Geo372
Vertiefung GIScience

Viewshed analysis

Herbstsemester

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Last week

- We looked at performing analysis on **terrain models**
- I emphasised the importance of **surface continuity**
- We defined a range of properties which can be extracted from terrain models: e.g. **slope**, **curvature**, **hydrological properties**
- We explored in some detail **alternative algorithms for slope**, and approaches to **curvature and hydrology**
- Finally, we looked at some examples of using **terrain properties in analysis**

Outline

- What is a **viewshed** – what can we use them for?
- Basic concepts of **viewshed algorithms**
- How viewshed algorithms **work in detail** – does it matter?
- **Alternative viewshed** representations
- **Applying** viewsheds in spatial analysis

Learning objectives

You will:

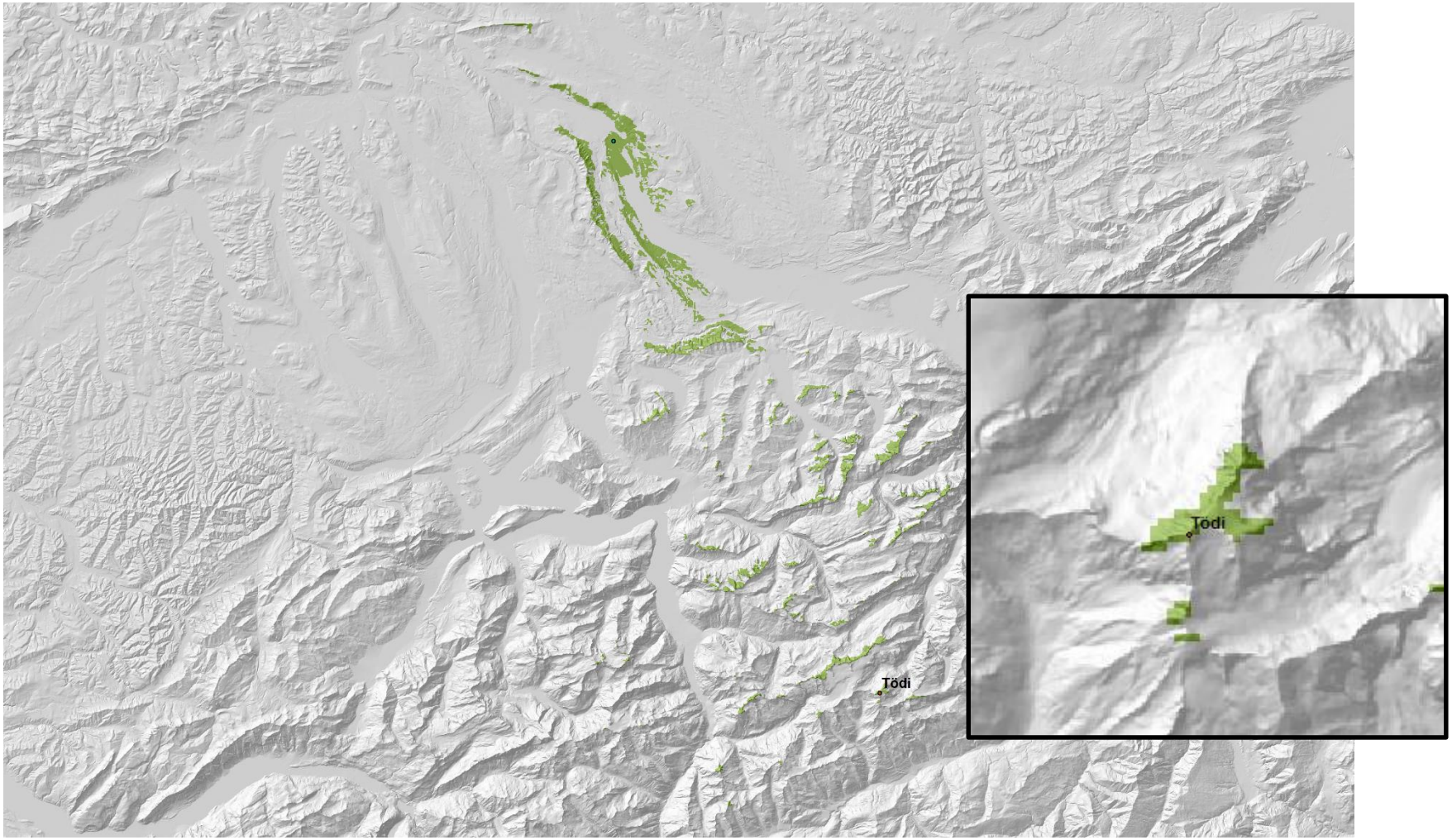
- **know** what a **viewshed** is, and can **explain** how it can be **calculated**;
- be able to **give examples** where the use of a **binary viewshed** is a poor choice, and can **explain** how we can improve our **representation of viewsheds**; and
- be able to **describe** and **discuss hypotheses** that can be **tested** by the use of **viewsheds**.

What is a viewshed?

- A viewshed is the calculation of **all the places** in a landscape visible from **a single location**
- Generally, viewsheds are represented with a point being **either visible or not** from a **particular location** (binary)
- Can you (always) see Tödi from Zurich?
- Is Tödi in the viewshed from Bürkliplatz or not?

From: www.travelbrochuregraphics.com/ .../Swiss_5/SwissAir4.htm

Viewshed from Bürkliplatz



According to ArcMap viewshed function, using 100m DEM
and including effects of Earth's curvature

What can we use viewsheds for?

From: www.gov.mb.ca/gs/_memo/fire.html

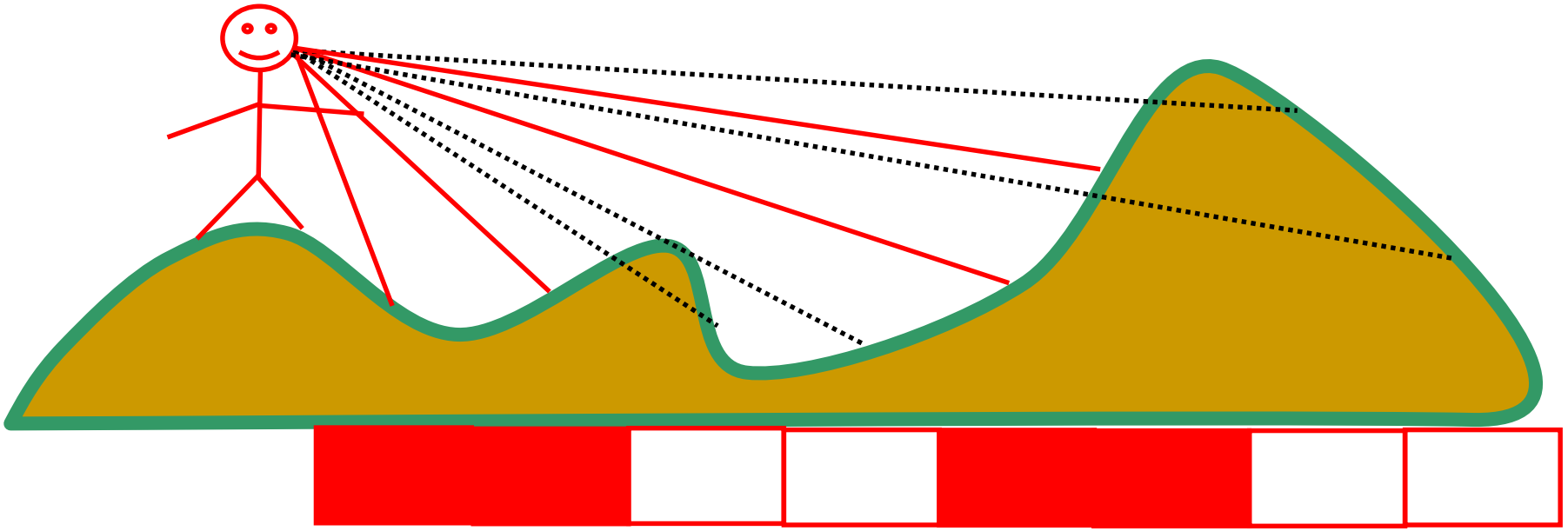
From: www.ramsantscotland.com/_let011013.htm

