Mapping the Visual Magnitude of Popular Tourist Sites in Edinburgh City

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Abstract

There is value in being able to automatically measure and visualise the visual magnitude of city sites (monuments and buildings, tourist sites) – for example in urban planning, as an aid to automated way finding, or in augmented reality city guides. Here we present the outputs of an algorithm able to calculate visual magnitude – both as an absolute measure of the façade area, and in terms of a building's perceived magnitude (its lesser importance with distance). Both metrics influence the photogenic nature of a site. We therefore compared against maps showing the locations from where geo-located FlickR images were taken. The results accord with the metrics and therefore help disambiguate the meaning of FlickR tags.

Keywords:

vista space, visual magnitude, landmarks, perception maps, FlickR tags

1 Introduction

Typically, a city is richly composed of stately buildings, public spaces, monuments, and residential buildings. Its varied topography and streets offer ever changing panoramas. Much research has been devoted to measuring the prominence and visibility of a city's many landmarks and places of interest – both from an urban morphology perspective, and as a basis for selecting content for wayfinding applications. It is acknowledged that various factors affect how people perceive the prominence of buildings and monuments in the landscape, and how this collectively affects their sense of place. In this research we report on attempts to visualise the visual magnitude of popular tourist sites. We compare these visualisations with maps showing the locations of where photographs were taken of the equivalent site. Edinburgh (Scotland) was chosen as a test case because it is a visually interesting city built upon a varied topography, occupied by many grand buildings and monuments. It is divided into an Old Town and a New Town, separated by a large public park (Princes Street Gardens) in a shallow valley and the city's main railway station. The openness of the park provides vistas of the old and new towns. Alongside is a large castle built upon a plug of an extinct volcano, which demands visual attention due to its dominance on the skyline. The paper begins with an overview of the visual magnitude model, then presents the mapped results of running this model for a selection of popular sites, and concludes with a comparison against photograph locations based on geo-tagged FlickR imagery (www.flickr.com).

2 Method

There have been numerous previous studies on urban visibility. Until recently these have tended to use the two dimensional boundaries of buildings to calculate isovists (Turner et al. 2001, Benedikt 1979, Tandy 1967), but now Digital Surface Models (generated from Light Detection and Ranging (LiDAR) data) include surface feature elevation at fine levels of detail and therefore provide a much richer basis for urban visibility modelling (Palmer and Shan 2002, Bartie and Mackaness 2006, Rottensteiner and Briese 2002). The idea of modelling visual magnitude was proposed by Llobera (2003) and is defined as a measure of the field of view occupied by an object in the user's view. The value changes as the user moves around a space depending on the viewing distance and angle, and occlusion of the designated target object. This differs from a viewshed in that the value reflects the amount seen of a target, rather than the view of the surrounding space.

In the model presented here, we calculated 1) the amount of a building visible (façade area) and 2) the perceived area (which factors in the viewing distance) (Bartie et al. 2010). The model did not consider cognitive issues such as size consistency (Boring 1964), or the ease with which a feature may be identified against background objects (Winter 2003, Sorrows and Hirtle 1999). The construction of the visual magnitude model is now described.

LiDAR data were used to create a Digital Surface Model (DSM) and Digital Terrain Model (DTM). This data were georeferenced to the corresponding OS Master Map data using the British National Grid coordinate system. The DSM and DTM were then cleaned to ensure that any vehicles present in the data capture were removed from the road surface. This was necessary to reduce the occurrence of target occlusion from temporary moveable surface objects. The process was automated by using the OS Master Map road polygons to define the road regions in the surface models, and by running a kernel function across the terrain model to identify regions of steep slope which would not be expected on roads. These regions were then replaced with interpolated values from the surrounding terrain model. The visual magnitude was calculated by modelling the lines-of-sight from a location in the study region to all of the cells in the 1metre resolution DSM. The vertical extent visible was recorded, with foreground objects creating visibility shadows on the more distant cells (Figure 1).

