A COMPUTATIONAL FRAMEWORK FOR THEATER DESIGN

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Abstract. This paper presents the results of an ongoing research on computational methods for the design of theatrical spaces. We demonstrate a systemic approach to design supported by a set of digital tools implemented for assisting the process. The primary purpose of the framework is to establish a formal basis for expressing and exploring explicit design criteria. At this stage the framework enables us to metrically access a range of design metrics that traditionally have been addressed through primarily architectural narrative. Moreover, our method strives in establishing a background where knowledge can be explicitly encoded and the results of analytical methods can be additively employed. In the future, the framework will assist as the platform for experimenting with generative or query-based design processes empowered by computation. We structured this paper / framework around three conceptual units: (a) a design intent toolkit assisting the processes of rapidly generating theater configurations; (b) an analytical system that evaluates a range of design metrics centered about aspects of visual comfort; and (c) a post-processing and visualization unit that binds the design metrics with existing data / studies and provide a range of representation methods. Overall, the methodology adopts existing knowledge in theatrical design, challenges traditional ideas of understanding the theater and proposes methods for evaluating its architectural performance. The conclusions focus on highlighting both the limitations and the potential of our system in the process of theater design. We also extend outside the boundaries of the current research into a brief discussion on the methodological impact of digital technology in architectural research. Finally we propose areas of future research and development.

1. Introduction

Digital methods have become the predominant mode of thinking in architectural research and design over the past decades. Their applications range from abstract form-finding to construction detailing and management. The success of a computational design method is in its ability to enable the architect to convey an architectural concept while gaining access and maintaining proximity to the pragmatic requirements and repercussions involved. Our research investigates computation in the context of theater design.

The field of theatrical design encompasses an extensive body of knowledge covering a broad and diverse set of expertise required for the successful design of both a spatial configuration and the human condition. This knowledge is captured by a typological and regulatory set of principles distilled from a wide range of theoretical studies, scientific contributions and built architectural precedents.

The domain of scientific computation and engineering has been involved with the auditory and lighting performance of theaters. Architectural computation is mainly concerned with their formal expression. We situate this research within the context of an informed investigation of architectural design through dynamic digital media that moves beyond its apparent form and addresses the internal dynamics of spatial configurations and their repercussions on human conditions.

The center of focus is placed upon a subset of the vast domain of the theater spatial design; namely, the design of the main theatrical space. We investigate the attributes arising from both its overall shape and elementary configuration and reflect in its performance in terms of visual comfort and spatial appreciation. Combinations of non-homogeneous analytic design metrics are employed for engaging with qualitative aspects of the theater space.

We developed programmatic and parametric tools for embedding into the system the traditional knowledge captured by analogue contraptions such as the sightlines diagrams. In this respect we attempt to establish a historical continuity and a common ground for communication. Moreover, we expanded this set of methods by introducing contemporary digital concepts and techniques. Those allow us to access a certain range of highly involved design metrics, such as spatial occlusion, visual accessibility and integration; all of which brings us in a position of revealing spatial aspects which was impractical to obtain in the past and may prove potentially valuable in the future developments of architectural design, computation and cognition.

2. Background

2.1. HISTORICAL EVOLUTION

The theater is a particularly interesting building type as its social and cultural significance overrides its primary function of being a place for the performance of arts. The theater becomes a built artifact that conveys a strong symbolic content about the cultural and social context of its time. Architecture of a theater thus is unique in that it is entrusted with the task of capturing this context and projecting it into the physical world.

Historical surveys reveal that the typology of the theater has been constantly evolving through time and studies explain how its configuration has been affected by a variety of factors ranging from economic to political. From Vitruvius’s Book V de Architectura to Michel Serres (1998), the architecture of theaters has been extensively discussed and analyzed. From the ancient Greek and Roman to the Renaissance theater (Scully 1991); a theater building has taken on a wide variety of forms as well as social meanings (Carlson 1989; Connor 2005).