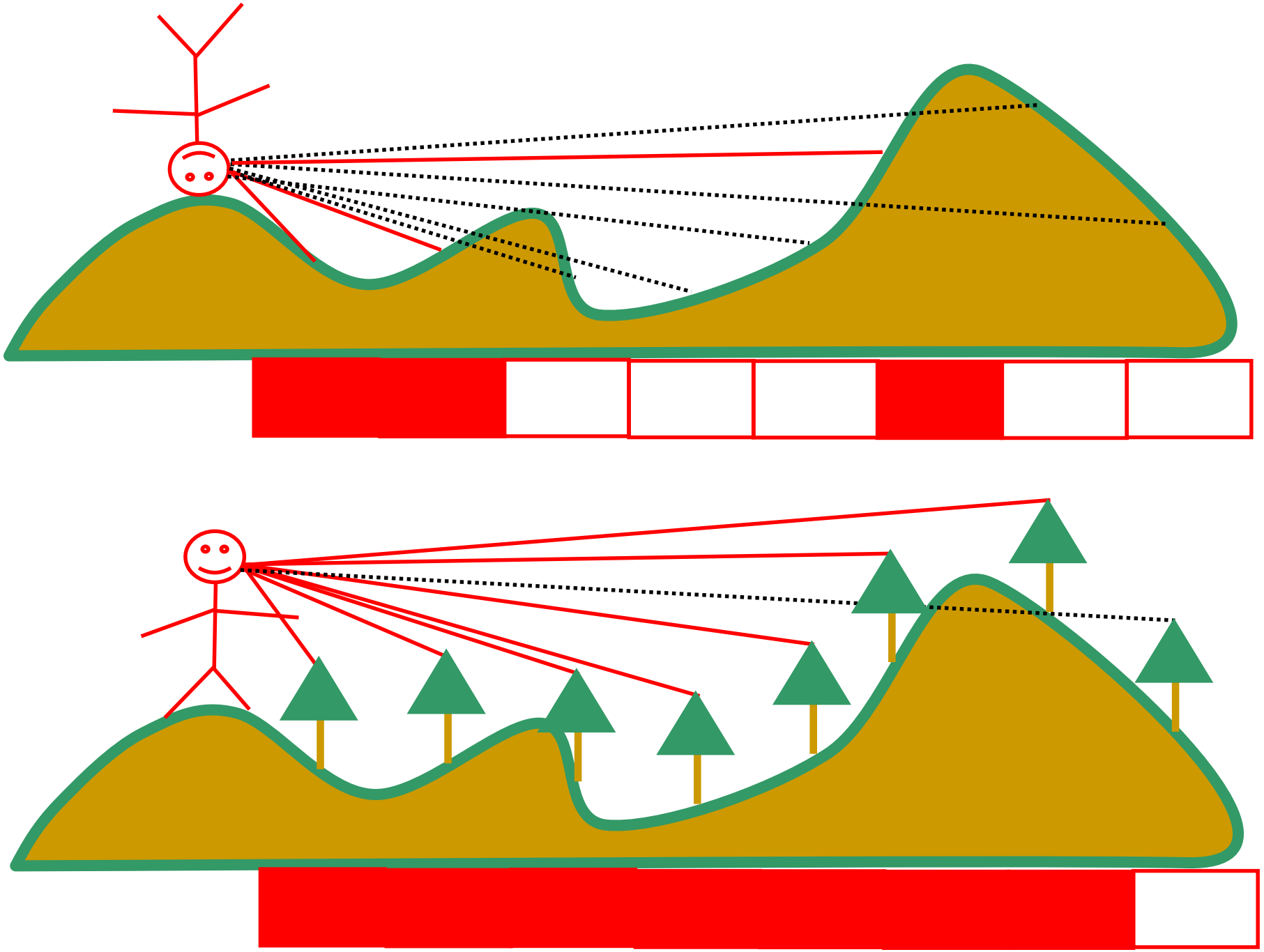
From news.bbc.co.uk

From: http://www.bwea.com/view/photo-stop/index.html

Calculating viewsheds - concepts

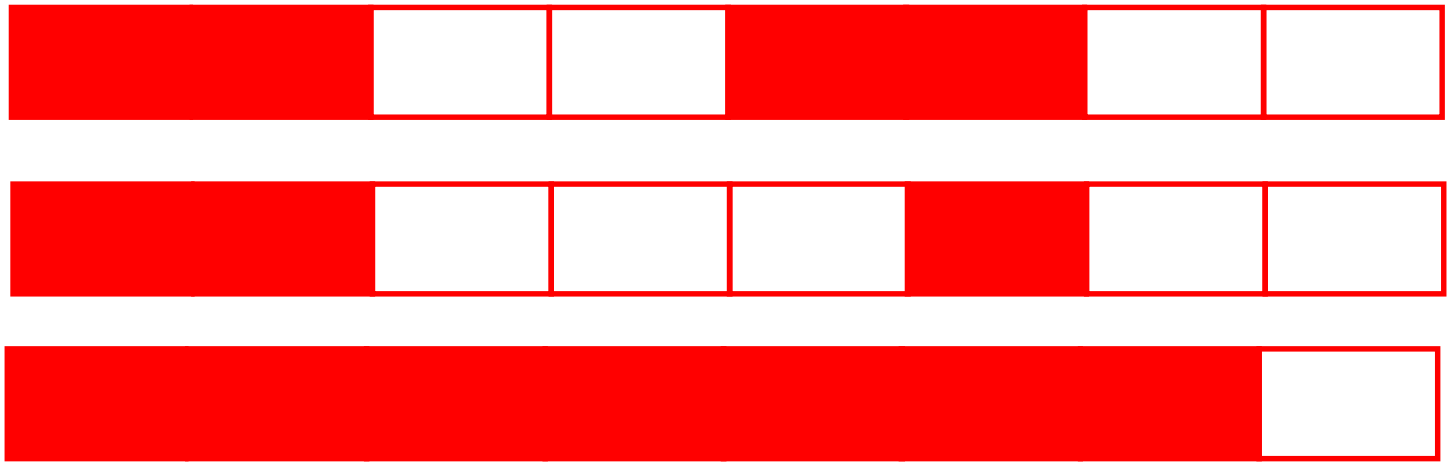
- To calculate a viewshed we test the visibility of very point in a landscape from some viewpoint
- We test this visibility by drawing a line of sight (LOS) from the viewpoint to the point being tested
- If the LOS **does not intersect** any **intermediate terrain** the point is **visible** – otherwise it is not





Calculating viewsheds – concepts (2)

- We have three different viewsheds for the same terrain – we applied a vertical offset to the viewer or the viewed objects and got a set of **binary answers**
- What would happen if an **offset object** (e.g. tree) obscured the next object?
- How **sensitive** is our viewshed to the point we choose to test?



