The impact of Dynamic Environmental Forces on Architectural Form in Digital Design

A Thesis

Presented to the Graduate School
Faculty of Fine Arts, Alexandria University
In Partial Fulfillment of the Requirements
for the Degree

Of

Master In Fine Arts Architecture Department

By

Mohamed Hasan Mohamed Elhosiney Abd-elfatah Zaghloul

The impact of Dynamic Environmental Forces on Architectural Form in Digital Design

By

Mohamed Hasan Mohamed Elhosiney Abd-elfatah Zaghloul

Examiner's Committee

Prof. Dr. / Hatem Abd-elmoneim Eltawil

Professor of Architecture

Faculty of Fine Arts

Alexandria University

Prof. Dr. / Basil Ahmed Kamel

Professor of Architecture

Faculty of Engineering

Cairo University

Ass.Prof. Dr. / Mona Hasan Hasib Elmasry

Assistant Professor of Architecture

Faculty of Fine Arts

Alexandria University

Approved

Advisor's Committee

Prof. Dr. / Hatem Abd-elmoneim Eltawil Professor of Architecture

Faculty of Fine Arts

Alexandria University

Dr. / Hebatalla Farouk Abouelfadl

Lecturer of Architecture

Faculty of Fine Arts

Alexandria University

th Dain

_intepor

بسم الله الرحمن الرحيم

(و ما أوتيتم من العلم إلا قليلاً)

سورة الإسراء - الآية (٨٥)



My father, mother, sister, brother and my wife

ACKNOWLEDGEMENTS

Before all and overall comes GOD, no words can express my appreciation for GOD's unseen support to complete this research.

I would like to express my gratitude to my supervisors:

Prof. Dr. Hatem A.Eltawil AND Dr. Hebatalla F.Abouelfadl for their continuous support and for discussions throughout the development of this thesis.

I would like to thank my precious examiners:

Prof.Dr. Basil A. Kamel AND Ass.Prof.Dr. Mona H. Elmasry for Accepting to read, evaluate my thesis and for their contributions enriched the final editing and structure of this research.

I would like to express my great thanks to **my father**, **mother**, **sister**, **brother** and **my wife** who always encouraged me and gave me a lot of moral support.

And at last I would like to express my great thanks to my friends specially **Ahmed Hussien** who helped me through discussions and references.

TABLE OF CONTENTS

ACKNO)WLEDGEMENTS	iii
Table c	f Contents	iv
List of fi	gures	vii
Introdu	ction	xix
CHAPTER		
1 DIGITIZ	ING ENVIRONMENT	1
	RODUCTION	
1.2 Th€	Environment Notion for architectural form	
1.2.1	Physical Environment	2
1.2.2	Non-Physical Environment	2
1.3 Co	mputer-aided architecture design	
1.3.1		
1.3.2		
1.4 Co	mputational architecture	
1.4.1	Performative architecture	
1.4.2	Topological architecture	
1.4.3	Isomorphic architecture	
1.4.4	Animate architectures	
1.4.5	Metamorphic architecture	
1.4.6	` 5	9
1.4.7	9	
	mputitional Architecture Classification	
	nclusion	12
CHAPTER		
	RMATIVE & GENERATIVE DESIGN STRATEGIES IN PHYSICAL & NO	
	ENVIRONMENTS	
	RFORMATIVE Design Strategies in Physical Environment	
2.1.1		
	Performative design approaches	
	.2.1 Performance Based on Analatyical process	I 3
	.2.2 Performance Based ON generative & ALGORITHMIC	1.5
	ERNATIVES Performative design process	
2.1.3	G .	
	.3.1 Analysis & Collecting Data	
	.3.2 Form generating process	
	.3.3 Evaluation & decision making	
2.2 Ge	nerative Forms Strategies in Non-Physical Environments	
2.2.1	Introduction	
2.2.2	Generative forms approches Animate Form	
	.3.1 Dynamic Environment by forces fields & particals	
	.3.2 Dynamic Environment by inverse kinematics	
2.2.4	Evelotionary Architecture "Genetics"	
	.4.1 Dynamic Environment by Genetic Algorithms	
۷.۷	.+. Dynamic Environment by Genetic Algorithms	∠ ∠ ⊃

