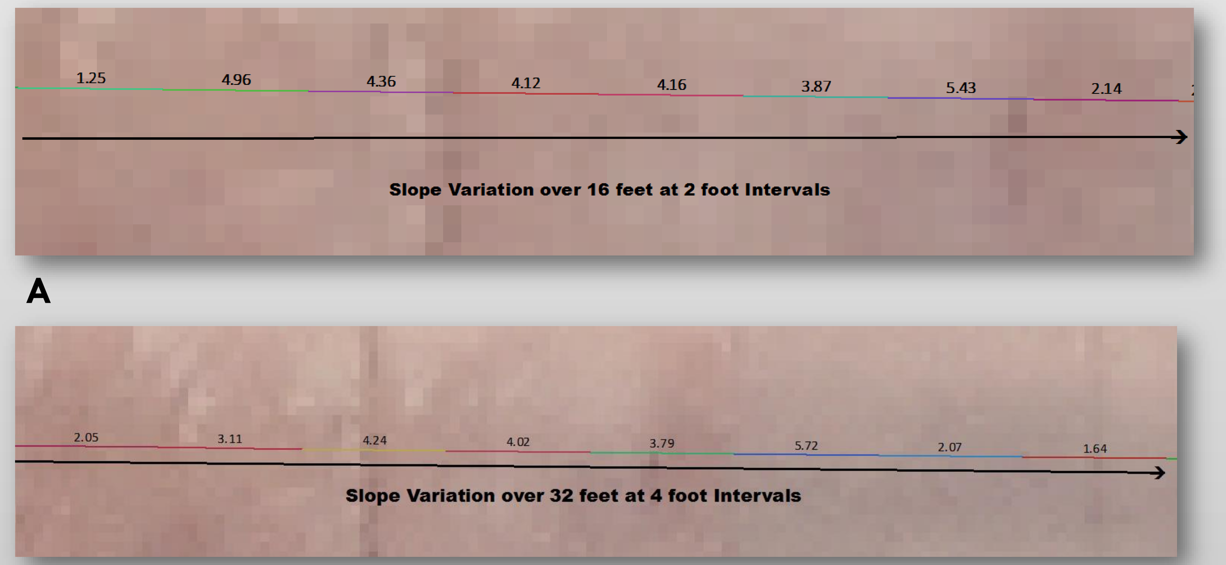

Figure 8A and B. *Comparison of slope variations measured at 2 and 4-foot segments by slope average*

Conclusion

This applied project showed the difficulties of trying to develop a methodology to measure ADA compliance using remotely sensed data for a slope analysis. Future work on the sidewalk slope analysis would include running the analysis on the centerlines at multiple intervals, beyond the two and four-foot intervals, to determine if there is a measured interval that provides the optimal results in relations to the field verified slopes. Non-compliant slopes appeared to be calculated when the sidewalk is adjacent to retaining walls or other tall structures causing interference in the slope calculation and returning wide variations in the minimum and maximum slope calculated. Field inspection of these slope anomalies could potentially reveal the cause of the large disparity between the minimum and maximum slope and thus make it possible to address this issue in the analysis to develop a more accurate slope calculation method.

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