RULED SURFACE MEDIA FACADES

Using ruled surface principles for developing and designing non-standard media facades

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Abstract. Traditionally media facades have been created using 2D surfaces, not dissimilar to televisions. As computational architecture continues to explore non-Euclidian shapes it is a logical process to investigate the use and possibilities of emerging complex curved surfaces for the display of media content to match architectural design aspirations with demands of ubiquitous city concepts of penetrating surfaces with information. Drawing on existing architectural knowledge of ruled surfaces the paper outlines the implementation of adopting existing principles from architecture and mathematics to contemporary discussions in media architecture. It demonstrates that ruled surfaces can function as media facades by simulating ten different ruled surface types in Grasshopper and overlaying them with different video content. Based on the results the team proceeded to build a 1:1 prototype of a hyperbolic paraboloid to test if the simulated results in the computer matched with the physical model. The prototype was further tested using media content to observe the visibility of the display from various viewing positions. Based on the findings the paper concludes that ruled surface media facades are feasible. This investigation, its proposed hypothesis, methodology, implications, significance and evaluation are presented in the paper.

Keywords. Media facades; responsive architecture; ruled surfaces; non-Euclidian spaces.
1. Introduction and outlining problem

Traditionally, media facades and large screens have been created using 2 dimensional flat surfaces, similar to television sets. The argument for mainly flat screens is demonstrated by the project selection published in *Media Facades – History, Technology, Content* (Haeusler, 2009) where all 36 but one projects, the Kunsthaus Graz, Austria are either flat surfaces or singular curved surfaces. This is particularly the case when using LED technology; a technology the paper concentrates on (and excludes projection facades as these ‘project’ on a façade instead of using a light source that is part of the façade and thus the complexity of the façade) as it is shown to be the most promising technology, as discussed in the above book.

The reason for primarily utilising flat media facades becomes obvious when analysing LED technologies discussed in Haeusler’s book (2009). Here three out of five technologies (SmartSlab, Mediamesh and Illumesh) are not suitable for curved screens or are only suitable for singular curved surfaces when altering them to a large extent. The two remaining presented technologies (Stealth and MiPix) have the potential of designing singular curved media facades without significant alteration, but none of the projects that use Stealth and MiPix technologies are double curved surfaces. A more recent publication on media facades (Haeusler, et. al. 2012) raises the importance of considering complex curved media facades as a field of interest in the discussion. Haeusler et al. (2012) explains why architecture is able to build non-Euclidian spaces with traditional materials, but not with media façade technologies when he states:

> Whereas most architectural materials such as wood, steel to name but two can be cut into any shape via laser cutting or CNC milling techniques this is not possible with most existing media facade products that come in a rectangular shape and can not later be cut into the required size. (Haeusler, et. al., 2012)

Arguably there are other publications discussing media facades and architecture but these are primarily situated in an HCI or media cultural field of enquiry (Dalsgaard, Halskov, et. al). In the context of the CAAD community the paper wants to concentrate in the following on papers in an architectural field of enquiry. As computational architecture continues to explore further non-Euclidian building shapes it is a logical process to investigate the use and possibilities of emerging complex curved surfaces (topological architecture) for the display of media content (media architecture) to match architectural design aspirations with the demands of ubiquitous city concepts of penetrating surfaces with information. Initial interest in combining topological architecture and media architecture dates back to the mid 1990s when Ste-

Perrella discussed media architecture as "an attempt to manifest information space," which would "bring the vitality of the electronic sign into the surface of architecture," as well as "establish an infrastructure for hypersurfaces only without its material aspects." (Perrella, 1998) Realized projects in the mid 1990s like the Saltwater/Freshwater Pavilion by Kaas Oosterhuis and Lars Spuybroek were projects that could be seen as precursors for the field of enquiry, yet they used projections instead of LED technology due to the cost and limitation of LEDs not being in full color at the time (Simpson, 1991). Contemporary LED technology developments such as curveLED or X-LED outlined by Haeusler et al. (2012) suggests that these technological challenges in the mid 1990s are no longer an issue and

