MOODY ARCHITECTURE:
EMOTIONALLY INTELLIGENT PROSTHESES

by

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AUTHOR'S DECLARATION

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ABSTRACT

The digital age has altered the prosthetic relationship between the body and its extensions. Communication devices have started to engage us in an emotional conversation, whereas the focus on the body in architecture perpetuates the mechanistic relationship that dominated during the industrial revolution. This lack of emotional connectivity in architecture challenges the idea of the normative body in light of an analysis of the relationship between empirical reality and classical doctrine.

This thesis proposition envisages architecture as becoming an emotionally intelligent prosthesis endowed with anthropomorphic characteristics. Phenomenology and cybernetic systems provide the tools to advance the relationship between the body and its prosthetics. A feedback loop demonstrating cognition and plasticity is a prerequisite for structurally coupling two such systems.

Architecture is conceived as evolving to interact continuously with the physical and emotional state of the user. This speculative world allows the thesis to consider how the body and the building might become the organs and prostheses of each other.

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In memory of my grandfather

TABLE OF CONTENTS

AUTHOR’S DECLARATION	III
ABSTRACT	V
ACKNOWLEDGEMENTS	VII
TABLE OF CONTENTS	X
LIST OF FIGURES	XIII
LIST OF APPENDICES	XXVIII
1. INTRODUCTION	1
PART I	5
2. A BODY-BUILDING RELATIONSHIP	6
2.1. The Body as a Projected Metaphor for the Building	6
2.2. Proportions and the ‘Norm’-alization of the Body	8
2.3. The Absence of the Body	11
3. THE BODY + ITS PROSTHETICS AND THEIR RELATIONSHIP TO THE BUILDING	14
3.1. Fragmentation of bodies	15
3.2. Technologically Enhanced Bodies	21
3.3. Body Plasticity, Extensions, Adaptation, Layers, Abstractions, Boundaries, Spaces, Invisibility and Augmentation	22
3.3.1. Body Plasticity	22
3.3.2. Body Extensions	24
3.3.3. Body Adaptations	28
3.3.4. Body Layers	28
3.3.5. Body Abstractions	32
3.3.6. Body Boundaries	33
3.3.7. Body Spaces	34
3.3.8. Body Invisibility	35
3.3.9. Body Augmentation	39

PART II	41
4. CYBERNETICS: THE NEED FOR CONVERSATION	42
4.1. Communication	42
4.2. Conversation Theory.	45
4.3. Ubiquitous Computing: Embedded conversations	49
4.4. Ubiquitous computing in architecture - Adaptive/Responsive Architecture	51
4.5. Emotionally Intelligent Environments (EIE)	55
5. ARCHITECTURE THAT LEARNS	62
5.1. Emergent Behaviour	62
5.2. Dialogue between participant and machine	65
5.3. The Body-Building Relationship as Phenomenon, Trope and Second-Order Cybernetic Systems	70
5.4. Self-Awareness and Self-Assembly	72
PART III	79
6. TENSEGRITIES AS COMPLEX SYSTEMS THAT CAN CONVERSE	80
6.1. Tensegrities: An alternative form of Structure	80
6.2. Tensegrities and Emergent Behaviour	82
6.3. Tensegrities in Nature, Cellular Reproduction, and the huMan body	83
PART IV	85
7. DESIGN RESEARCH PROJECTS	86
7.1. Design exploration 1: eMotive – an Architectural Tensegrity assembly	88
7.1.1. Addressing the Anthropomorphic Model	88
7.1.2. Addressing the Emotional Model	91
7.1.3. Addressing the Learning Model	96
7.1.4. Addressing the Self-Assembly Model	97
7.2. Design Exploration 2: The POD: formation of an Architectural Prosthetic body	102
7.2.1. The pod	104
7.2.2. The pod world	113
8. CONCLUSION	135

9.	APPENDICES	136
9.1.	Appendix A: Design Explorations Through Physical Modeling	136
9.2.	Appendix B: Design Explorations Through Digital Modeling	144
9.3.	Appendix C: Design Explorations Through Combined Physical and digital Modeling	147
9.4.	Appendix D: Design Explorations: Immersing into Media	150
	BIBLIOGRAPHY	158

LIST OF FIGURES

Figure 1. Being body-mind. Image by author	5
Figure 2. l’homme’. Source: https://www.centrepompidou.fr/en. ” (Gawne, 2015)	7
Figure 3. Trattato di architettura di Francesco di Giorgio Martini. Source: http://leonardodavinci.stanford.edu	7
Figure 4. Trattato di architettura di Francesco di Giorgio Martini. Source: http://leonardodavinci.stanford.edu/submissions/clabaugh/history/architecture.html	7
Figure 5. Caryatids of the Acropolis. Source: http://1.bp.blogspot.com/-dze4qn1T0uc/Ud2yXFdePyI/AAAAAAARTU/9A09E6oOtFA/s640/IMG_4232.JPG	7
Figure 6. Modular Man. Source: (Imrie, 2003, p. 48)	7
Figure 7. Body Allusions. The images represent the manner in which references to the relationship between architecture and the body have entered into the common lexicon of words and images (i.e., this house has good “bones”, the “skin” of the structure is permeable, eyes are the windows to the soul, etc.). Collage by author. Source: https://faceofnightmare.blogspot.ca/2014/11/peeler-by-xue-jiye.html?spref=pi , http://www.gettyimages.ca/detail/photo/girl-screaming-with-mouth-wide-open-high-res-stock-photography/129741234 , https://www.architectural-review.com/today/14-pivotal-architecture-drawings/8657619.article .	8
Figure 8. Beautiful Users. Source: http://www.thomascarpentier.com/Measure-s-of-Man-Architects-Data-Add-on	9
Figure 9. Mean average (50th percentile) dimensions of adult British males. Source: (Littlefield, 2008, pp. 2–1)	10

- Figure 10.** Dimensions of the Human Figure.
Source: (Ramsey, 1970, p. 2) 10
- Figure 11.** Template, Humanscale 1a: Body Measurements Selector, 1974. Henry Dreyfuss Associates.
Source: <https://collection.cooperhewitt.org/objects/51689281> 10
- Figure 12.** Carpenter Visual Arts Center, Harvard University. Le Corbusie. 1963.
Source: <https://www.studyblue.com/notes/note/n/aph-313-lindsey/deck/13693534> 11
- Figure 13.** The Bauhaus Dessau. Walter Gropius. Photographed in 1926 by Lucia Moholy.
Source: <https://www.bauhaus100.de/en/past/people/friends/lucia-moholy/> 11
- Figure 14.** Lever House. Skidmore, Owings & Merrill. New York City. Photographed in 1959 by Julius Shulman.
Source: <http://www.dezeen.com/2016/08/18/julius-shulman-modernism-rediscovered-photos-american-mid-century-architecture/> 11
- Figure 15.** Centraal Beheer Apeldoorn. Montessori School in Delft. Herman Hertzberger. 1968-72.
Source: <http://www.dezeen.com/2011/12/06/key-projects-by-herman-hertzberger/> 11
- Figure 16.** Toward ambulation.
Image by author 12
- Figure 17.** 13th century Anatomical Illustration.
Source: <https://cliojournal.wikispaces.com/The+Limitations+of+Medieval+Medicine> 16
- Figure 18.** Astrology and Medicine.
Source: <http://fineartamerica.com/featured/16th-century-medical-astrology-cordelia-molloy.html> 16
- Figure 19.** Visio Prima: Catoptri Microcosmographici. Johann Remmelin (1613).
Source: https://commons.wikimedia.org/wiki/File:Remmelin;_Catoptrum_microcosmicum_Wellcome_L0060924.jp 16
- Figure 20.** Visio Prima: Catoptri Microcosmographici. Johann Remmelin (1613). Illustrating “dismemberment”.
Source: <http://www.mephistophelia.com/remmelinproject.htm> 17
- Figure 21.** Collage of Leonardo Da Vinci Anatomical drawings. Collage.
Collage by author. Source images:

	Source: http://www.openculture.com/2016/03/download-the-sublime-anatomy-drawings-of-leonardo-da-vinci.html	18
Figure 22.	To Sell Oneself in Small Fragments, 1976–77. Source: (Donger, Shepherd, & Orlan, 2010, p. 106)	19
Figure 23.	Inasmuch As It Is Always Already Taking Place. Gary Hill. 1990. Source: http://www.moma.org/collection/works/81321?locale=en	19
Figure 24.	Blur. Diller & Scofidio. Source: http://www.arcspace.com/features/diller-scofidio--renfro/blur-building/	20
Figure 25.	Braincoat. Diller & Scofidio. Source: http://realtimecities.wikispaces.com/BlurBuilding_Braincoats	20
Figure 26.	Padaung women. Source: http://247newnews.blogspot.com/2014_12_02_archive.html	23
Figure 27.	Foot binding. Source: http://www.businessinsider.com/jo-farrells-photos-of-chinese-women-with-foot-bindings-2014-9	23
Figure 28.	Human Barbie. Source: http://www.nydailynews.com/life-style/human-barbie-race-mixing-prompts-plastic-surgery-rise-article-1.1748615	23
Figure 29.	(Left). First Surgery-Performance. Première Opération Chirurgicale-Performancen. Orlan. 1990. Source: https://heidifoss.wordpress.com/performance-orlan/	24
Figure 30.	(Right). Third Hand. Stelarc 1980-1998. Source: http://stelarc.org/?catID=20265	25
Figure 31.	Venus of Willendorf. Source: http://aaw3dart.blogspot.ca/2011/04/assignment-prehistoric-venus-sculpture.html	26
Figure 32.	Neolithic menstruation statue. Source: https://redtentmovie.files.wordpress.com/2014/03/xaghra-twins-figurine-34.jpg	27
Figure 33.	Venus figurine. Source: http://www.hiddenhistory.co.uk/wp-content/uploads/2015/01/Catalhoyuk-Mother-Goddess.jpg	27
Figure 34.	Igloo.	

- Source: <https://upload.wikimedia.org/wikipedia/commons/7/75/Igloos.jpg> 28
- Figure 35.** Spacesuit.
Source: <http://www.iainclaridge.co.uk/blog/8169> 29
- Figure 36.** Suitallon. Archigram. 1967.
Source: http://architecturewithoutarchitecture.blogspot.ca/2012_12_01_archive.html 29
- Figure 37.** Cushicle, from closed to unfolding. Archigram. 1966.
Source: <http://architecturewithoutarchitecture.blogspot.ca/p/cushicle-and-suitaloon-were-conceptual.html> 29
- Figure 38.** Walking City. Archigram. 1964.
Source: <http://www.arch2o.com/cities-of-the-future/> 29
- Figure 39.** Cronenberg's game-pods. eXistenZ. 1999.
Source: <https://svitlanamatviyenko.net/tag/david-cronenberg/> 33
- Figure 40.** St. Peter's Basilica. 1626. Interior.
Source: <http://www.cbcew.org.uk/CBCEW-Home/About-Us/The-Catholic-Church/Vatican-II> 34
- Figure 41.** Thoronet Abbey church interior alcove.
Source: <http://www.beyond.fr/sitephotos/thoronet-abbey-photo-gallery.html> 34
- Figure 42.** Antonio Gaudi. Sagrada Familia.
Source: <http://www.archdaily.com/438992/ad-classics-la-sagrada-familia-antoni-gaudi> 34
- Figure 43.** Church of the Light. Tadao Ando. 1999.
Source: <http://www.archdaily.com/101260/ad-classics-church-of-the-light-tadao-ando> 34
- Figure 44.** Bruder Klaus Field Chapel. Peter Zumthor. 2007.
Source: <http://www.arquiscopio.com/pensamiento/la-sabiduria-de-zumthor> 34
- Figure 45.** The chapel of Notre Dame du Haut. Ronchamp. Le Corbusier. 1954. Wall Alcove.
Source: <http://www.pointedleafpress.com/kabbalah-in-art-and-architecture> 35
- Figure 46.** Glasses.
Source: <https://quizlet.com/27099286/architecture-through-the-19th-century-pt-ii-flash-cards/> 36
- Figure 47.** Twin Towers Before and After.

Source: http://www.september11news.com/WTCArt.htm	36
Figure 48. Imponderabilia. Marina Abramovic. 1977.	
Source: https://www.visualnews.com/2013/10/25/creatives-work-emotional-performance-art-marina-abramovic/	37
Figure 49. Expanding in Space - Marina Abramovic - 1977. Collage from screenshots.	
Source: https://www.youtube.com/watch?v=HEQUC0-AIUo	38
Figure 50. Conversations.	
Image by author	40
Figure 51. “She thinks it’s a touchscreen.” Emily Flake. 2013.	
Source: http://www.newyorker.com/cartoons/flake-2013-01-28	42
Figure 52. Minimaforms. Becoming animal. 2007.	
Source: http://minimaforms.com/becominganimalmoma/	43
Figure 53. Tweenbot. Kacie Kinzer. 2009.	
Source: http://www.moma.org/interactives/exhibitions/2011/talktome/objects/146369	44
Figure 54. Movie “Her”. 2013.	
Source: http://www.wired.com/2014/01/will-influential-ui-design-minority-report/	44
Figure 55. Pask’s Definition of Cybernetics. Original images	
Source: https://beyondaesthetics.wordpress.com/2010/01/28/gordon-pask/ and (Pask, 1969)	46
Figure 56. (Bottom). SAKI. 1956.	
Source: (Pickering, 2011, p. 326)	47
Figure 57. (Right). Adaptive teaching machines. 1961.	
Source: http://hackededucation.com/2015/03/28/pask	47
Figure 58. (Top). Fun Palace. Cedric Price. 1961.	
Source: http://candychang.com/the-fun-palace-realized/	48
Figure 59. (Right). Fun Palace. Cedric Price. 1961. Organisational Plan as Programme.	
Source: http://candychang.com/the-fun-palace-realized/	48
Figure 60. Examples of Internet of Things (IoT) devices currently available on the market.	
Source: https://www.axa.com/en/spotlight/story/home-insurance-of-the-future	50

- Figure 61.** (Left) Sensor panel for light, temperature and sound. Also includes speaker to allow house to vocalize to inhabitant. Adaptive House. Michael Mozer. 1997.
Source: <http://www.cs.colorado.edu/~mozer/index.php?dir=/Research/Projects/Adaptive%20house/photos/sensors/> 51
- Figure 62.** (Right) Miles of cabling in the house terminate at panel to be fed into and processed by a PC. Adaptive House. Michael Mozer. 1997.
Source: <http://www.cs.colorado.edu/~mozer/index.php?dir=/Research/Projects/Adaptive%20house/photos/computers/> 51
- Figure 63.** Adaptive House floor plan. Michael Mozer. 1997.
Source: <http://www.cs.colorado.edu/~mozer/Research/Projects/Adaptive%20house/java%20interface/ji.html> 52
- Figure 64.** (Left). Layout of current incarnation of Intelligent Room with two ceiling mounted projectors. Cameras monitor the room to detect when peoplet point at images on wall. The Intelligent Room. MIT, Michael Coen. 1997.
Source: (Brooks, 1997, p. 272) 53
- Figure 65.** (Middle). Trackers can monitor the movements of several people in the room. Image on the left shows historical movement of four different people. Image on the upper rights shows view from camera. Image on lower right shows computer distinguishing between four separate individuals..The Intelligent Room. MIT, Michael Coen. 1997.
Source: (Brooks, 1997, p. 274) 53
- Figure 66.** (Right). Data gathered from monitoring a user walking around the room for a few minutes enables recreation of the structure of the room. The Intelligent Room. MIT, Michael Coen. 1997.
Source: (Brooks, 1997, p. 273) 53
- Figure 67.** Transform. Tangible Media Group from the MIT Media Lab. 2014.
Source: <http://tangible.media.mit.edu/project/transform/> 54
- Figure 68.** Transform. Tangible Media Group from the MIT Media Lab. 2014.
Source: <http://tangible.media.mit.edu/project/transform/> 54
- Figure 69.** Curiosity.
Image by author 60
- Figure 70.** Shoes designed by Francis Bitonti based on the Game of Life algorithm that models complex behaviour.
Source: <http://www.dezeen.com/2014/09/26/francis-bitonti-3d-printed-molecule-shoes-adobe-stratasys/> 62
- Figure 71.** Flocking Behaviours in Birds.
Source: <http://www.alaindelorme.com/works-murmurations> 63

- Figure 72.** Shoaling Behaviour in Blue Jack Mackerel.
Source: <http://www.wired.com/2013/03/powers-of-swarms/> 63
- Figure 73.** Cellular Automata Pattern Testing. Born: 2, Survive: 2,3.
Image by author 64
- Figure 74.** Cellular Automata Pattern Testing. Born: 2, Survive: 2,3.
Image by author 64
- Figure 75.** Cellular Automata Pattern Testing. Born: 3, Survive: 2,3.
Image by author 64
- Figure 76.** Cellular Automata Pattern Testing. Born: 3, Survive: 2,3.
Image by author 64
- Figure 77.** Generator Project.
Source: <https://hotcharchipotch.wordpress.com/2013/03/31/readapt-the-habitat/> 67
- Figure 78.** Escape.
Image by author 68
- Figure 79.** Sequence shows self-reproducing modular robot going through reproduction cycle.
Source: (Zykov, Mytilinaios, Adams, & Lipson, 2005) 73
- Figure 80.** M-Blocks connect to each other using permanent magnets embedded in their corners. Other magnets on their faces are used for alignment. The modules ambulate using the torque of an internal flywheel.
Source: (Romanishin, Gilpin, & Rus, 2013) 74
- Figure 81.** Self-Replicating Spheres explores the processes of growth, encapsulation and division through macro-scale objects on an oscillating table. The internal structure of the metal spheres provides the force of attraction for growing connections, flexibility and division. By adding more spherical units and oscillating the table, the system continuously grows and divides. Self-Assembly Lab, MIT - Dimitris Maitopoulos, Skylar Tibbits.
Source: <http://www.selfassemblylab.net/SelfReplicatingSpheres.php> 75
- Figure 82.** Distributed Flight Array modules move along the ground to find each other and then join together into a multi-propeller system capable of coordinated flight. The system is self-monitoring and adjusts thrust to correct for disturbances. If the modules detach, the whole process repeats itself. Each unit is self-contained and has its own sensors, but coordinates with its peers. // Raffaello D'Andrea. 75
Source: <http://raffaello.name/projects/distributed-flight-array/>
- Figure 83.** A prototype of NASA's Super Ball Bot built by Ghent University's Ken Caluwaerts. 2014.

