Using the ‘Subtracto-Silhouette’ parametric view-shed method in structure planning and architectural design

Marcus White
Faculty of Architecture, Building and Planning, University of Melbourne, Melbourne, Australia
Email: mrwhite@unimelb.edu.au

Abstract. Significant building silhouettes and city skylines are an important part of urban composition and contribute to a city’s identity. Pressure to accommodate higher population densities in the form of tower developments can threaten these silhouettes. This paper discusses a parametric view-shed design method for setting height restrictions or maximum building envelopes that maintain culturally significant silhouettes whilst allowing high density urban development. I describe the process of using digital special effects found in animation software reconfigured to create three-dimensional maximum planning envelopes. The technique called ‘Subtracto-Silhouette’ uses animated particle systems (normally used to simulate explosions), ‘shot’ from a specific viewing position, traced through vertices of a key building’s geometry, intersected with an extruded site boundary to create an envelope. Inside this envelope, a developer can build anything without affecting the silhouette of the building in question from the key viewing position. I demonstrate the ‘Subtracto-Silhouette’ technique by describing two case studies. Firstly I discuss input into a planning amendment for the City of Stonnington Forrest Hill Precinct in South Yarra in Victoria, where a three-dimensional planning envelope was generated to protect an historic silhouette of the adjacent Melbourne High School. The second study is an architectural proposal for the Flinders Street Station design completion where I show the technique used in both a preservation as well as generative manner. I discuss the results of the technique applied on both case studies, demonstrating its effectiveness in policy development with the resulting Amendment C58 for Forrest Hill and show how it can be used as an integrated part of schematic design process in the Flinders Street Station proposal.

Keywords: preservation, visual integrity, urban modelling, silhouette, skyline, view-shed.

Introduction

Cities can be understood as part of a visual culture through their skyline and formal composition (Lynch, 1960). Significant building silhouettes and city skylines are an important part of urban composition and contribute to a city’s identity (Oktay, 2002; Ford, 1998). Until the 20th century, key civic building silhouettes announced themselves on the skyline (Bluestone, 1988) be it library dome, gothic church spire or minaret, contributing to a visual representation of the accumulation of historic, social, cultural and economic structures of a city over time (Guney et al., 2012b).

The importance of size, shape and placement of these key civic buildings was amplified during the Renaissance when the relationship between graphic representation and composition intensified. Renaissance designers’ new understanding of the perspective drawing technique (Alberti et al., 1804) led to the city being represented with more accuracy as a whole, which influenced public understanding of the city skyline and urban composition (Cuthbert, 2003). In the second half of the 16th century, the general circulation of perspective representations of cities led to the urban realm becoming a collective concern within European cities – “perspective, the tool used to create these images was subsequently and
continuously employed for the rectification of urban settings” (Benevolo, 1995). Consideration was given to urban composition in terms of skylines and street networks that emphasised vanishing points (Bacon, 1967). Both the axial boulevards of the Beaux-Arts movements and the compositional landscape of the picturesque movement of the 1700s were influenced greatly by perspectival composition techniques (Field et al., 2013).

In cities today, the urban skyline is still an important part of legibility and composition and is also an extremely important component of tourism – the `image of a city' impacts on its potential as a tourist destination (Lim and Heath, 1994). Many cities throughout the world are currently experiencing the challenge of maintaining an historic `image' skyline or silhouette, facing difficulties reconciling conservation and development (UNESCO, 2013). With rapidly increasing urbanisation (Major Cities Unit, 2012) and a greater understanding of the relationship between transport, density and sustainability (Newman and Kenworthy, 1999; Newman et al., 2009), there is great pressure for cities to grow vertically. Cities need to accommodate higher population densities in established, well serviced, inner urban areas often in the form of low rise or high rise tower developments. These forms of development may be considered more sustainable environmentally (Newman, 2006) and financially (O’Hara, 1997) but can threaten city skylines or historic building silhouettes which may be considered an important part of social or cultural sustainability. Therefore, there is a growing need to protect the views to and from many cultural heritage properties (UNESCO, 2013) in numerous cities throughout the world.

This study aims to produce and test a new parametric view-shed design method for setting height restrictions or maximum volumetric building envelopes that maintain culturally significant silhouettes while allowing high density urban development. The study provides a brief background to the silhouette preservation issue discussing international and local examples. It outlines a description of the development of the new silhouette envelope generation technique and how it differs from other current practice methods. It presents two case studies, the first exploring the application of the technique in a planning legislation context, and the second describing the application to an architectural building design proposal. Finally, the paper assesses the effectiveness of the technique, limitations and its potential for further development.