2.2.5 Generative design process	25
2.2.5.1 Analysis & Collecting Data	
2.2.5.2 Form generating process	
2.2.5.3 Evaluation & decision making	26
2.3 Conclusion	26
CHAPTER 3	
3 COMPUTING THE PERFORMATIVE FORMS THROUGH PHYSICAL	
ENVIRONMENT	
3.1 INTRODUCTION	
3.2 building performance simulation	
3.2.1 Building Performance Simulation history	
3.2.2 Comutitional Fluid Dynamics CFD	
3.2.3 Data visualization and interface design	
3.3 Environmental Control Analysis	
3.3.1 Solar & Lighting Analysis	
3.3.1.1 Sun Path	
3.3.1.2 Natural Lighting Analysis	
3.3.1.3 impact of lighting aspects on architectural form	
3.3.2 Wind Analysis	
3.3.2.1 impact of Wind aspects on architectural form	
3.3.3 Thermal Analysis	
3.3.3.1 Basic Thermal Analysis	
3.3.3.2 impact of Thermal aspects on architectural form	
3.3.4 Acoustic Analysis	
3.3.4.1 The concept of sound rays	
3.3.4.2 Basic Acoustic analysis	
3.3.4.3 impact of Acoustic aspects on architectural form	
3.4 Intelligent Kinetic Systems (IKS)	
3.4.1 Controlling Kinetic Function by Computational Means	
3.4.2 Experimental applications	
3.5 Conclusion CHAPTER 4	50
CHAPTER 4 4 Computing the Generative Forms through Non-Physical Environments	51
4.1 ANIMATION software as a non-physical Environment (Animate Form	
Strategy)	
4.1.1 introduction	
4.1.2 Elements of the animation software environment	
4.1.2.1 Topological Forms	
4.1.2.2 Time & Parameters	
4.1.2.3 Forces Fields "Space wraps" & Particle systems	
4.1.2.4 Forces Fields "Space wraps"	
4.1.2.5 Inverse Kinematics	
4.2 GENR 8 (scripted program) As non-physical ENVIRONMENT features	
(Evoultionary Strategy)	
4.2.1 introduction	

4.2.2 E	lements of the Genr8 environment	59
4.2.2.1	Growth model	59
4.2.2.2	Forces	61
4.2.2.3	Boundaries	61
4.3 Conclu	sion	62
CHAPTER 5		
5 EXAMPLES I	FOR PERFORMATIVE & GENERATIVE FORMS IN PHYSICAL	& NON-
PHYSICAL ENV	/IRONMENT	63
5.1 INTROD	UCTION	63
5.2 EXAMPL	.ESError! Bookmark not o	defined.
5.2.1 C	City hall, London, Foster + Partners	64
5.2.1.1	Project Definition	64
5.2.1.2	Design procedure	65
5.2.2 V	'ibunhus office building, Denemark, BIG + parteners	69
5.2.2.1	Project Definition	69
5.2.2.2	Design procedure	70
5.2.3 S	wiss Re's building, London, Foster + Partners	71
5.2.3.1	Project Definition	71
5.2.3.2	Design procedure	72
5.2.4 L	og Cabin, USA, ARANDA/IASCH	75
5.2.4.1	Project Definition	75
	Design procedure	
	ort authority gateway competition, USA, GREG Lynn	
	Project Definition	
	Design procedure	
	sion	84
Chapter 6 (C		
	WIND ASPECTS FOR GENERATING FORMS IN DIGITAL DE	
	UCTION	
	aspects in generating architectural form	
	olar & Lighting Analysis	
	INFLUENCING FACTORS	
	npact of Basic daylighting design considerations on Bu	
	y	
	Form orientation	
	Building Envelope	
	spects in generating architectural form	
	Vind Analysis	
6.3.1.1		
	npact of Basic airflow design considerations on Building	_
	y	
	Form orientation	
	Building Envelope	
	Form openings & cross ventilation	
6.3.2.4	outdoor Organization	97