Source: https://www.wired.com/2014/02/nasas-super-ball-bot-revolutionize-robotics/	76
Figure 84. TensegrityEvaluations. 2013.	
Source:(Adrian Agogino, Vytas SunSpiral, & Atkinson, 2013, p. 6)	77
Figure 85. Confrontations.	
Image by author	78
Figure 86. Schematic of three strut tensegrity structure. 3D model.	
Image by author	81
Figure 87. Three strut tensegrity Kangaroo simulation.	
Image by author	81
Figure 88. An exploration of tensegrity form-finding based on dynamic relaxation over regular geometries	
Image by author	81
Figure 89. Physical model deformation and emergent behaviour studies. See Appendix A.	
Image by author	82
Figure 90. Models of vertebrate anatomy. Tom Flemons. 2005.	
Source: http://www.interactivearchitecture.org/designing-a-bio-tensegrity-exoskeleton.html	83
Figure 91. (Left) Actin geodome floating tension structure (tensegrity) form in cells attached to a surface revealed by fluorescence micrography of actin in an adherent epithelial cell.	
Source: https://cerebrovortex.com/2013/08/19/silk-island/	84
Figure 92. (Right). Cellular Tensegrity.	
Source: https://paul-thorpe.com/2015/02/06/bio-tensegrity/ The cellular tensegrity model states that the entirety of the cell is a pre-stressed tensegrity structure and that the constituent parts, such as the membrane and filaments of the cell are required in order for it to maintain structural integrity. In addition, they enable shapeshifting and other cellular functions.	84
Figure 93. Freeing emotions.	
Image by author	85
Figure 94. Conceptual eMotive model.	
Image by author	86
Figure 95. Assembling tensegrities into clusters.	
Image by author	87

Figure 96. Testing strut arrangement configuration.	
Image by author	88
Figure 97. Body tensegrity. Collage	
Image by author.	
Source: http://www.interactivearchitecture.org/designing-a-bio-tensegrity-exoskeleton.html	88
Figure 98. Physical model deformation and emergent behaviour studies. See Appendix A.	
Image by author	89
Figure 99. Tensegrity activation mechanisms and computational system. The kinect sensor captures the movements of the user and process them using a computer running an arduino script and a skeleton tracker plug-in. This information was then used in different models to generate motion in the tendons or struts of the tensegrity to demonstrate a response to the user's emotion.	
Image by author	90
Figure 100. Emotional impressions.	
Image by author	91
Figure 101. Body Volume.	
Image by author	92
Figure 102. Body Volume.	
Image by author	93
Figure 103. Proximity.	
Image by author	94
Figure 104. Motion Intensity.	
Image by author	95
Figure 105. Motion Intensity.	
Image by author	95
Figure 106. eMotive challenging the user versus improving the emotional state.	
Image by author	97
Figure 107. Proposed motion pattern and layout map.	
Image by author	98
Figure 108. eMotive physical model.	
Image by author	98

Figure 109. Tensegrity unit assembly diagram.	
Image by author	99
Figure 110. Assembly. Method 1.	
Image by author	100
Figure 111. Assembly. Method 2.	
Image by author	100
Figure 112. Layout. Method 1.	
Image by author	100
Figure 113. Layout. Method 2.	
Image by author	100
Figure 114. Prosthetic bodies.	
Image by author	102
Figure 115. Pod clusters. Plans.	
Image by author	104
Figure 116. Front section.Side elevation. Transverse section.	
Image by author	106
Figure 117. Pods connecting to agreggregate into larger structures.	
Image by author	107
Figure 118. Pod perspective view.	
Image by author	108
Figure 119. Pods connecting to create larger aggregations.	
Image by author	109
Figure 120. Pod in play.	
Image by author	111
Figure 121. Pod in play.	
Image by author	111
Figure 122. Pod world.	
Image by author	112
Figure 123. Pod community.	
Image by author	113

Figure 124. Pods matrix.	
Image by author	114
Figure 125. Accentuating and highlighting some of the autonomous and independent components that make up the Pod .	
Image by author	115
Figure 126. Pod physical model.	
Image by author	116
Figure 127. Pod physical model.	
Image by author	117
Figure 128. Bathing facilities.Perspective view.	
Image by author	118
Figure 129. Excretion facilities.	
Image by author	120
Figure 130. Excretion facilities.	
Image by author	120
Figure 131. Bathing facilities.	
Image by author	121
Figure 132. Bathing facilities.	
Image by author	121
Figure 133. Bathing facilities.	
Image by author	121
Figure 134. Bathing facilities.	
Image by author	121
Figure 135. Bathing facilities.	
Image by author	121
Figure 136. Bathing facilities.	
Image by author	121
Figure 137. Excretion facilities.	
Image by author	122
Figure 138. Excretion facilities. Perspective.	
Image by author	124

Figure 139. Transparent excrement collectors.	
Image by author	124
Figure 140. Excretion facilities. Plan.	
Image by author	124
Figure 141. Excretion facilities. Perspective.	
Image by author	124
Figure 142. Excretion facilities. Perspective.	
Image by author	124
Figure 143. Excretion facilities. Perspective.	
Image by author	124
Figure 144. Excretion facilities.	
Image by author	124
Figure 145. Excretion facilities.	
Image by author	125
Figure 146. Nourishment facilities.	
Image by author	125
Figure 147. Nourishment facilities.	
Image by author	126
Figure 148. Nourishment facilities.	
Image by author	128
Figure 149. Nourishment facilities.	
Image by author	129
Figure 150. Nourishment facilities.	
Image by author	129
Figure 151. Nourishment facilities.	
Image by author	129
Figure 152. Nourishment facilities.	
Image by author	129
Figure 153. Nourishment facilities.	
Image by author	129

Figure 154. Nourishment facilities.	
Image by author	129
Figure 155. View from inside.	
Image by author	130
Figure 156. View inside the Pod.	
Image by author	131
Figure 157. Pod world.	
Image by author	132
Figure 158. Pod world.	
Image by author	135
Figure 159. Six and eight strut assemblies.	
Image by author	137
Figure 160. Physical model deformation and emergent behaviour studies.	
Image by author	137
Figure 161. Interior and exterior systems.	
Image by author	138
Figure 162. Six strut tensegrity with polyester membrane.	
Image by author	139
Figure 163. Three strut tensegrity aggregation. Hand painted.	
Image by author	140
Figure 164. Three strut tensegrity aggregation. Hand painted.	
Image by author	141
Figure 165. Testing thermal shape memory behaviour in Smart Memory Alloys.	
Image by author	143
Figure 166. Testing thermal shape memory behaviour in Smart Memory Alloys.	
Image by author	143
Figure 167. Testing thermal shape memory behaviour in Smart Memory Alloys.	
Image by author	143
Figure 168. Initial Arduino setup and digital simulation.	
Image by author	144

Figure 169. Digital model behaviour studies.	
Image by author	145
Figure 170. Growth pattern through cell subdivision testing.	
Image by author. Script based on igeo tutorials	146
Figure 171. Actuator studies. Test 1.	
Image by author	148
Figure 172. Actuator studies. Test 2.	
Image by author	148
Figure 173. Actuator studies. Test 3.	
Image by author	149
Figure 174. Actuator studies. Test 4.	
Image by author	149
Figure 175. Light painting. Body as a medium studies.	
Image by author	150
Figure 176. Light painting. Body as a medium studies	
Image by author	151
Figure 177. Light painting. Body as a medium studies.	
Image by author	152
Figure 178. Light painting. Body as a medium studies.	
Image by author	153
Figure 179. Anastasija Dudnyakova performance. .	
Image by author	155
Figure 180. Anastasija Dudnyakova performance. .	
Image by author	155
Figure 181. Painting on water.	
Image by author	156
Figure 182. Painting on water.	
Image by author	157

LIST OF APPENDICES

APPENDIX A:	DESIGN EXPLORATIONS THROUGH PHYSICAL MODELING
APPENDIX B:	DESIGN EXPLORATIONS THROUGH DIGITAL MODELING
APPENDIX C:	DESIGN EXPLORATIONS THROUGH PHYSICAL MODELING
APPENDIX D:	DESIGN EXPLORATIONS: IMMERSING INTO MEDIA

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1. INTRODUCTION

Caveat lector! - This thesis does not adhere to a conventional format. Neither does it propose a traditional design. Instead, it describes a journey that evolved, somewhat organically, as it explored the notion of the “body” in architecture. It offers up certain observations, arguments and ideas gleaned along the way and paints a picture of an imagined world in which architecture has moved beyond the static to become engaged dynamically and harmoniously with the unique physical and emotional attributes of each user.

The Premise – The body-building relationship is an enduring tradition in architecture. It is a primal metaphor from which humanity has envisioned and constructed its world. Its use can be traced from ancient times right up to the present day. This thesis explores various arguments that have been put forth within the fields of architecture, philosophy and cybernetics that a visceral, bodily and emotional connection exists between the user and structure (i.e., the body and the built space). It considers arguments in favour of reversing the typically accepted phenomenology of architecture to create emotionally intelligent environments that communicate with the body in cybernetic terms. The thesis proposes imagining a world in which architecture has been endowed with flexibility and motility, along with the ability to understand and employ the language of the body with its user, so that together they can negotiate an emotionally satisfying space.

An investigation is made into tensegrities and their unique combination of rigid and bendable components that emulate bodily attributes. This is followed by a description of the imagined qualities that a personal, motile, interactive and emotionally intelligent environment might be like and how it might integrate with, influence, and be influenced by, the surrounding social community. In the envisaged scenario, the concept of the body and architecture becoming organs of one another, supporting each other in a reciprocating, self-sustaining and evolving manner is considered.

The Journey - The journey began with a traditional examination of the archetype long used to define the relationship between the body and built space: the Vitruvian man. This led to an exploration of the standards and norms that arise in architecture as a result of a design process premised on an idealized form. However, questions soon arose regarding the supposedly fixed and normative relationship between the body and built space, particularly in light of the infinite variability in sizes and shapes to be found in the bodies of “real” people. In short, empirical reality did not align well with classical doctrine. The dynamic capacity of the body, including all its appendages and organs, to undergo

self-directed change, and to be re-shaped by external forces, existed in sharp contrast to the theoretical archetype.

At this stage of the design process, multiple explorations were made into “flexible/malleable” building structures in an attempt to find those that would more faithfully emulate the continuously changing physical attribute of the human body. A closer examination of tensegrity structures, with their inherent flexibility and shape-shifting forms, revealed them to be suitable proxies for the highly changeable human body. Thus, they were good candidates for use in architecture that could more readily and accurately reflect the ancient body/building metaphor.

The design process then expanded into a deconstruction of the term “body”. Multiple meanings of the word “body” were put forth and evaluated against the conceptual benchmark of the “classical” body in architecture. The concept of variations in bodily sizes and shapes was thereby extended to include the mutability of the emotional and cognitive elements in the body, such as the mind, ideas, language, learning and identity. Just as corporeal components varied widely amongst individuals, it was recognized that their incorporeal forms, including all of the tools and extensions of our minds used to engage the physical world, are modifiable and differ amongst individuals. For example, twins; No matter how similar they may be at a physical, bodily level, they remain distinct individuals with different life experiences, and thoughts and ideas of their own.

This led to phenomenological analysis of the role of all aspects of the body, tangible and intangible, in experiencing and interacting with the world around us. From here, it became apparent that every constituent part of the “body” is a prosthetic for some other part or parts, be it cell, liver, brain or emotion. Collectively, they assist each other (i.e., as “prosthetics” or “extensions” of one another) to achieve their respective ends. In so doing, they generate the way in which we experience the world around us and, in turn, are shaped and altered by those same sets of experiences. In this way, a dynamic and reciprocating loop is created that forms and re-forms us, ceaselessly, as well as the environments that we inhabit.

At this point in the journey, the realization of the persistent presence of a continuous feedback mechanism between “body” and building drove an examination of the process across a wide range of social and cultural settings. It quickly became apparent that every inhabited milieu exists in a state of perpetual change, fueled by the symbiotic relationship between user and setting. Cultural “norms” revealed themselves to be norms only in the most transient sense, as participants and behaviours morphed over time in an endless dance between the Deluzian orchid and wasp. Similarly, architectural and design “norms” were demonstrated to be products of the “body” projecting itself, through its countless prosthetics, into a particular physical environment and re-shaping it to meet the ever changing needs and ideas of its inhabitants.

In the design process, this led to an exploration of the transient and ephemeral methodologies of creating and re-shaping space. “Painting” structures or spaces out pure light (i.e., light painting) evolved as a product of this study of the symbiosis of body, physical objects and the immediate environment. Solely through the use of light emitted from a burning hand torch, as captured in digital images, could the positioning, strength, balance, and direction of a “body” be used to produce different patterns/forms of “enclosures” (i.e., continuous curves produced in a circular motion for the duration of the burning of the medium).

Research was then conducted in a system of study known as cybernetics, developed to map and coordinate the interfacing of biological/machine and machine/machine interactions. The motivation for these investigations was to determine an optimal means for describing and controlling the interconnection between the “body”, in all its variability, and its prosthetic extensions, including architecture. A strong, historical relationship was uncovered as part of these examinations between the superficially disparate fields of cybernetics and architecture. Key figures in the cybernetic world have taken an active interest in developing complex, interactive forms of architecture that could more readily adapt and change to meet the needs of its users.

From here, a study of complex behaviour in emergent systems, as well as an exploration of ubiquitous computing and intelligent environments, was undertaken. These efforts yielded an appreciation for prior efforts that had been made to create cognitive (i.e., learning) architectures through the use of embedded technology that could respond to, and even predict, a user’s behaviour and preferences.

At this juncture, the design process began to explore notions of emotions as prosthetics and the relationship between emotions and architecture. A series of paintings was prepared that grappled with the feelings that different spaces conjure up within the individual, and depicted how different spaces affect people differently. This led to the realization that traditional architecture, *prima facie*, attempts to evoke one or more specific emotions in its users and that it does so using the normative “man” or “body” as a guide as to how people will likely react. For example, huge columns and vaulted ceilings are often used to create a sense of awe and to make the user feel relatively small and powerless. However, previous realizations had made it clear that no two people or “bodies” were the same and, consequently, no two persons could experience architecture exactly the same.

Consideration was then given to bringing all of the elements of the study collected to this point together, in an effort to envisage an emotionally intelligent environment that could exhibit flexibility and motility like a human body, and could recognize, respond and learn from its user’s emotions. In so doing, the goal was to generate a real-time, dynamic and reciprocating emotional feedback loop between user and structure, such that the two could enter into an emotionally satisfying accord.

The eMotive project was then introduced as an exploration of a possible embodiment of an aggregation of tensegrities into a shape-shifting, bodily form of structure with the ability to ambulate and interact with users. Various computerized simulations were then conducted to map a range of configurations and forms that such an assemblage could assume, which gave rise to further ideas on how users might interact with such a construct.

