Viewshed Analysis for UAS Flight Planning

Samuel Levin and May Yuan

The University of Texas at Dallas

UT DALLAS

GAIA Geospatial Analytics and Innovative Application Research Lab

ABSTRACT

This project was conducted in support of the UT Dallas Smart Campus Project, directed by the GAIA lab. As part of this ongoing project, drones will be used to survey the entirety of the UT Dallas campus. However, flying drones in a large, populous area such as the UT Dallas campus requires careful flight planning to ensure a safe and legal mission. For one, the Federal Aviation Authority (FAA) requires visual line-of-sight (VLOS) between the drone and collective ground crew to be maintained at all times during the flight. The drone must be easily visible without aid such as binoculars and cannot at any move into an obscured position where VLOS is not maintained by at least one ground observer (FAA 2016). Positioning of these ground observers can be recognized as part of the broader multi-observer sitting problem (Cervilla, Tabik, and Romero 2015).

Thus, an algorithm was developed to identify ideal observer locations that will maximize VLOS with the minimum number of observers. This was accomplished using Python scripting to select ideal observers from valid ground locations visible along the flight path until total coverage is achieved. The resulting algorithm determines the minimum number of stations required to maintain the line-of-sight and the locations of these stations. Additionally, the portion of the drone's flight path visible to each ground observer is mapped, delineating zones of observer airspace responsibility. These findings assure an effective distribution of ground crews to maintain UAS safety and FAA compliance. This algorithm may facilitate the planning and assessment of observation stations in future UAS surveys in similar urban areas. This assessment may be used as a supplement to FAA waiver and airspace authorization applications and reinforces the safety precautions that UAS operators should undertake when requesting such exemptions.

FAA VLOS COMPLIANCE

PROBLEM: The FAA requires visual line-of-sight (VLOS) between ground observers and the unmanned aircraft system (UAS) to be maintained during active flight. This must be achieved without visual aide such as binoculars. This condition can be difficult to achieve over large survey areas with significant visual obstructions.

OBJECTIVE: Identify the minimum number of ground observers and their locations that will fulfill VLOS mission requirements. Identify regions of airspace responsibility each observer is accountable for.

DATA SOURCES AND SOFTWARE

DATA SOURCES:

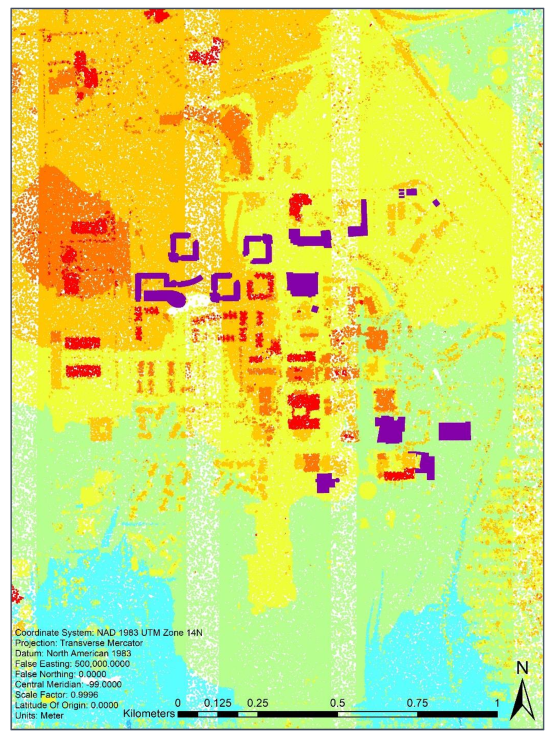
- Texas Natural Resources Information System, StratMap 2009 1m Dallas LiDAR
- City of Richardson Open Data, Streets Shapefile

