DESIGN INFORMATICS

(A case based investigation into parametric design, scripting and CNC based manufacturing techniques)

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Abstract. The research paper exemplifies a novel information integrated design technique developed at ONL (Oosterhuis and Lenard), Netherlands, specifically appropriated for envisaging complex geometric forms. The 'informed design technique', apart from being highly instrumental in conceptualizing and generating the geometric component constituting architectural form in a parametric manner, is also efficiently utilized for precise computer aided manufacturing and construction of the speculated form. Geometric complexities inherent in contemporary architectural constructs and the time spent in appropriation of such topologies, fueled the 'informed design' approach, which caters to issues of timely construction, precision oriented design and production (visual and material) and parametric modeling attuned to budgetary fluctuations. This design-research approach has been tested and deployed by ONL, for conceiving 'the Acoustic Barrier' project, Utrecht Leidsche Rijn in the Netherlands and is treated as a generic case for exemplifying the 'informed design' technique in this research paper.

The design methodology encourages visualizing architectural substantiations from a systems perspective and envisages upon a rule based adaptive systems approach involving extrapolation of contextual dynamics/ground data in terms of logical 'rules'. These rules/conditionalities form the basis for spawning parametric logistics to be mapped upon geometric counterparts exemplifying the conception. The simulated parametric relations bind dimensional

aspects (length, width, height etc.) of the geometric construct in a relational manner, eventually culminating in a 3D spatial envelope. This evolved envelope is subsequently intersected with a 'parametric spatio-constructive grid', creating specific intersecting points between the two. The hence extorted 'point cloud' configuration serves as a generic information field concerning highly specific coordinates, parameters and values for each individual point/constructive node it embodies. The relations between these points are directly linked with precise displacements of structural profiles and related scaling factors of cladding materials. Parallel to this object oriented modeling approach, a detailed database (soft/information component) is also maintained to administer the relations between the obtained points. To be able to derive constructible structural and cladding components from the point cloud configuration customized Scripts (combination of Lisp and Max scripts) process the point cloud database. The programmed script-routines, iteratively run calculations to generate steel-wire frames, steel lattice-structure and cladding panels along with their dimensions and execution drawing data. Optimization-routines are also programmed to make rectifications and small adjustments in the calculated data. This precise information is further communicated with CNC milling machines to manifest complex sectional profiles formulating the construct hence enabling timely and effective construction of the conceptualized form.

1.0. ONL and the notion of Multi-disciplinarity

ONL, a multidisciplinary office directed by Prof.ir. Kas Oosterhuis and visual artist Ilona Lenard performs as a design-research body driven by contemporary Information communication technologies, focusing upon issues of collaborative design in a media (digital and electronic) augmented spatial environment. The notion of visualizing a context embedded design solution, at ONL is conceived through building a generic connectivity between geometric styled-prototypes (spawned by existent spatial scenarios) articulated with parametric relations and a corresponding demographic data base of their contextual settings. The notion of fusing information (context driven data scapes): soft component with the physical materiality of architecture: hard component to generate a co-evolving spatiality drives the design-research ideology at ONL. The research paper focuses upon a design strategy: the 'informed design' exemplifying this synergistic merger (of design ideologies and multiple disciplines) for the case of the 'Acoustic Barrier' project (Fig. 01) developed at ONL.
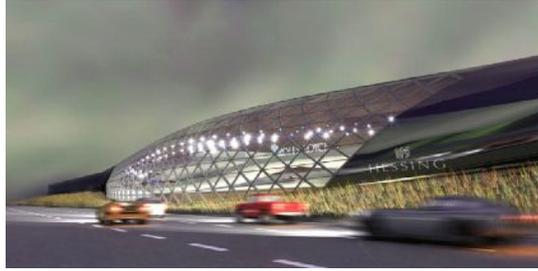
Fig. 01 The Acoustic barrier project (with the Cockpit/Hessing showroom): ONL

2.0. The Acoustic Barrier: Parametric Set-Up (Conceptual Resolution)

The project based in Utrecht Leidsche Rijn in the Netherlands aims to combine a 1.5 km long acoustic barrier with an industrial building (the cockpit/Hessing showroom) of 5000m2. The conceptual underpinning for the project is laid by means of articulating sets of NURBS curves, suggestive of a relation between height, width and the length of the barrier. These curves are stretched along the 1.5 km stretch of the highway and form the above-mentioned intuitive spatial guideline for the project.

