Mapping Form/Constructing Context:

an operatic proposal for boston

by

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Abstract

This thesis explores the relationship between form, context, and program through the optic of sound. The project consists of an open assembly of receptive surfaces (a multiple membrane system) that register and retrace different music tempos and acoustical events from the interior and the city's vibrations, rhythms, noises and breath, from the exterior. The oscillating effect between these parameters begins to define a thickened zone of space that mediates program and context through its deployment of surface, façade, flow and structure.

It is this deployment that becomes critical- it becomes a way of constructing one's own context- a coordinate system that belongs only to the project at hand. This coordinate system is a resultant of the mapping of forces- a diagramming of flows and influences that are present in the site, the program, the project and its methodology. A formal strategy evolves that is discovered rather than implemented, and as a result, the internal logic of the project becomes the generative mechanism (evolutionary) that sets in motion its transformations, deflections and formulation.

Ultimately the thesis proposes a way of dealing with the gap that exists between intuition and science, and decides where it positions itself along this bar. The computational model is developed initially from intuitive readings and mappings of the site- this intuition is then transferred into a context, or framework that can be tested. This testing becomes a critical part of constructing context- it is through testing that the intuitive meets the rational and calibrates the internal logic of the project.

Thesis Supervisor: Fernando Domeyko
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Acknowledgements

I would like to dedicate this thesis to my grandmother, Elena, who at the present age of ninety two is still as enthusiastic for life as if she were just 12. I remember as a child watching her sew on a sewing machine that operated with a pedal and a leather strap. It was a Singer sewing machine built in 1898. It still exists and she still sews with it, just recently sewing 2 wedding dresses for 2 of her grand children who recently married. I also remember, and still to this day watch her construct with her own hands every Christmas a nativity scene that takes up a whole living room. She always asks for the scraps of chip board and bass wood that I send her that she uses for material. She has been a tremendous inspiration to me and always reminds me of how precious it is to take care of the child within- she reminds me of my childhood.

To my mother, my rock, who has never stopped showing her love and for always being there, and for showing me to never take anything for granted.

I would like to thank my father who taught me that ones mind is possibly the most precious possession- who taught me the importance of thought and ideas, and the importance of fighting for them.

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To Talia, the one who taught me the most about myself, who showed me the simplicity and power that love and passion can bring to life, and the unwavering respect one should always have for oneself, but most importantly for simply reminding me it's never too late.

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Finally, to my advisor Fernando Domeyko for his dedication and love for the work of the students. In him I found a person with incredible depth and passion for architecture and life. From him I learned so much- he made me realize how hard it is to be a real architect. I can not say enough to describe the lessons I learned from him. He taught me the discipline of architecture. He taught me that architecture can only exist through experience and material, and in order to understand this one must adhere to a clear vision. Fernando taught me to think architecturally, something I thought I had been doing, but soon realized I had a long way to go. Thank you Fernando for opening a window to fly from.
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0.01 introduction
Mobile Forces and Fluid Mechanisms

Can architecture be delineated as a diagram of forces? How close can we get to generate an architecture that is truly bound by its context, program and the mobility of its users? What are the parameters that need to be explored in relation to the dynamic space of design, and how does the designer begin to engage these in a vital way? The role of the architect is seeing new light and potential in developing new methods of conceptualizing architecture from its own internal and external mechanisms. These mechanisms are subject to an array of issues that sometimes become too difficult to map and maintain a dialogue with. This new role for the architect is taking shape as co-producing technician, organizer and planner in a highly structured, co-operative process in which clients, investors, users, and technical consultants all take part. With this new role comes a move towards a new empowerment.

One can foresee an emerging policy of mobility and the incorporation into architecture the aspects of time, force and motion. A vital aspect of this method is the possibility to lay bare a multiplicity of layering of experiences, different “speeds” of activities, events and forces that interplay with program, surfaces, materials, and structure.

The combined use of automated design and animation techniques enables a working method integrating questions of user movement, urban planning, construction, and the potential for program to develop at certain points in this network. New computational techniques make it possible to simultaneously map these forces and activate this knowledge in new ways. When mapping movement patterns, the time-program relationship is not compartmentalized, but reflects synchronic, continuous time. Separate infrastructural layers may be classified, calculated, and tested individually, to be subsequently interwoven to achieve both effective flux and effective interaction. Temporal conditions are thus connected to programmatic themes in a simulation of the non-segmented manner in which time flows in a real situation.