Protecting `visual integrity' of world heritage skylines and silhouettes

The background paper prepared by the World Heritage Centre with inputs from ICOMOS, ICCROM and IUCN for the WHC International World Heritage Expert Meeting on Visual Integrity held in March 2013 in Agra, India, introduced the term ‘visual integrity’ stating that it “may pertain specifically to vistas, panoramas, viewpoints, and silhouettes”. The paper notes that visual integrity is “frequently considered a crucial element related to the preservation of cultural and natural World Heritage sites” (UNESCO, 2013). The paper cites the Operational guidelines for the implementation of the world heritage convention, describing the use of planning `buffer zones' to protect `visual integrity' or `important views':

For the purposes of effective protection of the nominated property, a buffer zone is an area surrounding the nominated property which has complementary legal and/or customary restrictions placed on its use and development to give an added layer of protection to the property. This should include the immediate setting of the nominated property, important views and other areas or attributes that are functionally important as a support to the property and its protection. The area constituting the buffer zone should be determined in each case through appropriate mechanisms. Details on the size, characteristics and authorized uses of a buffer zone, as well as a map indicating the precise boundaries of the property and its buffer zone should be provided in the nomination. (Cultural and Heritage, 1995)

The paper further describes specific examples where heritage views or silhouettes are threatened and their recommendations for preservation methods. Among the 13 examples discussed, the historic centre of Vienna (Austria) is described as being threatened by a development known as the Wien-Mitte Urban
Development Project. The World Heritage Committee threatened to remove Vienna from the World Heritage List unless a “comprehensive visual impact assessment” report was produced to provide evidence that views “of and from the area were not impacted” (Decision 26 COM 21B.35).

Another example, the Guia Lighthouse in Macau, China, has similarly been threatened by high-rise development with towers obscuring the view of the lighthouse from the sea “undermining the very function and character as a landmark of the city” and from the Monte Fortress to the West. To combat the potential impact of this development, the Macao SAR Government setup height restricted ‘buffer-zones’ surrounding the building. Though this action is praised, there is some doubt about the effectiveness of height restriction buffer zones due to the complex topography of the site concluding a “reactive monitoring mission to the property is necessary to determine the appropriateness of these new regulations with respect to future possible development proposals” (UNESCO, 2013).

A performance based method of control is described in the example of the Cologne Cathedral (Germany) where a visual impact study carried out by the University of Aachen identified the ‘classic’ view of the cathedral which was relatively intact and should be protected but also identified various ‘everyday citizen’ viewpoints which should also be protected through limiting development. A method for testing the performances (visual impact) of potential developments was developed by the Institute of Urban Design and Regional Planning at the University of Aachen. This involved:

overlying of [photographic] data with a digital computer model, which was generated with laser scan recordings, so-called scatter-plot, planned constructions can be visualized realistically and with millimeter precision. Through referencing these visualizations to earlier examination steps, it is possible to substantiate precisely, to what extent urban and landscape scenery is altered by the planned building activity (Kloos, 2012).

Melbourne examples

The issue of historic silhouette preservation is not limited to ‘ancient’ cities; Melbourne, Australia shares this concern. In the 19th century, Melbourne’s skyline was dominated by civic buildings, but like most cites, through the second half of the 20th century, the dominance of civic buildings was overtaken by increased prominence of commerce and the development of office towers (Dovey, 1992). Though height limits were proposed in Melbourne at various stages of the 20th century, for example to restrict building heights within the CBD to 40 m (El-Ghul and Ghanimeh, 2010), these restrictions have been relatively unsuccessful.

![Figure 1. Photo of the Shrine in the 1930s (LHS), and photo taken in 2006 (RHS). Note the absence of buildings in the background due to the preserved silhouette.](image)

There are, however, two key legislative regulations that have made an impact on the Melbourne skyline with respect to historic vistas/silhouettes: The Shrine of Remembrance (war memorial) (Burry, 2010) and St Paul’s Cathedral. The Shrine of Remembrance was built between July 1928 and November 1934 in memory of the men and women of Victoria who served and died in the Great War of 1914–18. The Shrine has been protected since the passing of the Shrine of Remembrance Act in 1978, with various master plans for the area over the years, all protecting the historic silhouette that can be seen when looking down St Kilda road to the South (Fig. 1).
The other important protection of historic vistas in Melbourne has been characterised by the highly publicised St Paul's Cathedral/Federation Square ‘Shard’ controversy (Mitsogianni, 2000, MacMahon, 2001, Dovey, 2005). In 2000, the Victorian State Government commissioned a report on the effects of the proposed Federation Square development. The report concluded with a recommendation that “the heritage vista of St Paul's Cathedral southern façade and complete silhouette should be preserved and protected in perpetuity” (Treasurer, 2000). This led to a redesign of the ‘Shard’ building so it did not interrupt the view or the silhouette of the Church (Fig. 3).