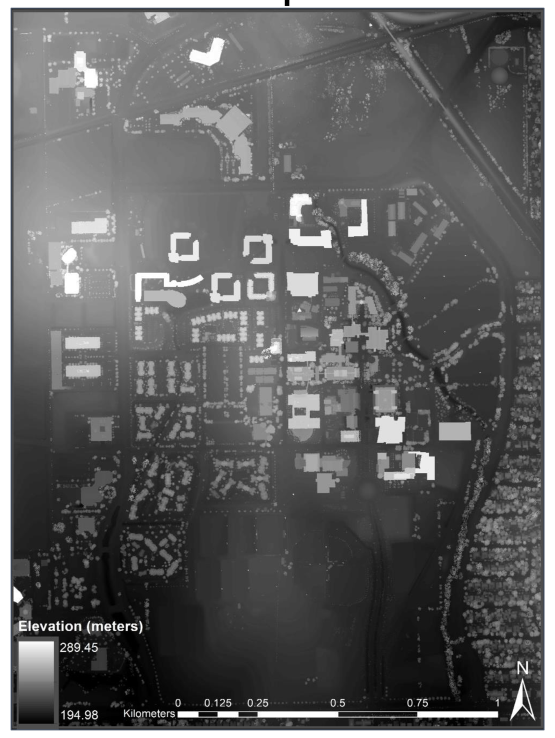
SOFTWARE:

- ESRI ArcGIS 10.6
- Python 2.7, Pandas 0.18.1

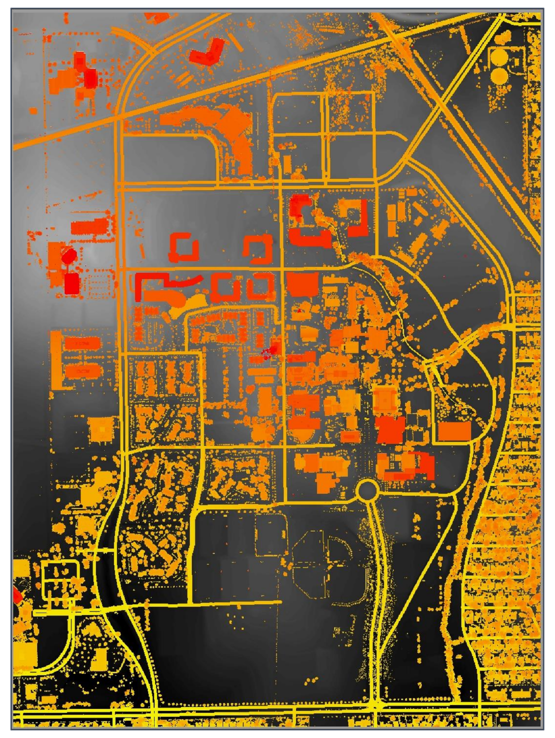
DATA PREPARATION

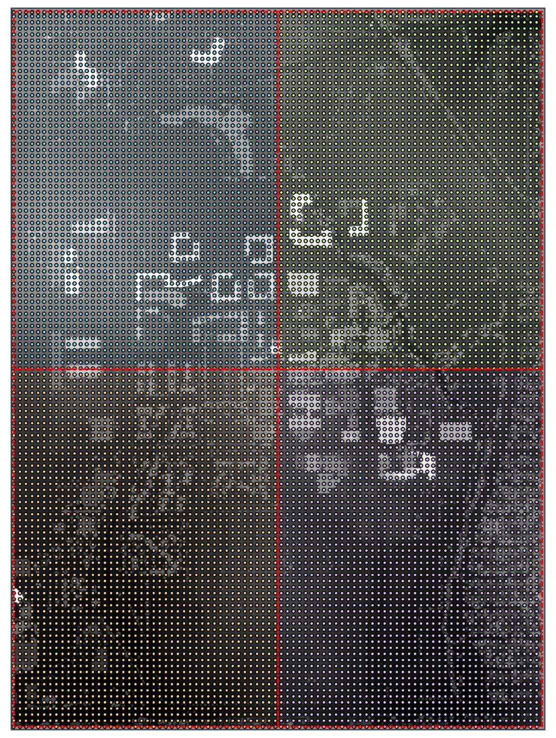
- **Construct Digital Surface Model (DSM) from existing LiDAR**
  - **add new construction since 2009 acquisition**