Several projects around the world demonstrate the end of these initial struggles that designers and developers of non-standard architectural surfaces and media facades were facing. (Haeusler et al., 2012)

X-LED and curveLED are very specific technologies similar to CNC-routed concrete formwork in comparison to standard flat panel formwork and making these media façades is very cost intensive. When considering the comparison between CNC-routed formwork and planar formwork and searching for examples in architectural history where designers developed non-Euclidian spaces, the Catalonian architect Antonio Gaudi comes to mind. Gaudi used ruled surfaces methods to develop buildings such as the Basílica i Temple Expiatori de la Sagrada Família (Sagrada Familia) in Barcelona, Spain. Burry et al. (2008). Burry discusses in his research and work on the Sagrada Familia the role of ruled surfaces. This paper seeks to adopt that knowledge and combine it with the quest to investigate whether or not complex curved media facades can be realised using ruled surface principles.

2. Research question

Observations in contemporary architecture are formed on buildings realised by Hadid, Gehry and others; scholarly debates in CAAD conferences; advantages of building complex forms out of flat or straight materials; recent advancements in LED technology; theoretical underpinning through the Hypersurface Architecture theory; and current interests in ubiquitous cities. Through these observations, the paper wants to argue that a research interest in complex curved media facades exists. The use of ruled surface principles is demonstrated in research by Burry et al. not only on Antonio Gaudi but also architecture and mathematics. Hence the research presented in this paper aims to consider and answer this key question:
Can media facades be built on ruled surface principles and if so which ruled surface type is the most suitable one to communicate media content and what knowledge for architecture and urban design could be drawn out of it?

3. Methodology

Drawing on existing architectural knowledge on ruled surfaces and mathematics in architecture (Burry, Burry, 2012); mathematical understanding of ruled surfaces (Edge, 1931) in particular paraboloids, hyperboloids, hyperbolic paraboloids, helicoids and conoids; and technological background in media facades (LED and content control software) (Haeusler et. al, 2013), the discussed prototype investigation applies action research and user-centered design as an overarching method for the development of the case studies. In order to answer the key research question, a series of form studies have been conducted to evaluate the ideal six surfaces to further investigate in a virtual environment (Hyperbolic Paraboloid; Hyperboloid of one sheet; Hyperboloid of two sheets; Helicoid; Oloid; and Right Conoid). These six surfaces were then examined by displaying six different media content, which were generated through a Grasshopper for Rhinoceros script to observe if the media content is visible from various positions. Based on these findings and material considerations a 1:1 hyperbolic paraboloids prototype was built to test and to compare the findings in the computer with the physical 1.5sqm prototype. The prototype used AHL s18 LED technology mounted into linear cable conduits to develop an installation using ruled surface principles and is able to communicate content through the LEDs at the same time.

4. Background research

Ruled surfaces are defined in detail in The Theory of Ruled Surfaces by Edge (1931), for the purpose of this paper and to provide a general definition,

In Geometry, a surface S is ruled (also called a scroll) if through every point of S there is a straight line that lies on S. (Wikipedia Ruled Surface, 2013)

In continuing with Wikipedia, "examples of ruled surfaces are given these include the plane and the curved surface of a cylinder or cone." Naturally these ruled surfaces are not in the interest of the discussion of this paper, as they exist already as screens, but others listed in the following. Of particular
interest are doubly ruled surfaces, where "through every one of its points two distinct lines lie on that surface." (Wikipedia Ruled Surface, 2013)

*Ruled surfaces in architecture* are subject of the work of the previously mentioned Gaudi, in particular his work on the Sagrada Familia in Barcelona, Spain (Burry, 2008). Another notable designer is the Russian architect Vladimir G. Shukhov (1853 – 1939) whose designs used hyperboloid structures amongst other structures. (Goessel, P.; Leuthaeuser, G.; Schickler, E.; 1990) Here in particular the *Water Tower* in Polibino, Russia built in 1896 and the Shukhov Towers in Moscow (1920-1922) and in Nizhniy Novgorod (1927-1929) are notable (Graefe et al., 1990)

*Media facades* discussed in an architectural context are the topic of recent conferences (Media Architecture Institute, 2013) where projects and developments were discussed alongside the presentation of contemporary projects. Here the first steps have been made towards a classification and definition of media facades. Knowledge about media facades was drawn from the conferences and literature review. (Haeusler, Tomitsch, Tscherteu, et al.)