The vision is one of an organic, responsive construct that supports both amorphous liquid forms and more rational mechanisms, creating a system that enables the possibility of continuous transformations in frameworks that evolve and are responsive to the dynamics
of forces present within a specific context.

What is explicitly implied by this method is a mode of calibration that enables the architect to detect, decipher and gauge the different parameters of a project in a dynamic system. Rather than looking at static modes of conception, based on monumentality, architecture evolves as an interface, a network that frames a newly conceived coordinate system that has evolved momentarily to provide a temporary scaffolding for architecture to dissolve around. Design is conceived not as a mission to problem solve, by identifying the functional requirements of a project and then discovering the appropriate means to satisfy the brief, but rather as a mobile force, a fluid mechanism that speaks of solvents rather than solutions.

**Prototyping Mobile Forces Methodology:**
This thesis is exploring the idea of architecture as a diagram of forces. One way that one can begin to imagine mapping these diagrams is through a rigorous prototyping method that looks into process, structure and form. How can we begin to literally imagine constructing the process, the method of development of form within design technologies? One can imagine that the development of animate prototypes that explore the abstraction of forces and vectors can begin to inform something latent in architecture. Henri Bergson suggests that it is futile to attempt to separate an object from the process of its becoming—its genesis or its genetic process. He speaks of the relationship that matter and materiality have to the forces that formed it. Likewise, D'Arcy Thompson’s *On Growth and Form*, describes how nature, as a response to the action of forces, creates a great diversity of forms:

“In short, the form of an object is a diagram of forces; in this sense, at least, that from it we can judge of or deduce the forces that are acting upon it; in this strict and particular sense, it is a diagram.”

More importantly though, Thompson offers a new system that is dependent on a dynamic and fluid set of parameters. This system describes a method of development that involves the mapping of transformations in response to external forces.

In looking at architecture from this perspective one begins to imagine “entering” the space
of design from a different "lens". It is not solely poetic, or metaphorical, but rather performative. Architecture is analyzed and developed from its material transformation, rather than from a purely rational or intellectual approach. A dialogue is established between the will of the mind and the will of form and material.

Figure 4. Study of the flow of gases and its deformation as it passes through an obstacle (Hentel, 67)

Figure 5. The form of the car is the direct resultant of the vectors delineating the forces acting upon the form. (Pearce, 76)
Figure 6. Motion studies of man fencing. Note the trace of the form left behind as a result of the movement (Braun, 271))

Figures 7, 8. Chronophotographic studies of air movement (smoke trails) created around obstacles of various shapes (Dagognet, 47)
Figure 9. Movements of a model airplane showing stalls. Drawing made from a chronophotograph. (Braun, 218)
0.02 history/context
Constructing Context - a process of calibration
The site: Downtown Boston

Downtown Boston is the dynamo 1.5 square mile center of the city. Despite its small size, the area is of remarkable historic, economic, social and cultural importance. In Colonial times, downtown Boston was the “cradle of the liberty” and birthplace of the American Revolution. Today, its Freedom Trail of historic sites attracts nearly two million visitors annually. But today’s downtown, enlarged over the years by filling in the harbor and riverfront, is also the vibrant center of a modern city and metropolitan area.

Every working day, downtown Boston draws an additional 100,000 people to shop in its wide variety of retail stores, to receive health care from its world-renowned medical institutions, to attend its many colleges and universities, or to see the sights and enjoy the wide range of cultural and entertainment opportunities that are available, day and night.

The Theatre District

Theater was first performed in Boston in 1758, and immediately made illegal. That law was finally repealed in 1805, but official censorship of plays did not cease until November 18, 1975. Within the Puritan climate of early Boston, theaters and theater artists were considered to be at the edge of morality at best, regardless of their stage or personal behavior.