2.2. PERCEPTION AND COGNITION

However, a theatron, (thea: the act of seeing), is also a thoroughly rational space designed with respect to a vast range of requirements (Ham 1972; Appleton 1996). A set of the most crucial of those is related to its performance towards the sensory perception of both its performers and audience.

The view to the stage is an “image” which has been opened to the gaze of the audience. Yet this image is far more complex than a two-dimensional representation, as it captures an audience's collective experience of the event, immersed in the architectural space. Every spectator is conscious of being part of an assemblage and part of an interface shared by both the audience and performers, generating a formal type of co-awareness. Co-presence, where visual access can be obtained among spectators, effects their visual spatial impression.

Scientists and philosophers have methodically studied the nature of visual perception in the past, and it is an active area of research involving many different disciplines, including cognitive science (Siegel and White 1975; Golledge 1992), cognitive psychology (Gibson 1950; Arheim 1969), neuroscience (McIntosh et al. 2004), computer science and artificial intelligence (Brooks 1984).

Visual perception of our surroundings is fundamental to spatial cognition and behavior. Sightlines are a key component of J. J. Gibson’s ecological theory of perception (Gibson 1979). He introduces the concept of “vistas” which he defines as the extended regions, semi-enclosures or sets of visible surfaces of a layout of environmental features that are presently visible. These surfaces operate as occlusion boundaries, as they obscure portions of distant objects (Nakayama et al. 1989). Our visual experience of the world is defined by this serial sequence of these limited views (Heft 1996). The visible surfaces in space and the occlusion boundaries have been described also by Benedikt's (1979) notion of the isovist: a visibility polygon that captures spatial properties generated by rotating a line of sight 360 degrees about a stationary vantage point. Various metrics can be obtained by the isovist such as its area, perimeter and distribution of the distance from the viewpoint to the perimeter. Those inform us about the degree to which these polygons are self contained or dispersed in space (Rana and Batty, 2004). Benedikt's initial measures are of interest to the space syntax theory (Hillier and Hanson 1984; Hillier 1996) and have been used as basic elements for the spatial analysis of geometric properties of spaces.

3. The Framework

The motivation for developing the present framework emerged from our involvement in various design exercises which gave us the opportunity to delve into the architectural background of theater design. This research begins with both an appreciation and a critique for the existing models for understanding and engaging with the design of the theater space as a built artifact. The goal is to expand both the expressive and analytical tools for the design of the specific and adjacent building typologies. We believe that this approach will empower the architectural design community in revisiting traditional ideas of what a theater design may and should be in the light of new technological advancements in design methodologies.

The methodology is influenced by of two primary considerations: (a) the incorporation of existing knowledge into a computational framework. (b) the investigation of novel quantitative design metrics and their implementation in interactive design tools.

The implementation of this framework is based on modular design principles. Specifically, we structured the computer applications around three conceptual units: (a) The Design Intent Module, (b) The Metric Analysis Module and (c) The Post-Processing and Visualization Module. We will be able to discuss the results of the framework's design in the evaluation section.

Technically, we developed a series of computational tools based on computer programming techniques. A computer software was developed in the C# programming language (from Microsoft). The modules are inter-operating with Computer Aided Design software for practically utilizing their graphical user interface and conceptually integrating within this contemporary version of the architectural drawing board. The original implementation was adapted as a tool-chain plug-in for the Generative Components software (from Bentley Systems). The prototypes were developed in the scripting environment of the Rhinoceros application (from McNeel & Associates). The integration and isovist analytical mappings were generated using the Depthmap (from A. Turner / UCL).

4. Design Intent Module

The design intent module provides a repertoire of expressive means for diagrammatically sketching a theater space. The module is composed of two parts: a) the stage definition and b) the seating arrangement. The conceptual decomposition in stage layout and seating arrangement falls from the split between the performers and audience. Even though in practice it is very difficult to design a theater space by considering seating and stage independently of each other, it is a preferable logical division. For instance, this separation allows us the flexibility of exploring combinatorial schemes based of different design concepts and functional requirements.