The project was further developed into a pod-like structure that was capable of fully enclosing the user. Here, the architecture was imagined as becoming a dynamic body that possesses human kinetic attributes and is also an emotional entity, where emotions are the mechanism that supply the architectural body with its reasoning and decision making qualities. The body and architecture become prostheses for each other and support one another. The human body takes care of the architectural body and it, in turn, takes care of the human body. Furthermore, by inviting people “in” to our pods (e.g., joining capsules) we would expose the interior of our architectural bodies, and by inviting people “out” (e.g., leaving our pods to socialize) the architecture would expose the exterior of our bodies.

PART I

Figure 1. Being body-mind.

2. A BODY-BUILDING RELATIONSHIP

2.1. THE BODY AS A PROJECTED METAPHOR FOR THE BUILDING

“The body is at once the most solid, the most elusive, illusory, concrete, metaphorical, ever present and ever distant thing - a site, an instrument, an environment, a singularity and a multiplicity” (Bryan S. Turner, [1984] 1996, 7–8).“ (Flanagan & Booth, 2009, p. 81)

There has always been a profound and intimate relationship between the body and architecture (see: Hight, 2008). Architects have been seeking inspiration from the human form for millennia (Gawne, 2015; Scott, 1956; Imrie, 2003; Ots & Alfano, 2011). The idea that human proportions are divinely inspired and set the standard by which all edifices should be constructed dates back to before the pyramids (Ots & Alfano, 2011, p. 14) It is a notion that continued with the ancient Greeks, most notably in the classic Roman text by Vitruvius *Ten Books on Architecture* (Gawne, 2015), and well into the Renaissance. (Scott, 1956)

As Imrie notes, the fundamental principle underlying this approach is that the dimensions of the human body and its relative proportions are translated into geometric terms in order that they may then be further transcribed into architectural designs. (Imrie, 2003) In this way, the designer is assured in advance that the resulting structure will possess the necessary harmony and balance in its construction. (Ibid.)

This anthropomorphic correspondence between the human figure and harmonious design, typically referred to as the “Vitruvian man”, has been adhered to throughout the ages by some of mankind’s greatest architects, including Vasari and Leonardo Da Vinci (Ots & Alfano, 2011). Michelangelo, summed up the thinking best when he wrote of architecture: “He that hath not mastered, or doth not master the human figure, and in especial its anatomy, may never comprehend it”. (Scott, 1956, p.164)

The approach can be seen in the drawing set out in Figure 2, from *First and Chief Groundes of Architecture* (1563) written by John Shute which was one of the earliest texts in the English language on the subject of architecture, depicting a Greek column beside a human figure to emphasize the relationship between their proportions (Gawne, 2015). It can also be seen in the drawings in Figure 3 and Figure 4, made by Francesco di Giorgio Martini in the 15th century, and in the image of the Caryatids at the Acropolis in Figure 5.

Figure 2. *l'homme*. Figure 3. *Trattato di architettura di Francesco di Giorgio Martini.* Figure 4. *Trattato di architettura di Francesco di Giorgio Martini.* Figure 5. *Caryatids of the Acropolis.*

The proportions of many buildings reference the human form without copying it directly. (Meiss, 1990, p. 58) Architectural theorist, Francesco di Giorgio Martini in the Middle Ages, sought to use the human body as a metaphor not only for columns, as depicted above, but for building plans and other design elements, including the building itself and its façade. (Ibid.) This anthropomorphic focus in architecture, which uses the human body as a basis for design, purports to form an intimate and enduring connection between man and building. (Scott, 1956, p. 164) The approach continued right up to the twentieth century with noted architect Le Corbusier employing it in his 1950's book *The Modulor: a harmonious measure to the human scale universally applied to architecture and mechanics*. (Gawne, 2015) (see Figure 6) Allusions to the body-building relationship have even found their way into everyday language with the use of terms like the 'skin', 'skeleton' and 'façade' to describe the parts of a building. (Meiss, 1990, p. 58) (see Figure 7)

Figure 6. *Modular Man. Concrete wall art by Le Corbusier at the Unité d'Habitation in Firminy, France*

Figure 7. Body Allusions. The images represent the manner in which references to the relationship between architecture and the body have entered into the common lexicon of words and images (i.e., this house has good “bones”, the “skin” of the structure is permeable, eyes are the windows to the soul, etc.).

The notion of the proportions of the human body having being metaphorically projected into the structure and layout of the ancient Greek temple was re-visited as recently as 1996 in Joseph Rykwert seminal work, *The Dancing Column*. (Rykwert, 1998) However, Rykwert took the idea of the connection between body and building a step further than his predecessors and argued that, while the relationship may vary over time or even fall into disfavour, it is always to be found in architecture in one way or another (Hight, 2008) Rykwert’s student, Alberto Perez-Gomez echoed a similar theme, arguing that the projection of the human body is not only the main objective of architecture but of humanity as a whole. (Ibid.) For both Rykwert and Perez-Gomez, the metaphorical projection of the body into architecture is the primary condition for forming a world with meaning and a requirement of being human. (Ibid., p.18)

2.2. PROPORTIONS AND THE ‘NORM’-ALIZATION OF THE BODY

With the advent of the industrial revolution and the accompanying introduction of factories, machines and assembly lines, architecture attempted to rationalize the overall approach of the profession and bring a degree of numerical order to the field. Imrie describes the general change that took place in architecture as follows:

“This, then, was a process of the geometrisation of lived space, in which things became numbers to be understood as objective and intelligible forms. Increasingly, the task of architecture was the creation of a spatial order and the search for a universal theory of standards. As Perez-Gomez (1983) suggests, design was seen as no more than a process seeking to solve algebraic equations. In this schema, space was reduced to a series of (fixed) points that were rendered socially and morally neutral” (Imrie, 2003).

The emphasis on geometric coordinates and logic-driven rules directed architecture and other spatially related fields to focus on units of measure and efficiency in the design and production processes (Pérez Gómez, 1985). One effect, in particular, that the adoption of Cartesian coordinates and rationality had on the profession was to reduce the notion of the body that occupied those sterilized and rationalized domains to a single, abstract type (Lefebvre, 1991). This mathematically inspired, average human became, literally, the new “norm.” Imrie described the problem as follows:

“Most architects’ reactions were similar or revolved around identifying proportional or anthropometric measures as the basis for defining the body. As another respondent said, I suspect that the general

Figure 8. *Beautiful Users*. Ellen Lupton. 2014

Figure 9. Mean average (50th percentile) dimensions of adult British males.

Figure 10. Dimensions of the Human Figure.

Figure 11. Template, Humanscale 1a: Body Measurements Selector. Henry Dreyfuss Associates. 1974

image of the body is what might be thought of as the normal figure, as in ambulant and roughly the size of yourself or those around you, and that's the general perception.” This is the paradigmatic docile and static body referred to by Lynn (1998) and indicated by another of the architects interviewed: we would sort of use a norm in the sense of working on a person being about 1.8 metres high, and then sight lines and visions and opening lights and what have you. I suppose we do work on a, well, what we would call a norm.” Such norms tend to (re)produce bodily conceptions which revolve around the (Vitruvian) proportional body, or, as Lynn (page, 37) suggests, the alignment of the body with measure”. (Ibid.) [Emphasis added]

This trend in architecture to normalize and idealize the body to a single type has been further exacerbated with the advent of institutionalized standards and the implementation of universal design. The issue is particularly evident in the adoption of manuals like the *Architectural Graphic Standards* (1932-2016) and the *Metric Handbook* (1998). (see Figure 9 and Figure 10)

2.3. THE ABSENCE OF THE BODY

Rykwert and Perez-Gomez both viewed the rejection of the Vitruvian body-building relationship as first beginning in the late seventeenth-century by writers like Claude Perrault, and felt that its replacement with scientific reason and mathematical rigour, led to an impoverishment of architecture because it cast aside notions of *poiesis* and replaced them with functionalism and technology. (Hight, 2008) However, Rykwert argued that the modernists, as they came to be known, could not actually remove the

body from architecture because the metaphorical body is at the very core of architecture and what it means to be human. In their attempts to remove the body and replace it with other metaphorical projections, such as science and culture, Rykwert argued, they only “monumentalized” the body by its absence. (Ibid.) For example, the human figure is traditionally excluded from architectural drawings or photographs. While such renderings often seek to accentuate the structure by casting it as the sole and solitary focal point of the image, they also aim to make the building appear unsoiled by human touch. As Jonathan Hill noted: “For the architect, the occupant is an intruder, analogous to dirt, in the sense defined by Mary Douglas as matter out of place⁴”. (J. Hill, 1998, p. 79) In so doing, they draw attention to the human body by its deliberate exclusion.

Figure 12. (Bottom Left). Carpenter Visual Arts Center, Harvard University. Le Corbusier. 1963. Retrieved from: <https://www.studyblue.com/notes/note/n/aph-313-lindsey/deck/13693534>

Figure 13. (Top left). The Bauhaus Dessau. Walter Gropius. Photographed in 1926 by Lucia Moholy. Retrieved from: <https://www.bauhaus100.de/en/past/people/friends/lucia-moholy/>

Figure 14. (Top right). Lever House. Skidmore, Owings & Merrill. New York City. Photographed in 1959 by Julius Shulman.

Figure 15. (Bottom right). Centraal Beheer Apeldoorn. Montessori School in Delft. Herman Hertzberger. 1968-72. Retrieved from: <http://www.dezeen.com/2011/12/06/key-projects-by-herman-hertzberger/>

Figure 16. Toward ambulation.

3. THE BODY + ITS PROSTHETICS AND THEIR RELATIONSHIP TO THE BUILDING

The body-building relationship contemplated by the Greek, Vitruvian and Renaissance models, as well as Le Corbusier's Modulor, all designate the body, and man's perceptions and bodily experiences, as the primary metaphors through which we create a meaningful existence. As Hight noted, "In such arguments the body metaphor in architecture is the foundation for humanity's poetic structuring of the world. Through the metaphorical projection of our body the world of things reflects our sense of embodiment." In other words, following the line of thought developed by Lakoff (1999) and Johnson (2008), Hight maintains that we organize the bodily experiences of what we sense and perceive into a meaningful existence by employing our bodies as the primary metaphors. We then project this meaningful arrangement through our bodies and its various extensions. According to Hight, this includes all of our tools, our knowledge and even our architecture, which is to say our prosthetics. The term "prosthetic" is sometimes used to refer to "an artificial device that replaces a missing or injured part of the body" ("Dictionary and Thesaurus | Merriam-Webster," n.d.). However, it can also have a much broader meaning. As Marquard Smith and Joanne Moore noted in "The Prosthetic Impulse", the term "has become a staple in the armoury of metaphors and tropes" for describing the relationship between the body and technology (Smith & Morra, 2007, p. 2). In this way, everything through which we project our bodily experiences can be thought of as either a material or metaphorical form of prosthetic, as further discussed in Section 3.3. Steigler (Stiegler, 1998) took a similar view when he wrote "The prosthesis is not a mere extension of the human body; it is the constitution of this body qua 'human'." Freud also espoused this position when he explained that with each tool man perfects his own organs, making him "a kind of prosthetic God."

The modernist and post-structuralist movements all rejected Vitruvian-type body model, but as Hight demonstrated, each operated within the same field of reference of the body-building dialectic. Accordingly, it follows that when contemplating the body-building relationship it is critical to consider not only the body proper, but all of parts of the body and its prosthetic extensions, including all of the tools, writing and architecture referred to by Hight. All of these components, both material and metaphorical, serve as a bridge between the human body with the world that it inhabits. Similarly, it is important to consider the internal/external and tangible/intangible constituent parts of the body (such as our minds, thoughts, and ideas) including one's sense of personal/social identity that also serves to shape the bodily experience.

Architecture can be considered one of the three primary, external prosthetics on

which human life depends; the triumvirate usually being referred to more colloquially as food, clothing and shelter. Through architecture, we create safe and comfortable places in which to live, thereby protecting our corporeal/physical selves (and, as a consequence, our incorporeal/cognitive selves) and extending our life spans beyond what could otherwise be expected in nature.

3.1. FRAGMENTATION OF BODIES

“A Part may be thus defined, viz. It is a bodily or solid substance, cohering with, making up, and partaking of the life of, the whole and serving for some function or use. It must cohere with the whole, that is, be continuous to it... It (with others) must serve to complete or make up the whole... It must partake of the life of the whole.”(Gibson, 1703, p. 2)

In considering the various types and appearances of the body, both corporeal and incorporeal, it becomes necessary to delineate where the tangible/corporeal body begins and the intangible/incorporeal body ends. Attempts to separate them leads to a dissection of the “holistic” body into its constituent “parts”, including the obvious division of limbs from trunk and head, and the distinguishing of individual digits, orifices and sensing organs, such as eyes, ears, nose, tongue and skin. Returning momentarily to Figures 2, 3 and 4 above, it can be seen how these component parts of the human form were “sliced apart” by the architects of old in their drawings in order to determine their proportions relative to each other. These “fragmented” body parts (e.g., forehead, face, and neck in Giorgio Martini’s sketch in Figure 3) were then re-assembled in a specific order so as to project the metaphor of the idealized man directly into the structure. However, only the exterior body parts were considered in such designs. The sensory organs, which clearly lead a dual existence because of their being both internal and external to the outer body, were only recognized in their capacity as topical features. Internal organs were ignored completely.

In time, interest developed in the hidden interior of the body. The Middle Ages saw a period of heightened interest in the inner workings of the human body. While the Catholic church encouraged the abstraction of the body to support religious doctrine, the developing field of medicine began to probe internal anatomy to reveal distinct organs with specific functions. (Cruz, 2013, p. 11) As a result, the image of our bodies as protective shells began to be replaced with notions of there being an “inside” and an “outside” to our bodies.

Initially, the new frontier of the internal body with its various organs appeared to render the body “chaotic” and “unknowable”. This idea can be seen, for example, in ,

in which the body is splayed open and each of the internal pieces are assigned a specific zodiac symbol. However, in time, order began to emerge through increased use and exposure to the internal organs. As Mazzio and Hillman note, references to individual and fragmented body parts filled literary and cultural works of sixteenth and seventeenth century Europe. (Mazzio & Hillman, 1997, p. 4) Dismemberment as a form of punishment, the use of individual body parts in pictures, poetry and paintings and the cataloguing of the anatomy for medical and scientific purposes all flourished (Ibid.) As a result, a notion of the “parts” forming the “whole” began to emerge. In anatomical drawings, such as those of Leonardo Da Vinci, organs were drawn separately, with the artist noting that knowing the part of the body “enables the creation of the finished masterpiece”. (Ibid., p. 7) (Figure 21) Similarly, we see in Figure 19, Figure 20 Remmelin’s *Catoptrum Microcosmicum* which, at first glance, appears to present the body and its internal organs as disorderly and decontextualized. (Ibid.) However, on closer inspection, the image is revealed as being designed to present the content in an orderly manner, with clear delineations between inner and outer, male and female. (Ibid.) As order began to be imposed on the internal and external attributes of the human body, the idea of the parts implying a relationship to the whole began to gain ground and the presence of one became linked to the suggestion of the other. (Ibid.)

Figure 17. 13th century Anatomical Illustration.

Figure 18. Astrology and Medicine.

Figure 19. Visio Prima: Catoptri Microcosmographici. Johann Remmelin. 1613.

Figure 20. Visio Prima: Catoptri Microcosmographici. Johann Remmelin. 1613. Illustrating "dismemberment".

Figure 21. Collage of Leonardo Da Vinci Anatomical drawings.

Figure 22. *To Sell Oneself in Small Fragments*. Orlan. 1976–77

Figure 23. *Inasmuch As It Is Always Already Taking Place*. Gary Hill. 1990

Some artists, such as Orlan et.al and Gary Hill, grappled with this notion of the dispersed and fragmented body as implying the complete corporeal body. (Flanagan & Booth, 2009, p. 91) In Hill’s project, “Inasmuch As It Is Always Already Taking Place” (Figure 23), randomly placed monitors projecting video images of naked, individual parts of his body are used to deconstruct the “whole” body into its constituent parts, all the while suggesting the larger, holistic body that is absent. (Ibid.) In Orlan’s project, “To Sell Oneself in Small Fragments” (1976–77) (Figure 22), people were given the opportunity to purchase pictures of parts of her body glued on wood, in an artistic attempt to disassemble her body into fragments and to allow others to have a “part” of her, and in that way be close to her, no matter how far apart they might be from her holistic self. (Ibid.)

