School of Earth and Environment
Te Kura Aronukurangi

UC UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

GEOG-DIGI205-GISC422
Introduction to Geographic Information Systems
Foundations of Geographic Information Systems

Lab 10: 3D Analyst: Viewshed Analysis and Visualisation

Objectives

In this lab you will use the ArcGIS Spatial Analyst and 3D Analyst/ArcScene extensions for viewshed analysis, visualisation, and the creation of a short, animated flyover.

Lab scenario

You are going to investigate the visual impact of a proposed (fictitious) subdivision at Clifton on the Port Hills of Christchurch, where existing residents are concerned that they will lose their views of the estuary and ocean. Your task is to analyse their 'viewshed' before and after the subdivision and create a 3D view of it to communicate your findings to all concerned. While required graphics are specified below, how you are presenting layer visibility and symbology is up to you. Working in 3D consumes a lot of computing resources and can make the software unstable, so save your work early and often.

Assessment

Lab online quizzes are due by 09:00 on the Monday following the lab. Answer the numbered questions highlighted in red in the lab handout via the LEARN> GEOG-DIGI-205-GISC422> (Weekly) Modules. *Tip: Multi-choice and matching-answer questions have clues in their answers!*

Lab reports for labs 8-10 are submitted as one hand-in in PDF format to preserve formatting, with your username in the file name. Always check how your PDF looks before submitting – it needs to be clear and legible. Due dates are in the course handout.

The required hand-in is a single document with a cover page with the course code, your name, student ID, lab stream (day), and date, followed by two pages per lab starting with its title. GEOG205 lab reports are limited to two pages per lab, and they are comprised of 2 parts: the first part is summarizing each lab without the fine detail (max 300 words); and the second part includes required graphics with short descriptive captions (excluded from word count) and referred to in the summary. The first part (summary) should incorporate a brief introduction, your method and results, and any concluding observation, so that the reader understands and can potentially repeat the exercise in conjunction with the lab handout. Please be succinct without repeating the lab instructions, and do NOT include the quiz questions and answers.

Due dates and assessment values are in the course outline, while information on lab report hand-ins are in LEARN> GEOG-DIGI-205-GISC422> (Weekly) Modules. You'll submit this lab as a batch under "GIS Analysis II: Labs 8-10" at the end of week 12.

Required graphics

- Task 1: One 2D graphic of the output from the Viewshed tool.
- Task 2: Two 3D graphics of the views of the proposed subdivision.
- Task 2: Submit a 10 second animation to the LEARN Assignment Dropbox in AVI format.

Note: Capture graphics using the Snipping or Snip&Sketch tool, after making them as large as possible on screen to ensure good quality resolution for your hand-in. Copy and paste directly into a Word document and add text to identify which is which - you can resize and arrange later.

Getting Started

Get the data to your OneDrive - Geog205 folder by copying the folder for this lab from the Geog205 class folder or download it from LEARN> GEOG-DIGI-205-GISC422 > Lab Materials> Lab Data Downloads in compressed ZIP format. The downloads are in *.ZIP format and must be uncompressed for ArcGIS to 'see' it – full instructions are given on the download page.

Please work locally in your PC (better processing speed) but don't forget to back up your lab report work or do your report in OneDrive.

Start by opening the ArcGIS map document ViewshedAnalysis.aprx in your current lab folder through the Catalog pane. The lab data has been drawn from a variety of sources and clipped to the Port Hills study area. Some is already in the map document, while some is still in labdata.gdb. It includes:

Dataset	Description
Buildings	building footprints
Bldg_pnts	building centroids
Port_coast	coastline
Port_roads	road centerlines
Port_dem	Raster: 25m Digital Elevation Model (DEM)
m36-1601.tif	Image: high resolution (0.5m) greyscale image of Sumner
n36-0101.tif	Image: high resolution (0.5m) greyscale image of Sumner
Subdiv	subdivision boundary

Set up

- Click Catalog> Databases > to check that the Default Geodatabase points to your labdata.gdb geodatabase. You can do this by selecting the database through 'Folders' in Catalog, right clicking the labdata.gdb and selecting 'add to project' then from the databases folder, right click and select make default. and that Pathnames to data sources are relative.
- Click Project > Licensing to ensure the licenses for both 3D Analyst and Spatial Analyst are Licensed.