Fisher and viewsheds

- **Peter Fisher** wrote a series of articles investigating viewsheds
- He was interested in a number of aspects of viewshed, including:
  - How do **results** vary according to the **algorithms** used to derive viewshed?
  - How sensitive are the results to **errors in elevation**?
  - How useful is the basic concept of viewshed in different fields and **how can it be extended**?
- We are going to look at Fisher's results for each of these 3 aspects in turn...

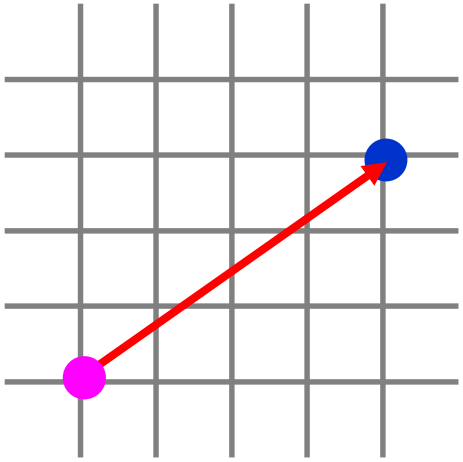
Algorithms for viewsheds – raster data

- The basic algorithm is simple
  - For every point in the landscape to be tested **draw a line of sight** (LOS) from the **viewpoint**
    - Test for intersection of that LOS with the surface at some interval – if **intersection** is found point is **invisible**
    - If **no intersections** are found point is **visible**
  - These operations must be repeated for every point we want to test
- The principles are the **same** whether the data structure is a **raster** or a **TIN**

Deconstructing the algorithm

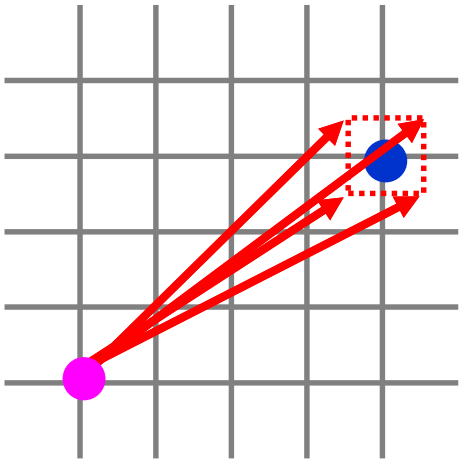
- Although the algorithm is very simple to express there are **different ways** in which it can be implemented
- We will consider the raster case (although the questions for a TIN are similar)
    1. Are we treating the **viewpoint** and the **test points** as **points** or **cells**? (This also determines the LOS used)
    2. How do we **calculate elevation** as we travel along our LOS?
    3. How do we calculate if a **particular location** is **above or below** the point being viewed?

1: Viewpoint as point or cell?



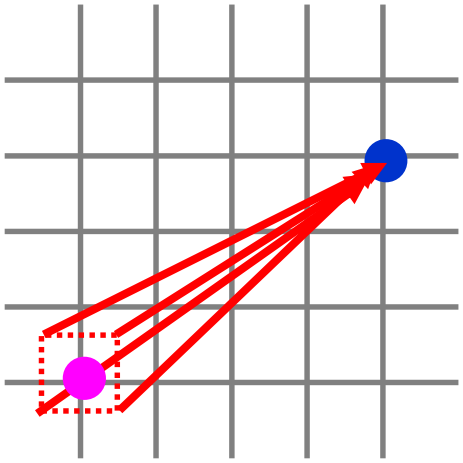
In tests with more than one LOS what is our test for visibility?

Once, twice, more than 50%??

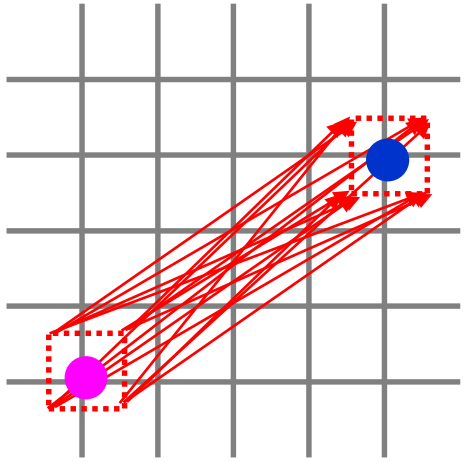


Here we simply test whether we can see a **point** from a **point**

Here we test for a cell – we test each corner for visibility



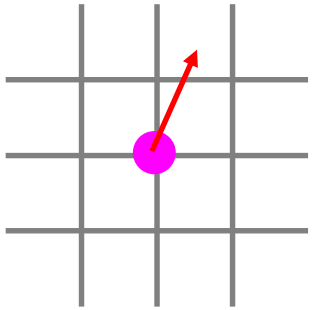
In Fisher's experiments visible >1 implied visibilty



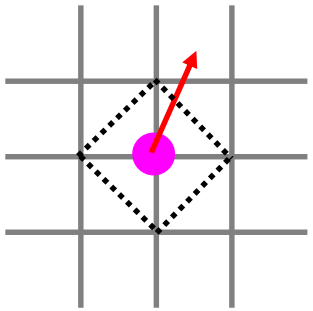
This is just the reciprocal of the above case

If we test for cell to cell there are 16 LOS if we use the corners!

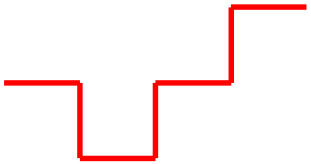
2: What elevations should we test?

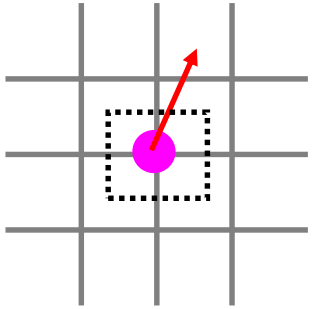


Here we test every time we cross a line. The value at the crossing is simply the linear interpolation between the nodes of the grid **(a)**



In this case we add to the locations by triangulating. Again we test every time we cross a line. Note that the triangulation changes from point to point, so different elevation values are implied… **(b)**





Finally we can consider each cell as a horizontal plane with the same value everywhere and abrupt changes at the edges **(c)**

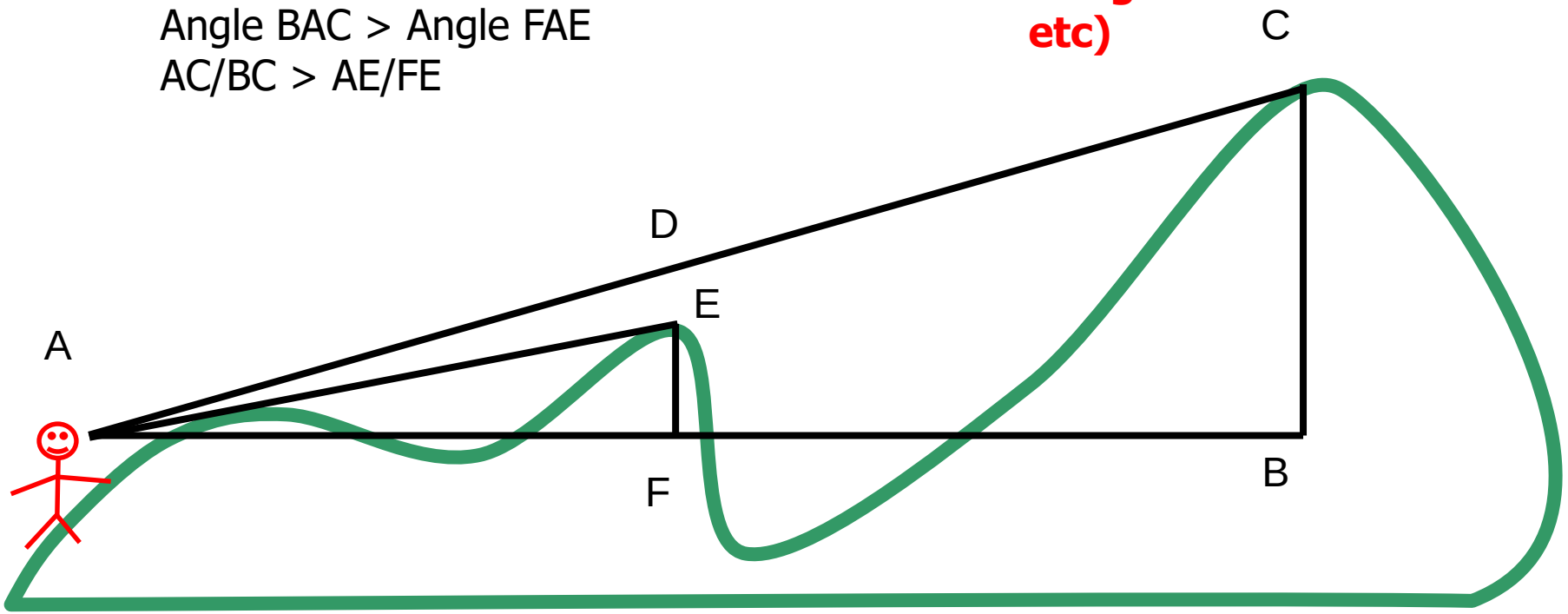
The cross sections give a schematic idea of the variation in elevation along a line