This notion of the “whole” versus the “part” that has developed as a result of the exploration over the ages of the inner and outer parts of the Vitruvian man, and emergence of the relationship between the two; the one suggesting the other, has led to the notion in our society that every part of the body can serve as a proxy for whole. As a result, each portion constitutes a means to identify with and access the whole. As Flanagan and Booth note: “The concept of holism in relation to fragmentation of bodies authorizes every bit and every piece of the fragmented body to take over the body as a whole, to serve as interface.” (Flanagan & Booth, 2009, p. 91) According to Flanagan and Booth, this age of technology and new media has enabled the holistic body to endure, not as an integrated whole, but in a dispersed manner; by enabling each constituent “part” of the body to interface with technology and thereby form new and different forms of multiplicities (Flanagan & Booth, 2009, pp. 96–98)

Figure 24. *Blur*. Diller & Scofidio. 2002

Figure 25. *Blur* building braincoat system diagram. Diller & Scofidio. 2002

The idea of interfacing with different parts of the body, as opposed to the idealized “holistic” body of the Vitruvian man has been explored in architectural projects, such as the *Blur* “building” (2002), by architects Diller + Scofidio. The work, which consisted of a “cloud” covered framework generated by mechanized fog producing system, emphasized bodily perceptions of the users over their sense of sight. Visitors were provided with a “braincoat” that contained input sensors, haptic and LED output devices and access to wireless data communication and processing networks. By engaging with the project wearing their “braincoats”, as visitors passed each other their coats were able to compare profiles and display the degree of affinity or repulsion (Ibid.) (Figure 24, Figure 25) According to Flanagan and Booth: “this dialogue between the body as a whole and as a multiplicity of fragments has been expressed in haptic terms (*Blur*) through the body of mediation and the age of mediatic proliferation.” (Ibid., p. 93)

3.2. TECHNOLOGICALLY ENHANCED BODIES

The idea that technology can enhance our bodies by interfacing with the fragmented parts of our corporeal body, and mediate the way in which we connect with the parts of ourselves, with others and with the world around us, is a pervasive one in the current digital age. One of the seminal works to explore the boundary between human/machine and the biological/technological, was Donna Haraway's *A Cyborg Manifesto* (1991). In that work, Haraway's concept of the cyborg served as a means to investigate how the increasing ease with which our physical bodies merge with digital technologies could impact the manner in which we understand and operate in this world. (Boys, p. 94)

Marcos Novak provided a description of the ultimate merging of the body and architecture via technology in the form of "liquid architecture", which he describes as architecture whose "form is contingent on the interests of the beholder; it is an architecture that opens to welcome you and closes to defend you; it is an architecture without doors and hallways, where the next room is always where it needs to be and what it needs to be. It is an architecture that dances or pulsates, becomes tranquil or agitated." (Novak, 1991, pp. 251-252) He notes that if architecture is an extension of our bodies, a protection from the elements for a fragile form, then "liquid architecture" (or architecture that is completely interfaced with the user) is ourselves becoming our own changing shelter. (Ibid.)

If such notions of the body and architecture merging through technology seem extreme, Greg Lynn invites us to simply change our notion of what we mean when we employ the term "body". As he notes:

"Instead of railing against the possibility of body analogies in architecture let me suggest that what we used to call bodies have simply mutated and transformed into something else. The bodies themselves are probably the same as they always were but our concepts have changed... the combinatorial model of the body is founded on the changes in identity that take place with greater degrees of complexity and connection." [Emphasis added] (Greg Lynn, 1997, pp. 171-172)

In this way, the range of possible forms that our fragmented body "parts" can be re-assembled into becomes a means to envisage a new form of architecture.

3.3. BODY PLASTICITY, EXTENSIONS, ADAPTATION, LAYERS, ABSTRACTIONS, BOUNDARIES, SPACES, INVISIBILITY AND AUGMENTATION

According to Anthony Vidler “[i]f, for the first machine age, the preferred metaphor for the house was industrial, a “machine for living in,” the second machine age would perhaps privilege the medical: the house as at once prosthesis and prophylactic.”² (Cruz, 2013, p. 192)

Having examined how our bodies can be fragmented (Section 3.1) and its parts integrated and re-assembled through technology (Section 3.2), consideration is now given to the multitude of ways in which our bodies (and our body parts) can be altered, extended, abstracted, broadcast and made invisible, as well as the ways in which they can be augmented through technology.

3.3.1. BODY PLASTICITY

From the moment of conception, the body undergoes great change; it recombines, evolves, grows and adapts. Simultaneously, from the embryonic state the body is continuously changing, reshaping and designing (and being changed, reshaped and redesigned by) its mother’s womb to accommodate their respective needs. Both working in sync to provide survival, growth and development. This is because the instruction set for building the body is contained within the body itself, stitched together and continually remade from proteins as directed by the genome. (Shryock, Smail, & Earle, 2011, p. 67) The body is the product of its parents, but it recombines the genetic blueprint of each into a unique plan all its own. That same plan may contain deviations, mutations or alterations not possessed by either parent and so can give rise to entirely new forms. Through the mechanism of epigenetics, it is now recognized that the body can also be altered by environmental factors experienced either by the parents or by the body itself, making it extremely plastic during the course of its lifetime. (Ibid., p.67) These environmental influences can be both imposed or self-directed including, amongst other things, climate, diet, and physical or emotional stresses to which the body is subjected. (Ibid., p.68)

Self-directed changes can, as Shryock pointed out, have an enormous impact on shaping the body and, simultaneously, send powerful messages about the rank and social status. A person can adopt, either through changes in their own physiology or through different modes of dress and display, many different forms. For example, the body can be made fatter in regions of scarcity (i.e., to demonstrate personal access to abundance), and fitter in areas where free time is limited; a person can also takes steps to decorate their

hair and body with make-up and styling products, in order to highlight attractiveness and suitability for mating; they can adorn themselves with fashionable clothing and accessories to increase appeal while simultaneously indicating luxury, prestige and social standing; and they can surround themselves with goods and property (e.g., cars, livestock, large home(s) and properties) to signal power, vigour and wealth. (Shryock, Smail, & Earle, 2011, pp. 72–73)

More aggressive forms of altering the body can similarly transmit complex social signals. Cosmetic changes can be made semi-permanent in the form of tattoos, piercings and plastic surgery. In some African cultures, women's necks are elongated using heavy necklaces. In China, women's feet were sometimes bound tightly starting in childhood to keep them cripplingly small, all in an effort to appear more attractive and desirable, as well as to elevate and express social status. (Ibid., pp. 72–73) More modern physical alterations reflect society's current obsession with youth and virility. As Shyrock observed, "current practices of plastic surgery, Botox injections, hair replacement, lip and penile enhancement, stomach stapling, and the like are merely the most recent instances of long-standing practices." (Ibid., pp. 72-73)

Each of the forms that a body takes on, through physical changes or decoration, has the potential to alter the manner in which the individual perceives space. Changes in bodily form can also modify the ways in which the individual moves through and interacts with different spaces.

Figure 26. Padaung women.

Figure 27. Foot binding.

Figure 28. Human Barbie.

Figure 29. (Left). *First Surgery-Performance. Première Opération Chirurgicale-Performancen. Orlan. 1990*

Figure 30. (Right) *Third Hand. Stelarc 1980-1998*

3.3.2. BODY EXTENSIONS

In this age of digital technology, the very notion of what constitutes our own “skin” is being called into question. As Cruz notes, the work of artists such as Orlan and Stelarc highlight the rise in surgical procedures that modify the skin, insert artificial organs under the skin, and make use of advanced prosthetics and the like. (Cruz, 2013, pp. 170–172) (Figure 29, Figure 30) Each of these interventions, Cruz maintains, alters our understanding of what is natural and synthetic, and changes our ideas of what constitutes a normative body. (Ibid.)

In each of the examples discussed in the preceding paragraphs in Section 3.3, the body as the ‘primary metaphor’ is modified in some way. The result, according to Hight, is that our bodily experiences are also altered, as is the way in which we organize those bodily experiences into a meaningful existence. (Hight, 2008) This is true whether the changes are to the body proper and its inherent extensions (e.g., arms, legs, organs, etc.) or its ‘prosthetic’ extensions, such as clothing (e.g., under/over garments), mechanical tools

(e.g., hardware, appliances, vehicles, etc.), environmental control suits (e.g., underwater, hazmat and flight suits, etc., like NASA's spacesuit discussed below) and artificial limbs and accessibility aids. (Ibid.)

In other words, when a fatter body is more valued than a slimmer body because the larger body demonstrates wealth or sexuality (as an example “*allure and fertility in female bodies of the Baroque period*” (Cruz, 2013, p. 50)) (or any other reason) then the sensory and perceptual experiences of having a larger body will become the primary metaphor through which the world is organized into a meaningful experience, as will the absence of a fatter body (i.e., a skinny body) which will define the body-metaphor through its omission. In each case, the perception of space (i.e., too small, too narrow, too high), will be shaped by this body metaphor and will be expressed through the body and its various extensions. This will include the architecture and furnishings adapting to reflect the importance of a larger girth (e.g., larger stools or pedestals, shorter stairs, wider doorways and hallways, ramparts, etc.), as well as other ‘prosthetic extensions’, such as clothing that accentuates size and curves and, in some cases, sexuality (see Figures 31-33).

Figure 31. Venus of Willendorf. 28,000-25,000 BCE

Figure 32. Neolithic menstruation statue. Xanga Twins Figurine. 4,100-2,800 BC

Figure 33. Venus figurine. Seated Mother Goddess. Catal Huyuk. 7000—6000BC

Figure 34. Igloo.

3.3.3. BODY ADAPTATIONS

The reciprocal relationship between the body, the environment and prosthetics can also be seen where the physical environment is benign, harsh or even extreme. For example, polar climates will promote changes (physiological adaptations) in the body-building relationship and their related prosthetics that enable its inhabitants to flourish in an unforgiving climate. Body types will adjust to account for limited but glaring sunlight, frigid temperatures and high-fat diets. Prosthetics, such as clothing and tools will adjust accordingly, as will architecture that will make use of local resources (i.e., ice/snow) and take on appropriate shapes to retain heat to provide maximum strength against battering winds (see Figure 34).

3.3.4. BODY LAYERS

Outer space is another example of an extremely harsh environment for which mankind has had to develop new prosthetics. New tools, clothing, shelter and ideas, have all had to be invented in order to survive in the void of space. However, an important lesson is provided by the architecture created to envelope the bodies of the astronauts for the Apollo missions. (Monchaux, 2011, p. 2) The protective clothing required for such a cold and unforgiving setting was not rigid and armour-like, but highly sophisticated, soft, flexible spacesuits. (Ibid.) Rather than some sci-fi like combination of man and machine that looks like a cyborg or Iron-Man®, it turns out that what astronauts really needed and could actually wear (and work in for extended periods of time) was made not of mostly metal and plastic, but of multiple layers of comfortable, technologically advanced, pliable

Figure 35. Spacesuit

Figure 36. Suitaloon. Archigram. 1967

materials fitted to their bodies by a bra company (i.e., Playtex, people who understood the implications of the form of the body). (Ibid.)

The “Cushicle” (1967), “inspired by heroic efforts to inhabit alien environments [...] in outer space” (Sadler, 2005, p. 129) was a form of mobile structure that included an inflatable envelope. It was connected to a chassis component that contained, amongst other things, a support framework for the envelope and a heating system. (Steiner, 2009, p. 172) Other modules, such as for food and water could be added to the unit. (Ibid.) The “Cushicle” was imagined as one day becoming a mobile system or “personalized environments”. (Ibid.)

The opening pages of the Archigram anthology in 1972 imagined a fanciful reality influenced by the space race of the time and the associated micro-environments of the spacesuit. (Sadler, 2005, p. 113) The “Suitaloon”, the “architectural equivalent of the space suit” (Ibid., pp. 5) was made from an imaginary material that could form a strong,

Figure 37. Cushicle, from closed to unfolding. Archigram.1966

but incredibly thin and transparent bubble that would protect the wearer from the outside environment. (Ibid.) Both the “Cushicle” and the “Suitaloon” are examples of flexible, portable enclosures that served “as lightweight, anti-monumental skin and guts”. (Ibid.) As Steiner notes: “The Suitaloon, with its view into the autonomous bubble for one, occasionally two, offered a glimpse at technology, not as the machine-for-living cliché, but as adapting to biological exigencies of life.” (Steiner, 2009, p. 172)

In this way, our bodies shape our environments and give them meaning and we, in turn, project that meaning through our physical bodies and prosthetic extensions, including our architecture, in a reciprocal manner. This dynamic feedback loop between a vast matrix of constituent parts, causes all three elements, the body, its prosthetics and architecture to blend until the boundaries between them blur and it is difficult to determine where each one ends and the other begins.

Figure 38. *Walking City*. Archigram. 1964

Similarly, during the age of “the failure of postwar urban planning of London” (Pickering, 2011, p. 365) the Archigram group envisioned the city to “become a self-organizing system able to reconfigure itself in real time in relation to its own emerging situation.” (Pickering, 2011, p. 365) Both projects, “Walking City” and “Plug-In City”, gave power to its inhabitants to continuously reconfigure the environment “in relation to the shifting needs and desires of its inhabitants”. (Pickering, 2011, p. 364) (Figure 38) These otherworldly renderings of architectural landscapes, presented imagined and artful views of the possible that were grounded in actual phenomena of the day (e.g., the space race). (Sadler, 2005, p. 5) In so doing, they depicted architecture that was simultaneously “realistic and crazy” (Ibid.) as a way to more clearly perceive “imaginative and optimistic” (Ibid.) possibilities.

3.3.5. BODY ABSTRACTIONS

The prosthetic extensions of the body include abstract extensions that are grounded within our physical bodies, such as the *incorporeal* constructions of thought, culture and linguistics. (Hight, 2008, p. 38) This includes other incorporeal constructs such as memories, feeling and emotions which give rise to abstract prosthetic extensions in the form of ideas and knowledge, as well as identity. These extensions of the body also form part of the 'primary body metaphor' and are similarly organized as mental experiences into the fabric of our existence. As with our physical bodies, we project these mental elements through our incorporeal prosthetic extensions. As Hight notes, those extensions include writing and architecture. (Hight, 2008)

Presumably then, our ideas about space and how we should inhabit it are captured in our language and cultural knowledge, including math, engineering, material sciences, etc., and serve to shape our tools and built spaces.

Similarly, the prosthetic extension of identity can also play a role in how a user inhabits a space. The manner in which an individual interacts with a space, and with other individuals and groups in that space, may dictate their level of comfort in that space and in their own bodies. (Karandinou, 2013, p. 178)

3.3.6. BODY BOUNDARIES

Hansen points out that for Marshall McLuhan, every technological advancement is an extension of the body's senses (e.g., clothing as an extension of our skin), including media (Hansen, 2003) McLuhan stated: "[...] our human senses, of which all media are extensions, [...] configure the awareness and experience of each one of us [...]". (McLuhan & Lapham, 1994, p. 29) With each new technological development, we extend our reach further from our corporeal selves thereby transforming the relationship of our incorporeal selves and society to our physical bodies. (Ibid.) In particular, McLuhan thought of ourselves as becoming part of the media tools around us. Hansen likened this to the fictional experience in the David Cronenberg film *eXistenZ* (1999), which imagined a multi-layered virtual reality game that users would plug into directly through their nervous system and leave their corporeal selves behind (Ibid.)

According to Hansen, McLuhan suggested that we take fragments of ourselves and distribute them through the media, only to re-assemble them again through the same media, but in a manner that is increasingly removed from our original selves. (Ibid.) Hansen argues that Merleau-Ponty took a different view from McLuhan, maintaining that as a result of new technologies our organs have become, in a sense, detachable and no longer limited to our physical bodies. As a result, we can no longer define our body as the "housing" or embodiment of our senses, even though we know rationally that our original, corporeal selves remain grounded in the real world. (Ibid.)

Figure 39. Cronenberg's game-pods.
eXistenZ. 1999

3.3.7. BODY SPACES

Like media, as described by McLuhan, architecture can also be thought of as a prosthetic extension of our bodies. For example, religious buildings can be seen as extending our corporeal bodies by housing and supporting the expression of religious beliefs of their occupants and extending and connecting the communal body of their believers. In some churches, the nave (naval) area allows people to ‘plug-in’ as a group, while side chapels and alcoves allow individuals to merge seamlessly with a deity through the building in a

Figure 40. St. Peter's Basilica. Interior. 1626

Figure 41. Thoronet Abbey church interior alcove.

Figure 42. Sagrada Família. Antonio Gaudí. 1882-

Figure 43. Church of the Light. Tadao Ando. 1999

Figure 44. Bruder Klaus Field Chapel. Peter Zumthor. 2007

smaller ceremony. (Figures 43-45) Even when “not occupied” by people, some religious facilities are thought by followers to be occupied by deity and saints. When plugged-in, the body is transferred into the “virtual reality” (Cruz, 2013, p. 71) of this cultural phenomena.