4.1. STAGE ARRANGEMENT

The stage arrangement can be abstracted by the archetypal dichotomy between polar and parallel layouts of the visual field towards it. The former captures the design intent for an omni-directional field pivoting about a central point of interest, while the later hints about a frontal parallel alignment towards the viewing plane of the proscenium. Historical developments, such as the perspective stage of the Renaissance, begins addressing the geometry of the stage as a three dimensional volume rather than a viewing point or plane. The system allows us to explore of both the nodal, planar and volumetric schemes encompassing a wide range of geometries. We tried to weaken the strong bond between the stage and the audience's spatial configuration by going back to the first principles of the stage's properties.

The most significant geometric aspect of the stage's physicality is its finite dimensions and their repercussions on the boundary conditions of both the performers and viewers. A good abstraction that captures this relationship is a convex bounding volume. The properties of this volume are directly related to the performance criteria of the space and the overall experience. A simplified volume such as a box or a frustum captures the general idea for instance. The convexity requirement is related to rather more complex volumetric arrangements, where only their “inner” convex-hull may be considered as the set intersection between the performers' and audience's visual interaction spaces. The analytical module requires this specification for performing various calculations. Conceptual components of the stage may then be extracted from or attached to this definition, such the proscenium plane, the rear stage plane, centers of attention etc.

4.2. SEATING LAYOUT

Reciprocal to the stage arrangement is the seating layout. The framework abstracts the seating layout by its geometry in order to enable interactive explorations of various alternative configurations and also prepare the groundwork on top of which the analytical modules operate. The design module is decomposing the seating layout in two conceptual parts: a) The general gesture related to the overall seating arrangement in conjunction to the stage. This refers to the main floor and configuration of the galleries. b) The micro scale of a seating layout is dictated by anthropometric aspects of a seated spectator and regulated by functional constraints such as the escape routes and circulation.

We can distinguish two fundamentally different seating topologies, a structured and an unstructured one. The structured layout is based on the idea of a biaxial network of seats which describes all rectangular, diagrid, radial and free-form geometries of a single sheet. This topology maps naturally to the concept of a series of seating rows independent of them being arranged in a concentric or a parallel configuration. In this fashion we may express the vast majority of existing seating layouts but we can also capture all of the variations of this scheme (Figure 2).

An unstructured layout is based on a discrete lattice, where the connectivity between seating nodes is arbitrary. This topology is better suited for either open theaters or experimental plays, where the seating layout is physically volatile rather than fixed on some built infrastructure. We may consider this topology as being more generic is this respect (Figure 1).

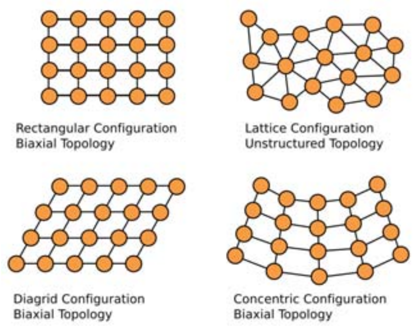

Figure 1. Structured and unstructured seating layout topologies.

The current implementation is based on the structured paradigm for implementation convenience. This simplifies the process of micro-scale exploration as it provides easy access to important geometric calculations such as seating connectivities. We are using a BSpline surface definition for expressing the general seating “scaffold” on top of which the actual seats are situated. This allows us to freely form the seating levels with out bounding their design to a deterministic “ideal rake” solution. Instead we will deffer the evaluation of a specific seating layout until the introduction of the design metrics.

The seating stools are typically bound within a small range of available dimensions. There is an inherent problem of alignment that springs from the fixed size of a seating module in relationship to the variable size of the seating rows. It is usually more evident in non-rectangular seating layouts. In practice, the problem is globally compensated by employing an axis of symmetry about the center of the stage and evenly distributing the residual space along the circulation routes. It is also possible to absorb the variances locally by introducing a few different types of seating modules or adjusting the space between them.