6.4 Bours	e Office Building, AL-Manshia, Alexandria, Egypt	99
6.4.1	Project Definition	
6.4.2	Objective	100
6.4.3	Impact of analyzing the sunpath on the form	100
6.4.4	Impact of analyzing the airflow on the form	109
6.5 Conc	clusion	115
	ons and Recommendations	
8 Summery	/	118
9 REFERENC	CES	121
10APPENDIX	X	I
10.1	SHADING DESIGN	I
10.2	COMPUTER OPTIMIZED SHADING DESIGN	I
10.2.1	Rectangular shade	I
10.2.2	Optimized planer shade	IV
10.2.3	Ecotect generated shadeing alternatives	VI
10.3Wing	walls" case study"	VIII
	Computer simple wingwalls design	
	ummery	

LIST OF FIGURES

Figure 1: above Ciudad de la Cultura de Galicia complex and the relation to the city, below the 3d model showing how it has the rhythms of nature
Figure 2: Computational formal explorations do not eradicate human imagination but rather extend its potential limitations
Figure 4: showing a deformed clyinders through using an existed deformation modifiers in 3d studio max, as an example for using a computerization methodology in design process
Figure 3: Light catchers on Nurbs surfaces arryed through computing the sun path movement, that an example for using the computer through a computation methodology in design process
Figure 5: Photorealistic Radiance rendering of the Fyvaskytii Music and Arts Centre auditorium entrance with Radiance, Dorota Palubicka, 19974
Figure 6: moving rooms according to gravity or collision detection, therfore allowing certain objects to move in three dimentional space4
Figure 7: Lighting simulation for Yokohama Port Terminal, Japan, FOA4
Figure 8: City Hall, London, London, UK,1998-2002, Architect Norman Foster 5
Figure 9: Topological Architecture, partial view of north elevation for bilbao museum6
Figure 10: Axinometric drawings for bilbao museum6
Figure 11: Standard Dears Tower, model view, Greg Lynn6
Figure 12: water drop was selected as the concept for BMW Pavilion7
Figure 13: Showing the blob structure as Disconnected primitives used to compose an isomorphic polysurfaces, then asan Isomorphic polysurface with primitives fused into a single surface
Figure 14 polysurface keyshapes7
Figure 15: Animate architecture: Lynn's Port, Authority Bus Terminal in New York
Figure 16: Using particle emission in beachness hotel project, NOX8
Figure 17: model development process, Peter Eisenman8

Figure 18: the paracube 1997-1998 ,Parametric architecture,Marcos novak9
Figure 19: showing parametric deformation in 8 steps for a cylinder 50story residential tower for Kostas Terzidis9
Figure 20 Interactivator (1995), by John & Julia Frazer: Exprimental evolution of form by interaction of actual visitors and environmental sensors9
Figure 21showing models generated and growed by functional envelopes
Figure 22: Computitional Architecture Classification
Figure 23 INCREMENTAL CYCLICAL PROGRESSION OF CAD MODELING 14
Figure 24 an analysis of surface curvature across a range of formal alternatives extrapolated from a computer animation by Mattew Herman (gradute student at the university of Pennsylvania)
Figure 25: showing the final repitted circle on different elevations according the lighting levels and sunpath17
Figure 26 Building performance design process methodology
Figure 27:showing a detailed environmental data analysis
Figure 28the use of particle emission in the port Authority Bus Terminal in New York Compitition project, Greg Lynn21
Figure 29 final fourth prototype of the House in Long Island Project, Greg Lynn22
Figure 30: inverse kinematics is used in the House Prototype in Long Island Project, architect Greg Lynn22
Figure 31 emergent forms under solar influance, Guy Westbook 1993 23
Figure 32 a physical model, fabricated via CNC milling, based on a Genr8 surface24
Figure 33: Final rendering of strawberry bar which grown and affected with the environment in Genr824
Figure 34: Left, an overview of some of the surfaces obtained during the evolutionary process of creating the strawberry bar, the right image shows a rendering of the final result