**5. Building a ruled surface media façade prototype**

The following research findings are concluded in regards to the implementation of adopting existing principles from architecture and mathematics to their application for contemporary use in media architecture and specifically curved media surfaces as outlined above. The Hypothesis is realised through the construction and testing of a series of ruled surfaces embedded with media imagery under set conditions. These are validated through the fabrication of a prototype providing a proof of concept.

*Conceptual Model.* To generate a conceptual model, the main testing environment for the purposes of this research was done using virtual 3D modelling software. The advantage of using virtual models is to maximise the accuracy of the build whilst giving flexibility for adjustments to the models. Creating virtual models minimises costs by mitigating the risks of making expensive mistakes that may otherwise occur when building physical models. In order to validate the virtual models, a physical model needs to be constructed to confirm the feasibility of the conceptual modelling. This acts as the proof of concept for the conceptual model.

*Grasshopper* for Rhinoceros was used to create the surfaces in their 3D forms as conceptual models. Scripting allowed the models to be parametric in form and thus easily adjusted to specific requirements and controls to fulfil project demands.

*Ten different ruled surfaces* were researched in a first iteration in a virtual environment (See Figure 1 below). A set of parameters was setup to main-
tain consistency in testing the various selected ruled surfaces in the virtual environment providing an accurate comparison study. Furthermore, these parameters were applied to the physical prototype model for compliance in testing for proof of concept.

- Rulings are represented by straight lines, LED pixels as spheres
- Number of rulings per façade = 30 and Length of ruling = 1.5 m
- Number of pixels per ruling = 30
- Resolution = 900 pixels (30 x 30)
- Pixel Pitch = 5cm

These parameters were chosen based on the research and background findings, as well as in consideration of building a true physical model to afford the proof of concept. The plane was considered as standard geometry for media façades and thus was used as a control to demonstrate atypical behaviour of the application of imagery. Thus if the parameter set holds true to expectations then those parameters are viable for testing on curved surfaces.

Form studies. In order to gain a better understanding of the forms and to draw first conclusions prior to modelling in Grasshopper, a series of bamboo sketch models were constructed. The following six geometries were chosen
due to their form, diversity of shape/ruling and/or prevalence in architecture, thus reducing the original eleven different surfaces by five. Based on the form studies the research team further decided to:

- Build one prototype (Hyperbolic Paraboloid) – chosen for the simplicity to build and being a form used in architecture. Thus leaving further form exploration to following research iterations.
- Use the bamboo sketch model as illustrations of other geometries, which may be also expressed as prototypes.
- Use 3D modelling to illustrate the ruled surface geometries and experiment with media façade surfaces in the virtual environment.
- Compare the results of the 1:1 prototype with the conceptual model to draw conclusions on the potential results of the other surfaces.

Media content was the next consideration after form studies. The research team did not want to make any statement with the images and videos chosen, thus selected simple, non-descriptive images. The chosen imagery for testing purposes was as outlined in Figure 3.

![Figure 3. Non-descriptive imagery used for testing the ruled surface media façade these are in detail (Left to right) Circle – a basic shape to test visibility; Arrow – a simple image to test for orientation of the image; Flower – a more complex image to test for details; Stop sign – a simple image to test for readability; Bouncing balls video – a simple clip/live video to test moving imagery; and Webcam – to test for real-time interaction.](image)

Images and videos had a 30 x 30 pixel resolution to match number of LEDs, resolution being the number of pixels per square unit and is equal on the x and y direction. In comparison a high definition picture is 1920 x 1080 pixel. Despite the comparatively low pixel number used in the prototype, research has shown that content can be perceived on low-resolution facades. To give a comparison the Kunsthaus Graz listed earlier has a total of 930 pixels (fluorescent tubes) and is able to communicate various forms of content (Haeusler, 2009). The team used the Grasshopper plugin Firefly for overlaying image information onto the various ruled surfaces, but had to learn that the minimum aspect ratio of Firefly is 40 x 30 pixels. After some experimentation it was decided to run the video at the same 30 x 30 pixel ratio and expect a quarter width section of the video not to display as on testing it only cut rather than distorted the image. It was concluded the application of un-
distorted moving imagery on the surface was sufficient investigation for scope of the project. From observations, it may be assumed that high-resolution displays will produce significantly improve results in readability. Using a relatively low resolution should result in baseline results on which a ruled surface media display may be improved and refined.