The task of allocating space for individual seats is already quite complex even though we haven't even started discussing about its repercussions on visual comfort. For instance, a staggered alignment may be preferable to a direct axial alignment because it minimized viewer-to-viewer occlusions. Again the design module doesn't make assumptions about the performance of each spatial allocation scheme, visual or functional, but just assists in its geometric layout. This will allows us later to revisit the sets of parameters that defined a specific layout and under the light of the measured performance redefine its premises.

On the technical side, we implemented a chord-length subdivision algorithm that allocates fixed size modules along the BSpline geometry by iteratively scanning its parametric domain, given the desired dimensions and alignment hints. The process is quite straight forward for scaffold surfaces that stay within a small scales of deformation per seating row but becomes progressively more challenging as the seating scaffold distorts by the introduction of non-constant curvature.

5. Metric Analysis Module

While the Design Intent Module assists in the geometric modeling of theater spaces, the Metric Analysis Module is confined in performing a range of analytical tasks that result to design indices. Design indices are the means that enable us to design theater spaces while interactively operating on both the design and its performance.

The design indices were developed in an attempt to understand and explicitly express aspects of what may be the constituent parts for achieving a better viewing experience from a visual appreciation point of view. None of them is sufficient for completely capturing the complexity of the visual experience but combinations there of, may provide valuable cues for steering design towards better solutions.

5.1. THE PHYSICAL DISTANCE METRIC

The simplest design metric in any visual study is extracted by the physical distance or proximity between the observer and his/hers focus of attention. The physical distance also easily correlates with the capacity of a spectator to identify physical characteristics of the performers. Yet the nature of the metric relationship and its boundary conditions is not as simple as such. On the contrary, it depends heavily upon combinations of anthropometric and theater functional factors. For instance, in certain types of plays, such as contemporary dance, the clarity in the perception of the configuration of bodies in the stage is more crucial than the identification of facial expressions. In theatrical functions that involve auditory events, the physical distance may be altogether omitted. Thus the upper and lower boundaries may be adjusted to suit certain functional requirements. The Metric Analysis Module implements this index by either measuring a distance between each seating node towards a central stage node or by a projected distance on the viewing plane, which is a rather more fair measurement for elongated stage configurations (Figure 2).

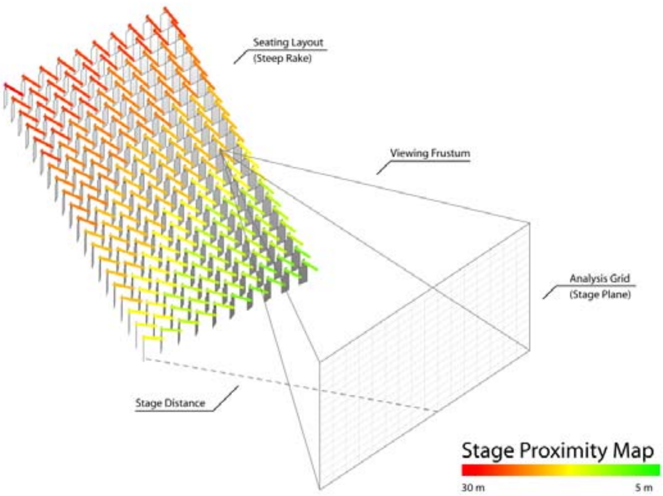

Figure 2. A typical map of the physical distance metric.