3: Calculating relative positions…

If any of the following is true then
C is not obscured by E
(where C is higher than A):

AD > AE
DF > EF
Angle ACB < Angle AEF
Angle BAC > Angle FAE
AC/BC > AE/FE

We can calculate these tests in different ways which could give rise to different results… (through rounding, integer arithmetic etc)



Does it matter?

- These might all seem relatively trivial concerns
- BUT – **which** does ArcGIS use?
- Fisher implemented the different algorithms and compared the viewable areas for 2 test sites on 100x100 DEMs
- He found that for the **first two** alternative sets of implementation **significantly different results** were obtained
- The last – how we do the actual height calculation was much less sensitive

Fisher's results (visible cells)

Viewing point	Test site 1	Test site 2
Point to point	2381	2034
Cell to point	3328	2271
Point to cell	2707	2666
Cell to cell	3970	2907

Elevation approx.	Test site 1	Test site 2
Grid (a)	2381	2034
Triangulation (b)	2312	1917
Stepped (c)	656	92

Are these results what you would expect?

How could we test the significance of these results?

What is the impact of errors in elevation on viewshed?

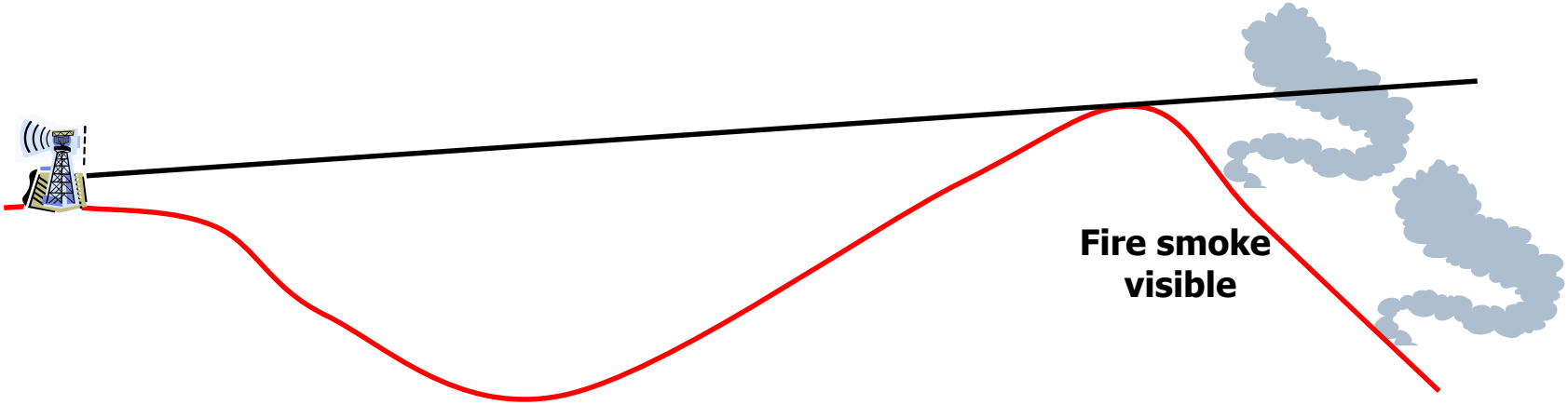
- Fisher also wished to examine how **error** in **height values** could influence viewshed generation
- He applied **random errors multiple times** to the same DEM and compared the **viewshed areas** from the set generated with the original viewshed
- He found that the viewshed in the DEMs with error was **consistently smaller** in area that in the DEM with no error

What do Fisher's results mean?

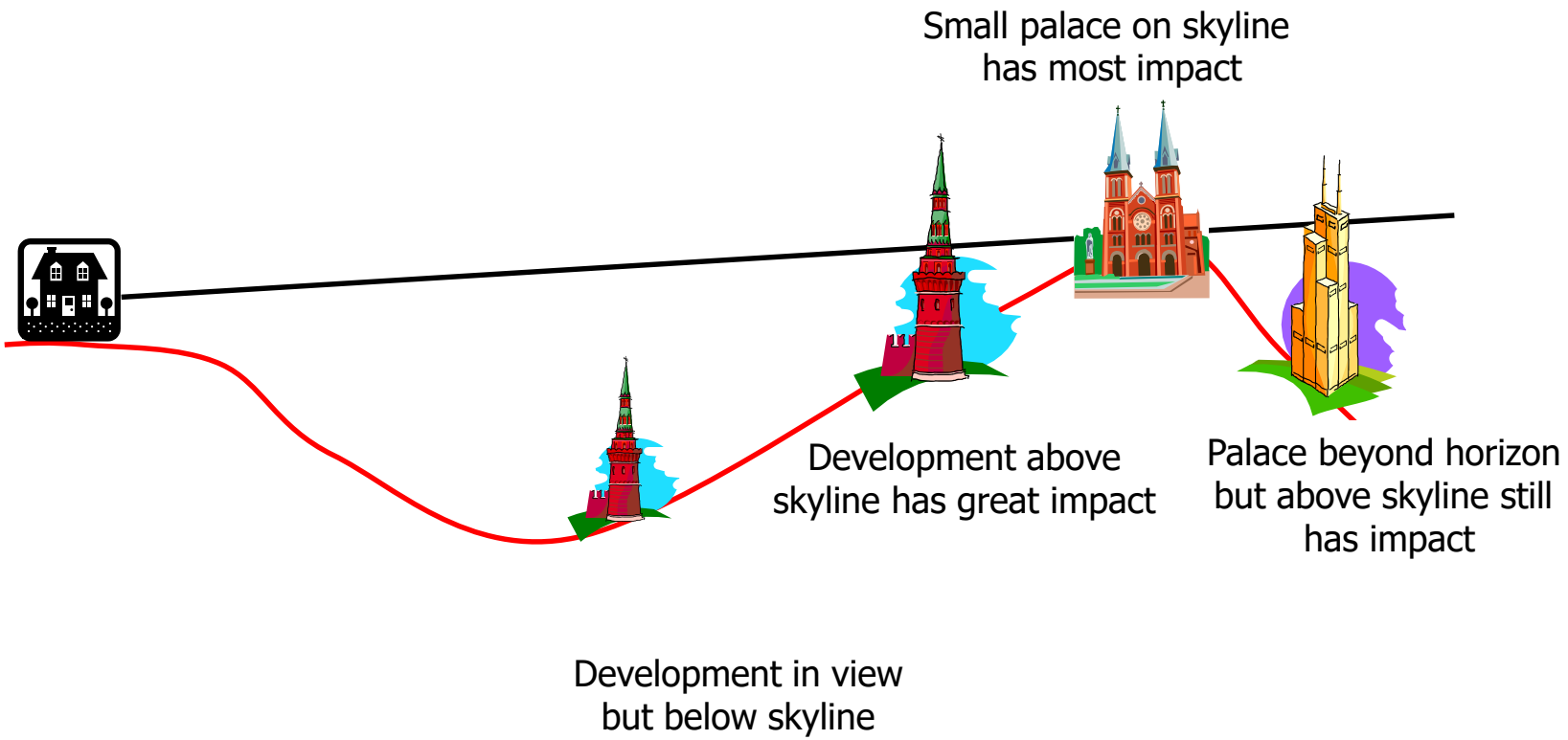
- Fisher found that the **actual algorithm** used and **error** in the DEM could both lead to significant variation in the viewshed calcualted
- He argues that treating viewshed as a binary surface is inappropriate, and rather that we should assign a **probability of a location** being seen
- He shows how **probability viewsheds** can be generated using Monte Carlo Simulation (more in a few weeks)…