Create a hillshade

Now create a hillshade to provide a visual impression of the terrain. Open the Geoprocessing window and type in hillshade and press enter to find the Hillshade (Spatial Analyst) tool. Use the view help window in the top right corner to search for 'hillshade' to receive comprehensive help for the tool, otherwise hover the mouse over each input and click the blue to get context for what input requires. For Input raster select port_dem (the Output raster should automatically go to your lab labdata.gdb), then take note of the defaults for azimuth and altitude. Click Environments tab… to set both the Processing Extent> and the Raster Analysis>> Cell Size to be the 'Same as layer port_dem'. Then click Run.

Q1. When creating the hillshade, what are the default values for azimuth and altitude?

Once created the hillshade should automatically be added to your map document. Click it in the Contents Pane to open the 'Raster Layer' tab in the main toolbar then change transparency to 50% so that you can see underlying port_dem layer for added effect. 

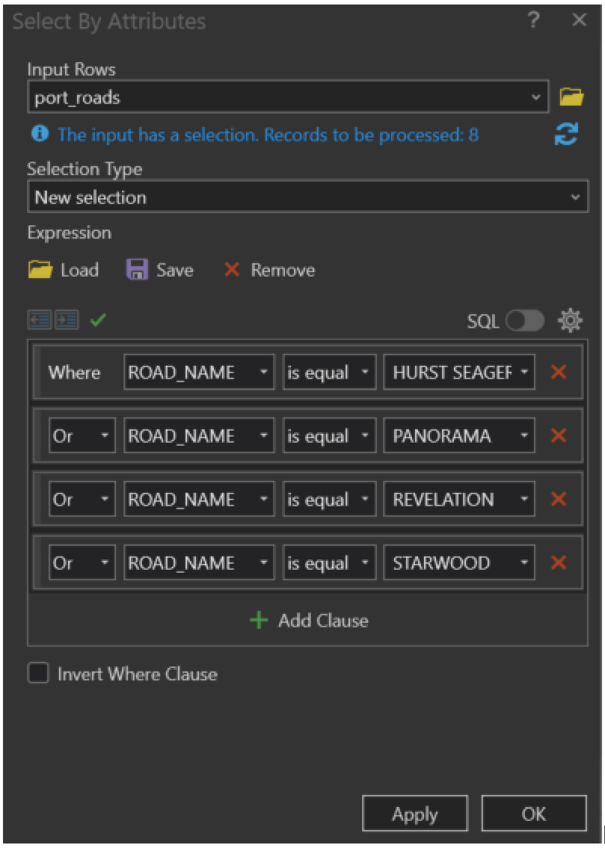
Task 1: Viewshed Analysis

The concern about the visual impact of the proposed subdivision came from residents in Hurst Seager, Panorama, Revelation and Starwood roads. You are going to use the ArcGIS Viewshed tool to create two visibility surfaces (i.e. one before and one after the development of the subdivision), to model the visual impact of its 'building envelope' (i.e. the maximum horizontal and vertical extent) on the roads in question.

Use the ArcGIS Pro Help to read about the Viewshed tool (3D or Spatial Analyst are the same) and learn how it works. You'll see that it requires two inputs: a surface raster (DEM); and observer features (i.e. either point or polyline features). For the latter you'll use the roads named by the concerned residents.

Viewshed Before

1. Use the Explore tool on the roads layer to see if it contains an attribute for road names.
2. Having established that it does contain road names, build a query to select the affected roads by name: **Hurst Seager, Panorama, Revelation,** and **Starwood**, as follows:

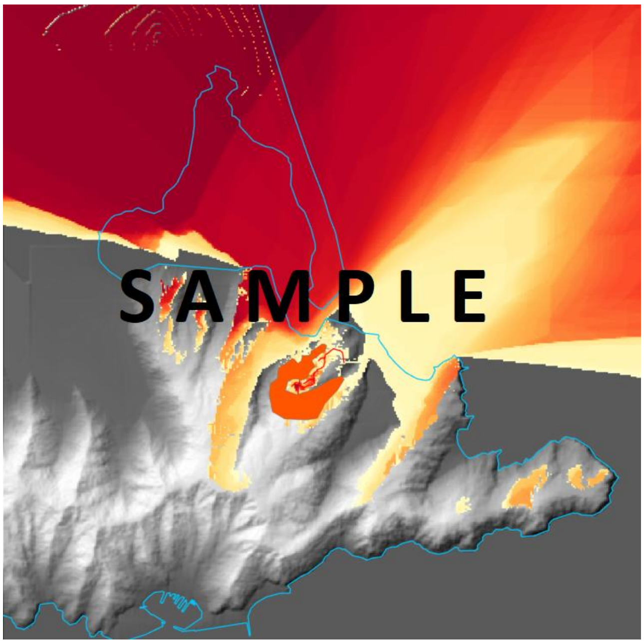
a. 

From the main toolbar, open Map > Select by Attributes, ensure Layer: is port_roads. To begin building the expression, make sure that 'ROAD_NAME' is selected for 'Where' then select 'is equal to' and start typing a target road name into the box, and when the name appears click it or press enter to enter it into the query.

b. Add to the query by clicking the 'Or' button and repeating step a. for the remaining road names.

c. Click Apply, and if successful you should have 8 features selected and highlighted in blue in the data frame. A way to check is to click attributes from the selection toolbar or looking in the lower right corner of the map frame. Click OK.

3. Export this subset of roads as a new layer for use in the next step: Right-click port_roads in the Contents Pane and click Data> Export Features..., the Name: to be residents_roads, and then check if it is in your lab labdata.gdb geodatabase. Click OK and you should see the layer present in the map.



4. Use the Geoprocessing pane to find and launch the Viewshed tool (3D or Spatial Analyst are the same). For Input raster (DEM) select port_dem; for 'Input point or polyline observer features' select your new residents_roads; change the name of the Output raster to Viewshed_before and ensure that it's going in to your lab labdata.gdb geodatabase, and while the cursor is in that field use the Show Help>> to learn how the output raster cell values are calculated and what they mean (you'll need this to answer the next question); then click Run.

5. The viewshed output should be added to the Contents Pane and symbolised as either Not Visible or Visible (it should look similar to the graphic above).

Once you have the viewshed, open its Properties... Source tab and scroll down to view its Statistics to answer the following question. Capture a graphic with the Snipping tool for your hand-in.

Q2. What is the minimum and maximum cell (pixel) value, and what do they mean?

Viewshed After

The next step is to re-run the viewshed analysis to visualise change after the subdivision is built. To do so you are going to add the height of the subdivision 'building envelope' to cells in the original DEM surface that fall inside the subdivision, leaving those outside as is, to create a new DEM for input to the viewshed analysis.

The subdivision boundary is in a vector layer called subdiv – a single polygon feature with an attribute called Bld_height, value = 10 (i.e. 10 meters above the original ground surface). To add this to the original raster DEM surface you first need to convert it from vector to raster, as follows:

1. Search for and open the Feature to Raster (Conversion) tool. For input use subdiv, for Field use Bld_height, and set the output to your labdata.gdb as subdiv_raster. The Environment settings you made at the beginning will set the extent and resolution to match port_dem, but make sure the environment is set for each layer and then run the tool.