The total visual magnitude for each OS Master Map polygon was calculated by summing the model output for all cells within the defined polygon boundary. Two metrics were calculated: the total façade area visible and the perceived area. The total façade area does not vary with distance, but is a measure of the total frontage surface area that is visible from an observer location. The perceived area uses this figure but includes a ‘decay with distance’ function, at a distance squared rate (the further from the user, the smaller the area captured on the retina). The visual magnitudes for all OS Master Map polygons were calculated from 75,000 pedestrian accessible locations within the study region. Pedestrian accessible areas are defined as those outdoor places a pedestrian could access including roads, pavements and open spaces but not roof tops, water bodies, or rail regions.

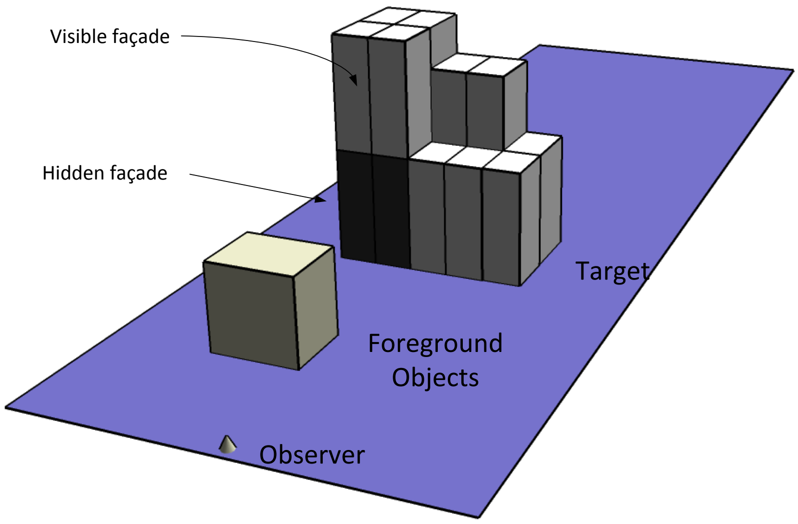

Figure 1: Visual Magnitude Model

3 Results

The visual magnitude for all objects can then be summed for each location within the city to produce a cumulative visual magnitude map (Figure 2). This differs from other cumulative maps in that it is the summation of visual magnitude maps which include vertical extents of objects (façade area), rather than just a count of the number of times a cell is visible.