5.2. THE FRUSTUM TORTION METRIC

The viewing angle metric attempts to capture the intuitive understanding that central sightlines are preferable to peripheral. The metric in itself is also very direct as it is expressed as the angle between the normal directions of the seating arrangement and stage plane (Figure 5). The human factors related to this metric decouples the viewing angle in two components: horizontal and vertical angles. They both relate to the comfort zones of a person turning his/her head towards a given direction and also the metric angular properties of his/her frustum of vision. The decomposition of the angle is employed also in expressing the difference in the importance of the being off-centered horizontally close towards the edges of the stage and/or vertically in an upper gallery (Figure 3). The viewing conditions are expressed as either law curves or discrete level-sets under which the visual performance of a seating node is degrading (from a direct frontal orientation). We also detached filtering of the collected metric from the analytical module and situated them as tools of post-processing and visualization.

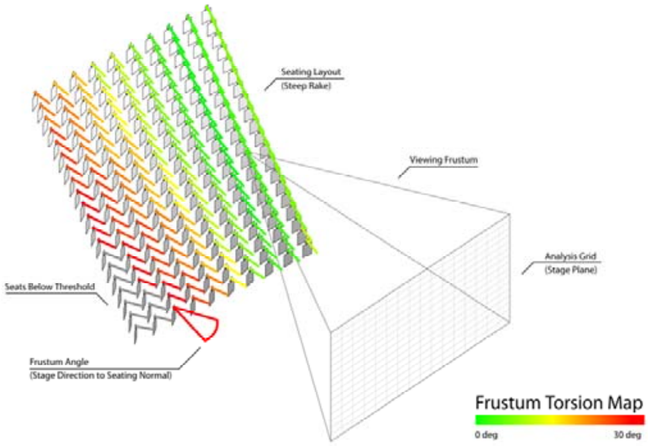

Figure 3. Typical maps of the frustum torsion metric.

5.3. THE VISUBLE VOLUME & AREA METRICS

As already mentioned the stage may be abstracted to a central viewing node or a plane. A single node may capture adequately the viewing conditions for the ancient Greek orchestra and the viewing plane is a good model for the screen of a cinema. Yet the stage of a theater is spatial entity. The maximal visible volume and area indices address this aspect of the performance of a spatial configuration using an experimental technique. Conceptually the maximal visible volume may be expressed as the solid intersection of a viewers frustum and the stage's hull. The ratio of the measured volume to the stage's total volume provides an abstract index of the visual capacity of a seating node. A similar metric may be extracted by measuring the area of intersection between the total area of the rear plane of the stage and the perspective projection of a viewer's node over the proscenium opening on the same plane (Figure 4).

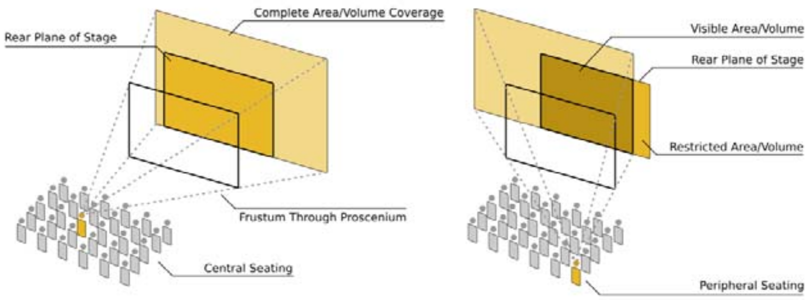

Figure 4. The principle of the maximal volume and area calculation.

The indices map the performance of a seating position in relationship to the boundary layer between performers and audience. This is typically the proscenium but also any other adjustable fixtures and scenery that adjusts the stage's frame. In this fashion we may acquire information that are not captured by the frustum torsion index which operates independently of the stage's shape.

There exist formal regulations regarding the boundary conditions of the minimum allowed unoccluded area for the stage (ABTT+DSA 2002). Yet the specific metric may be enhanced only once we factor terms of “spatial relevance” of the stage across its volume / area. In other words, we may extract rather more practical monotonic relationships from the cumulative volume-index and area-index by capturing and factoring in the empirical knowledge that a stage is not equally important across its volume. We partially address this later challenge but this may as well be a topic for future research on theater design metrics.