The Boston Museum was among the earliest theaters catering to The Proper Bostonian. Its name, furnishings, and overall look were intended to address their prejudices against regular playhouses. The strategy was a great success. The Boston Museum spawned a thriving “high society” theater district in the region near Scollay Square and the Financial District. That balanced the “vernacular” theatre district of Lower Washington Street, then known as the Haymarket District, near the Liberty Tree at Boylston and Washington Streets, which catered to travelers from the port and by land. As the “high society” district became legitimate, it soon outgrew its facilities and began an exodus to more exclusive quarters. Two new theatre districts were formed: on the new land in the Back Bay, and on the land near Boylston and Tremont Streets that had been vacated by Boston.
Public Library -- where the Theatre District stands today. As the Library, Museum of Fine Arts, Boston Symphony Orchestra, New England Conservatory of Music, Mass. Horticulture, and such institutions left downtown, their former buildings were reused as "vernacular" theatres. The former Boston Symphony Hall, for example, became Lowe's Family Vaudeville house. It remains active today as the Orpheum Theatre, a nearly 3,000-seat rock palace. Many of the Scollay Square theatres began catering to sailors with bawdy revue.

With the Boston Museum's -- and Scollay Square's -- days obviously numbered, The Colonial Theatre opened in 1900 and the Emerson Majestic Theatre opened in 1903, at the former site of the Boston Public Library, on the southeast corner of Boston Common. The Emerson Majestic opened only 3 months before the Boston Museum was demolished.

Symphony Hall serves the Boston Symphony Orchestra. The Colonial Theatre presented sophisticated performances that came to be known as "Broadway Theatre." Department store heir Eben Dyer Jordan built 3 opera houses -- the Majestic in 1903 for small to medium operas written through the early classical era, Jordan Hall at New England Conservatory for concert opera, and the Boston Opera House on Huntington Avenue, demolished in 1963, but built for large-scale grand opera. Along with the Boston Atheneum, still across from the State House at the top of Beacon Hill, these facilities satisfied Boston's need for "high society" theatres.

The vernacular theatre also grew rapidly just after the turn of the century. Some rugged and some extraordinarily beautiful facilities were built, both in the downtown theatre district and in Boston's neighborhoods and suburbs. Entrepreneur Benjamin Franklin Keith built many of the most beautiful "Palaces for the Common Man," eventually creating a Boston-based empire of nearly 1,000 theatres that became the RKO Cinema chain (Radio Keith Orpheum.) There were over 55 operating theatres downtown, and another two dozen in the neighborhoods and suburbs, by 1935.

Television radically effected the entertainment industry. Movie attendance declined rapidly and precipitously. Movie palaces were big, lavish and expensive to operate, so
became unprofitable and closed under the pressure.

A few of these “vernacular” palaces remain today, restored as houses for Broadway blockbusters and the occasional classic film festival. But the “high society” facilities remain alive, vibrant, and supportive of the diverse cultural life Boston has to offer. Indeed, some of the “vernacular” palaces have begun supporting resident performing artists, and there is talk of building new facilities for New England’s extraordinary resident arts groups as we move into the 21st century.

Figures 11-18. The early days of the theatre district in Boston.
0.03 dynamic strategies/
transformation of the site
Dynamic Generative Diagrams

At some architectural schools and in some few practices, students, tutors and architects are inventing and exploring new techniques and design strategies adapted to the use of computers. In many of those cases the computer is used as a means to apply generative material in the design process. Though the arguments for doing this are many and diverse, from a perspective of design methodology such generative material is meant to produce an unanticipated output that would fertilise the design process.

The use of such generative material raises a series of questions about the design process as such and the role of the designer. Though there are many diverse interpretations of what creative processes are, common to most explanations the emergence of the unanticipated. (1) Creation implies the arrival of something new, something, which has been unimaginable before.

If we directly leave this to computerized emergence (2) it would have at least two negative impacts. The designer is reduced to a less creative workhorse in the design process. But more serious, the results would be unprocessed formalism with no cultural content or meaning, since culture in human interpretation is meaningless for machines. (3) The techniques suggested here indicate a slightly altered but not alien role for the designer through selection, interpretation, analyses and modification.

Generative diagrams animate us to look at any type of graphical information and computational process in an abstract and structural way. Diagrammatic thinking in this sense opens the possibility to free computer generated material and computer software from its determined context. The material can therefore be reinterpreted, redefined, re-mapped and re-coded to instrumentalize it in a design process. All this is done in a qualitative and visual manner based on playful and intuitive manipulation of graphical represented information on the search for new formal input. The technique gives a creative boost and helps to break established design parameters or “resist the motivated”. (4)

Since the computer (in such a process) is an engine for the production of the unanticipated the designer’s attention is moved from production to preparation and to postproduction,

Figure 19. Sound graph by author showing the relationship between amplitude and frequency as functions of time.
which means coding (projection). To use the computer this way implies an intimate human-machine relation since the result is only unanticipated in context.