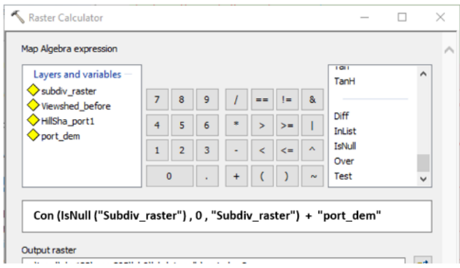
2. When subdiv_raster is added to your data frame use the Identify tool (just click it) to check its cell values. Note that values inside the subdivision boundary will be 10, while those outside will be ‘NoData’. NoData overrides all other cell values in raster analysis such as adding two raster’s together. To keep the original DEM values outside the subdivision boundary NoData needs to be converted to zeros so that the original value + 0 = the original value. ArcGIS has a couple of ways of doing this, and we’re going to take the opportunity to introduce Map Algebra in the Raster Calculator as an efficient alternative to using a series of graphical tools and dialog boxes.
3. Open geoprocessing to find and launch the Raster Calculator (Spatial Analyst). Click on the help button to see an illustration of the Raster Calculator components, and read down as far as the example of the general format of a Map Algebra expression, which just happens to use the conditional Con tool with IsNull to change NoData to 0 on the fly! Search the ArcGIS Help for Con (Spatial Analyst) and Is Null (Spatial Analyst) to see their usage and syntax.
4. In essence, Con performs a conditional if/else evaluation on each of the input cells of a raster, and if true it outputs one value, else if false it outputs a different value. Additionally, IsNull can be used to change NoData values to zero, and the result added to the DEM. Create the following expression by clicking on the Raster Calculator buttons and layers, and be careful to ensure you have the required number of commas in the right places, as in this example:

    a. In Raster Calculator, double-click Con, then scroll down to find and double-click IsNull, then double-click the layer Subdiv_raster to get the following:

       Con (IsNull("Subdiv_raster"),)

    b. Then place the cursor immediately after the first comma and enter 0 followed by a comma, then double-click the layer Subdiv_raster to get:

       Con(IsNull("Subdiv_raster"),0,"Subdiv_raster")



    c. Finally, place the cursor after the last bracket and click the + followed by double-clicking the port_dem layer. Your Map Algebra expression should look like this:

       Con (IsNull ("Subdiv_raster") , 0 , "Subdiv_raster") + "port_dem"

       This expression says: if a cell in the subdivision raster is NoData then replace it with 0, else use the cell value in the subdivision raster, and then add the result to the DEM.

    d. Name the output raster port_dem2 and click Run.

5. Once port_dem2 is added to the map document you should see that it has values ranging from 0 to 480, just like the original - only values inside the subdivision boundary will have changed.

Now you are ready to re-run the Viewshed tool, this time using port_dem2 as the input raster surface. Output it to your lab folder as Viewshed_after, and once added to the map turn its visibility off (deselect the layer in the Contents Pane) and on to look for differences with Viewshed_before –

you may have to turn off the visibility of other raster layers in between. The difference is subtle, and you may have to zoom in to see it. You can also check the Statistics as before to confirm that they are in fact a different (the min max may be the same, but the mean should be different).

Viewshed Lost

The Viewshed raster cell values are a count (ranging from 0 to ~98) of the number of observation points (i.e. vertices along the road polylines) that can see each cell in the input DEM. To address the residents concern about losing views of the estuary and ocean you want to highlight the absolute change in visibility. To this end you need to reclassify the viewshed cell values as either Not Visible = 0 or Visible = 1, and then subtract the resulting before raster from the after raster to identify just what has changed. The logic of this process is shown in Table 1 and illustrated in Table 2, the result having just three values: -1 = Lost, 0 = No change, and 1 = Gained.

Viewshed _after (reclassed values)	minus	Viewshed _before (reclassed values)	equals	Viewshed_change (output values)
0 (not visible)	-	0 (not visible)	=	0 (no change)
0 (not visible)	-	1 (visible)	=	-1 (lost)
1 (visible)	-	0 (not visible)	=	1 (gained)
1 (visible)	-	1 (visible)	=	0 (no change)

Table 1: Absolute visibility loss.

Viewshed After					Viewshed Before					Reclassed (After)				-	Reclassed (Before)				=	View changed			
0	0	2	3		0	3	6	2		0	0	1	1		0	1	1	1		0	-1	0	0
0	0	5	4		0	5	5	6		0	0	1	1	-	0	1	1	1	=	0	-1	0	0
0	0	3	1		0	4	8	4		0	0	1	1		0	1	1	1		0	-1	0	0
1	0	6	2		0	3	5	3		1	0	1	1		0	1	1	1		1	-1	0	0

Table 2: Illustration of the required steps

Once again, you are going to use the Raster Calculator with the con tool to create a Map Algebra expression to get the desired result in a single step. In this case there are no NoData values to deal with, just 0 to ~98. The ArcGIS Help for Con (Spatial Analyst) > Usage states that "if the evaluation of the expression is nonzero it is treated as True", so you can use this to output viewshed values > zero as 1, otherwise output values as 0.