5.4. THE SPATIAL OCCLUSION METRIC

One the most indicative methods employed for quickly evaluating a seating and a stage spatial configuration is performed through the rendering of a series of architectural images from a few key positions. This approach operates adequately in terms of visual thinking because it consolidates the apparent perception of the finished space and allows the architectural gaze to pick up on visual deficiencies and potential performance problems.

We appreciate this approach and as a matter of fact we implemented a visual prototyping script that compiles visualizations from all seating positions of a layout. Analytically though these representations don't provide any metric information that may be employed numerically among alternative options. Yet, this technique proved to be an inspiration for us in an attempt of accessing the convoluted metric of spatial occlusion. Spatial occlusion describes the blockage(s) within a viewer's frustum. Those may be caused by other viewers or by architectural artifacts (structure, galleries, balustrades etc). The spatial occlusion term is a critical metric that indicates both the performance of a given seating node and overall of the seating layout. No matter the values of any of the previous metrics, if spatial occlusion is high, a layout scheme may be invalidated.

The occlusion term of a spatial configuration is a calculation intense operation as it requires processing large amounts of geometry. More over it is not sufficient to extract rough indications of occlusion by counting the geometric elements within a viewer’s frustum because while they may be a few, they may occlude an important part of the visual field. It is possible to create a metric where a centrality term of occluding elements within a given frustum is co-factored, we actually started from this, but this would also fail to capture the actual visual impression.

A recent paper on visual thinking (Nagakura and Chatzitsakyris 2003) describes a method of extracting visual design metrics from the data buffers employed by the pipeline of a rendering engine. There are also multiple recent papers in the field of computer graphics that employ technologies, namely raytracing and spatial quantization, for recovering convoluted light behaviors such the ambient occlusion term from spatial configurations of arbitrary complexity (Landis 2002; Bunnel 2005; Tarini et al. 2006). These provided us with a background for our algorithmic method.

We developed a simplified sight-tracing engine that allows us to compute the spatial occlusion term per viewer in interactive levels of performance. The algorithm decomposes the rear stage plane in an analysis grid and performs a series of culling operations for minimizing the calculation of occluding objects. It employs a basic object-in-frustum culling technique to eliminate irrelevant geometry and also utilizes the rectangular topological configuration of the seating layout for reducing the inter-viewer potential occlusion calculations. Finally it renders a projective map of the viewers’ visual field for which we can directly measure the area and shape of occlusion.

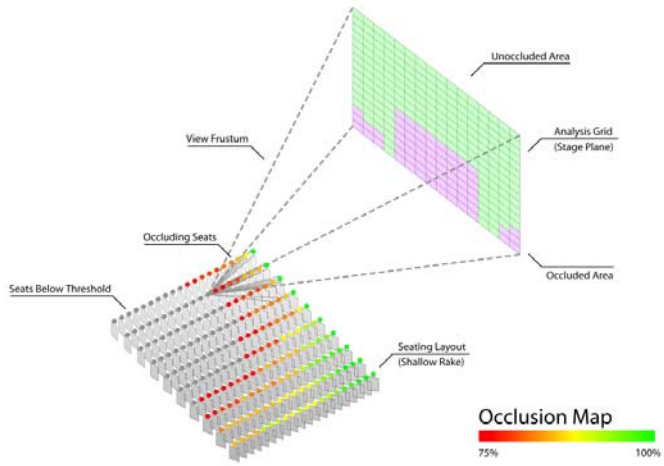

Figure 5. *Spatial occlusion analysis map of a single viewer.*

As with the previous metric of the maximal visible volume and area, spatial occlusion may be augmented with a coefficient map that expresses the field of importance of the stage's area. The attention thereafter turns towards global analytical methods for capturing properties of a viewer's visual field and creating a network of supplementing tools.