3.3.8. BODY INVISIBILITY

Prosthetic extensions of our bodies can also be notable by their absence or “invisibility”. For example, a common pair of reading glasses are clearly an extension of our sense of sight. However, the prosthetic glasses can easily become so comfortable for the user as to “slip away” from consciousness and become an “invisible” extension of the user. In fact, some prosthetics such as glasses and artificial limbs can sometimes be thought as functioning optimally precisely when they blend so perfectly with the user as to become unnoticeable to them. (Ihde, 2009, p. 108)

Figure 45. The chapel of Notre Dame du Haut, Ronchamp. Wall Alcove. Le Courbusier. 1954.

Figure 46. Glasses.

Architecture can also become an invisible prosthetic extension. The twin towers were an iconic part of the body of the New York City skyline, but were arguably taken for granted by most of the city's inhabitants in their day-to-day lives (i.e., had become “invisible” to the user like the glasses in Figure 46). It was only following their violent destruction that people who had previously failed to take regular notice of them despite their skyline defining quality, suddenly became acutely aware of their absence.

Figure 47. Twin Towers. New York. Before and After.

Sept. 12, 2001

Aug. 14, 2000

Figure 48. *Imponderabilia*. Marina Abramovic. 1977

Architecture that was previously “invisible” or part of the background can also be made “visible” and restored to the foreground without the need to resort to its violent destruction. As Abramovic and Ulay demonstrated in “Imponderabilia” (Figure 48), simply by reconfiguring the relationship of our bodies to a structure, we can transform it and make it hyper-relevant to our senses and an immediate extension of ourselves. As Abramovic said regarding “Imponderabilia” that herself and Ulay “wanted to be the door of the museum for three hours”. (Abramović, Italy), & Ratti, 2002, p. 33) By forcing a clothed figure to pass between two naked persons strategically placed in a doorway or alcove, the entranceway is altered from being a banal passage and transforms into a gauntlet of body, gender and sexuality issues that the clothed figure must navigate. In this way, the doorway becomes highly noticeable to everyone in the vicinity and is no longer lost in the background. Suddenly, it has become a clear and pressing extension of our corporeal selves. Similar efforts at changing the prosthetic nature of space were undertaken by the performers in other works, by moving walls and columns, and placing their own nude bodies, in the performances “Installation One” (1979) and “Expanding in Space” (1977).

It follows that, like the physical or corporeal aspects of the body, the abstract or incorporeal elements of our bodies (i.e., knowledge, beliefs, identity, customs, writing, etc.) become and shape abstract prosthetic extensions of our fragmented, and re-assembled corporeal selves in a dynamic and reciprocating manner. The result is a similar blurring of the lines between all them until they become a single, indistinguishable integrated whole. Deleuze and Guattari referred to these type of multiple, varied connections that form acentered, asubjective, interwoven networks, with multiple configurations and interpretations as “multiplicities”. (Deleuze & Guattari, 1987, p.8)

Figure 49. *Expanding in Space* - Marina Abramovic. 1977

3.3.9. BODY AUGMENTATION

Since the body, its prosthetic extensions and architecture are all inter-related, it also follows that a change to any one of them would cause changes to reverberate through the whole. In this age of rapidly evolving technology and ubiquitous computing, it has been noted that the accelerated pace of change in our prosthetic extensions, such as our ideas, materials and tools, will have the effect of drastically changing our current perception of our own bodies/identities and impact our perception and use of space.

We can imagine that as technology becomes increasingly prevalent in everyday objects and shrinks into the background (e.g., micro-electronic devices embedded under the skin), such prosthetics are likely to blend more fully into the corporeal body. As they begin to seamlessly reproduce all of the qualities and characteristics of the body, they will not only be able to enhance all aspects of the original functions of the part, but also add new functionality. For example, a prosthetic eye may one day not only faithfully reproduce and replace a normal biological eye, but may be able to imbue the user with the ability to see other portions of the electromagnetic spectrum (e.g., x-rays, UV light, radio waves, etc.), provide excellent night vision, allow the user to see for miles and even display digital information like a tablet or smartphone right into the user's optic nerve. ("Porting Digital Memory - h+ Media," 2010) In this way, with our bodies, minds, identities and emotions augmented by our prosthetics, we will begin to perceive, use and even interact with the built space in entirely new and previously unforeseen ways.

Figure 50. *Conversations.*

PART II

4. CYBERNETICS: THE NEED FOR CONVERSATION

4.1. COMMUNICATION

“Talk to Me: Design and the Communication between People and Objects thrives on this important late-twentieth century development in the culture of design, which can be described as a shift from the centrality of function to that of meaning, and on the twenty-first-century focus on the need to communicate in order to exist (fig. 2). From this new perspective, all objects occupy a unique position in material culture, and all of them contain information beyond their immediate use or appearance.” (Antonelli, 2011, p.7)

Figure 51. “She thinks it’s a touchscreen.” Emily Flake. 2013

In the previous section, the idea that prosthetics are both part of, and external to, our fragmented and re-assembled, corporeal bodies was explored, along with the idea that the feedback loop exists between the two, with each shaping the other in a continuous and iterative process. The notion that the “parts” inform the “whole”, and *visa versa*, and that the “parts” can include elements outside of our physical selves (e.g., our tools, other people, ideas and architecture, etc.) raised questions about how rapid changes in technology

might alter the nature of our relationship with our body parts. Kenzo Tange in the 1960s suggested that “an information revolution prosthetically extends the nervous system in the same way that industrial revolution physically extended the body”. (Chun & Keenan, 2006, p. 387) In other words, when the purpose of our tools was to enhance our physical properties, such as our strength, speed and endurance, the relationship between mankind and its prosthetic extensions was more mechanical in nature. Now, as we enter the age of ubiquitous computing, we can observe the shift in focus from the anthropomorphism of our physical bodies, and the corresponding functional qualities of our tools, to engaging our cognitive and emotional capacities. In the information age, we look to our devices in terms of how they can extend our ability to perceive and communicate, as opposed to how we operate mechanically (e.g., enhancing our physical attributes). As Antonelli noted: “Already in the present, objects have developed the same complexity and requirements as humans, progressing to individual identities and characters. The emotions - from joy to anger - we therefore project onto them result in expectations that go way beyond the fulfillment of a simple, mechanical function.” (Antonelli, 2011, pp. 6-8) From this perspective, as we begin to engage and evaluate our prosthetics in terms of how they relate and communicate with us, the more we will project the metaphor of our emotional body onto them, and the less we will project the trope of our “holistic”, corporeal body onto them. As a result, our fragmented “extensions” will begin to project increasingly back onto us in emotional terms, in order that we may better “understand” and communicate with them.

Figure 53. Minimaforms. Becoming animal. 2007

In the 2007 installation “Becoming Animal” by UK experimental architecture studio Minimaforms, the audience was given dog masks with embedded LED lights in them and invited to engage in a dialogue with a digital simulation of Cerberus, the multi-headed guard dog of the underworld in Greek mythology. (Minimaforms, 2007) The performance encouraged human-to-human communication in a machine-based environment in which the users employed a prosthetic extension of themselves, in the form of the mask, to engage and interact. The work underscores the growing emotional and communicative role of technology in our society. It serves to demonstrate how, as technology begins to recede increasingly into the background of our day-to-day lives, its role will evolve into one which emphasises communication and connection, as opposed to increasing our physical attributes.

Another example of human-machine communication can be seen in the “Tweenbot” projects, created by Kacie Kinzer. These tiny, human dependent robots relied on humans to help them to get to their destination. (Kinzer, 2009) The cute robots were assisted by many kind individuals in the streets of New York, and none of the robots was ever lost or damaged during the experiments. The project highlighted the ability of very simple technological devices to drive complex human interactions and create networks of activity, when the device demonstrates emotional characteristics such as vulnerability and intentionality requiring assistance. (Ibid.) In this way, it demonstrates our tendency to project emotions on to our devices and our desire to interact emotionally with them.

Figure 54. Tweenbot. Kacie Kinzer. 2009

Figure 55. Movie “Her”. 2013

The 2013 motion picture “Her”, from director Spike Jonze, depicted more complex human-machine interaction with an imagined artificial intelligence operating system from the “slight future”. In the film, technology has receded into the background and the emphasis is placed on communicating and connecting with the machine, instead of technology being seen as an end in itself. (VanHemert, 2014) According to the movie’s production designer, KK Barrett, this was intentional: “We decided that the movie wasn’t about technology, or if it was, that the technology should be invisible, [...] And not invisible like a piece of glass.” In other words, in this imagined near future “[T]echnology hasn’t disappeared[...] It’s dissolved into everyday life”.(Ibid.)

4.2. CONVERSATION THEORY.

“ ‘Men may be divided into two types: men of words and men of action. The first speak, the latter act. I am of the second group. I lack the means to express myself adequately. I would not be able to explain to anyone my artistic concepts. I have not concretised them. I have never had the time to reflect on them. My hours have been spent in my work.’ “ (Roe, 2009)

The body-building relationship, discussed above, is premised on projecting our sense of reality not only through our bodies, but also through each of the extensions of our bodies that we employ, including our tools and architecture. This projection through our bodily extensions necessarily requires us to control and communicate with those prostheses. A system for understanding the control and communication amongst and between biological and mechanical systems emerged in the early twentieth century with the coining of the term “cybernetics” by Norbert Wiener in 1947. (Pickering, 2011) This new field, introduced in Wiener’s book *Cybernetics; or, Control and Communication in the Animal and the Machine*, combined a number of disparate areas of study, including servomechanics, neural networks, digital computing, psychology and various social sciences. (Ibid.) Cybernetics is applicable whenever a system that includes a feedback loop is employed, and can be used to study and describe how external changes made to an environment by the system that is being studied prompts internal changes to that same system. A simple example of such a system would be a sensor (e.g., in a thermostat) which responds to a change in the temperature of a building by turning the heat on or off, thus affecting the local temperature and potentially affecting the system in a continuous, causal loop.

Cybernetics offers a means to examine the relationship between the body and its extensions. As such, it provides a framework to analyze the body-building relationship and to understand how the two might better communicate with and control each other.

Figure 55. Pask's Definition of Cybernetics. Gordon Pask. 1969

Through the cybernetic lens, the body can be viewed as a biological system that changes its environment and then responds to those same changes, thus prompting further changes. The building can be similarly viewed as a mechanical system that produces changes to its own environment (e.g., via its thermostat(s)) and responds to changes in that environment. The two systems of the body and the building form complex, inter-dependent systems that feedback on one another.

These types of inter-connected systems can quickly form complex reciprocal relationships as they continuously change and respond to one another. For this reason, cybernetics is often associated with the study of emergent properties; the tendency for complex behaviours to emerge from simple systems. Systems with as few as two interconnected feedback loops can, for example, give rise to extremely rich and diverse behaviours that are often entirely unpredictable. (Ibid.)

One of the key figures in the history of cybernetics, Gordon Pask, based his theories of how biological and mechanical systems learn on the principles of cybernetics. (Ibid.) In a series of books published in the mid-seventies, Pask developed a comprehensive framework called "Conversation Theory" for charting, analyzing and understanding communications and learning that can take place between people and/or machines. Pask also developed a number of mechanical systems to demonstrate conversation theory by facilitating the learning process through directed man-machine interfaces. For example, in 1956 he constructed the first self-adaptive keyboard trainer (SAKI) (Figure 56, Figure 57) which was a predecessor of all modern typing tutors. (Ibid.) The system was designed to help meet the growing need for trained punchboard operators for the then newly emerging punchcard industry, an early ancestor of today's powerful computing industry. The SAKI

machine challenged the trainees to punch the appropriate set of keys in sequence and then responded to the trainee's performance, either accelerating the pace or revisiting problem areas, gradually progressing the student to more complex tasks. (Ibid.) Pask viewed the human operator in his systems as part of a reciprocating loop that fed into the apparatus, and back into the human operator, in a continuous fashion. (Spiller, 2002, pp. 76–77)

Pask's ideas offered a means to bridge the divide between the human body, its prosthetic extensions and the field of architecture by providing the tools to map, analyze and mediate the relationship between the body and the building in a complex but manageable way. As Spiller notes, Pask "wanted architecture to go much further in comprehending itself as one of the fundamental conversational systems in human culture." (Ibid., p.77) Pask saw architecture as something that should be a resonating and reciprocating system based on a dynamic feedback loop with the user(s).

Conversation theory, as developed by Pask, offers a sophisticated methodology for coordinating structured conversations between participants, including mechanical systems. These dialogues between man and machine can be mapped via the framework and language that he developed and used to reach a common understanding between man and machine on an agreed upon subject matter. In this way, conversation theory affords a means for architecture to engage in a complex, interactive dialogue with individuals in order to reach a consensus, as opposed to following a pre-determined set out possible outcomes.

Figure 56. (Bottom). SAKI. Gordon Pask. 1956

Figure 57. (Right). Adaptive teaching machines. Gordon Pask. 1961

INVENTOR
Andrew G. S. Park

Figure 58. (Top right). Fun Palace. Cedric Price. 1961

Figure 59. (Tor left). Fun Palace. Organisational Plan as Programme. Cedric Price. 1961.

Pask had the opportunity to apply his theories to an architectural project, the Fun Palace by Cedric Price. Although it was never constructed, the “Fun Palace” was designed to be an expandable and changeable environment. The hope was that users would continuously alter the layout of the massively reconfigurable, multi-story entertainment facility. In this way, it was hoped that the “Fun Palace” would become a mechanism of social interaction and leisure. Price worked closely with Gordon Pask in an attempt to incorporate a complex cybernetic system into the project that would enable it to manage day-to-day activities of the premises, as well as learn to predict trends in the behaviour of users and respond to them. However, the project was ahead of its time and, although very nearly realized, arguably lacked the powerful and highly miniaturized computer and information processing technology (that today are commonplace) necessary to make the project a reality.

As Spiller notes “Today, over thirty years on, it is possible for us to see the insight of Pask’s work. Architecture is slowly becoming able to appreciate the artificial and natural ecologies in which it sites itself... ‘Response’ and ‘reflex’ are the key to the next generation of spaces.” (Ibid., p. 77)

4.3. UBIQUITOUS COMPUTING: EMBEDDED CONVERSATIONS

While attempts by early pioneers in the field of cybernetics to apply their theories to architecture were hindered by the insufficient computing power available in their day, the time is rapidly approaching when computer systems will be so pervasive as to render the problem moot. In 1988, Mark Weiser foresaw this change and coined the term “ubiquitous computing” to describe the exponentially increasing degree to which computing devices would become embedded in everyday objects and activities. (Fox & Kemp, 2009, p. 16) Today, with the prevalence of smartphones, tablets and computerized cars, users interact with a large number of computational devices over the course of a single day. Weiser envisaged an even later time when computing would become so ubiquitous that users would not even be aware that they were interacting with it. (Ibid.) He referred to this as “the age of calm technology, when technology recedes into the background of our lives”. (Weiser & Brown, 1997, pp. 75–85) While some argue that we have already begun to enter this period of “calm technology” predicted by Weiser, with technology quietly suffusing everyday objects (see Alkhatib, Rine, Podobnik, Trzec, & Jezic, 2008, p. 20), others maintain that technology will always be somewhat visible, messy and requiring of attention (see Dourish & Bell, 2011, p. 25) However, the idea of frequent and commonplace use of technological devices (e.g., texting every few minutes) should be distinguished from the “messy” technology described by Dourish and Bell since frequency of use may not necessarily be indicative that a technology has not receded into the background and become an invisible prosthetic (like the glasses referred to in Section 3.3).

Attempts to implement the idea of “computationally enhanced environments” have been underway for decades, beginning with the development of technologies that enabled the monitoring of a range of building inputs (e.g., temperature, humidity, air pressure, etc.) so that structures could become increasingly ‘self-aware’ (Fox & Kemp, 2009, p. 16) As efforts were stepped up to improve energy efficiency, and attempts were made to facilitate management of building systems, user interfaces for these large control systems became more simplified and graphical. As the number of computational devices and systems integrated into everyday objects and activities continues to increase exponentially, it will become possible for those systems to gather large amounts of detailed data about how those spaces are used. That data can then be processed in a manner that allows for an understanding of how users behave in the space and to learn, and even help shape, a user’s preferences in a dynamic and reciprocal feedback loop. As Fox and Kemp noted:

“new ubiquitous networks have the ability to physically understand how we use space, interpret this data, and respond to this data in interactive ways. As technology has advanced and as computers have become smaller and cheaper, we are seeing that we now have the potential to think of space as being organized in a computational

network. Objects can have both the fundamental logic and hardware to allow them to be extremely good at executing the specific tasks they were intended to do while simultaneously networking into a collective whole that can be controlled by an overarching logic. The idea of ubiquitous computation is about embedding hardware and software, information processors and coded intelligence, into all aspects of our lives” (Fox & Kemp, 2009, p. 62)

Integrating computing in a ubiquitous manner into the built environment will enable the development of commonplace man-machine interfaces within architecture. On this point, Nicos Komninos in “The Age of Intelligent Cities: Smart Environments and Innovation-for-all Strategies” (Komninos, 2014, pp. 67–68) noted the rapid development and deployment of the ubiquitous computing in what is commonly referred to as “the Internet of Things” or IoT. He states:

Figure 60. Examples of Internet of Things (IoT) devices currently available on the market.