The swarm of cars streaming at a speed of 120 km/h along the acoustic barrier site lays the rationale for deriving parametric rules, specifically linked with developing generic geometric relations between the NURBS curves. The barrier, a "one mile building" seen from the perspective of the highway, (considering the above mentioned criteria) derives its reptilian form on the basis of a context driven rule: the length of the built volume of the Cockpit emerging from the acoustic barrier will be 10 times more than its height. This parametric relation once set, and mapped onto the sets of curves yields a relatively smooth curvilinear surface with an equally smooth transient bulge, which houses the cockpit/Hessing showroom space (Fig. 02). This 'informed geometry', which creates the three-dimensional skin for the acoustic barrier not only operates as a 'form generator' but also proves to be a 'form regenerator', owing to the geometrically relational (parametric) dependence of the generic curves. Any parametric alteration made to the curves, consequently leads to a regeneration/re-appropriation of form in accordance with the context based, basic rule (which induces the relation between the dimensional aspects of the 3d form) hence reflecting a new, yet controlled spatial configuration.
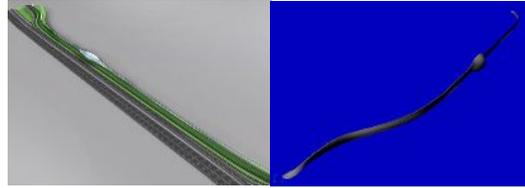
Fig. 02 Set of related curves with the parametric relation mapped onto them resulting in the bulging topology

2.0.1. PARAMETRIC SET UP (FINER RESOLUTION: THE POINT CLOUD)

In order to derive a finer degree of control over the obtained (conceptual) three-dimensional form (from the network of curves), a 'parametric structural grid', which obtains its dimensional logic from an optimal construction, oriented perspective (e.g. dimensions of glass panels) is mapped onto the surface of the conceptual construct. This intersection results in the extraction of a distinct series of nodes/points, collectively called the 'point cloud' (Fig. 03).
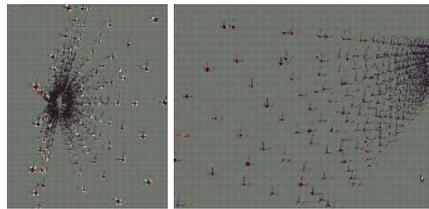

Fig. 03 Point cloud generated from the conceptual 3D envelope

The point-cloud represents a parametric set-up: it describes the volume by points and establishes spatial relationships between them: by serving as a generic information field concerning highly specific coordinates, parameters and values for each individual point/constructive node it embodies. The sound barrier contains approximately 7000-point objects, whose relations are administrated in a database. These relations are directly linked with precise displacements of structural profiles and related scaling factors of cladding materials. This linkage is further extracted from the point cloud body by running specialized 'Scripts' developed at ONL.

Such an approach also releases the design process to collaborative engineering opportunities during the execution phase of the project and hence creates an open framework for generating meaningful interactions between clients and users.

3.0. Generative and (Re) Generative Design by Scripting

In order to develop a constructive spatial structure and to manufacture the glazing and cladding material for the acoustic barrier a novel application is programmed. This application, programmed in diverse scripting languages [MAX-script, Auto Lisp] connects to a database system developed for handling all point-data and their relations. The developed scripts operate on a simple rule: all points should look at and analyze their neighbors (in terms of co-ordinates and proximity). Such a rule-based interaction is akin to the notion of Flocks: Boids, replicated in the case of the digital model by points/constructive nodes, are active members of a flock, calculating their position in real-time in relation to each other. The programmed script-routines, based on such flocking principles, when applied on the point-cloud iteratively run all the calculations to update:

1. Steel-wire frames with its databases
2. Steel-lattice-structure including all the execution drawings
3. Dimensions and Execution drawings of glass plates.

The scripting computational component operates at three levels, each component embedding within it a series of iterative operations.

3.0.1. SCRIPT 01

Loads the Rhino generated .DWG files containing the point clouds > Makes a single mesh out of them > Offsets this mesh by the r brace value (radius of the braces conceived by the glass manufacturer that will be used for the assembly of the glass plates) > Creates a series of spheres cantered to the vertices of this mesh that represent a second point-cloud to be used exclusively for the glass plates.