More from Fisher…

- Fisher spent a lot of time working on these ideas
- This prompted him to think about what we were actually using viewshed **for**
- We use viewshed to **model something else**, for instance:
  - To position a tower for **observing forest fires** – here we are concerned about our ability to spot fires, not the ground. Seeing smoke is a good indicator of fire!!
  - To decide on the **visual intrusion** of a planned building or object – in this case a location on the skyline (horizon) is much more visually intrusive than one against the skyline

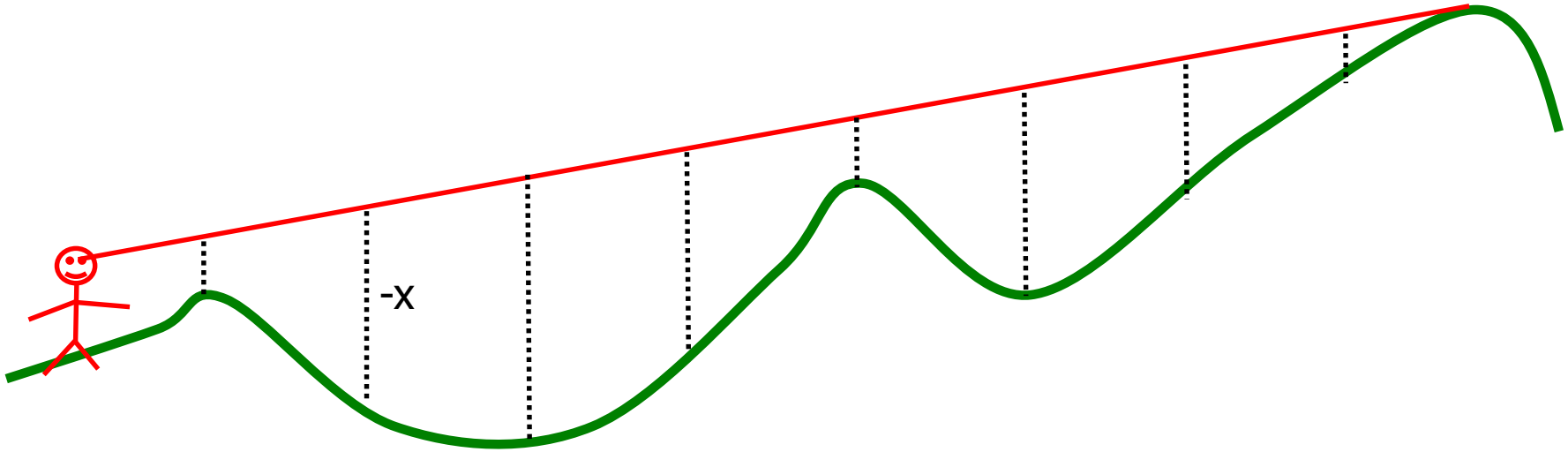


We can see fire smoke for some distance beyond the horizon…



Alternative viewsheds

- Fisher proposes alternative viewsheds which give more information about such problems, two of these are:
  - **1: Horizons viewshed**: a location is in view (1), a local horizon (for example, a hill top) (2), a global horizon (3) or not in view (0)
  - **2: Global offset viewshed**: if **in view** report the offset to the global horizon, if not in view report the negative offset to the global horizon



BINARY	1	0	0	1	1	0	0	1	1
1: Horizons	2	0	0	1	2	0	0	1	3
2: Global offset	x	-x	-x	x	x	-x	-x	x	0

These viewsheds give **alternative sets of information** which can be used to further inform our interpretation of viewsheds.

Such ideas further demonstrate how we can explore what appears to be a single GIS command…

You should think about problems where we could use these…

Summary

- Viewsheds are usually **binary surfaces** telling us what is seen and not seen
- We calculate viewsheds using **lines of sight** from a view point to every point in a landscape
- If a line of sight intersects terrain before the point we are trying to view, it is not visible
- The way we **define** these lines and the ***viewed*** and ***viewing*** points has impacts on our defined viewshed
- Fisher suggests a **probable viewshed** is a more sensible proposition
- He also presents some **alternative definitions** of viewsheds

Viewshed examples

- In the first half of the lecture we explored the viewshed function in some detail
- In the second half we will look at three examples of the use of viewshed in spatial analysis:
  - **Archaeology**
  - **Studying corridors through a landscape**
  - **Assessing impact of forest operations from a visibility perspective**

Using GIS in archaeology

- Archaeologists are often interested in **spatial patterns**
- Viewshed analysis has been used by archaeologists to try to **explain position** of ceremonial, defensive and settlement sites
- For instance, they ask questions like:
  - Are **stone circles** positioned to allow **viewing a particular part of the sky** or landscape?
  - Are **forts** positioned to **guard against attack** from one direction?
  - Do **settlement sites** provide the best locations for **spotting potential prey?**

From: www.sypeland.freeserve.co.uk/_site77.htm

From: www.harb85.freeserve.co.uk/ orkney/oalbum/oalbum.htm

From: www.har

From: http://easyweb.easynet.co.uk/~aburnham/scot/skarahi.htm

Using viewshed in archaeology (1)

- A paper by Lake et. al. explained that archaeologists often use viewsheds to examine whether one site is visible from another
- They state that

  "At present archaeologists run the risk of letting the software, as designed for non-archaeological applications, dictate the questions they ask of the data and how they go about answering them. "

Using viewshed in archaeology (2)

- If sites are **intervisible** this is then used to suggest that their **siting** was in some way influenced by visibility
- However, Lake points out that if we wish to ascribe importance to intervisibility **we must show** that it the sites in question are **unusual in their viewsheds** with relation to the rest of the area
- This is of course **basic science**– but we often forget it!