Figure 35: Generative design in non-physical environment proces methodology2
Figure 36: Showing on left an arrows to describ the air flow (representation of vector data), on right as contor graph (representation of scaladata
Figure 37: CFD simulation and analysis for the PennDesign building durin the schematic design phase2
Figure 38: <i>Scale model of buildings used in wind tunnel.</i> 2
Figure 39: <i>Viewer</i> with HMD (Head Mounted Display)3
Figure 40: Registeration of room in real-space
Figure 41:Transferring human perceptual cues as hand movements withit AR environment
Figure 42: Interacting with CFD datasets
Figure 43 the left side displays a 3d sun-path for the current day as a dotte line running across the model. When this is displayed, you can click an drag the sun with the mouse, and the other displays the annual sur path through the sky for the first day of each month of the year
Figure 44 polar sun path diagram3
Figure 45 Natural lighting analysis " Daylighting levels
Figure 46 showing the benifits of lighting design aspects on form geomtry 3
Figure 47:Smart arrows used by architects to predict airflow in and aroun buildings
Figure 48:model of the bio-climatic proposal (ofice building, archited Hamza & Yeang)3
Figure 49: CFD results in the center of the rooms with stack effect (red high, yellow - moderate high, green - moderate low, blue - low) 3
Figure 50:Wind distribution on the building site, (a) original design and (bound design with four proposed
Figure 51: showing the impact of wind design aspects on form geometry. 3
Figure 52: Computer simulation showing temperature distribution withi

Figure 53 shows hourly temperature graph3	39
Figure 54 shows hourly heat gain3	39
Figure 55 shows monthly space loads4	10
Figure 56 shows a contour range of the temperature of zones 4	10
Figure 57 showing the impact of THERMAL design aspects on form geometry4	
Figure 58 sound behavior in a large room with curved surface	12
Figure 59 Greater London Authority (GLA) building; architects: Foster Partners; acoustic engineers: Arup Acoustics	
Figure 60 generating rays using several different methods and up to ar reflection depth and the rays are linked directly to model geometry, you moved the reflector around it will also interactively update rapaths	if ay
Figure 61 Even outdoor borders of the form can be deformed direct according to the reflected rays, in the left picture this angle will cause a series of reflections, although the other will get direct rays without reflection	se ut
Figure 62: Statistical reverberation graph4	14
Figure 63:Sprayed acoustic rays & particles	14
Figure 64:Acoustic response graph4	15
Figure 65:showing the benifits of acoustic design aspects on form geomto	
Figure 66:Intersection of Embedded Computation and Kinetic Architecture	
Figure 67 Dynamically reconfigurable 3D screen reacts in real time t surrounding motion and sound, transforming <i>Hyposurface</i> 's comple topography and colors, "Aegis Hyposurface, architect Ma Goulthorpe/dECOI"4	∋x ırk
Figure 68: Responsive In-Direct control diagram4	18
Figure 69: Kinetic wall4	19
Figure 70:Moderating Skylights4	19

and joined along its edges to form a self-intersecting surface. Enclosed volumes are trapped within the surface by both the joining and intersecting operations
Figure 72: transformation of a ring into a cup through flexibility of a single surface
Figure 73:Example for a composite curve created in a Radii curve method
Figure 74: A similar curve described using spline geometry53
Figure 75: Drawing a second degree Bezier curve by hand 53
Figure 76: showing degrees of spline and a spline surface of mesh, and the spline surface, or mesh, constructed out of groups of splines whose control vertices are connected across one another
Figure 77: Using computer techniques, Key frame animations simulating a double Syslem of reaction between the membranes and sound input were produced, SaraJevo Concert Hall for Ammar Elouini "Digit-All Studio"
Figure 78: The non renderable forces afecting surfaces with different deformation55
Figure 79: Push disperses a cloud of particles
Figure 80: Particle stream caught in a vortex56
Figure 81: Particles falling because of gravity56
Figure 82: wind effect on particles57
Figure 83: Deflector repelling particles57
Figure 84: Partical system organization58
Figure 85:Inverse kinematics skeleton 58
Figure 86: simplifing the skeleton into a linear structure so the influence of the site forces could be read more clearly
Figure 87 Genr8 surface grown in an environment where it has been pulled down by gravity on top of a spherical boundary