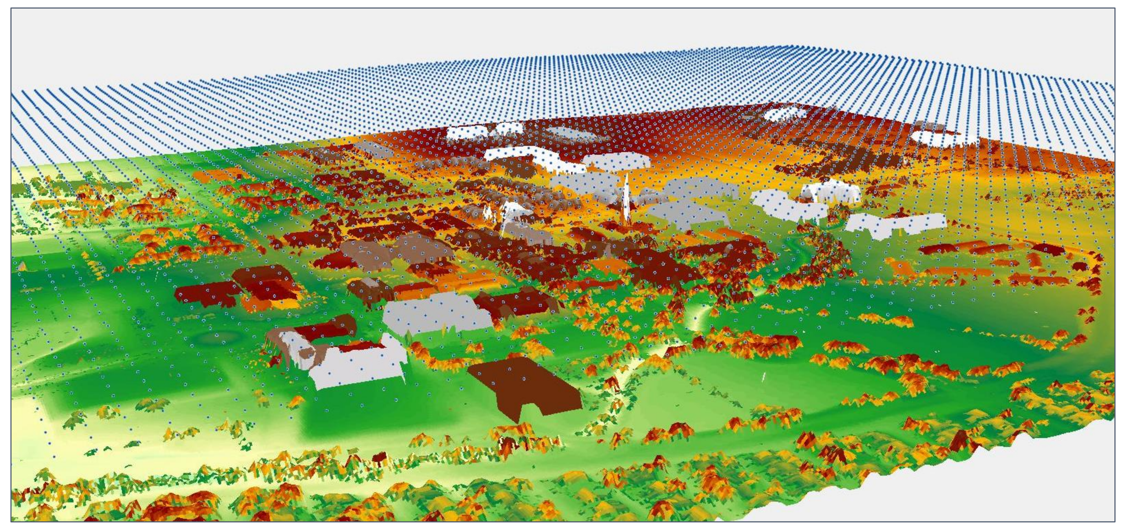




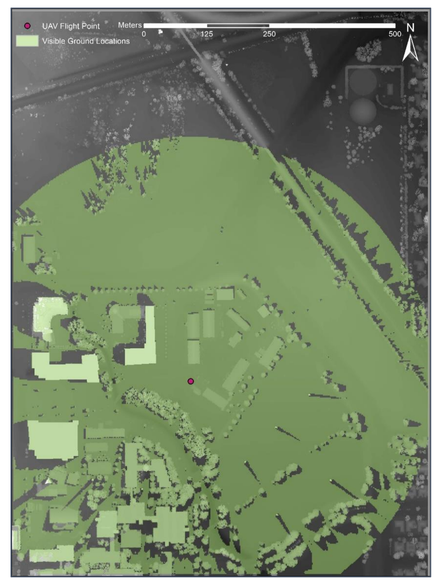
- **Build invalid surfaces mask (e.g. rooftops, roads, etc.)**
- **Generate 3D flight points that approximate the UAV's location during each flight**
  - **19x19 meter transect spacing, 121.9 meters (400 feet) above-ground-level (AGL) elevation**
- **Divide campus into survey quadrants**







- Viewshed Parameters:
  - Reverse viewshed run from individual 3D flight points to DSM
  - 500 meter 3D distance outer radius (conservative estimate of the maximum distance a drone is visible)
  - 1.63 meter surface offset (average eye level of adult human)