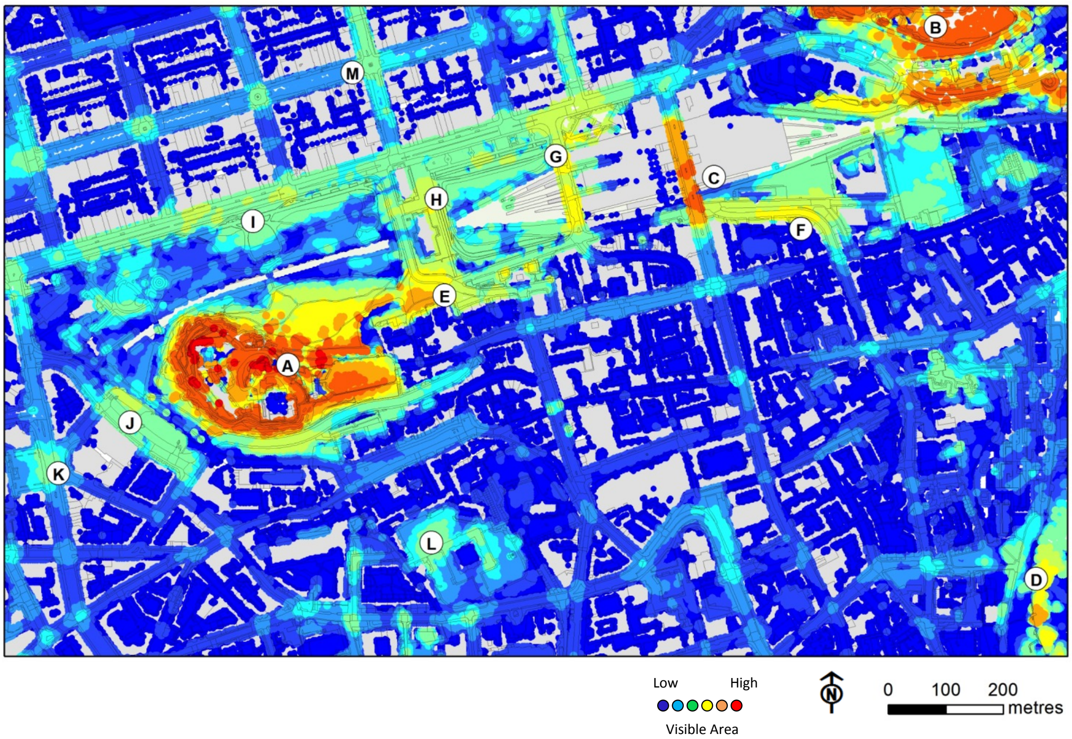

Figure 2: Cumulative Visual Magnitude across Edinburgh

The highest visual magnitude for the city are from Edinburgh Castle (A) and Calton Hill (B), meaning these locations offer the greatest combined view of city objects. The south side of North Bridge (C) is also a good photo location as it has open views to the east and west and clear views of Waverley train station, Princes Street Gardens, and the more distant Holyrood Park which includes Arthur's Seat and the Crags (D) to the South East. Views from the Crags (D) themselves are extensive to the west, but blocked by the cliff face to the east. The Mound (E) is a street on a hill with a northerly outlook and has clear views of the Princes Street Gardens, and Royal Scottish Academy (H). Cranston Street (F) offers exposed views north across the city council building, the eastern part of Waverley train station, North Bridge (C) and Calton Hill (B). Waverely Bridge (G) is a road which runs through a shallow valley and therefore has reduced views compared to the higher bridge crossing at (C). The Royal Scottish Academy (H), Castle Terrace (J) and Usher Hall (K), and the open playgrounds of George Heriot School (L) exhibit similar scores. Princes Street Gardens (I) has some good views, but also regions of limited view due to the tree canopy obscuring more distant objects. It is worth noting the increase in cumulative visual magnitude at junctions where the views open up to see a greater number of city objects. This is particularly noticeable along George Street (M).

3.1 Mapping Visual Magnitude for Sites

The OS Master Map polygons represent the smallest identifiable units from aerial imagery, such as individual buildings, parks, and road regions. However people sometimes refer to entities (or 'sites') which consist of many of these polygons. For example Edinburgh Castle consists of 326 polygons (Figure 3), but is typically considered as a single entity. It is possible that any polygon can be the member of a number of sites. For example polygons that contribute to the Edinburgh Castle site are also considered as part of the Old Town.

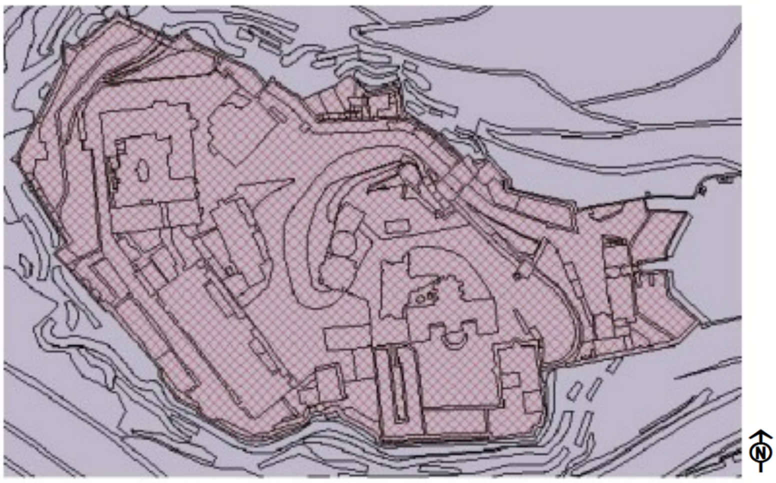

Figure 3: The 326 polygons comprising the Edinburgh Castle Site

To reflect this view of the city, polygons were grouped according to site, for a number of popular tourist sites in Edinburgh (Figure 4). Their visual magnitude was then calculated.