The human's role is to be the "un-anticipator". Human sense (meaning, culture) is projected to the material through the process of coding, which gives the generative material content and makes it ready for reuse. Though projection is increasingly important compared to a "traditional" (internal self-centered) design process, the designer is by no means totally removed from production. But the production process is altered. The designer is in phases obliged into a state of disinterest and detachment, operating the parameters of the processes rather than being the process engine him or her self.

To utilize the initially un-coded and generic material it is on one hand investigated for its structural inherent organization, on the other it is related to external information or use, be it form or program. A simple and direct associative and metaphorical based projection might be most obvious. But there is a high risk that such an approach will lead us into non-productive banalities. We need to extract processable material, which is open-ended either because it is not detriment (complex, blurred, unclear, open for several interpretations) and/or because it operates on a generic - diagrammatical level. This implies visual thinking and depicting emergent material on a structural level. Diagrammatic thinking will open up diverse modes of interpretation, which helps to avoid a direct and banal translation of the generative material.

For informing formal issues the material could serve more as scaffolding than template. The scaffold though supporting final form and thus related to final form is at the same time free to possess its own structure and appearance. But even more: the scaffold is structurally dependent on final form so it is (re-) generated simultaneously with final form. The difference lies in the degree of directness in the translation of the diagrammatic material into form. This can be done through the construction of descriptive notions, or through formal findings of possibilities and negotiations of the potential spaces indicated by the diagram. In some cases the formal input can be used in direct ways and then negotiated towards surroundings.

The diagram's role in the process of giving form is to give resistance to the obvious, which is central in any creative process. Eisenmann described this as overcoming the motivated
where the diagram is to act as a resistant agent to "...separate form from function, form from meaning and architect from the process of design." (Eisenman) page 214

Recent work by Lynn, NOx, and Van Berkel contributes to how the generative computer generated diagram can embrace time through the appliance of animation techniques. The generative diagram unfolds over time through animation processes. This is called the dynamic generative diagram. (12)

The unfolding of time-based sequences of events is inherent in program and hence in architecture. Such sequences operate in fields of simultaneity (time), mutual influences and relations called Channelling Systems. (13) The diagrammatic force-space is central to the understanding of any artefacts program. Programmatic issues need therefore to be treated considering duration, adaptability and change. The generative material can be applied to the diagrammatic field of forces to articulate it qualitatively in a similar way as landscape articulates travelling. But since form also is able to trigger program (to host, embed, "dock" and spin off events) the qualitative articulated treatment of form generates a seamless interrelation between form and program. The generic material introduces qualitative articulation to the program. It gives form to the forces and introduces therefore implications to the very core of design (giving form) and hence design creativity.

From that point the generative material can be used for suggestive purposes, to modulate gestures of actualities, to rehearse triggering conditions, adaptability to unexpected events or uncontrolled scenarios. Computer animation is the ultimate tool to produce large arrays of possible solutions in an mechanical disinterested and uncontrolled way. Since such arrays are sequential they can be remapped and recoded in systems where the linearity of time is manipulated through superimposition, reversal, scratching, merging, collapse, and the separation of sequence and duration.

In spite of all the digital advances a return to physical analogue modelling, where the physical model appears as generative mechanical diagrams in combination with digital models is explored extensively. The digital techniques are here translated and reinvented in another medium. This immigration between media deforms the use of dynamic generative diagrams because of its altered possibilities and limitations. (14)
The oscillation between computer-based and physical diagram constructs a unique seamless bridge between the abstract generative, the abstract representative and represented program, form and construction. This latest step, where the virtual and physical is merged, concludes this suggestion of a design strategy for the digital age.

**Finding Strategies/Finding Form**

The goal of this thesis is to develop an evolutionary and iterative process of design using the computer as a collaborator in form-finding that begins to explore the possibilities of creating an architecture that is carefully calibrated to its physical context. The thesis proposes to search for processes of formalization that combine multiple interacting systems, from which a series of methodologies are set in motion with the goal to explore new geometries and forms that emerge from the play or diagramming of forces. These systems can be the combination of forces that are interacting with a site in a particular context where context is looked at not simply as a set of physical conditions, but rather, as a complex interweaving of forces that are dynamically interrelated. If architecture can be developed in this way, it will be a dynamic system in tension with its surrounding, while remaining physically stable. What is being searched for is a more vital and dynamic conceptualization and construction of form. Methods of mapping and prototyping can now be developed to be deployed dynamically for new geometries to take form. The idea of working with the dynamics of a physical context opens up design to a whole world of possibilities. No longer is site or context looked at simply as a set of physical conditions, but rather it is looked at as a complex interweaving of forces that are dynamically interrelated.