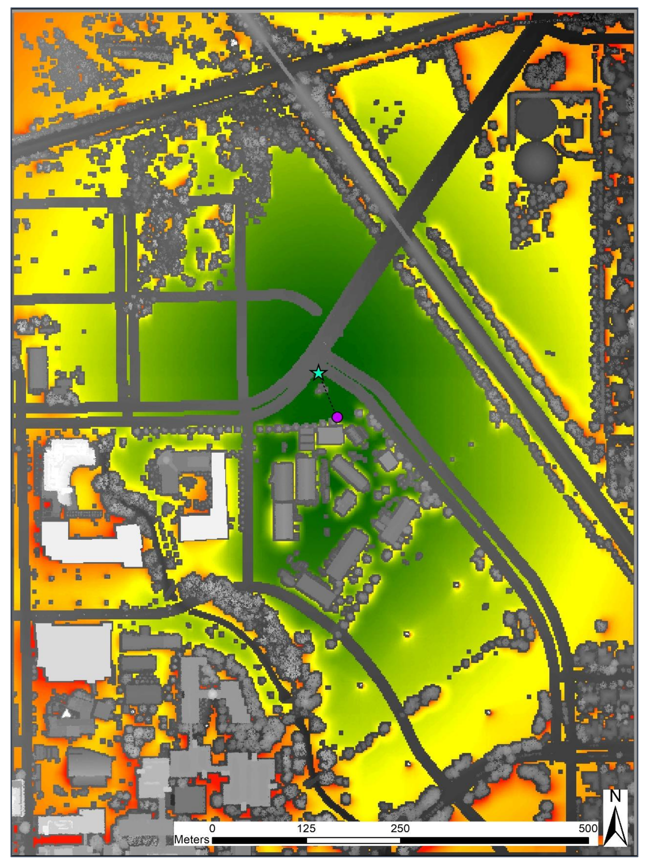


BEST OBSERVERS ALGORITHM

- From list of UAV flight points:
  - Calculate number of flight points visible at each ground location
  - Select ground location where :
    - Maximum number of flight points are visible AND is closest to mean center of visible ground locations
    - Save as best observer
  - Remove UAV flight points visible from this location
- Continue until all UAV flight points have been accounted for
- Implemented in a series of python™ scripts

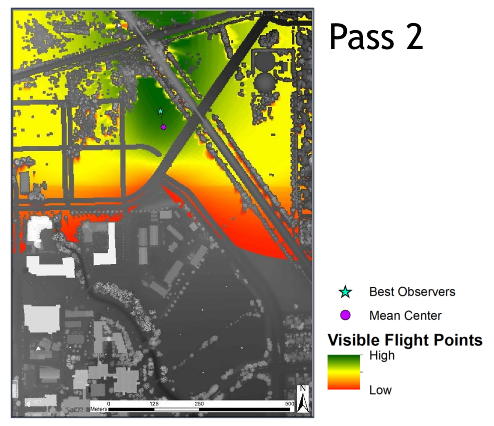
```python
import arcpy
import pandas as pd
import CumulativeVS
import BestObservers

surface = 'C:\\Users\\path\\to\\UAS_Viewshed.gdb\\Surface'
mask = 'C:\\Users\\path\\to\\UAS_Viewshed.gdb\\InvalidSurfaceMask'
flightpts = 'C:\\Users\\path\\to\\UAS_Viewshed.gdb\\FlightPts'
path = 'C:\\Users\\path\\to\\UAS_Viewshed.gdb\\'

n_pts = int(arcpy.GetCount_management(flightpts).getOutput(0))
all_fltpts = list(range(1,n_pts+1))
unseen_fltpts = all_fltpts
count = 0

best = pd.DataFrame()
obsvis = {}

while len(unseen_fltpts) > 0:
    passleft.append(len(unseen_fltpts))
    CumulativeVS.calcVS(unseen_fltpts,mask,count,path)
    best = BestObservers.findbestobs(count,path,best)
    best_x= best.iloc[count]['POINT_X']
    best_y= best.iloc[count]['POINT_Y']
    passviewed = BestObservers.findvisible(path,all_fltpts,best_x,best_y)
    totalvis.append(len(passviewed))
    cumlviewed.append(best['grid_code'].sum())
    obsvis[count] = passviewed
    unseen_fltpts = [us for us in unseen_fltpts if us not in passviewed]
    count += 1

savebest = 'C:\\Users\\path\\to\\OutTables\\bestobservers.csv'
best.to_csv(savebest)

spatialref = arcpy.Describe(arcpy.Raster(surface)).spatialReference
arcpy.MakeXYEventLayer_management(savebest,'POINT_X','POINT_Y',"BestObs_Lyr",spatialref)
arcpy.FeatureClassToFeatureClass_conversion("BestObs_Lyr",path,"BestObservers")
arcpy.AddField_management(flightpts,"Observers","TEXT")
arcpy.CalculateField_management(flightpts,"Observers", "\"\"", "PYTHON_9.3")

for c in range(0,count):
    with arcpy.da.UpdateCursor(flightpts,['OBJECTID','Observers']) as cursor:
        for row in cursor:
            if row[0] in obsvis[c]:
                row[1] = row[1] + str(c)
                cursor.updateRow(row)
```