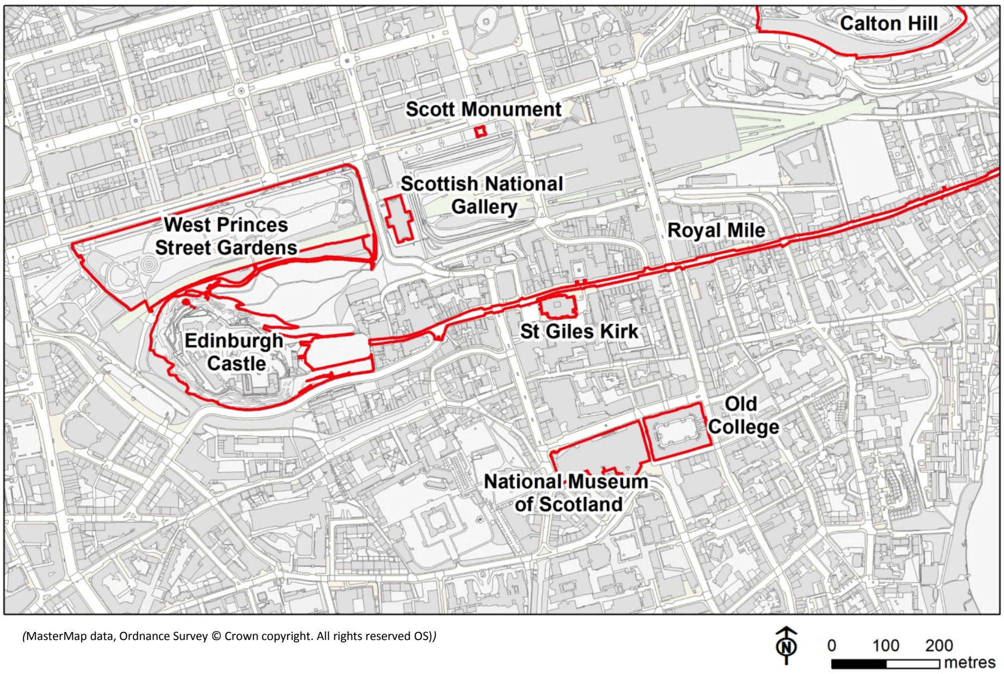

Figure 4: Grouping of polygons according to some popular tourist sites

The Visual Magnitude Map (see separate PDF – mini copy below) shows the Façade area and perceived area maps for six of the sites (Carlton Hill, St Giles Cathedral, Scott Monument, The Royal Mile, Edinburgh Castle and Princes Street Gardens). The third column in Figure 5 is based on a frequency count of the location from which FlickR images were taken of that particular site. Previous research reveals ambiguity in how FlickR images are located and tagged. To reduce these errors a filtering process was carried out whereby the set of tags for each geotagged image were compared against all other tags from images within 50 metres. The tag comparison was performed using trigrams allowing for fuzzy string matching which ignored minor spelling mistakes, stop words (e.g. of, the), and word order (e.g. National Art Gallery, National Gallery of Art). The most popular tag by unique user count was considered as the main tag for each image. The more common items which occur across the map were ignored, such as 'Edinburgh', 'Scotland', 'Nikon' ,'2011' using a tf-idf approach (Mackaness and Chaudhry 2013). Once the main tag had been determined for each image it was possible to filter out those tags which were only used by a few users, to leave the more robust FlickR image locations.

There are some interesting things to note when studying the Visual Magnitude Map. Calton Hill was identified earlier as a place which offered good views of the city (Figure 2 site B). It is noticeable from the Façade map that the majority of regions that can see Calton Hill have a good view of it (shown in red), with some of the best regions being North Bridge (Fig. 2 site C), Edinburgh Castle (Fig.2 site A), and the Crags (Fig. 2 site D). The Perceived area map gives an indication of how large the site is in the field of view, considering the viewing distance. This correlates fairly well to the top FlickR tags, noteably on Calton Hill itself, but also the more distance vantage points of Edinburgh Castle, and North Bridge.

St Giles Cathedral is a visually exciting building with a crown steeple, situated on the popular Royal Mile. It attracts a lot of attention as can be seen by the density of FlickR image. However due to the narrow streets and surrounding buildings it has a fairly limited visual impact. There are some locations from within Edinburgh Castle that can see a high façade area, and indeed this has been taken advantage of by FlickR photographers. There are also FlickR images from the National Museum of Scotland (see Fig 4 for location), which were not identified in the visual magnitude output. This is because the visibility model was only run from an observer at street level, while the National Museum has roof top access from which the Cathedral is visible.