*Figure 25. Drawing of a dynamic system by author*
Form and structure that is responsive and calibrated to the topological relationships of forces interacting on a site begins to suggest a more ecologically tailored set of parameters that are engaging within a context. In nature, the global and the particular can be found to be operating simultaneously. Nature is uniform only in certain respects, and in others it is highly variable. I don't mean to formally look into nature, or to represent nature, but there are processes that develop naturally and dynamically which serve as inspiration. This is certainly not a new idea. Nature has been a source of inspiration before, but more as a metaphor rather than an operative entity that informs more tangibly the process of making. In this sense, new technologies begin to open up an integrative discourse for design and its technologies. We can now imagine a space frame constructed of non-repetitive members and varying nodes, which behave like an ecology of components, exhibiting collective behavior and regulation.

The challenge for contemporary design is to integrate within its technology factors of time and motion in order to make conceptual jumps. Throughout its history, advances in descriptive methods have impacted architectural design and construction. Events such as the advent of perspective, stereometric projection and other geometric techniques have extended the methods in which designers describe and construct architecture. Today we are confronted with yet another opportunity to further develop this discourse, advances in technology relating to both design and manufacturing give the designer a new critical outlook in making architecture.

The idea of mapping intangible forces and working with the dynamics of a physical context on a site begins to open up the possibilities for architecture (discipline), design technologies (strategies) and the building industry (trades) to become more integrated with each other in the conceptualization and manufacturing of form. Form no longer simply responds only to the force of gravity. Building envelopes and structural systems are freed up in ways that were unimaginable. The degrees of freedom that one can achieve in building systems are increasing.
Figure 27. Time-motion study generating form. By author
Figure 28. Form study being generated by a scripting language set with specific parameters.
Figure 29. Example of a dynamic generative diagram depicting the relationship between various parameters. by author
Creativity and the internalized elements of the creative process remains a puzzling and unexplored phenomenon. Many different explanation models contribute to the understanding of creativity. These models span from pragmatic, psychometric, cognitive, social-personality models to confluence models that try to embrace creativity as a multiple component phenomena.

For an overview of the latest academic research on creativity see “Handbook of Creativity” (Sternberg 1999).

Parallel there exists an intuitive profession based and still partly unrecognized understanding of creativity through praxis, a perspective that often might be more productive for design research.

Greg Lynn says that the failure of artificial intelligence suggest a need to develop a systematic human intuition about the connective medium rather than attempting to build criticality into the machine. (Lynn 1999) page 19

In this way of treating the creative process we look at it simply from the perspective of the output and not as an internalized process. We rather investigate the symptoms (products) of creative processes than their internal causes. I suggest this as a productive attitude for the design researcher towards the problem of creativity.

Though meaning is already present since the designer introduces a priory an intention-driven selection through the choice of technology, design of process and selection of parameters.

Disinterest and personal detachment to the process of creativity connects on one side to ethics of science (CUDOS) on the other to certain movements in art. This gives this mode of work its fascinating potential. See also Eisenmann: My use of the diagram proposed a different rationale, one that could be both more logical and more involved with a process of architecture somewhat distant from the design process of the traditional author-architect. (Eisenman 1999) page 49

Structural in its literal sense as the organization and layout of formal issues like framework, outline, distribution, direction, density, border conditions and similar features of form in general.

Visual thinking as described in detail by Arneim. (Arneim 1969) Visual thinking in this sense is here seen as the precondition for diagrammatical thinking.

The diagram is in that sense an engine for data reduction since it clarifies and emphasizes certain readings of the material while disguising others.

Stan Allen refers to certain structures serve as scaffolds for events unanticipated by the architect. (Allen 1999) page 54

I imagine here a process similar to that in a qualitative research, open coding and following analyses that produce linguistic, though diagrammatic effects.