5.5. VISUAL FIELD METRICS

An important aspect regarding the previously documented metrics is that they all examine visual performance from a viewer's point of view towards the theater space and more specifically the stage. This directionality is better suited for capturing the viewer-stage relationships. Yet we would like to address relationships lurking within the ambient space and the interpersonal spaces among the viewers. This section employs a method that follows the opposite direction, from space to the person and attempts to pick up those behaviors.

The visual field of a spectator can be analyzed using the concept of the isovist. Benedikt (1979) defines the isovist as the space that can be seen from any vantage point and sets of such spaces form the visual field (Figure 6). The visual field expresses a perceptual metric that is directly related to the state of a spatial configuration. While isovists are non-syntactic, the integration there of (Turner and Penn 1999) allows global relational measures to be developed which reveal spatial dynamics in terms of visual perception. Moreover, in order describe the spatial characteristics of environmental spaces (Montello, 1993) beyond a single observation point, Turner et al. (2001) have developed the Visibility Graph Analysis (VGA), a spatial analysis technique that permits the integrative analysis of multiple positions within an environment by computing the intervisibility of positions regularly distributed over the whole environment.

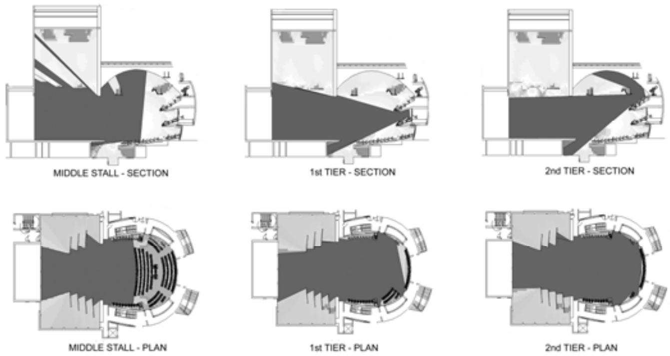

Figure 6. Isovist graphs from different seating positions.

The mappings generated through these analytical methods provide us with information about the visual potential of space across its volume. The visual integration index for instance (Figure 7) reveals the ambient visual accesibility of space which spans across the whole theater rather than merely focusing on the stage. We can therefore obtain perceptual aspects of the theater space rather than the comfort levels of its users. We need though to clearly state that a lot more work is needed for decoupling and correlating these metrics with relevant characteristics.

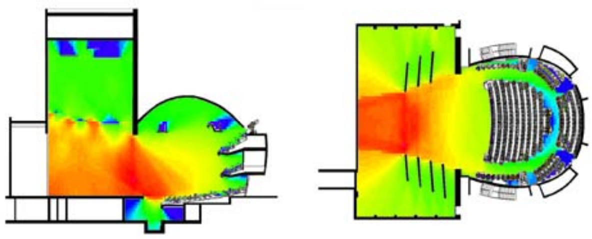

Figure 7. Visual integration for a prototypical theater.

6. Post-Processing and Visualization Module

The last component of the framework concentrates on the post-processing and visualization of the information harvested from the analytical module. The task of filtering and representing data is not less important than design or analysis. On the contrary it is equally crucial for enabling us to correctly interpret and successfully utilize and communicate this information.

The interpretation part is related to filtering data according to existing regulations and knowledge about theaters and human factors. For instance, in order to achieve viewing comfort the maximum comfortable amount the head can be turned from the seat centerline is 30 degrees horizontally to either side (Ham 1972).

Utilization implies of constructing a theater study scenarios that are informed by the specific needs of its use rather than generic regulations. We already mentioned how the type of a play may significantly prioritize certain metric aspects over others.

Post-processing is implemented as either boundary conditions (low / high values) or coefficency maps superimposed over the generated metrics. For instance we may typically need to impose cut-off zone on the distance metric since we do not care about the metric beyond a reasonable distance or we may desire to point out the realm beyond the scheme doesn't work. We may also need to factor in transformations on certain metrics to better fit their empirically measured data or intensify certain zones of interest.