SINGLE QUAD EXAMPLE



Pass 0

Pass 1

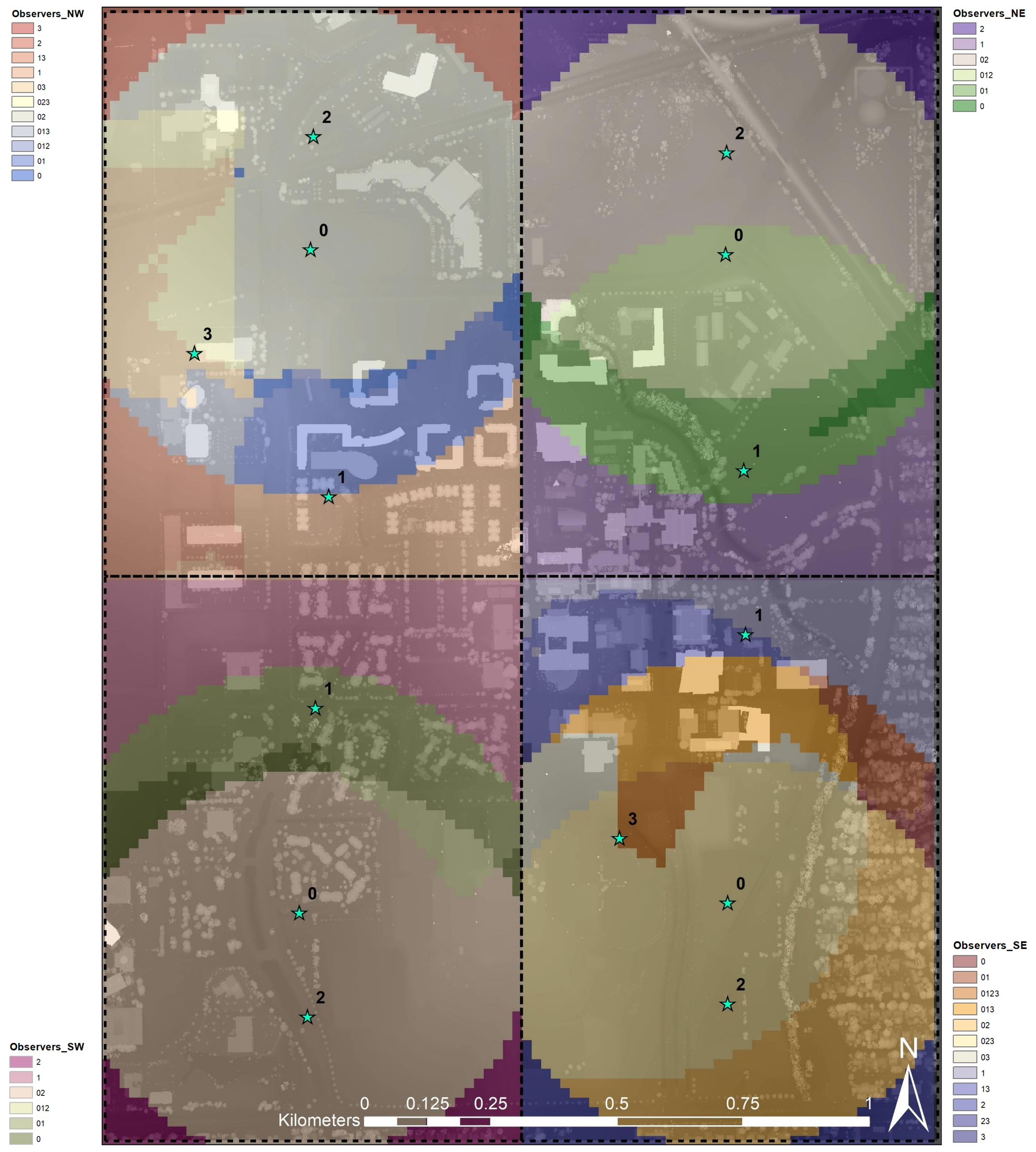


Pass 2

BEST OBSERVER	X COORDINATE	Y COORDINATE	PASS VISIBILITY	PASS COVERAGE	OBSERVER VISIBILITY	OBSERVER COVERAGE	CUMULATIVE COVERAGE
0	710528	3652824	1918	73.12238 %	1918	73.12238 %	73.12238 %
1	710564	3652396	510	72.34043 %	1402	53.45025 %	92.56576 %
2	710530	3653026	195	100 %	1654	63.05757 %	100 %

- Output table summarizing the contribution of each observer to comprehensive VLOS coverage

FULL CAMPUS RESULTS



- With best observers for each quadrant identified, flight points are attributed with their unique combination of ground observers.
- Areas of airspace responsibility can then be defined. This identifies the combination of ground observers accountable for maintaining VLOS at any given position in the UAV's flight.
- By overlaying this result on live flight plans, the remote-pilot-in-command can communicate transitioning VLOS responsibility to the team of ground observers.

DISCUSSION

Similar LiDAR datasets exist in many urban areas, where VLOS compliance presents a particular challenge. The algorithm developed in this study could be applied to UAS missions where these data are available, or where a suitable DSM exists. This tool will be made freely-available at https://gaia.utdallas.edu/research. Its results can provide a significant supplement to FAA Part 107 waivers, where the added safety precautions of the mission must be thoroughly planned and justified.

CONTACT

- Samuel Levin, M.S. Student, Geospatial Information Sciences, The University of Texas at Dallas, samuel.levin@utdallas.edu