1. Use the Raster Calculator to create and execute the following expression (spaces have been added for clarity), and name the output viewshed_change:

Con("Viewshed_after" , 1 , 0) - Con("Viewshed_before" , 1 , 0)

Inspect the result – it should have values of -1, 0, and 1, as per Table 1 (i.e. -1 = Lost, 0 = No change, and 1 = Gained).

Q3. Why might you have some gain in visibility?

2. Symbolise the output to highlight only those cells that have been lost.

Save your map document, keeping it open for use in the next task.

Task 2: 3D Visualisation

This task converts a map to a scene, a 3D map that allows you to navigate and interact with your 3D data.

View > Convert > To Global Scene

1. Find and select the Navigate tool from the view toolbar and drag on the scene to rotate and tilt it, scroll the mouse wheel to zoom in and out, and press the mouse wheel and drag to pan.
2. Reset the scene to Full Extent.

2D to 3D

Each layer needs to be draped over a 3D surface. In the **Contents** pane, under **Elevation Surfaces**, click **Ground**. Then Add elevation source layer and add 'port_dem'.

1. Select Hillshade in the Contents Pane, then the
    a. Display tab to set 'Resampling type' to one of the continuous data options for a smoother looking surface, ensure transparency is set to 0.
    b. Ensure more important layers render on top of the hillshade which is only included to provide spatial context. You can change the Rendering quality from High (quality) to Low (speed) from Project > Options > Display which can greatly improve redraw speed. Click OK and zoom/pan to admire your hill shade in 3D.
2. Select viewshed _change in the Content Pane, then the

    a. Display tab to set 'Resampling type' to one of the continuous interpolation methods for a smoother result with a fuzzy boundary.
    b. Symbology tab and highlight the absolute change or view lost by selecting a distinctive colour for cells with the value -1, then select and remove the other two classes.

Fine tuning

Polygon vector layers with a solid fill such as subdiv may not drape well over raster layers such as the hillshade. If so click the subdiv symbol in the Contents Pane to change its Fill Colour to No Colour and give it a standout outline width and colour.

Add Built Objects to the scene

Next, add some virtual buildings to the scene. If you have building footprints (polygons) in vector format, (e.g. CAD or shapefile), then you can 'extrude' them on top of the surface.

1. Add buildings to the 3D scene from your labdata.gdb. These are notional building foot prints and do not represent real buildings.
2. Select buildings … then select the Feature Layer tab. Under the Extrusion group > Type, select Max Height, and use the expression builder button to the right of 'Extrusion field' to select Height (this is an attribute of the building layer which has two values: 5m or 10m) then OK.
3. To answer the following question, experiment with the options for 'Type' and choose one that keeps your buildings below the subdivision 'building envelope'.

Q4. Given the maximum height of the building envelope, what option should you **NOT** use and why?

3D building symbols as an alternative to building footprints.

1. Turn off the buildings layer and add bldg_pnts to the 3D Scene. This is a point layer representing the centroids of the building footprints.
2. Select bldg_pnts then click the
    a. Feature Layer tab > Symbology > Format Point Symbol…, search 3D – OK, select the house of your dreams.

b. Symbol> Size to make them larger, but be realistic and acknowledge that 'buildings are not to scale'.
c. Vary symbology by attribute > Rotation > Rotation style… to rotate at random; or using an expression with a constant value (e.g. 90 so they all face north); or drawing on a numeric attribute field if present such as ROTATION which has a range of values between 10 and 100.

Finalise your scene by rotating it to the best angle to convey your findings, remembering that the concern is the potential loss of estuary and ocean views by existing residents.

You might also like to try draping some airphoto images (m36-1601.tif and n36-0101.tif in the lab folder). These don't cover the full area, and you may have to experiment with their drawing priority to get a good result, so only try if you have time.

Capture two graphics with the Snipping tool for your hand-in: one view looking north; one looking south.