The use of animation in such a way has been suggested earlier. (Lynn 1998; Rakatansky 1998; Lynn 1999)

Chanelling Systems see AD spring 2000 (OCEAN) (Bettum and Hensel 2000)

Both representations in fact being analogue we intend to create a topological transformation between the media. See also Brian Massumi (Massumi 1998)

Both representations in fact being analogue we intend to create a topological transformation between the media. See also Brian Massumi (Massumi 1998)
0.04 mappings
The mapping component: where an operational matrix is constructed as scaffolding to build upon. This matrix is formed by the mapping of forces occurring on the site that constructs and structures the topological network of forces on the site.
Urban Carpet

The initial studies undertaken were “bit map sketches” that looked at the distribution of light and color intensities. From these a series of displacements were extracted. The idea was to search for a strategy that would ‘sense’ parameters that were yet not evident and transform them into form. The ‘from’ would be developed as an intuitive process of mapping and constructing a context yet not perceived wholly, but rather sensed partially. As a result the diagrams begin to adhere toward a sensibility that generates the surface as topologically incumbent on its urban context. This becomes central to the thesis, where an ‘urban carpet’ is conceived as the organizing principle- a principle that begins to allow the urban framework of the site be a continuous programmable membrane that flows into the site highlighting the intensities of its context.

Figures 30-33. Bitmap light and dark grafts with corresponding surface heighfield
Light-scapes

Light was studied as a structural urban element. These "light" studies exploit the potential of light to either generate strong images, identify intensities and erase whole parts of the urban fabric. Through filters and animations light was studied in time cycles as a flattening device that would begin to conceptualize such an intangible force as light to take form. The following images depict one example of many that were studied.

Figures 33-37. Series of figure ground studies of contrast on the site extracting intensities of light and darkness. First high contrast filter was applied, then inverted, and finally blurred.
Figure 38 The surface generated from the light study shows a height field of intensity that diagrams the relationship that the force of light has on the site at a particular moment.
Urban Dynamics

The map at the right shows a series of reference points that are identified on the site as main attractors or influences. These points become the main forces on the site that attract the dynamic elements of the area. At the same time one gets a reading of the 'time' lapses occurring as a dynamic element moves from the center of the downtown area towards the outer edges of the 'force' field. This force field is the dynamo or heart of Boston's downtown district. The rings depict intervals of 5 min. distances.

This diagram is a beginning strategy that was used to map the forces on the site. The idea was to begin to look at context and site as a set of dynamic conditions that influence each other. In this case the attractors are the main reference points which include the theatre district. The 'repulsor' becomes the force that presently creates an unwanted, yet powerful presence on the site- this being the Big Dig project shown in orange. All of these conditions are 'weighted' in terms of their influence on the site and a dynamic animation is set off where a series of particle emitters begin to create a pattern based on these topological relationships.
Figures 39, 40. Diagram above shows dynamic elements and the force attractors. Below is the captured frame put through a blur filter.

Figure 41. Graft above shows line of intersections from the surface ht.. field generated. These lines of intersection begin to define edge conditions and areas of intensities.

Figure 42. Curvature analysis showing more clearly areas of intensities.
Figure 43. A surface is generated of the site based on the light map studies. This becomes an operational matrix or frame to work on.

Figure 44. Extracted horizontal surface cuts for tooling a contoured surface either by CNC milling or laser cutter.
Figure 45, 46.
Vertical cut sections describing levels of intensities.
0.05 sound/acoustics
On Acoustics for Opera

The traditional concert hall form is the tall shoebox with one or two side balconies. The acoustical characteristics of a good concert hall include, clarity of music, reverberance, strength and envelopment. These acoustical characteristics can be explained by associating objective attributes (such as early energy levels) to room shape thorough geometric acoustics studies.

Figures 1 & 2 show the typical tessellation produced by a simple geometric acoustics model of a concert hall (Musikvereinssal, Vienna). Such a model can be used to explain the acoustical characteristics of the early sound field. The development of diffuse reverberant sound can also be predicted in shoebox concert halls using geometric acoustic models (Cremer, 1).

The geometric acoustics model is reasonably valid in concert hall design because the wall surfaces are large compared to the wavelengths of interest, and because the diffracted sound from balcony edges is only a small component of the sound field and can perhaps be ignored.