“According to technology hype cycles published by Gartner from 2009 to 2013, The Internet of Things (IoT) is among the most important components of the current technology shift in smart cities, combining active sensors and RFID for robust and cost-effective identification of many different objects in terms of functionality, technology, and application fields in cities. Sensor networks in cities can gather an enormous amount of information from connected smart objects and grids over utility networks. Real-time responses and predictions become possible with high capacity processing and computing power.” (Komninos, 2014, p. 68.)

Such systems would enable buildings to engage in the sorts of dialogues contemplated by Pask’s conversation theory discussed in the prior section and, in so doing, permit a complex interaction between the user and the space to be used.

4.4. UBIQUITOUS COMPUTING IN ARCHITECTURE - ADAPTIVE/RESPONSIVE ARCHITECTURE

“[...] ‘inhabitation’ will take on a new meaning - one that has less to do with parking your bones in architecturally defined space and more with connecting your nervous system to nearby electronic organs. Your room and your home will become part of you, and you will become part of them. (Mitchell, 1996, p. 30)

There have been a few prior, notable attempts to implement ubiquitous computing into built environments in an effort to generate interactive spaces. An examination of these earlier undertakings illuminates some of the benefits (as well as the limitations) of creating self-programming spaces that modify their actions by observing and predicting human behaviours.

Figure 61. (Left) Sensor panel for light, temperature and sound. Also includes speaker to allow house to vocalize to inhabitant. Adaptive House. Michael Mozer. 1997

Figure 62. (Right) Miles of cabling in the house terminate at panel to be fed into and processed by a PC. Adaptive House. Michael Mozer. 1997.

As Fox and Kemp note, the last two decades of the 20th century witnessed a huge change in the field of computer science as new areas of study, such as “intelligent environments” (IE) emerged to research the integration of ubiquitous computing and networked communications into architecture. (Fox & Kemp, 2009, p. 67) The goal of these studies was to augment ordinary spaces by seamlessly embedding information technology within them so as to improve the user experience.

One such project was Michael Mozer’s experimental “Adaptive House”, created toward the end of the 1990s. (Ibid.) Mozer renovated a 90-year-old Colorado schoolhouse by installing a large number of computerized sensors and switches into the lighting and environmental controls of the building. These sensors allowed the system to monitor user activities to predict future behaviour. Data on everything from room temperature, light and noise levels, movement, the opening and closing of doors, and all HVAC and hot water heater activities was gathered by 75 sensors. This information was then processed by the system and used to reprogram itself to anticipate user preferences. For example, when a person walked into a room the motion detectors would sense it and turn on the lights

Figure 63. Adaptive House floor plan. Michael Mozer. 1997

automatically to a pre-determined level of brightness. If the user wanted a different level of ambient lighting, it could be adjusted by pressing a wall mounted light switch. The system would record that fact and use it to change its behaviour the next time around. In this way, “the “Adaptive House” essentially programmed itself by monitoring the environment and sensing actions performed by the inhabitants, observing the occupancy and behavior patterns of the inhabitants, and learning to predict future states of the house.” (Fox & Kemp, 2009, p. 67)

One of the limitations of the “Adaptive House” is that the processors and sensors are dedicated solely to tracking environmental conditions internal and external to the building. As computer technology has continued to shrink in size, while at the same time increasing exponentially in capacity and capability, it has become easier and cheaper to embed computer chips into many different objects in the environment. This has resulted in a shift in IEs from gathering data related solely to lighting and heating, to collecting huge data sets about how the user is interacting with the entirety of the space and the items contained within it. (Ibid.) This can include more sophisticated sensors that can track direction, orientation and acceleration, as well as monitoring and identifying user voice, face and kinetic input. (Ibid.) The result has been that each generation of IEs has been growing smarter and smarter. In these IEs, the user can interface with the space in a multitude of unconventional ways that more closely resemble human forms of communication. As Fox and Kemp point out:

“The increased definition of sensors enables a more personalized response with the ability to detect not just where and what a person is doing within a space but also who that person is, whereby a response can be tailored on an individual basis.” (Ibid., p.77)

This makes possible interactions between the user and the built environment that exhibit some of the attributes of those outlined by Pask’s conversation theory. (Ibid.)

One example of this more complex type of IE was MIT's "Intelligent Room", directed by Michael Coen. The project was an attempt to design a highly integrated, interactive environment with computer sensory, actuating and processing power. The computer system was capable of monitoring and addressing every single item that a user might interface with inside the space, including ordinary furniture that contained no embedded or attached sensors. As Coen notes, the room was intended "to experiment with different forms of natural, multimodal human-computer interaction." (Coen, 1998, p.1) The ultimate goal was to enable users to engage in activities in a built environment that had previously not been done using computation and in a manner that more closely resembled human forms of communication. (Fox & Kemp, 2009, p. 16) The "Intelligent Room" included various computer vision, voice and Kinect sensors to recognize users and their emotions and body language. Coen was particularly interested in employing advances from the field of artificial intelligence to maximize the system's potential to calibrate itself without the need for manual intervention." (Coen, 1998, p. 1) A sample interaction included recognizing a user when she entered the room and lay down on a sofa, understanding this and dimming the ambient light in response while simultaneously closing the curtains and putting on relaxing music. The room could then ask the user when they would like to be woken up. (Ibid.)

One of the challenges that Coen and his team faced in attempting to build such highly integrated environments was the limited state of computing technology and artificial intelligence in the late 90's. High quality, low cost vision, speech and gesture recognition technology, combined with extremely powerful, globally connected computer processing power has only become available to the average North American in the past few years, in part due to the proliferation of powerful smartphone computers and near ubiquitous

Figure 64. (Left). Layout of current incarnation of Intelligent Room with two ceiling mounted projectors. Cameras monitor the room to detect when people point at images on wall. *The Intelligent Room*. MIT, Michael Coen. 1997.

Figure 65. (Middle). Trackers can monitor the movements of several people in the room. Image on the left shows historical movement of four different people. Image on the upper right shows view from camera. Image on lower right shows computer distinguishing between four separate individuals. *The Intelligent Room*. MIT, Michael Coen. 1997.

Figure 66. (Right). Data gathered from monitoring a user walking around the room for a few minutes enables recreation of the structure of the room. *The Intelligent Room*. MIT, Michael Coen. 1997.

wireless networking. Even updated versions of the intelligent room project, from a recently as 2007, were still limited by having to deal with a diverse array of cameras, digital displays and user interfaces in a wide range of different appliances and hardware from televisions and cell phones to refrigerators and thermostats. Today, users more commonly interface with the digital world through their smartphones, tablets and computers. All other devices and equipment are rapidly evolving to speak the same computer protocols so as to allow them to integrate more seamlessly into user's activities. This has led to automobiles, dishwashers, wearable electronics and home security cameras that all connect seamlessly and inexpensively to a user's computing devices (i.e., the Internet of Things (IoT)).

With these more advanced forms of IEs integrating truly ubiquitous computing into the built environment, the potential now exists to enable sophisticated conversation between the body and the building.

An example of one such advanced form of IE is the “TRANSFORM” (2014) system developed by the Tangible Media Group from the MIT Media Lab. “TRANSFORM” is a dynamic shape display that consisting of a thousand pins that can be digitally controlled to take on a number of forms in real time limited only by the number of pins and the volume of the construct (i.e., a 3D surface that you can touch and that can touch you back; that you can give objects to (real, virtual or both) and that can manipulate them and give them back to you). Extending this approach to architecture yields the possibility of “pixelated” space in which users can be surrounded by a structure that is as reconfigurable as their TV, computer and smartphone displays. Furniture could be made to appear and vanish, as could partitions, stairs, and environmental controls (e.g., light, air, heat, cooling, sound suppression, etc.) While some might argue that this represents the ultimate form of

Figure 67. Transform. Tangible Media Group from the MIT Media Lab. 2014

Figure 68. Transform. Tangible Media Group from the MIT Media Lab. 2014

interactive architecture, others might say that it offers “everything” to everyone and in so doing offers “nothing”, like a blank TV screen waiting for a show to display.

4.5. EMOTIONALLY INTELLIGENT ENVIRONMENTS (EIE)

An alternative approach to the highly mechanistic solution offered up by projects like “TRANSFORM” is to create powerful IEs using cutting edge technology that may become available through the Internet to provide truly ubiquitous computing. Such an environment would make use of current, commonplace, high speed wireless networks to access the raw processing and analytical power of artificial intelligence systems like IBM’s “Deep Blue” and “Watson”, the world champion chess and Jeopardy playing computer programs, respectively. (Grunewald, 2012) By employing cloud-based, computing engines with such massive horsepower, the system would be able to provide ultra-cheap, state-of-the-art, constantly improving voice, face and gesture recognition from anywhere in the world that could, in the future, be employed to identify a user’s emotional state. It would, one day, be able to harvest vast amounts of data from commercially available, Internet enabled appliances and utilities (e.g., similar to today’s Nest® home thermostats, smoke and carbon monoxide detectors, Dropcam® digital cameras, LG Smart ThinQ™ web enabled refrigerator and similar washers, dryers and dishwashers, etc.) that could, ideally, be easily installed and maintained using then existing, trained technicians and support personnel used by such companies. The system would also someday be able to gather data from the user’s own devices, such as their smartphone, tablet and computer, as well as their wearable computing devices (e.g., similar to current devices like Fitbit®, Apple® or Android® watch, etc.) and would be able to connect with any newer, more powerful devices as they become available. In this way, a truly intelligent environment (as compared to the attempts made to date) could be realized as was predicted by Weiser, in which technology recedes into the background and becomes almost invisible to the user. With such a truly powerful IE that exhibits genuine ubiquitous computing, and that would be capable of interfacing in a manner that more closely resembles the way humans do, the stage would be set, finally, to generate a meaningful body-building relationship. Architecture would then be capable of engaging in a dynamic, reciprocal feedback loop with the user to meet their respective needs. The human form would extend through all of its digital and mechanical prosthetics to blend seamlessly with architecture and, as Freud predicted, architecture would reach right back and shape the machinery and the body, in turn.

However, in order for such a fusion to occur between our minds/bodies and the built space, more advanced forms of IEs, yet to be created, would need to possess an

ability lacking in their current incarnations; the means to generate an appropriate emotional response in the user. To better understand this requirement for architecture to be capable of producing emotions in its inhabitants, an understanding is first required of the role that emotions play in relation to the body as a whole. Put differently, an appreciation is needed *a priori* of the relationship between, on the one hand, the fragmented part of our incorporeal selves that is our “emotions,” and on the other hand, the “holistic” corporeal, reassembled self that is our “body”. This is required in order that we may better understand how our prosthetic emotions influence the projection of our metaphorical bodies onto the prosthetic of our architecture.

The influence of emotions on our bodies is commonly thought of in terms of the impact that our feelings have on our “minds” and how it influences our bodily actions. There is a strong tendency, or “bias,” to perceive emotions as negatively affecting the cognitive and rational components of our thoughts. Emotions tend to be thought of as being irrational feelings that drive out ordered and logical thinking from our minds and encourage us to behave erratically, unpredictably and sometimes even violently. Jealousy, disgust and hate, for example, are all often associated with thoughts that lead to physically acting out in ways that are contradictory to the responses dictated by rationality and careful contemplation. Even positive emotions, such as love and desire, are usually thought of in terms of how they “cloud” our judgment and impair our ability to “think clearly.” (Hinshaw, 2013)

Our emotions, however, are better thought of as a critical means to organize our thoughts so that we can generate appropriate behaviors and communicate effectively with those around us. In other words, each of our emotions drives a physical response that can then be assessed cognitively in terms of our past experiences to influence how we chose to behave. For example, when we feel fear it drives the impulse within ourselves to either fight or flee. Based on our past experiences, we can attempt to evaluate the specific context in which we find ourselves to determine how best to respond. We may choose to stand our ground and fight or turn and run away. Regardless of which choice we make, our intelligence manifests itself in the manner in which the emotional impetus is evaluated against the sum of our experiences (and learning) to drive a particular output. For this reason, as an example, we do not necessarily run away whenever we are required to do that most fearsome of things: speak publicly. As Robert Zajonc noted, emotions organize a wide range of physiological and cognitive processes to shape goal-oriented behavior. (Zajonc, 1980)

The manner in which we decide to behave, once we have been motivated by our emotions and have intelligently evaluated the options available, sends a strong signal to those around us. Stated another way, the manner in which we choose to act (or refrain from acting) in response to our emotions communicates our intentions to other emotionally

cognizant bodies in our environment. Frequently, it is these same “bodies” or “actors” in our surroundings that are the source of our initial emotional reactions. Our behavior in response to their actions (i.e., their behavior) establishes a reciprocating feedback loop that drives the interaction between us in the form of an emotional conversation that can be modeled in cybernetic terms. For example, when one “actor” in the environment threatens another, the targeted actor might experience feelings of fear or anger (or even laughter). (Hinshaw, 2013) The target will then process these inputs in the context of past experiences and biases to generate a behavioral response. Whatever the action taken (or not taken) by the target of the threats, it will become a physiological input for the first actor. This will cause the first actor to experience emotions that will then be evaluated and used as the basis of their next response. In this manner, the two bodies will engage in a dynamic process in which the emotions/behavior of the one drives the emotions/behavior of the other.

Since each of the bodies involved in an emotional/behavioral exchange can necessarily attempt to evaluate the emotions/behavior of the other, it follows that emotions themselves are capable of being measured or quantified, if only subjectively. In other words, when one body performs an action that influences the emotions of some other participating body, then the receiving body can subjectively assess the impact that the behavior has had on its emotions (e.g., feeling very afraid vs. slightly afraid) in order to formulate a response. Whatever the response, it will often manifest physiologically in the form of facial expressions, changes in heart rate, pupil size, blood flow and perspiration. More obvious expressions of the response can (unless self-controlled through experience and learning) also take the form of the person’s posture (e.g., aggressive vs. submissive; open vs. closed, etc.) In this way, a Paskian-type of conversation is entered into between the two bodies as each body communicates through its own body and interprets the body language of the other participant.

The reciprocating feedback loop between two communicating bodies, described above, is possible because many core human emotions and bodily displays of emotions are either innate, (and, therefore, universally experienced) (Darwin, 1872) or culturally acquired (and, therefore, capable of being interpreted by all participants in that culture). (Ekman, 2006) For this reason, at least six basic emotions (i.e., happiness, sadness, anger, fear, disgust, and surprise) (Ekman, 1992) can typically be identified correctly by a person from a photograph of another person’s face, regardless of their respective countries of origin. (Ekman et al., 1987) As human beings, we are capable of interpreting these basic facial expressions regardless of the other person’s nationality or culture. This near universality of much of our body language enables the dynamic communication process described above (see, for example, (Jackson, 2012, pp. 132–134)), which is driven by our emotions and our bodily responses to others. Other displays/muting of emotion may be more culturally specific (see, for example, Leeds-Hurwitz, W. (Leeds-Hurwitz, 2009)) in how they are manifest (e.g., mother-child affection) (Mead, 1928) and controlled (e.g., the

suppression of anger/aggression). (Briggs, 1971) Nevertheless, culturally specific emotions serve the same communicative purposes as innate/universal emotions, but only among the participants in the culture and can be learned.

Returning now to the role of emotion in architecture; having considered the critical role that emotions play in inter-human communication, it becomes clear that in order for an intelligent environment to enter into a truly meaningful feedback loop with a user, the IE must be capable of identifying and exhibiting emotional behaviour. As we have seen, emotions enable us to generate appropriate responses and signal our intentions to others. It is these signals, and the ability to recognize them in others and respond to them correctly, that form the basis of the reciprocating dynamic between two communicating entities. In order for architecture to truly be able to communicate with users it must be capable of both recognizing and generating emotional responses.