These two Melbourne examples of regulations to restrict development to protect heritage silhouettes or vistas are based on performative restrictions. The performative restrictions state that a particular viewing position is privileged and that new development cannot detract from the heritage value of this particular view. Both of the examples discussed above have been difficult to communicate and enforce and consequently have been surrounded in controversy, particularly the example of Federation Square (Brown-May et al., 2005).

The onus is placed on the architect and developer to design potential buildings on impeded sites, test the design’s impact on the silhouette using physical modelling or 3D digital models, then alter their design in a ‘trial and error’ manner. This trial and error process is made more difficult as no publicly available digital city model is available that has the kind of millimetre accuracy described in the Cologne example discussed earlier or that described in the Vilnius – Lithuania Management of Visual Integrity of the Historic City Centre paper (UNESCO, 2012).
Method: the ‘Subtracto Silhouette’ technique

This section of the paper explores an alternate method for analysing and generating volumetric permissible envelopes using a parametric ‘view-shed’ design method. The technique is demonstrated by discussing two case studies. The first case study describes the application of the technique to inform planning envelopes for an inner urban Melbourne council. The second case study describes the technique applied as part of an architectural proposition for a prominent inner Melbourne site.

In order to provide unambiguous volumetric restrictions based on a silhouette for either a city skyline or historic building as an alternative to performance base criteria, a method was needed for modelling the urban scenario. This included setting up perspective view positions and being able to extract silhouette lines that could be used to generate a height restriction envelope.

Skyline extraction and analysis has not usually been available in current GIS functionality (Guney et al., 2012a) and, where it has been used, it has been a raster based (digital elevation model) analysis lacking the required architectural level of detail for this particular form of analysis. Relatively recent developments in GIS programs have expanded this functionality to be able to assess mesh geometry such as the ‘Skyline tool’ within the 3D Analyst™ add-on extension to the latest version of ESRI’s ARC GIS 10™ (Biology, 2012). This add-on allows for the assessment of ‘view-sheds’ within the GIS model with a potentially wide range of applications such as military airspace modelling (Shephard, 2010), visualising terrorist sniper hazards (VanHorn and Mosurinjohn, 2010), and environmental sensitivity visual analysis modelling (Shephard, 2010; Kim et al., 2004).

This research was conducted within architectural practice without access to ARC GIS with additional 3D analyst software and was preformed prior to the release of ESRI’s ‘Skyline tool’. For this reason, a technique a call ‘Subtracto Silhouette’ was developed. This works within Autodesk’s 3dsMax™ animation software, which is common within architectural practice for modelling and rendering. The technique involves five steps to create a maximum envelope for a particular site so as not to impact upon a historic silhouette.

The first step involves creating an accurate digital model of the historic building with particular care taken in the modelling of the upper elements of the building such as ridge and parapet heights. Survey data or 3D scanned point cloud data can be used in this step but must be converted to simplified polygon meshes for best results (Fig. 4 L).

The second step is to extrude the perimeter boundary of the site in question to a nominal height to create a site’s potential maximum envelope prior to silhouette consideration. This creates a solid mass higher than the expected maximum height for the site, from which the silhouette is then subtracted (Fig. 4 R).

*Figure 412. Digital model of existing historic building (LHS). Development site boundary extruded to create a site envelope (RHS).*
The third step is to set up a camera within the digital model in the exact position designated to be the point at which the silhouette should be preserved. The decision for choosing a particular viewing point may be straightforward and based on a particular historic photograph or may be the result of community consultation or a heritage report (Stonnington, 2005). Depending on how this point is chosen, a camera is created in the scene and moved to position (XY) as well as height (Z) to match a specific georeferenced coordinate. If a silhouette from an historic photograph is to be preserved, the ‘camera-match’ utility can be used to accurately match a digital camera position to a physically taken photograph.

The fourth step involves an animated particle system (normally used to simulate explosions), which is parametrically linked to the specific viewing position, used to generate particle rays that move from the eye (camera) position through each of the corners (vertices) of the historic building then an marker point (X,Y,Z) is left where the particles intersect with the site in question’s extruded volume (Fig. 5R).