The geometric acoustics model is not valid in traditional European opera house design because the exposed wall surfaces are heavily shaded by the multiple balcony tiers, and as such are relatively small compared to the wavelengths of interest. Also, the diffracted sound from the balcony fronts is a larger (or even the predominant) component of the sound field due to the disposition of the balconies within the space and the relatively small vertical distance between them.

Boxes and balconies have been common for operas since earlier times. They were designed to show off the inhabitants of each box in all their glory, particularly the female members who would wear lavish gowns and makeup. As part of the dynamic of attending an opera, the boxes were preferred in order to achieve the social aspect of the opera. This created a condition where the box opening and its depth would be critical in the acoustics of the space. Some opera houses, like the Teatro alla Scala in Milan, Italy are small, thus giving more reflected sound to the center cubic volume, thus giving more
sound to the audience seated below in the audience. This is good for those seated below, but it is bad for those seated in the back of the boxes, who receive a weak and muffled sound. So the issue becomes a process of calibration between the size of the opening of the box, its depth and its relationship to the center cubic volume. It is a balance that would be hard to achieve with today's technologies that are more geared to analyzing multi-purpose theatres, and concert halls that depend more on reverb times.

The geometric acoustics model used in these theatres is not valid in traditional European opera house design because the exposed wall surfaces are heavily shaded by the multiple balcony tiers, and as such are relatively small compared to the wavelengths of interest. Also, the diffracted sound from the balcony fronts is a larger (or even the predominant) component of the sound field due to the disposition of the balconies within the space and the relatively small vertical distance between them.

A geometric acoustics model may apparently show that the traditional European opera house room shape cannot work, either because of focusing of the early sound (see Figure 4) or because of a lack of reflected sound (see Figure 5). Clearly, these rooms do work acoustically, and leads to the opinion that the geometrical model is not valid for these rooms because of their inability to properly illustrate the effect of diffraction off of the balcony fronts.

Opera house acoustics are very different from concert hall acoustics. The key differentiation is diffraction at the balcony fronts. Diffraction at balcony fronts is to the opera house acoustic as reflections from walls is to the concert hall acoustic. When a wave front impinges on the balcony fronts, each point on each balcony front becomes a secondary sound source, as in Figure 6.

The wave front is of course spherical, and where the spherical wavefront intersects the balcony fronts, the diffracted sound will be generated (see Figure 7). However, this "universal" view of the acoustic process does not represent when the diffracted sound arrives at a particular listener. If we consider sound propagation between a source-receiver pair in a two dimensional representation, the locus would be an ellipse (see Figure 8). The envelope of an equal-delay-time solid will thus be an ellipsoid rather than...
a sphere (see Figures 9).

The elements of a good opera space are determined by the combination of the singer and the orchestra. Due to this combination, the orchestra, which has a more forceful sound must be suppressed in a pit. The focus of the opera has to be placed on the singers and the sets. The architectural design for an opera must strike a balance between these two forces by projecting the full power of the voices uniformly over the audience while preserving the beauty of the orchestral music. That is why, according to Beranek the acoustics for opera are dependent on the design in plan, the ceiling plan, balcony design, long-section design and the stage and pit design. In addition there is a tremendous amount of program that must be accommodated for in the backstage to support operatic events.

Figure 52. Ellipse representing the locus of an equal-delay-time contour. The foci of the ellipse are located at the source and the receiver. In 3D, this becomes an ellipsoid.

Figure 53. The ellipsoids expand from the source-receiver line, with increasing delta T.

Figure 54. Intersection of ellipsoid at balcony fronts identifies the source locations of diffracted sound.

Figure 55. Diagrams of backstage organization (Charlet)
Figure 56. The Metropolitan Opera of New York (Charlet)
0.06  
rapid modelling
Rapid Modelling

Rapid modelling is a process of generating a multitude of options quickly. It is a method I have developed while at MIT—combining the power of computing and the intuitive nature of design—literally sketch and sculpt with the computer. There are forms that would be difficult to generate physically, or even conceptualize physically due to the complexity of the geometry. Geometric modelling capabilities of computation give the designer an array of prototyping capacities. This is not to say that the physical model is not relevant. On the contrary, it becomes even more relevant in the process of testing ones intuitions. It is critical to develop a methodology that takes you out of the box into the physical world. It is a back and forth process, where adjustments are made in the digital model, tested through visualization, then prototyped physically in order to sense the form.