3.0.2. SCRIPT 02

The second Script based operation is responsible for segmentation of the entire point–cloud body into bays of 9.33 m. This generation of segments dissects the barrier into three bays with 118 points each and derives its logic from the sequence in which the foundations for the construct have to be laid. This basic dissection of the volume apart from being appropriate for physical construction also proves to be beneficial in terms of CPU usage and data handling and hence tends to be much more efficient and performative in the long run. Each segment contains a group of points and its corresponding mesh. The meshes in turn describing the glass plates and the amount of displacement needed by the extracted glass plates in between adjoining segments.

3.0.3. SCRIPT 03

Builds the axis of the steel profiles that form the structure > Projects the planar surfaces generated between the points, defining shape and position of the glass panels > Generating steel construction (Fig. 05) elements and Generating Glass plate elements (Fig. 04 bottom)
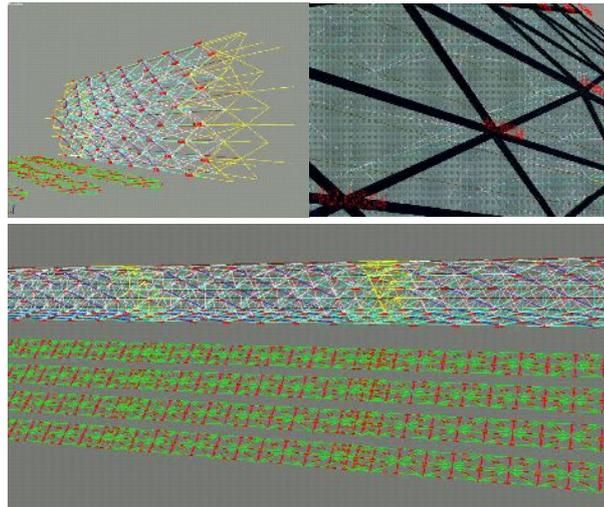

Fig. 04 3d wire frame model (above) displaying a segment of the acoustic barrier and the relations between the points in the point-cloud, (bottom) 3d wire frame model displaying a segment of the acoustic barrier and the administration of all unique glass plates [generated by script]
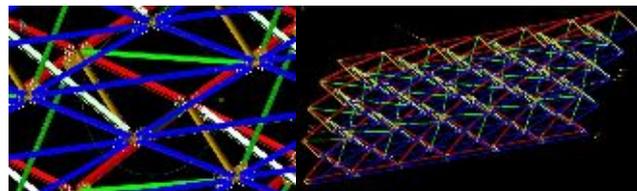

Fig. 05 3d model displaying a construction node [= point in point cloud] of the acoustic barrier and the steel profiles, steel plates and welded joints [generated by script]

This comprehensive and precise data, processed via the Scripting and Generative design components is further communicated to the manufacturing units for computer aided manufacturing purposes (CAM).

4.0. CAM techniques

CAM strategies are dealt with in a rather coherent fashion throughout the design and development stages of the acoustic barrier project. The protocol developed for storing information in the database at subsequent stages of the design process is also directly linked with the manner in which CNC machines would process the design data. However, as a generic outcome of the computational processes mentioned above, one can extract three basic strategies deployed over architectural form to reach the production process:
- Conversion from point cloud to steel-wire frame model and administration of all its parameters in a database
- Conversion from steel-wire-frame model to steel-lattice-structure and generating execution drawings (Fig. 06)
- Conversion from point cloud to glass plate manufacturing and administration of all dimensions, codes and specific values plus generating execution drawings.

Fig. 06 3d steel lattice model and its corresponding execution

The excel database which stores the data in a numeric array corresponding with the generated execution drawings and 3d segments is bundled together and further communicated to the manufacturing units as a concise production schema. This assists in speeding up the production process and hence results in accomplishment of complex projects within the specified timeline. The assembly phase (Fig. 06 right) is hence reduced to an exercise of connecting precisely named/numbered parts (more like a kit of parts scenario) in a sequential manner to produce a holistic topological marvel.

5.0. Conclusion

The design-informatics 'Informed-Design' technique, while promoting a parametric mode of operation, which enables one to communicate smoothly with three dimensional models and the project database, inherently involves a collaborative design approach, entailing derivation and appropriation of diverse tools and techniques (programming/scripting, graphic design, architecture, engineering and CAM) towards manifesting spatial constructs.

The 'Informed-Design' technique opens up the design process for collaborative engineering in the phase of the execution of the project and hence promoting the design process as a meaningful medium of interaction with the clients and the users.

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