Scott Monument is a tall gothic looking structure on the busy Princes Street shopping area. This area is fairly open to the south where Princes Street Gardens is located, and this shows up in the magnitude maps which extend a long way south of the site across the valley to the opposite hill. It is not a very large object so although it is recognisable from many locations, it does not occupy a large part of the field of view. As it is a tall structure and is situated in an open region it has a fairly consistent façade area region (shown in green).

The Royal Mile (fourth row) is the commonly used name for the High Street which is a tourist favourite. It is long thin cobbled street and only really visible from within the street itself. Although it can be seen from the connecting road network the main region for photographing it is on the actual street itself.

Edinburgh Castle is a magnificent site on top of a volcanic plug, overlooking the city. It is obvious from the visual magnitude maps that this site can be viewed from much of the study region, and often a large portion of the site is visible. This is evident in the widespread locations of FlickR imagery including distant photo locations such as the North Bridge at 800 metres from the castle, and Calton Hill at just over 1km. The magnitude model and perceived area map both confirm these are sites which offer good views of Edinburgh Castle. It is also evident from the façade model output that the views from inside the Castle are often more limited, and there is even a gradient in the amount of the site visible (as can be seen on the esplanade to the East of the Castle). This occurs because inside the site some of the buildings occlude the view of the rest of the site, while in other places the open regions allow for much better views of the site itself. The model fails to show the good views from the roof top of the National Museum (since roof space was not modelled), indicated in the FlickR imagery map.

Princes Street Gardens are situated in the valley between Old and New town, and are mainly visible from within the garden or the Castle. The south side of the gardens are on a steep slope and have had restricted access due to landslides, closing paths which may have contributed to the lower count of photographs from this region.