Generating the Opera

The opera space organizes itself around a focal point—the force element called singer. From this source point a series of generating lines are established that organize the space and the structure. This geometric abstraction is a resultant of the idea that there is an internal force that influences the form, just as there are external forces. A balance is searched for between intrinsic forces and extrinsic forces. This relationship is what establishes form and context on the site.

The three elements that become the generators of form are:

1) Focal Point (Force Source)
2) Generating Lines (Sound and Sight projection)
3) Control Points (For Surfacing)

These three elements in turn become the constructing devices for the project, in where a set of varying conditions can be manipulated on the fly, tested, prototyped, calibrated, retested, reprototyped and recalibrated.
Figure 60. Series of study exploring different alternatives.
Initial Studies

These initial studies show the generation of form from within the opera space, based on acoustical principles modeled on the computer. The aim was to find a form that can fit - the skin or surface would be draped over the parameters established. This idea is generated as if the opera were wearing a long flowing gown that could be pushed and pulled by its control points. The focal point and regulating lines control the deployment of the difficult geometries. Once a form was found, it was then prototyped in a series of physical models (see next page).

These study models begin to establish the topology of the program on the site - the relationship between the 2 theatre spaces, one for ballet and one for opera. It was consequently decided to design one theatre with opera parameters, due to the fact that a dance theatre has more flexibility in the design than an opera theatre.
Surface Studies

The studies below began to look at the relationship between the acoustical space and the foyers. It was necessary to capture the dynamics of people moving in and out of these surfaces as they traveled into the building from the street- the foyer in turn becomes an extension of the urban dynamics. These surfaces provide the connection between the intrinsic and the extrinsic.
Study of surface and structure. These prototypes began to look at the relationship between the interior and exterior.
Opera box studies. The location of the dividing piers begins to define the opera box location based on sight lines and acoustics.
Model of the structural bay pier of horizontal slabs and vertical piers with surfaces attached.
0.02 prototypes for an opera
Acoustical Space Models

*Preliminary 1/16" model*
Laser cut out of chipboard, this model studies the form of the acoustical space and the opera boxes. It provided a frame to study surfaces and motion.
Further development begins to orient the vertical piers in line with the focal point projection. An analysis of sight lines and acoustics was looked at as a generating element at this stage.
Site Sketch
View towards the commons
Final Model of Opera Space
with backstage and auditorium

1/6" Final Model
The jump in scale allowed to extensively examine the space, the balconies and the support structure. Also the relationship to the backstage and the service area.
Final Model of Opera Space with backstage and auditorium

This model allowed the exploration of the laminated surfaces that would encompass the roof structure and the facade.
Final Model of Opera Space with backstage and auditorium

Here one gets a sense of the experience of being in the opera space with its multicolored balconies, emphasizing the social aspect of the opera as part of a multi-cultural city.
Final Renderings

Tremont street Elevation

Boston Commons Elevation
Perspective view from Washington Street
Aerial Views
Final Remarks

This thesis posed a question that I think was difficult to answer in such a short period of time. The idea of incorporating dynamic aspects of the urban context and incorporating intrinsic forces influencing from within has been a very difficult task. The use of computation in this process has been very helpful. There are many things that become successful in “discovering” relationships that are not clearly evident in the beginning, but allowing one to open the process of design to a dynamic approach is a start to look at multiple dimensions. It is difficult to control such a process. The parameters have to be clearly defined from the beginning to be able to do so. This is problematic, because in pre-determining so much in the beginning, one runs the risk of not opening up the possibilities. This process has enabled me to realize the difficulties of architectural design, and has reinforced the role of the architect as form giver and organizer.

What I hoped to achieve was simple in concept, but the methodology can not be applied universally. Working in a digital environment solely sacrifices many aspects of the design process that a simple sketch or a simple model would accomplish. In addition, the digital world offers so many possibilities, sometimes too many, and it is difficult to define physical constraints in a virtual world. That is why I found it very helpful, but quite difficult to oscillate between the physical and the digital. This is a very demanding task for one person working alone, but in working as a team, it would definitely allow for a very robust approach to design. Therefore it’s clear that these techniques are beneficial to design, but it requires a greater discipline and rigor to maintain control of a process that has always been one of discovery and exploration.
Bibliography

*Note: all images by the author, unless otherwise noted. All references to images given in bibliography*


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