Using viewshed in archaeology (3)

- Lake et al. demonstrate the idea by **forming a hypothesis**
- For 8 Mesolithic sites on Islay they asked the question:
  - Is the view at these sites any **more extensive** than would be expected by chance alone?
- In order to test this they needed to know the number of cells visible from every location in the landscape (this is often called the **cumulative viewshed**)
- The cumulative viewshed is **computationally intensive** to calculate
- The **null hypothesis** is that there is **no difference** between the **cumulative viewsheds selected at random** from the landscape and the **settlement sites**

From: http://www.ministryofpropaganda.co.uk/blogimages/20050402-islay-jura-big.jpg

Implementing their tests

- The sites were located in an area 390 km^2
- The viewsheds were calculated for a 50m DEM
- Thus there are 39 x 10 x 20 x 20 cells in the model
- The experiments compared a **random sub-set** (5%) of data with the sites
- The authors considered **edge effects**, but found these to have no influence for this case

Results

- There was **no visible difference** between the sites and randomly selected non-sites in distribution of viewshed size
- As the authors said:

"there is no evidence that Mesolithic sites on the Rhinns of Islay were sited preferentially with respect to commanding views."

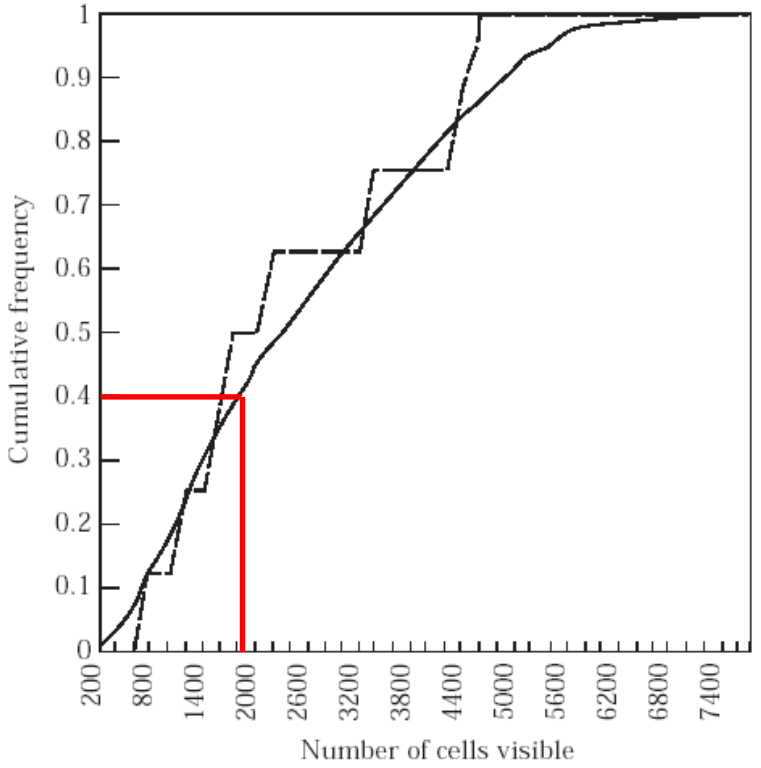
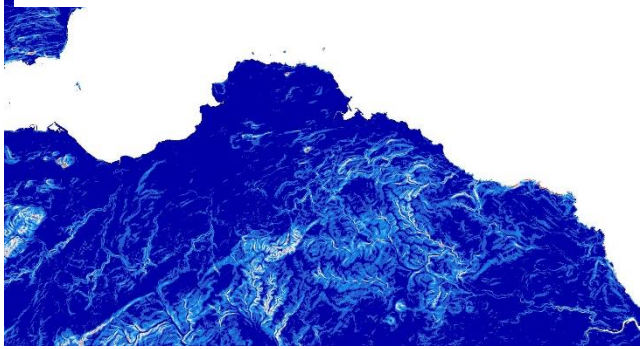


Figure 13. View from sites compared with 5% sample from background not including sea. ——: Background; – – –: sites.

From 40% of cells, up to 2000 cells are visible.