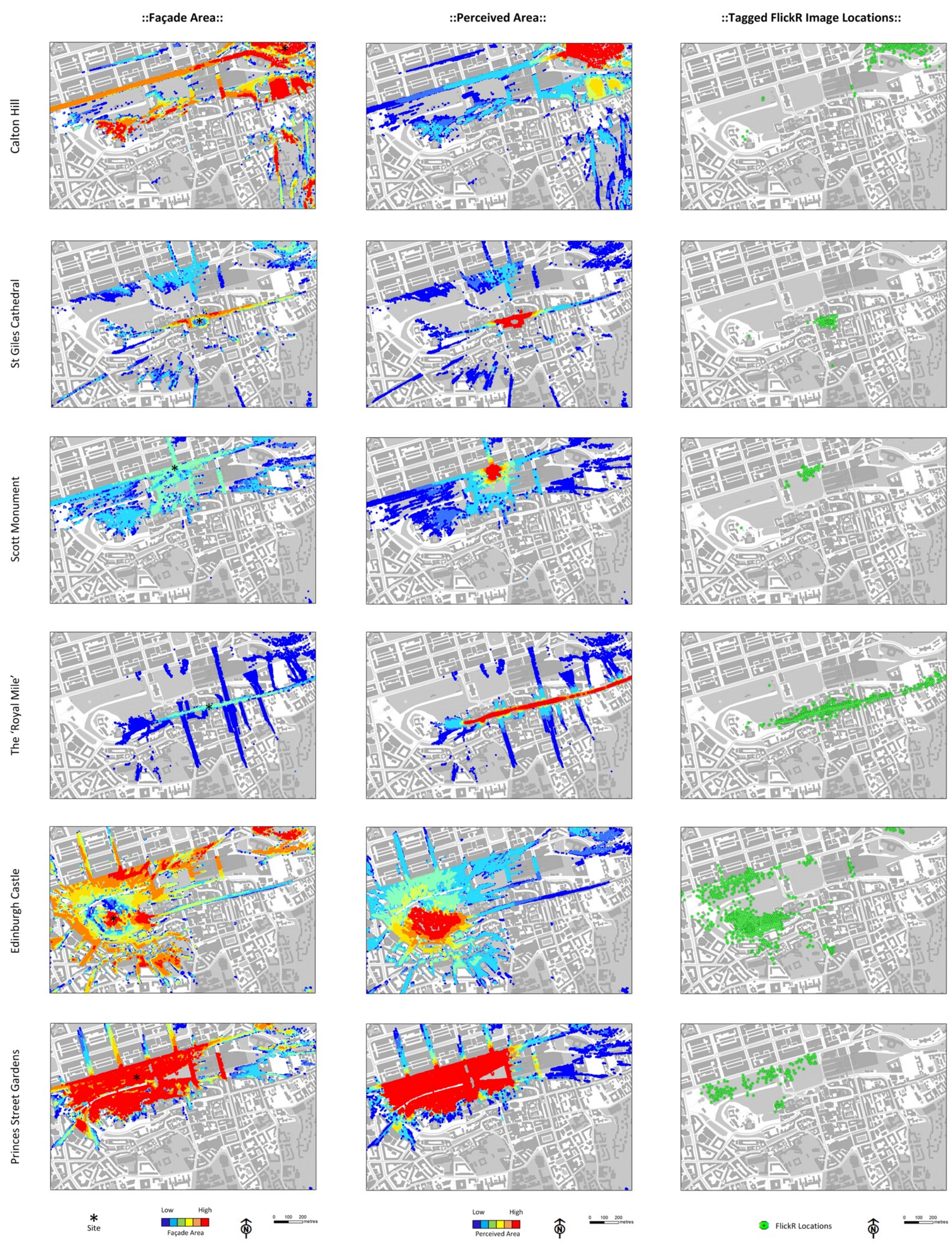

Figure 5: Visual Magnitudes for Selected Sites (Reduced Copy of Main Map available as separate PDF)

4 Conclusion

Though qualitative in nature, comparison between the visual magnitude maps and location of photographers makes interesting comparison. The magnitude maps make interesting predictors of photographer's locations. Currently researchers have to deal with uncertainty in FlickR geotags – where it is unclear whether the location given is of the object photographed or the actual location of the photographer. Using the approach presented here, it is possible to discern the difference between the two. We argue that such visualisations have broader application in terms of modelling the visibility of the city and lend themselves to measures of city aesthetics.

5 Acknowledgements

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7 Software

- Custom C#.NET application for modelling visual magnitude
- PostgreSQL + PostGIS + Quantum GIS for data storage and analysis
- ESRI ArcGIS for final map production
- Microsoft Visio for final map layout

8 Data

- OS Master Map
- DSM and DTM (from LIDAR data) from the Environment Agency
- OpenStreetMap
- Gazetteer for Scotland

9 Map Design

- A pedestrian accessible layer was created using OS Master Map data, these were the roads, pavements, open spaces, but excluding building roofs, rail and water regions not considered accessible to the general population.
- 75,000 random viewing locations within the pedestrian accessible area were created.
- The visual magnitude for all visible objects from each viewing location was calculate. This resulted in Figure 2 which shows how much of the city (including vertical extent of buildings) can be seen.
- In addition to generate visual magnitude maps for selected tourist site, the top tourist sites were selected from the Gazetteer for Scotland. Each site region was defined and the contributing OS Master Map polygons were recorded in a database table (eg Edinburgh castle consisted of 326 polygons).
- The visual magnitude of each polygon was calculated and summed to form a combined visual magnitude for each site, from each of the 75,000 viewing locations. This was performed using a custom C#.NET application.
- The output datasets for each tourist site were saved as CSV files recording Façade and Perceived Visual areas and loaded into ArcMAP to overlay on a base map

sourced from OpenStreetMap. These maps were exported as TIFs from ArcMAP and loaded into Microsoft Visio.

- In addition another custom C#.NET was written to access the FlickR API and extract all georeferenced images within the study region. These were loaded into PostgreSQL (with PostGIS) and the tags were filtered for each site name with tolerances for misspelling through the use of trigrams. The resulting files were visualised and exported using QGIS, before being loaded into ArcMAP as Shapefiles, overlaid on the OpenStreetMap base layer and exported as TIFs.
- Text, titles, annotations and final page layout were carried out in Microsoft Visio, with the final output exported as an Adobe PDF.