Arguably, all architecture is intended to evoke an emotional response. Temples, as the supposed homes of the Gods, were imbued with massive columns and vaulted ceilings in order to evoke a sense of awe and reverence from the worshippers. An office building is intended to convey a sense of trust and responsibility to customers and staff, alike. Homes are designed to foster a sense of comfort, security and belonging. Literally by design, the built space is crafted from the outset to evoke a predetermined set of emotions in its users. Stated differently, the phenomenology of architecture (as discussed in Section 5.3) focuses, *a priori*, on generating a predetermined emotional experience in the user. It presupposes what the user's emotional response will be to a given set of design parameters and sets out to generate those emotions. By conceiving, beforehand, the end state emotional experience that it seeks to evoke, architecture necessarily assumes the existence of a normative body that will exhibit a common and known set of emotional values. The idea of the Vitruvian man (see Section 2.1), then, is really one of projecting architecture back on to the idealized, standardized, or average person and assuming in advance that a certain emotional response will result.

However, while architecture can clearly generate emotions, the same architecture may generate different emotions in different people. In other words, it is essentially impossible to design a structure using traditional architectural techniques that is capable of evoking the same emotions in every person. This is because, as discussed above, our emotions are predicated on our thoughts, which are based on our experiences. For this reason, a lavish cathedral that might evoke feelings of admiration and awe in one person, might cause another person to experience disgust at its excess. Just as there is no single, ideal body type (as discussed in Section 3), there is no identical experience for each person. If, as discussed above, every person's body is different and capable of enormous change, if it contains the inherent ability from the moment of conception until death to change and grow in response to its environment and to be shaped by its surroundings in a dynamic and

reciprocating feedback loop, then no single form of architecture can be experienced in the same way by every person.

Since there exists an infinite degree of variation in people (e.g., an unlimited number of environmental and genetic variations) both in the corporeal bodies as well as in their incorporeal thoughts, ideas and identities, then the phenomenology of architecture needs to operate in reverse. Instead of presupposing the emotional response of some hypothetical user to generate the design, architecture should begin with each individual user and proceed from there to the design, in a reciprocating and iterative manner. In other words, for architecture to be able to evoke feelings of satisfaction in each person, it must respond to and reflect the continuously changing thoughts and emotions expressed through the human body. Being able to mirror human emotions in that manner requires architecture to be able to evaluate and learn from the information received from people's bodies. In addition, architecture must have its own body, in order to perform actions in response to the thoughts and emotions being expressed by the bodies of other people.

By combining the idea of intelligent environments with a phenomenology of architecture that places the individual first, it becomes possible to conceive of an adaptive built space that could communicate with the user in a human manner to gauge their emotional state and generate an appropriate structure in response. Such a speculative future space would be reflective of the body and identity of the user from moment to moment, thereby creating an emotionally intelligent environment (EIE). It follows from the discussion in Section 3 that this type of environment, being an extension of the user, would be another form of prosthetic, thus making it an emotionally intelligent prosthesis.

Figure 69. Curiosity

5. ARCHITECTURE THAT LEARNS

5.1. EMERGENT BEHAVIOUR

In the previous Section 4.5 it was argued that intelligent environments, and in particular, environments that are emotionally intelligent, could give rise to true Paskian cybernetic conversations between the body and the built space. However, this raises the question as to how exactly, in practical terms, such complex modes of communication can be generated between mechanical and organic systems.

As discussed above, simple systems consisting of as few of two components can give rise to diverse and unpredictable behaviour. (Pickering, 2011) When such interconnected systems enter a reciprocating feedback loop, as can be modeled using cybernetic theory, they dynamically re-shape each other in a manner that is not merely interactive or responsive, but structurally coupled. (Maturana & Varela, 1980) In such cases, the system and the environment are shaped by each other through repeated interactions defined not by one of the systems accommodating the other, but by the systems changing in response to each other. (Ibid.) The distinction is key to understanding the difference between

Figure 70. Shoes designed by Francis Bitonti based on the Game of Life algorithm that models complex behaviour.

complex behaviour that can emerge from a simple set of behaviours, but is limited to being responsive, and higher order systems that adapt as a result of their own plasticity and the plasticity of their environment. (Diniz, 2008)

In nature, there are many systems that display emergent behaviour (complex patterns or behaviours that can emerge from a series of simple rules governing the relationship between a number of constituent parts) and that are responsive without being structurally coupled. Emergent behaviour is pervasive throughout nature precisely because it generates complex functions and behaviours from the interaction of simpler sub-components. For example, when a flock of birds flies together there is a set of basic rules that governs the distance between each bird and its neighbor, relative to the lead bird. These rules result in the birds quickly settling into an organized pattern (e.g., a flying V-shape) and also cause the birds to turn and twist together in flight, following their leader. These coordinated dips and dives can appear to be extremely complex, but are only as a result of the individual birds responding to their neighbors and following a few basic rules. Another example is a hypothetical cellular matrix in which the nucleus in each cell must be located a certain minimum distance from the nuclei on every side of it. (Warwick, 2012, p. 119) This simple rule can cause complex patterns of behaviour to emerge when the position of the nuclei of a single cell is changed. When this happens, every other cell may need to change its position relative to its neighbouring cells. (Ibid.) It is then possible to witness perturbations moving through the entire matrix as the cells seek to achieve equilibrium (see, for example author's simulations of cellular automata in Figures 73-76 created using Grasshopper software). Small, intentional changes to the state of one or more of the constituent nuclei can then be seen to cause regular patterns of perturbations to move throughout the whole matrix. (Ibid.) Similar qualities can be seen in the human body, which can be thought of as a balanced system made up of its constituent, fragmented parts (as discussed previously in Section 3.1). In the system that is the human, corporeal body, each of the “parts” will influence the behavior of the “whole”. As a result, if I move my arm, there are many other, connected body parts that must move seamlessly together, in coordinated maner, in order for the “holistic” body to retain its integrity. This is true whether the body is at “rest” or in motion, so that wherever the human body is in space at a given moment in time, it will seek balance and equilibrium of all of its parts.

Figure 71. Flocking Behaviours in Birds.

Figure 72. Shoaling Behaviour in Blue Jack Mackerel.

Figure 73. Cellular Automata Pattern Testing. Born: 2, Survive: 2,3.

Figure 74. Cellular Automata Pattern Testing. Born: 2, Survive: 2,3.

Figure 75. Cellular Automata Pattern Testing. Born: 3, Survive: 2,3.

Figure 76. Cellular Automata Pattern Testing. Born: 3, Survive: 2,3.

An architectural project that seeks to be responsive to user(s) could implement a similar set of simple rules governing the reaction of the structure to the movements of the users. In this way, complex patterns could be generated under varied circumstances (e.g., the user moves in a particular direction and all elements of the structure “swarm” in the same direction). However, note that in such a system neither the user nor the structure would be fundamentally changed by one another. Instead, the structure would be responding to the user and the user could choose whether to respond in kind, without the two being integrally bound together. This type of “responsive” architecture lacks the higher order adaptive dynamics necessary to demonstrate true structural coupling. As a result, unless a great many complex and interdependent rules are carefully programmed into the building system, the behaviour that will emerge on the part of the structure will largely be limited to being responsive to the user (e.g. following the user’s movements). As a result, such systems may fail to account for differences among user body-types and identities and may fail to appropriately learn from trends in the behaviour of the users. While user differences and learning can be programmed into the base rules, the overall system is still limited to its initial parameters and is not self-programming or highly reconfigurable. As a result, it cannot achieve Paskian cybernetic conversations that resemble human forms of communication.

5.2. DIALOGUE BETWEEN PARTICIPANT AND MACHINE

In order to generate higher order communication between two systems, whether mechanical or biological or both, it is necessary for each system to be capable of adapting and changing itself in response to the other, inter-connected system. Nature is also filled with examples of this form of evolutionary adaptability. As discussed in Section 3.3 above, the body is extremely adaptable and plastic as a result of its instruction set being directly encoded into its own modifiable genome. (Shryock et al., 2011, p. 67) This is true of every form of life on this planet, whether plant or animal, protozoan, bacterial or viral, but each is based on a very simple set of instructions. As Frazer noted:

“The ‘sheer imponderable complexity of organisms’ overwhelms us now as surely as it did Darwin in his time. The developmental processes of nature inevitably lead to complexity, but they work with simple building blocks and an economy of means to achieve complexity in a hierarchical manner. The coding of all natural forms in DNA is achieved with just four nucleotides, which in turn use just twenty triplets to specify the aminoacids that manufacture protein...”
(Frazer, 1995, p. 19)

A similar approach can be taken with mechanical systems, by basing them on a handful of simple rules to generate enormous complexity and plasticity (Chapman, 2013, p. 172). (for greater clarity, the term “plasticity” refers to the adaptability of an organism to changes in its environment or differences between its various habitats (see Oxford English dictionary) that rises above the level of mere interaction or responsiveness. The concept has been extended to architecture with attempts to create complex arrangements based on a limited number of predefined building blocks. This type of interactive architecture has a fundamental appeal. According to Fox and Kemp:

“When the space becomes interactive, when it can understand what it is that we appreciate about it, and when that space can sustain, replicate, or even enhance the aspects that make it special on a personal level, then this process can provide a true attachment to space” (Fox & Kemp, 2009, p. 158)

One such undertaking was the 1970’s “Generator Project” by Cedric Price, which sought to reduce the components of the building to a finite set of interconnected elements capable of an infinite number of combinations and permutations. The project was never built, but the proposal called for an array of prefabricated foundation pads and a permanently installed mobile crane that could be used to continuously move around the various building components in an effort to find the ideal configuration for whatever the task at hand. (Ibid., p. 101)

While the reconfigurable nature of the “Generator Project” demonstrated the potential for plasticity in architecture and, therefore, the potential for structural coupling between body and building, an additional element is required for plasticity to attain higher order communications. For this missing link, we must turn to second-order cybernetics or “new cybernetics”. This field of study evolved from original or “old” cybernetics (the study of observed systems) into the study of observing systems and reached its pinnacle in the 1960s and 70s. (Diniz, 2008) Second-order cybernetics introduces the notion of knowledge being acquired by the system through the cognition of the system itself (i.e., the observer). In this way, one or more of the systems that are structurally coupled (i.e., highly plastic and adaptable to the influences of one another) becomes capable of cognition and, therefore, of acquiring knowledge about the adaptations taking place. It uses this knowledge to organize its experiential world and, in so doing, feeds its knowledge back into the reciprocating loop within the larger system. In architecture, this is the primary metaphor of the body that man uses to organize his experiential existence and then projects back into his prosthetic tools, writing and architecture. (Hight, 2008)

The “Generator Project” sought to include this type of cognitive ability, by integrating circuits into every building component so that the system could learn about itself and generate its own configurations. As Pask notes:

Figure 77. Generator Project. Cedric Price, John Frazer, Julia Frazer 1976-79

“The computer program was developed to suggest new arrangements of the site in response to newly defined needs. By embedding electronics in every component and making connections to the foundation pads, we effectively turned the site into a vast working model - a gigantic reconfigurable array processor, where the configuration of the processor was directly related to the configuration it was modeling...The building thus became ‘intelligent’...” (Frazer, 1995, pp. 40–41)

Once a building is adaptable and plastic like its biological user, and once the building can demonstrate cognitive abilities to observe the structurally coupled system in which it is participating, then it can have a second-order dialogue with the user employing the language of cybernetic conversations pioneered by Pask. Such a dialogue can lead the participants toward a mutually agreeable “understanding” for a specific subject matter. As Fox and Kemp pointed out, “When architectural space has a true communicative capability, it can foster a heightened sense of attachment.” (Fox & Kemp, 2009, p. 158)

Figure 78. Escape

5.3. THE BODY-BUILDING RELATIONSHIP AS PHENOMENON, TROPE AND SECOND-ORDER CYBERNETIC SYSTEMS

As discussed in Section 2.1 above, the body-building relationship is a fundamental metaphor in Western architecture. It posits the notion that the ideal human body (aka the Vitruvian man) represents the perfect proportions for ensuring the design of a harmonious and balanced structure. (Warden, 2013, p. 86) This relationship between the body and the built space was also fundamental to the phenomenological approach to architecture and played a large part in the philosophy of Husserl (descriptive) and Heidegger (interpretive). (Warden, 2013, p. 86) Phenomenology is the branch of philosophy that studies the emergence of phenomena. It seeks to determine how people experience the world around them and how they progress from their sensory impressions of their physical environment to constructing a coherent and meaningful view of the world. (Diniz, 2008, p. 511) Edmund Husserl, considered by many to be the father of this field of study set out to define in rigorous scientific terms how we make sense of our everyday experiences in the natural world. (Ibid.) The phenomenological analysis addressed the implication of the architectural experience and how it contributed to our ‘sense of self’ and the extent to which “the designed environment could be seen as both an extension or projection of the self into the world, and likewise as extensions of social/cultural worlds toward the self.” (Hale, 2008, p. 1)

For Husserl, architectural theory and, indeed, every theory ultimately had its roots in the original perception or observation. (Diniz, 2008, p. 511) This transcendental, or purely thought based, form of phenomenology, of bringing order and understanding to our experiences, occurred solely only in our minds. (Ibid.) Heidegger and his student Merleau-Ponty rejected this purely thought based view of experience and understanding, and opted instead in favour of recognizing a “primordial coexistence between the body and its world.” (Ibid., p.511) Whereas Husserl believed that the construction of a coherent worldview was solely a cerebral exercise, Heidegger rejected the doctrine of Cartesian dualism, the separation of mind and body. (Ibid.) He argued that the world has meaning to us in terms of our physical relationship to it and our social practices within it. (Ibid.) This view of phenomenology based on our existence in the physical world (i.e., existential phenomenology) re-introduced the importance of our corporeal bodies into our understanding of the world around us, including our architecture. This idea of focusing phenomenology on the bodily perceptions and regarding the body of the central point of mankind’s understanding of the world, was further advanced by Maurice Merleau-Ponty, a student of Heidegger, and moved phenomenology from a purely intellectual based exercise, to something based on our visceral experiences in the physical world. (Ibid., p. 512) In so doing, Merleau-Ponty created a fundamental link between the philosophy of our understanding of the world and the body-building relationship of the Vitruvian

man that forms a pillar of Western architecture. In essence, he posited that we can only understand the built space and have a meaningful view of it as a result of our physical abilities. The body, then, in existential phenomenological terms, is the source of shaping and understanding all architecture.

As Hight notes, in *Architectural Principles in the Age of Cybernetics*, Rykwert drew heavily on the ideas of Merleau-Ponty to inform his own views in the *Dancing Column* on the idea of the human body being metaphorically projected into the structure and layout of the built space. (Hight, 2008) Rykwert essentially adopted the existential phenomenological view that our bodies are the primary lens through which we experience our physical environment and form a coherent world view. (Ibid.) Both he and his student Perez-Gomez argued that the body cannot be divorced from architecture (just as Heidegger and Merleau-Ponty rejected the doctrine of Cartesian dualism espoused by Husserl) because the metaphorical body is at the very core of architecture and what it means to be human. (Ibid.)

The somatic-building trope also extends to the realm of cybernetics. As Diniz notes, “*Phenomenological Architecture objectives meet with Second Order Cybernetics ones.*” This is because at the outset, the original theories of cybernetics (or “old cybernetics”) were focused almost exclusively on the observed system. They adopted an approach similar to Husserl’s view of phenomenology which sees all knowledge and experience as being cerebral. For the early cyberneticists, knowledge gained by biological and mechanical systems was to be understood purely in terms of a “passive reflection of the external, objective reality.” (Ibid., p. 512) However, second-order cybernetics evolved to include the notion of the “observer” in the system. This approach, outlined in the works of Bateson, Maturana and Varela, recognized that knowledge is actively constructed by the cognizing subject. (Ibid.) In this way, second-order cybernetics came to resemble the approach outlined by Heidegger and Merleau-Ponty, and subsequently adopted by Rykwert and Perez-Gomez. It changed its focus from a purely intellectual model of knowledge to one in which a meaningful and coherent view of the subject’s world is mediated through their physical body and can only be understood in terms of their physical abilities and actions. In other words, the somatic-building (subject/environment) relationship in which the subject interacts with another system, including its environment, can only be understood by that subject based on their own physical experiences, and these experiences, in turn, shape the subject’s action within that environment and, as a result, have the effect of re-shaping that environment. This re-shaping, in turn, feeds back on to the subject in a reciprocating and dynamic loop in which they re-shape each other, forming a Deleuzian multiplicity. (Deleuze & Guattari, 1987, p.8)

It is this multiplicity, the combination of the body and the building, that must inform the Emotionally Intelligent Environment. Only when the building can be cognizant

and form its understanding of the user, can it enter into this type of dynamic, reciprocating feedback loop with its own understanding.