Testing images on ruled surfaces were undertaken by recording the images from different angles and distances to gain an understanding and results regarding the attributes of curved surfaces as media displays. Each of the ruled surfaces was tested for an optimal viewing angle from which to explore a series of media properties. The optimum orientation chosen is based on the angle, which provides the maximum visibility and readability of a basic image. The surfaces are 3D and therefore it is expected that not all of the image can be seen from any one particular angle. Therefore where an image is easily identifiable, except for the fact that only a portion of the image can be seen, then it is considered to be readable. The optimum orientation chosen for the surface is used to display various media properties.

The testing criteria of the media properties were chosen for the potential viability of a variety of media on the ruled surface. The following questions were used to equally evaluate each result.

- Visibility – can an image been seen?
- Orientation – can the orientation of the image be identified?
- Complexity – can a complex image be identified?
- Readability – can text be read?
- Moving image – can a moving image be portrayed?
- Real-time – does the surface support real-time interactivity?

6. Results and implementation in prototype

The results of the study of ruled surface media facades and content in a virtual environment are outlined at following:

<table>
<thead>
<tr>
<th>Table 1. Communication of results when testing six different rules surfaces (see Figure 2) with six different media contents (see Figure 3)</th>
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<tbody>
<tr>
<td>Hyperbolic Paraboloid</td>
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<td>Hyperboloid of 1- sheet</td>
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<tr>
<td>Hyperboloid of 2- sheet</td>
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<tr>
<td>Helicoid</td>
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<tr>
<td>Oloid</td>
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<tr>
<td>Right Conoid</td>
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Based on these foundations the research team started, for reasons outlined earlier, to build a 1.5x1.5m hyperbolic paraboloid prototype using 25x25mm cable ducts; a steel frame for support and stability; and 900 AHL s18 LEDs.

Figure 4. Set up prototype ruled surface media façade. From left to right: Finished LED ruling; ruling connection; cable management; LED test; and perspective of finished prototype.

The LEDs were controlled with an AHL controller unit and the content was visualised via the AHL Easy Player software. In order to draw conclusions of the virtual testing to the physical testing and thus to gain knowledge for built surfaces upon virtual testing the same viewing positions of the ruled surface media facade were chosen in both tests. The results of both testing are compared through the image series below.

Figure 5. Testing in virtual environment (top) and with prototype (bottom row) using both the same media content (Circle) with (left to right) front view; 45° to front; left; and right.

7. Significance and Evaluation

The study in this paper demonstrated that ruled surfaces are viable for media facades and that there are a multitude of curvatures would allow new media façade design solutions. This is significant as media facades will play a major role in realising a shift from a personal device to a public device (Weiser, 199x) and consequently communicate information of a Smart and Ubiquitous City to its citizens. When analysing buildings in Smart Cities like Songdo in South Korea, a large discrepancy was seen between design discussions
and form finding processes in computational architecture and what has been built. Without dwelling too long on the reasons for this discrepancy, the research team wants to argue that this study has made a first contribution in how computational architecture could communicate information through its building skin. Unfortunately not all questions could be answered within the scope of this research. The extent of this study raises questions into the possibilities of utilising anamorphic principles for the revelation at certain vantage points of a full image. The propensity for these surfaces to produce quasi-subliminal content to the public by way of ‘surprise’ revelation is worthy of further investigation, in particular in the context of urban interaction design. Here the ‘author’ of the interaction cannot always clearly identify on a flat screen where everybody sees the same. A ruled surface media façade with an anamorphic perspective might define a privileged position for only one ‘author’ and leave the rest of the screen for ‘surprise’ effects for others.

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References