- May Yuan, Ashbel Smith Professor, Geospatial Information Sciences, The University of Texas at Dallas, myuan@utdallas.edu

REFERENCES

- Cervilla, A.R., S. Tabik, and L.F. Romero. 2015. "Siting Multiple Observers for Maximum Coverage: An Accurate Approach." *Procedia Computer Science* 51 (1). Elsevier Masson SAS: 356–65. https://doi.org/10.1016/j.procs.2015.05.255.
- City of Richardson. 2018. *Streets*. City of Richardson Open Data. https://opendata-richardson.opendata.arcgis.com/datasets/streets.
- ESRI. 2012. "Using Viewshed and Observer Points for Visibility Analysis." ArcGIS Resources. 2012. http://resources.arcgis.com/en/help/main/10.1/index.html#//009z000000v8000000.
- FAA. 2016. "Advisory Circular: Small Unmanned Aircraft Systems (sUAS)." *AC No. 107-2*. U.S. Department of Transportation. https://doi.org/AFS-800 AC 91-97.
- Feng, Wang, Wang Gang, Pan Deji, Liu Yuan, Yang Liuzhong, and Wang Hongbo. 2015. "A Parallel Algorithm for Viewshed Analysis in Three-Dimensional Digital Earth." *Computers & Geosciences* 75 (February). Elsevier: 57–65. https://doi.org/10.1016/j.cageo.2014.10.012.
- Kang-Tsung, Chang. 2010. *Introduction to Geographic Information Systems*. 5th ed. New York, NY: McGraw-Hill.
- Kim, Young-Hoon, Sanjay Rana, and Steve Wise. 2004. "Exploring Multiple Viewshed Analysis Using Terrain Features and Optimisation Techniques." *Computers & Geosciences* 30 (9–10): 1019–32. https://doi.org/10.1016/j.cageo.2004.07.008.
- TNRIS. 2009. *StratMap 2009 1m Dallas Lidar*, Texas Natural Resources Information System (TNRIS). https://tnris.org/data-catalog/entry/stratmap-2009-1m-dallas/.