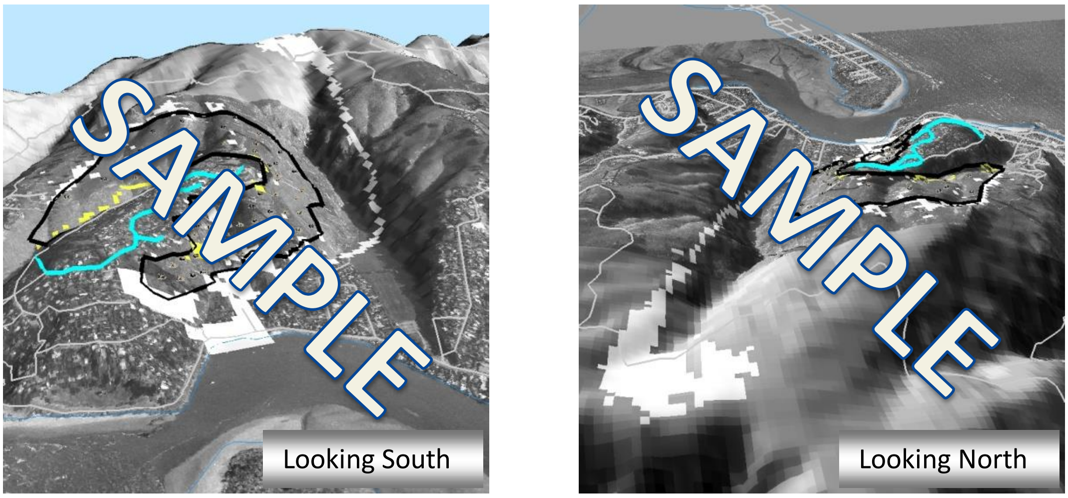


Figure 1: Two views of the proposed subdivision (black outline), with white areas showing absolute view shed loss to existing residents (blue lines).

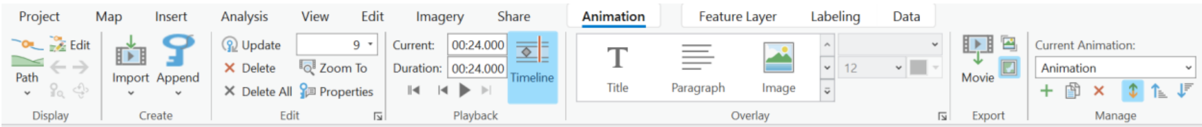
What can you now say about the visual impact of the proposed subdivision on the estuary and ocean views of existing residents? How realistic is your representation?

Animation

As a final task you are going to create an animated fly over of your scene, and export it in AVI format for playback in a standard media player. Animations are useful in presenting a realistic views from multiple perspectives. Note that they can also be time consuming to create and generate very large files, at the rate of ~10MB per second. The file submission limit in LEARN is ~250MB including your final report, so you need to limit your animation accordingly.

To create a smooth and controlled animation in ArcGIS Pro Scene it is best to create a series of keyframes along the track you want to take before animating it.

1. Start by ensuring that the Scene window is not maximised to full screen, otherwise things can get very slow.

2. 

   On the **View** tab, in the **Animation** group, click **Add** . The Animation tab appears as well as the Animation Timeline pane to display keyframes as you create them..
3. To ensure you are starting with a clean slate, under the Manage group > Current Animation, click Delete Animation.

4. Navigate to a suitable start position and perspective in your scene, then click Append to capture the first keyframe. Move to a new position to capture the next keyframe, and repeat until you're ready to play.
5. Click the Animation Controls play button to view the result. You can edit the fly path using Animation> Edit , or using to update the camera angle of a selected key frame, or remove key frames and replay, or start afresh with Delete All.

Once you are happy with the result, save it as a standard media player select Animation> Movie… Save as type: AVI (.avi), using the defaults for video compression. When finished, check the file size of your output in Windows File Explorer, and double-click to play it. If you want to know more, search the Help.

Q5. Search the Help to find: What is an animation, and why you would use it?

Save your document, and upload your animation to the Learn Assignment Dropbox in AVI format.

Finally

In your Learn quiz, be sure to select Finish attempt… and **'Submit all and finish'** so it is submitted for assessment.