Aside: Least cost paths…

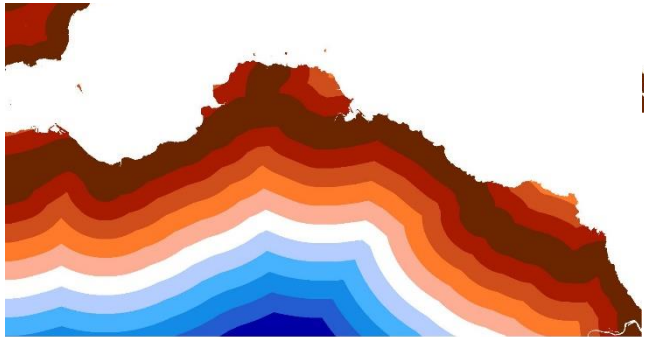
Steep slopes

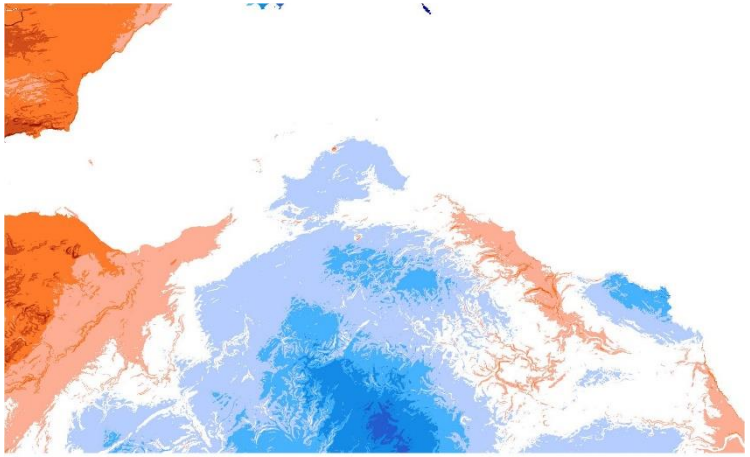


Near tourism

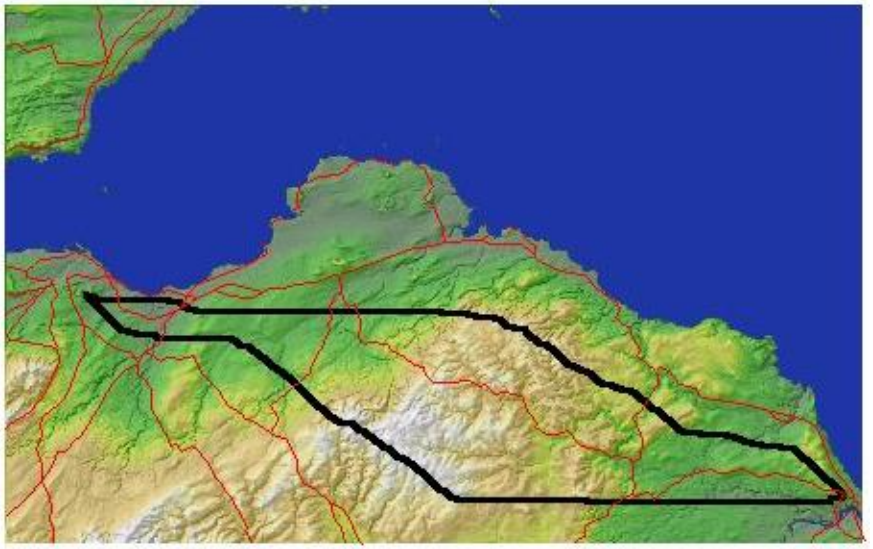
Far from roads

Far from railway



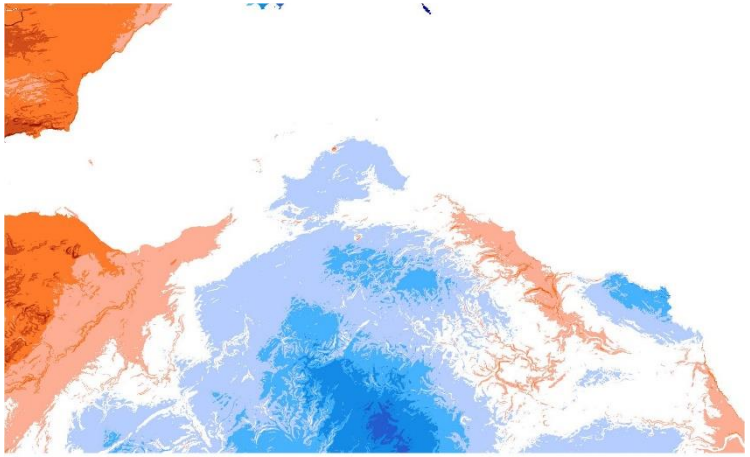


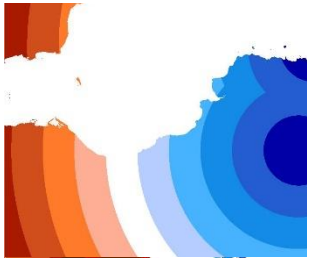
Cost surface



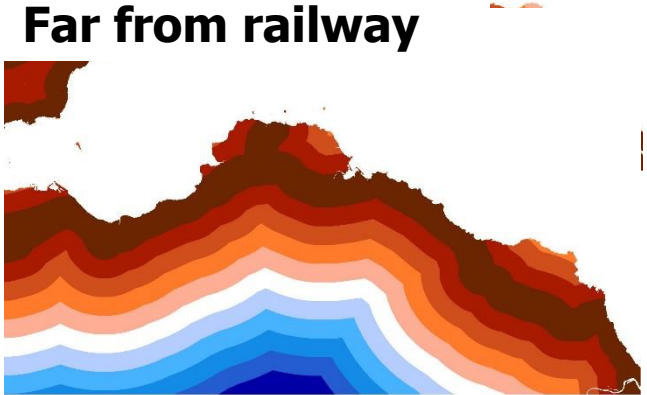
Cost path

Aside: Least cost paths…





Lee and Stocky illustrated the use of **viewshed** in finding least cost paths…

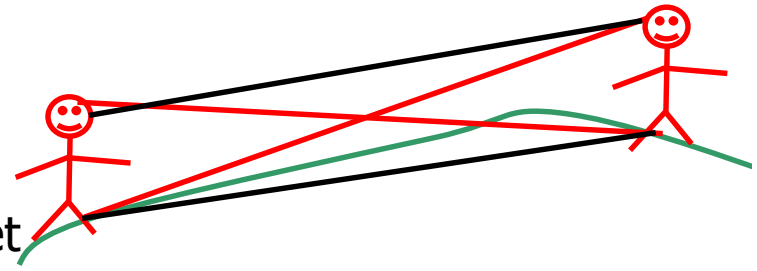


Cost path

Using viewshed in cost paths (1)

- If we calculate the viewshed at every point in our landscape, we can calculate for every cell the number of cells visible (again, the cumulative viewshed)
- We can also calculate the **number of cells from** which the cell is visible
- These two numbers are only equivalent if the height of the viewpoints and the viewed points is the same with respect to each other e.g:

I can see your head
I can't see your feet!
My feet can't see your feet



I can see your head
I can see your feet!
My feet can't see your feet

Using viewshed in cost paths (2)

- Lee and Stucky define these as:
  - viewgrid (VG): for each cell how many cells are visible
  - dominance viewgrid (VD): how many cells is each cell visible from
- They then define 4 paths through the landscape:
  - **Hidden path** – *the path between two points which minimises being seen*

$$\min \sum_{k=1}^{n} VD_k$$

  - **Scenic path** – *the path which maximises what you see*

$$\min \sum_{k=1}^{n} VG_k^* \quad \text{where for each cell} \quad \mathrm{VG}_k^* = \max \mathrm{VG} + \min \mathrm{VG} - \mathrm{VG}_{ij}$$

Note that since we must find a **least cost path** we actually **invert the values** for the scenic path

More cost paths

- **Strategic path** – *the path between two points which maximises what you can see, whilst minimising how much you are seen*

$$\min \sum_{k=1}^{n} V_k \text{ where for each cell } V_k = \max(VD, VG^*)$$

This equations sets the worst case for each cell and then the least cost path attempts to minimise it in each case

- **Withdrawn path** – *the path which is not only minimally visible but also sees the minimum amount possible*

$$\min \sum_{k=1}^{n} V_k \textit{ where for each cell } V = \max(VD, VG)$$

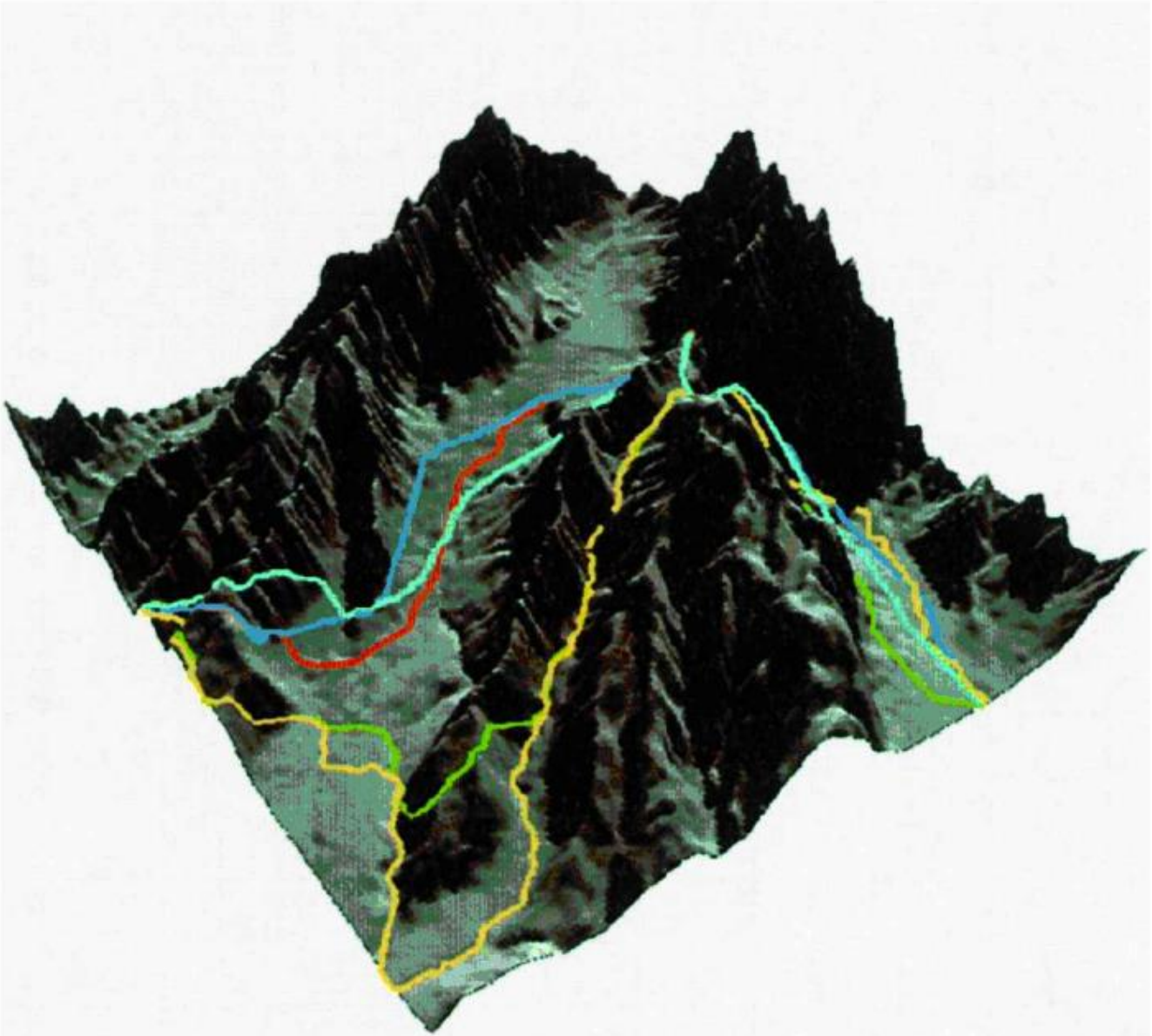


Figure 5. Reconnaissance path scenario, looking NE.