7. Evaluation

7.1. APPRAISAL AND RESULTS

The theater design framework and the implemented toolkit allow us to quickly sketch theater configurations, analyze various metrics and explore design options interactively. In this application-oriented evaluation it performs two tasks: it automates the labor-intense process of setting out a layout and also reinforces a dynamic understanding of a design action and its reactions. This form of interaction stands in between the realms of the practice/exercise of design and the education of/about design. The mode of the engagement externally is intuitive and implicit.

On the methodological level, that is internally, the system sets up a construct for capturing architectural knowledge of the theater space explicitly. This provides not merely the means for recording knowledge but also challenging its grounds and expanding its borders. The medium of this capture, that is computation, is also an important aspect of the framework as it offers a procedural interface that entails both the methods as well as the products of those.

7.2. APPRECIATION OF THE LIMITATIONS

There are a few points that we would like to consolidate in this section after having enlisted the network of methods that constitute this framework. We would like to draw the attention on the fields of knowledge that are adjacent to this research and may provide valuable input in the specific approach.

On the one hand, a scientific body of knowledge is needed for augmenting and validating the premises of our assumptions regarding the correlation between empirical phenomena and their explicit computational modeling. In other words it is paramount for our efforts to further relate the mappings to measured data. At this point we can only evaluate relative ordinal relationships among theater designs. While this is actually helpful it would be also valuable to integrate hard coded boundary conditions and explicit maps such that we will be able to access the metrics (whenever possible) from a cardinal perspective.

Another arena in which this framework would be benefited is the corpus of built architectural precedents. In this respect we may be able to identify characteristics that make existing theater spaces distinguished and learn from them. We could also refine and enrich these models by converting tacit architectural knowledge to analytical criteria. Finally, integrating adjacent design considerations to visual performance, such as functional requirements, will allow us to negotiate among the multidimensional drivers of theater design.

7.3. METHODOLOGY AND TECHNOLOGY

The purpose of the modular structure of the framework is part of an overall computational design methodology. The modular scheme provides us the means for introducing conceptual junctions between: what is architecturally possible, design-wise preferable, physically possible, regulatory applicable, performance measurable and so on. It is also very transparent in terms of its internal assumptions and biases. Each section denotes its internal assumptions and whenever possible suggests alternative schemes of representation, implementation and interpretation.

In contrast to our approach, traditional guides suggest that following certain rules of the thumb will provide designs with certain assurances regarding their outcome. The rules of the thumb are products of distilled knowledge acquired by historical precedents and scientific models. Therefore we see no evil behind their intentions but rather an innate tendency towards consolidation. Our criticism is that is seems to us that design recipes are characteristically deterministic and as actionable sets of facts they tend to fuse the concepts of what a performance of a specific theater space may be (in its analytical notion), with how may every configuration should be (in its design notion). Moreover they do not foster a deeper understanding of the reasons behind the empirical phenomena they dictate a regime upon. The rate of absorption of information about the theater space seems more important that the appreciation of the governing laws beneath its surface.

Our methodological approach strove in capturing explicit dynamic relationships of viewer’s perception. We avoided setting up these relationships as a definite sets of “do”s and “don't”s but rather tried to reconstruct their implicit behaviors even though this tends to be more adventurous (and dangerous). Yet it is a conscious decision of ours that responds towards our critique of a wide range of regulatory frameworks that provide sets of thumbs up or down evaluators. Our focus is not to define what is the best, worst or nominal theater design standard but rather provide a systematic framework for bettering design within a frame of interest.

7.4. FUTURE DEVELOPMENTS

Our future plans for this framework are both the technical and methodological. On the technical side, our sight-tracing algorithm has the potential of unifying all of our analytical metrics in a compact integrated system. On the methodological side, we have started already harvesting the fluidity of our system and experimenting with computational methods of optimization. Those may be on one hand reveal novel solutions within the complex domain of heterogeneous theater design parameters. On the other hand we will be able to refine a preferred scheme by closing down and converging towards its optimal configuration.

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