The fifth and final step involves these points being used to generate a surface which, in turn, is used to subtract the geometry above the silhouette line (Fig. 6). This process creates an envelope, inside which a developer can build anything without affecting the silhouette of the building in question from the key viewing position.

**Case study 1: Melbourne High School**

As part of the Chapel Vision Structure Plan for the Melbourne suburbs of South Yarra and Prahran, an analysis of potential future development adjacent the historic school was undertaken. The heritage report
produced by Bryce Raworth Pty Ltd. Conservation recommended that the view of the school from the corner of Yarra Street and Alexander Avenue should be retained unimpeded by development – ‘the castle hill view’ (Fig. 7). Due to its form and castled parapet, it was considered that the ‘visual perception of the ridgeline against the sky is indeed a defining feature in an appreciation of the siting and prominence of the 1920s building’ (Keaney, 2008) and the building’s silhouette should be preserved. Any development to the east of the school must therefore be restricted in height (MGS, 2007).

To work out the permissible heights, the Subtracto-Silhouette technique was employed (Fig. 8 and Fig. 9). The resulting envelope maximised the potential yield of adjacent sites while ensuring the heritage silhouette is protected.
Figure 9. Particle rays projected from camera intersecting with site boundary planes, leaving intersection marks used to generate ‘maximum permissible envelope’.

The proposed envelope was incorporated into the planning report (MGS, 2007) and has been presented and approved by the Stonnington City Council having also successfully undergone a public consultation process. The building envelope described using this technique became part of the structure plan for the City of Stonnington resulting in changes to the planning scheme with Amendment CS8 (DPCD, 2009) and Schedule 8 To The Design And Development Overlay DDO8 Forrest Hill Precinct (Stonnington, 2009). The technique has proven to be as accurate as the surveyed digital model and can be tested by checking with independent 3D cameras.

Thus far the technique has withstand the scrutiny of a Civil Court challenge by developers but remains a contentious issue (Keaney, 2008). The preservation silhouette form remains as a restricting condition on development sites adjacent the Melbourne High School, though there is scope in the regulations for this silhouette to be interrupted if an “architectural solution can be demonstrated as to be suitable high quality and have minimal visual impact upon the view” (Keaney, 2008).

Case study 2: Flinders Street Station competition entry

The second study is an architectural proposal for the Flinders Street Station design competition where the technique was used in both a preservation as well as part of the form finding design process. In March 2012, Victoria’s then Minister for Major Projects, Denis Napthine, announced the State Government’s intention to hold a design competition for the renewal of the Flinders Street Railway Station in Melbourne, Victoria. The competition’s briefing documents outlined challenges for the site such as the expected doubling of transport patronage in the next decade; the need to improve integration with surrounding precincts such as Federation Square and the Yarra River; and restore areas of the heritage-listed existing building (Victoria, 2012c). One of the competition’s critical objectives listed in the Statement of Key Objectives briefing document stated that the “new building forms must maintain important view lines of significant landmarks on the station land such as the main dome” (Victoria, 2012b).
This sentiment was reinforced in the competition submission requirements which explicitly stated the importance of the historic ‘post card’ views of the railway station:

The dome, Elizabeth Street clock-tower and frontage to Flinders Street form the ‘iconic’ view of the station. New development must not be sited within close view of, and must minimise impact on, views of these elements and open sky behind (Victoria, 2012a).

Another requirement was that each competition entrant must produce a rendered perspective view from eight chosen view points, one of which was the ‘postcard’ view of the main dome (Victoria, 2012a).

As in the previous case study, the Subtracto-Silhouette technique was applied to generate a maximum envelope to directly respond to the preservation of the iconic silhouettes of the existing heritage railway building. This application differs from the previous project in that the technique was used multiple times simultaneously for different important silhouettes (including the dome ‘postcard’ view and the historic Sandringham rail link view) (Fig. 10). The technique was also undertaken concurrently with a series of other subtractive processes which directly informed an architectural form generation. Other subtractive processes included: the solar access preservation technique discussed elsewhere (White, 2012); structural optimisation in response to railway infrastructure location and potential structural placement, internal planning/internal light optimisation; and the introduction of a light rail connection on a secondary eastern concourse utilising a re-activation of the Sandringham Bridge to service the Fisherman’s Bend development. These subtractive design aspects along with the many other design considerations will not be discussed in detail in this paper. However, it is worth noting that the Subtracto-Silhouette process was highly integrated into a design process which involved a great number of other design considerations.