Euclidean – cyan

Scenic – blue

Strategic – red

Withdrawn – green

Hidden – yellow

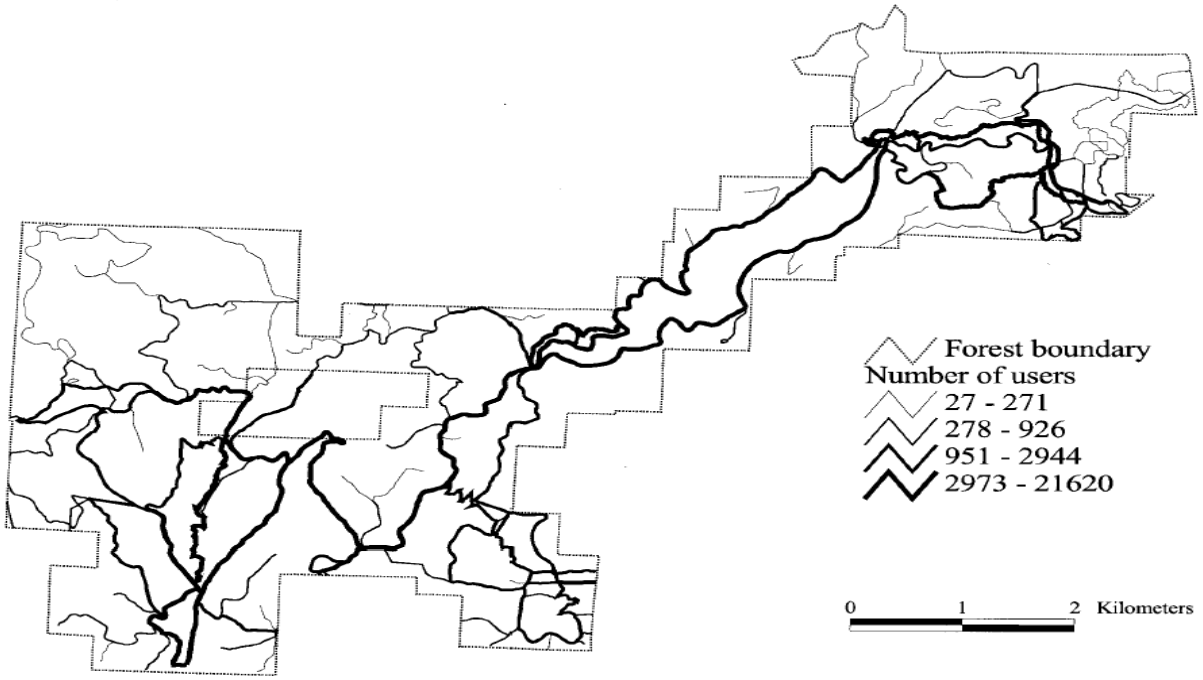
Note that no path is allowed to cross slopes **steeper** than 50°

What could we use these for?

- All four of these paths might be useful in **planning** or considering paths
- What might we use
  - The **hidden path** for?
  - The **scenic path** for?
  - The **strategic path** for?
  - The **withdrawn path** for?
- Note that in these results **edge effects** seem to cause problems in some of the scenarios

Quantifying forest visibility

- Wing and Johnson investigated **forest use** and visibility
- They collected **questionnaire data** to find out **which routes** people took in the forest and then calculated which area of the forest were seen by the most visitors from their **linear routes**
- This information can then be used in forest management – by using **statistics on visits** to the forest it is possible to identify in which areas timber harvesting will have the most **visual impact** with respect to **recreational forest use**…



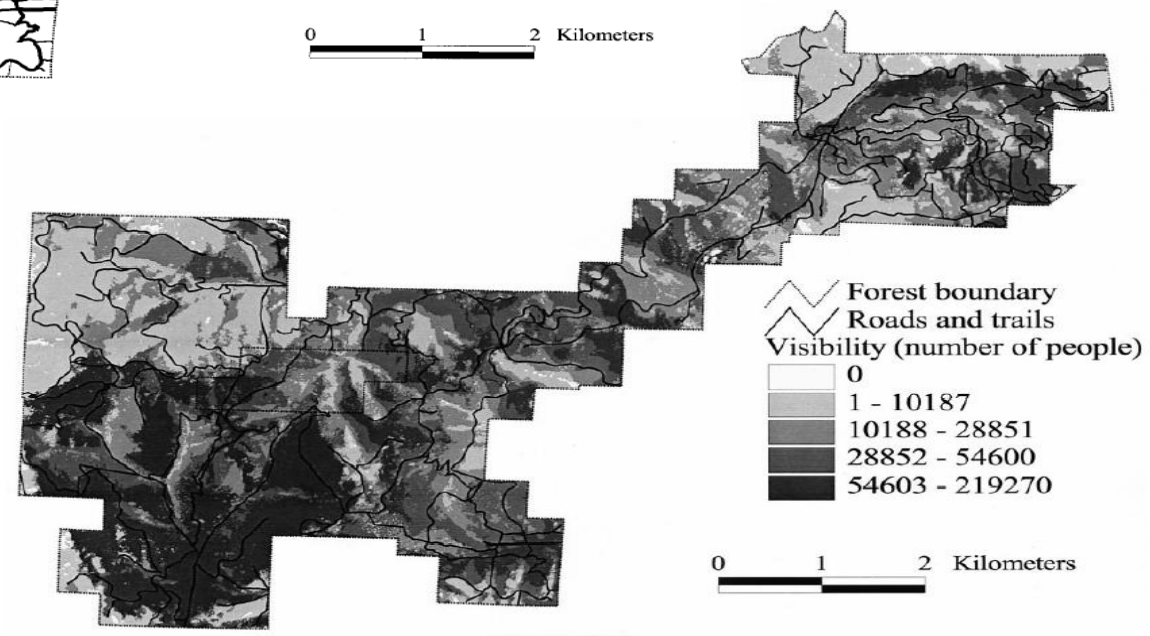


Figure 4. Visibility analysis results.

More on the forest

- The area is small (29km^2)
- **Tree height is important** in visibility analysis(!!) – information was digitised about tree height in small polygons and these heights added to the DEM heights…
- The study assumes that users travelling along a road constantly look in **all directions** (dangerous ☺ and unlikely!)
- However, this study is a useful attempt to use viewsheds in a **practical management application**

Summary

- We saw three applications of viewshed
- You should think about what **sorts of spatial analysis** was going on
- **None of them** used a simple binary viewshed from a single point
- They all used some kind of **cumulative viewshed** to make decisions or describe landscape properties
- All of these examples extended the concept of viewsheds in a useful way…

Next week

- We are going to return to errors and uncertainty (recall our first lecture)
- How can we usefully quantify notions such as precision and accuracy?
- What forms can errors take and how can we document them?
- How can we describe uncertainty in categorical data?

References

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