Figure 10. Camera position matched to ‘post card’ view of Flinders Street Station entry and dome. Subtracto-Silhouette process applied.
The resulting geometry of the process creates an architectural form that does not impact the historic view. The resulting architectural envelope (Fig. 11 and Fig. 12) is formally expressive with the design process clearly legible from views other than those designated as heritage views. As one moves away from the designated preserved views, the new architecture is revealed, with a dynamic relationship between the old and the new.

**Figure 11.** The resulting geometry of the process creates an architectural form that does not impact the historic view.

**Figure 12.** Aerial view showing resulting architectural form in the urban context of Melbourne.
The proposal directly responded to key aspects of the brief, creating a variety of spaces to suit a diverse set of programmed uses. The form allows for a large area of new development with over 40,000m² of new floor space within an important central location in Melbourne without detracting from the historic architectural qualities of the existing 19th century buildings and urban morphology as demonstrated in the rendered perspective view of the dome (Fig. 13).

Discussion

The technique and case studies

The Subtracto-Silhouette technique has been demonstrated to be a flexible method for generating envelopes to protect historic silhouettes. The technique is rapid to apply, particularly when compared to performance based methods of trial and error modelling and allows designers and policy makers to test potential implications of volumetric heritage overlay strategies in both a large scale on numerous sites at a structure planning level and at a micro scale of individual buildings.

The technique can be used as part of policy development as illustrated with the City of Stonnington’s Amendment C58 for Forrest Hill case study but also how it can be used as an integrated form-finding component of the design process in the Flinders Street Station proposal.

The case studies illustrate the important relationship between buildings and the broader urban context, where buildings on a single site can dramatically influence the reading of a city and policy and design decisions can either enhance or detract from a heritage reading.

Urban densification maximisation and links with picturesque

The technique described shows how it is now possible to balance one particular visual aspect of heritage (the silhouette) with densification in urban settings. In both case studies, sites were maximised in terms of potential yield while not losing the heritage qualities of urban space or detracting from civic formal gestures of important heritage buildings and skylines. The technique also allows the co-existence of old and new urban fabric, setting up a non-static hierarchy where the relationship between the old and new changes dynamically as a person moves through the city. At some vantage points, only the old is visible, in some points only the new is visible, and at some points juxtaposition of old and new occurs.
This relationship between the viewing location or ‘vantage point’ and the heritage view has striking similarities with the picturesque movement of 1700s which was mentioned earlier. Picturesque landscape designers such as Capability Brown and Uvedale Price used the projected perspective views as a compositional tool informing their landscape plans (Broglio, 2008). Key moments along a path were chosen as viewing points where one would dismount from their horse and view the intended perspective composition of the estate. In the contemporary projects described in this paper, instead of the spectator being the English ‘leisured class’ showing off their designed estates to colleagues during horseback ‘pleasure rides’ (Clark, 2004), the spectator is the general public. Instead of the composed view being an artificial composed rural landscape, the view is the protected heritage building and skyline within a dense gridded cityscape.

Other aspects of urban morphology

It should be noted that although the technique was useful in the demonstrative case studies, the envelope generation technique is limited in relation to considering other morphological aspects when designing buildings or urban design guidelines near heritage or significant buildings. In addition to important views and silhouettes, there can be many other aspects which can include visual and non-visual aspects (UNESCO, 2013). Function, materiality, formal articulation, colour and detailing might be considered important when assessing visual impact, particularly in cases where scope in the regulations allow for silhouette to be interrupted if a suitable ‘architectural solution’ can be demonstrated such as in the first case study (Keaney, 2008). However, a key advantage of the technique is the fact that the modelling all takes place within a 3D visualisation program which is capable of testing many other assessment criteria such as material or colour contrast, formal articulation and shadows at different times of day.

Further development

The technique and the case studies outlined in this paper suggest the potential usefulness of the method within the architecture and urban design disciplines. The effectiveness of the technique warrants further development to take it from a ‘step by step’ process requiring a highly skilled CAD operator, to a user-friendly design tool with a simple graphic user interface. The tool could potentially be developed as a software ‘plug-in’ for a variety of CAD programs such as Autodesk’s 3dsMax™, Maya™, AutoCAD™ and Trimble’s Sketchup™.

This research suggests the potential application of the technique on other sites within Melbourne and other cities internationally. As noted earlier, many cities throughout the world grapple with increasing urbanisation and urban densification, while seeking to protect existing heritage buildings and skylines. The technique may also be useful in the design of new cities which may have natural topographical heritage features that may need to be protected both environmentally and visually. New cites might also incorporate new civic urban gestures which can relate to placemaking strategies or ideas of social, environmental and cultural sustainability.

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