“If smart structures are to graduate to intelligent structures, there has to be a provision for learning and decision making.” (Wadhawan, 2007, p.5)

This approach is supported by a number of researchers and writers in the area of adaptability. For example, Negroponte posits that artificial intelligence must be incorporated into architecture in order to create a sufficiently responsive environment. (Negroponte, 1975) Gramazio and Kohler, on the other hand, maintain that the role of architects is not limited to only transformation of form, but must include the design of behaviors. (Gramazio & Kohler, 2014)

5.4. SELF-AWARENESS AND SELF-ASSEMBLY

“In the human body, the self-assembly process is similar to the way your bones grow [...] Self-assembly occurs spontaneously when the human body converts food, water, and air into a variety of acids, sugars, and minerals. From these materials cells, blood, tissues, and muscles are created. All of these biological functions are due to the self-assembly of molecules in the human body [...]“ (Mongillo, 2007, p. 44)

Communication among the components of a system creates the potential for self-configuration into a range of different forms and functions. (Aranchii, Jiang, Bart, & Santos, n.d., p. 31) In other words, it is through the localized exchange of information between the parts of the whole that a larger, aggregate structure can come to possess the inherent ability to adapt to changing circumstances. (Ibid.) The concept of self-assembly in architecture flows naturally from the idea of these types of intelligent environments. In such cases, the structure itself possesses the necessary means to identify challenges in its surroundings and can be made to include the necessary mechanical parts for self-automated and self-directed reconfiguration without the need to resort to external sources of assembly/disassembly (e.g., manual labour and construction equipment). (Ibid.)

For a system or structure to have a concept of “self” or, perhaps more compellingly “I”, it must be capable of storing memories as symbols and processing those symbols by communicating with its component parts in order to form higher order abstractions. The internal logic of the system must drive this iterative and reciprocating process of

data collection; abstraction; analysis; and finally, output, so that the larger whole can be understood. For intelligent environments in architecture, and for emotionally intelligent environments in particular, each part of the whole must, therefore, possess a degree of “identity”.

This sense of “self” or “I” can be achieved through a set of basic rules that drive the emergence of complex behaviour (e.g., swarming of birds, fish, bees, etc. or the movement of living cells within an organism in response to environmental changes, including changes in the state of their neighbouring cells). (Ibid.) As each part of the larger whole responds to the initial change in state by changing its own state, a cascading effect spreads through the aggregate structure, in a continuous and reciprocating manner, as equilibrium is sought. Each such iteration can be monitored and processed by the individual components, as well as the collective whole, and harnessed to drive optimal (i.e., efficient) responses.

One of the main objectives of enabling each component of the larger system to “know” its own state relative to its neighbouring parts is the development of strategies of coordinated action. (Ibid.) Using local interactions (i.e., communication), each component of the whole can come to recognize its position relative to the larger, collective structure. This feature of inter-unit communication is critical to achieving the necessary reciprocating dynamic without which the collective structure could not make the requisite “decisions” to guide its overall coordinated actions. (Ibid.) This means that, in order for learning and self-

Figure 79 Sequence shows self-reproducing modular robot going through reproduction cycle.

Figure 80. M-Blocks connect to each other using permanent magnets embedded in their corners. Other magnets on their faces are used for alignment. The modules ambulate using the torque of an internal flywheel.

assembly to take place within architectural structures (see, for example, Distributed Flight Array in Figure 82) each constituent component must possess a degree of self-awareness to enable it to communicate and coordinate with its collective self and, ultimately, the user.

The key benefit of empowering each part of the system with the ability to “know” or be “aware” of its own state relative to its adjacent parts, is that it imbues the the larger framework with the ability to more rapidly problem solve how to respond to changes in the surrounding environment. (Ibid.) Without a sense of “self”, the individual element is unable to determine an optimal response which, in turn, prevents the collective structure from processing an “intelligent” response for the whole. (Ibid.) In other words, coordinated communication between the underlying parts leads to a unified decision, enabling the system to move and respond effectively within its environment in a coordinated manner.

Figure 81. Distributed Flight Array modules move along the ground to find each other and then join together into a multi-propeller system capable of coordinated flight. The system is self-monitoring and adjusts thrust to correct for disturbances. If the modules detach, the whole process repeats itself. Each unit is self-contained and has its own sensors, but coordinates with its peers. Raffaello D'Andrea.

In this sense, the self-aware system is capable of learning about its surroundings and circumstances for self-assembling (/disassembling/re-assembling, shape-changing, etc.) without the need to resort to a predetermined course of action. (Ibid., p. 33)

This open-ended approach generates enormous flexibility for the aggregated unit to adapt effectively to new situations and scenarios. Potentially, it even allows for a system to develop the means to process abstracted information without the need for immediate intervention (i.e., to imagine possible scenarios in the abstract and how it would address them) in order to problem solve effectively. For example, a system capable of storing input in aggregated symbolic form for processing, could potentially further abstract such information and knowledge for higher order processing in order to simulate possible scenarios within its environment that it has “learned” have a likelihood of occurring, and then formulate different scenarios to address novel circumstances (e.g., speculate, dream, predict, etc.) Just such an approach has been used by NASA to have its tensegrity robots learn to walk more efficiently in a shorter period of time. Rather than subject the robots to endless trial and error in the real world, scientists modeled the tensegrity robots in digital simulations of actual environments and allowed them to try out huge numbers of combinations and permutations of “movement” at a greatly accelerated pace inside the

Figure 82. Self-Replicating Spheres explores the processes of growth, encapsulation and division through macro-scale objects on an oscillating table. The internal structure of the metal spheres provides the force of attraction for growing connections, flexibility and division. By adding more spherical units and oscillating the table, the system continuously grows and divides. Self-Assembly Lab, MIT - Dimitris Mairopoulos, Skylar Tibbitts.

Figure 83. A prototype of NASA's Super Ball Bot built by Ghent University's Ken Caluwaerts. 2014

simulation. The knowledge gained from these “virtual” excursions was then processed and passed on to the real world tensegrity robots so that they learned to navigate complex spaces in a greatly reduced period of time.

By providing components within a structure to have a sense of “I” or “self”, and enabling them to learn from their past actions (and, in so doing, enable the collective structure to generate self-awareness), the aggregated form will gain understanding and become capable of providing the basis for an architectural system that can pursue specific goals. The aggregate structure can then adapt itself to its surroundings and make (and communicate) the necessary decisions internally to its constituent parts, to effectively act on those plans, and achieve its desired outcomes. In this way, an intelligent structure could communicate not only with itself but with its environment. In so doing, it can communicate with the user in a Paskian manner that works toward a mutual, negotiated equilibrium.

By imbuing the system and its underlying components with a sense of “I” or “self-awareness,” the fundamentally human act of the projection of the body-building metaphor is taken to its logical conclusion. A structure that possesses a degree of understanding of its own “layout” or “structural form” relative to that of its users, is able to know its own “body” and, therefore, project that somatic trope back onto the users. It is, to paraphrase in Deleuzian terms, “a becoming-body of the building and a becoming-building of the body.” (Deleuze & Guattari, 1987, p.10)

Note that there is a real question of the degree to which the building and its components can be described as being truly “self-aware”; they would arguably not have achieved “sentience” or “consciousness”, knowing as they do only their relative and aggregate positions to each other and the users. Nevertheless, it is interesting to note the willingness of authors like Aranchii, Jiang, Bart, & Santos to attribute to a building and its constituent parts “self-awareness” (i.e., to anthropomorphize). Human beings seem unwilling to attribute self-awareness to other members of the animal kingdom (Rowlands, 2016, p. 1), but seem more willing to bestow it on their mechanical devices (see Section 4.1). Whatever the degree to which such structures have actually been made self-aware or developed a sense or “I” may be irrelevant to this discussion, however, if we consider for a moment that the act of declaring them to be self-aware is itself an example of projecting the bodily self through these prostheses and onto architecture. When architecture is free to experience its own bodily-form (i.e., structural layout) then, like the humans that created it, architecture becomes capable of experiencing the world in phenomenological terms. It can make sense of and order its “reality” in terms of, and relative to, its own bodily experiences, and it can project those experiences out into that world and onto the human bodies that built it and inhabit it.

Figure 84. *TensegrityEvaluations*, 2013.

Figure 85. *Confrontations.*

PART III

6. TENSEGRITIES AS COMPLEX SYSTEMS THAT CAN CONVERSE

6.1. TENSEGRITIES: AN ALTERNATIVE FORM OF STRUCTURE

The term “tensegrity”, coined by Fuller and Snelson in 1962, is generally applied to any self-stabilizing, form-finding structure that maintains its stability by employing compression struts and tension cables (see Fest, Shea, Domer, & Smith, 2003; Paul, Lipson, & Cuevas, 2005; Xu, 2010) through the separation of the purely compressive and purely tensile structural elements in the system. Although some variations in construction exist (see Robbin, 1996, pp.25-37), typical tensegrities have the advantage of being able to adapt to changing environments by adjusting their self-stress. This makes them useful for employing in varied conditions where they may be less likely to fail structurally (see Fest, Shea, Domer, & Smith, 2003). Figure 86 and Figure 87 show the schematic and simulation of a simple tensegrity structure.

The shape of tensegrity structures can be adjusted by varying the characteristics of the tensile elements and compression struts. (Fest et al., 2003) However, this requires sensing and actuating technologies to be added:

“Changing the self-stress to adapt to changing environments requires tensegrities to be equipped with sensors and actuators. Sultan (1999) formulated control techniques that use a minimal energy optimization. Skelton et al. (2001) built on this work and provided a closed mathematical formulation for the simulation of active tensegrity structures.” (Fest et al., 2003)

The resulting changes allow the tensegrity structure to take on a wide range of new shapes as it automatically form-finds its new equilibrium. (Riether, Putt, & Wit, n.d., p. 666) In addition to variation based upon length of compression and tension members, the potential range of shapes and changes varies greatly, depending on the number of elements in each tensegrity (see Figure 88). As Paul and his colleagues noted, the challenge of form-finding in tensegrities is two-fold: determining the pattern of connectivity to permit a stable form, and calculating the length of the compressive and tensile elements for a given pattern to yield a stable outcome. (Paul et al., 2005) They further noted:

Figure 86. Three strut tensegrity Kangaroo simulation.

Figure 87. Schematic of three strut tensegrity structure. 3D model.

“Early structures developed by Fuller and Snelson, used convex polyhedra as the basis for form-finding. These methods were focused on specifying connectivity patterns that could enable a tensegrity. This approach resulted in various configurations which were summarized by Pugh (Pugh, 1976). However, these were all based on regular geometries. Subsequent methods were developed which primarily focused on determining the length parameters of the rigid and tensile elements in the stable configuration. These methods involve the use of non-linear programming (Pellegrino, 1986), dynamic relaxation and calculation of force density (Schek, 1974)(Linkwitz, 1999)(N. Vassart, 1999).”(Paul et al., 2005)

Figure 88. An exploration of tensegrity form-finding based on dynamic relaxation over regular geometries Figure 88. An exploration of tensegrity form-finding based on dynamic relaxation over regular geometries

6.2. TENSEGRITIES AND EMERGENT BEHAVIOUR

Tensegrities also demonstrate qualities of emergent behavior (see Section 5.1) because they exhibit complex responses from simpler constituent parts. In other words, like a flock of birds flying in formation, or the patterns that emerge from cellular automata, a limited number of rules govern the behaviour of the underlying tension and compression elements of a tensegrity system. The combination of these simple rules that are built into the tensegrity (e.g., if a tensile element is shortened then the related compression elements will move toward it) lead to a complex, form-finding behaviour that can adjust to changes in the environment and automatically seek a new equilibrium. As noted above, the shape of any tensegrity structure can be adjusted by varying either the tension in the tensile elements or the length of the struts. (Fest et al., 2003) The resulting changes allow the tensegrity to take on a wide range of new shapes as it automatically form-finds its new equilibrium. (Riether et al., n.d., p. 666) In addition, if individual tensegrity units are combined to form

Figure 89. Physical model deformation and emergent behaviour studies. See Appendix A.

a larger tensegrity, the aggregated construct will exhibit emergent structural behaviour, like cellular automata, as the “rules” built into each tensegrity unit affect its neighboring tensegrities and feedback on each other in a dynamic and reciprocating manner.

6.3. TENSEGRITIES IN NATURE, CELLULAR REPRODUCTION, AND THE HUMAN BODY

For the purposes of this study, in order for a built structure to communicate emotionally, it must employ kinetic attributes that are similar to our own. The tensegrity seems to be an ideal structure for replicating some of the flexibility and motility of the human body. It has been observed that the robust and adaptable qualities of the tensegrity structures have resulted in them becoming prevalent in key biological systems or “biotensegrities”. This is as a result of their structural stability through arranging their components to economize energy and minimize mass. (Galil, 2010, p. 43) As noted by Donald E. Ingber, Harvard Professor of Bioengineering, tensegrity principles apply at virtually every observable scale in the body. (Ingber, 2003) All of the bones in the human skeleton are drawn upwards against gravity by the tensile pull of muscles, tendons and ligaments, and at the cellular level in the body, proteins and other critical molecules also stabilize themselves in the manner of tensegrities. (Ibid.) Similarly, Jáuregui noted:

Figure 90. Models of vertebrate anatomy. Tom Flemons. 2005.

“[...] the continuous tension-discontinuous compression has also been shown to be a basic principle of nature; therefore, this work makes an effort to gather more information from various fields, other than Architecture, and to find out what the derivations of these phenomena are, especially in the so-called biotensegrity.” (Jáuregui, 2004)

For example, the mechanism used within individual cells of many living organisms to reproduce through division are based on tensegrity-like mechanisms. (Fest et al., 2003,

p. 515) Similarly, spider fiber is classified as a tensegrity structure because of its network of tension and compression members. (Galil, 2010, p. 44) The mammalian body has also been described as being a tensegrity structure comprised of a careful balancing of forces between muscles, bones and fascia (i.e., Galil referred to the human arm as being an example of higher order tensegrity since it included rigid bodies that did not touch each other). Fox and Kemp maintained that the human body is made up of various “kinetic” parts controlled by a core nervous system. Similarly, Riether, Wit and Putt point out:

“Different from conventional construction systems that are based on continuous compression under gravitational loads, tensegrity systems are based on the concept of continuous tension. Rather, these systems are similar to the structures within the human body where bones act as compression struts and the muscles, tendons and ligaments form the tension members (Ingber, 1998)” (Riether et al., n.d., p. 665)

Through a combination of tension and compression components, tensegrities are able to demonstrate flexibility, motility and form finding capacity like our bodies. The tensegrity provides the built structure with the framework to both understand and speak our most basic language of expression – body language (i.e., using our limbs, posture, movement and facial expressions to communicate).

Figure 91. (Left). Actin geodome floating tension structure (tensegrity) form in cells attached to a surface revealed by fluorescence micrograph of actin in an adherent epithelial cell.

Figure 92. (Right). Cellular Tensegrity. The cellular tensegrity model states that the entirety of the cell is a pre-stressed tensegrity structure and that the constituent parts, such as the membrane and filaments of the cell are required in order for it to maintain structural integrity. In addition, they enable shapeshifting and other cellular functions.

PART IV

Figure 93. Freeing emotions.

7. DESIGN RESEARCH PROJECTS

7.1. DESIGN EXPLORATION 1: EMOTILE – AN ARCHITECTURAL TENSEGRITY ASSEMBLY

Section 7.1 discusses some aspects of two design explorations that grew out of, and informed my research (as presented in the preceding Sections). The first such design exploration, eMotive, proposes to reinforce the oscillating entanglement between the body and built space by emphasizing the anthropomorphic, emotional and cognitive components within architecture.

Figure 94. Conceptual eMotive model.

The project exhibits somatic characteristics of flexibility, ambulation, volumetric change and re-configurability, imbuing its *corpus* with the potential to more fully project the primary metaphor of its own form back onto the user. It possesses a wide range of adaptable configurations, positions, stances and patterns of motion, enabling it to choreograph gestured responses, attitudes and body language that communicate and emotive (i.e., portray emotion in a theatrical manner) to the user. The collective, self-aware eMotive body interprets, and is interpreted by, the user. Each reacts viscerally to the other, learning and challenging one another, sharing a dialogue composed of movement and space.

Figure 95. Assembling tensegrities into clusters.

7.1.1.ADDRESSING THE ANTHROPOMORPHIC MODEL

A corporeal reflection of our tangible selves, eMotive seeks to emulate the bone, sinew and muscle of our embodied forms, physically representing, through pliability, mobility and scalability, the long standing relationship between architecture and the body. It proposes an approach to built space that both understands and speaks our most basic language of movement and expression. It does this by projecting our bodily form directly into its constituent mechanical parts of frame, joints and leverage.

By deconstructing the human machine into its essential elements, what remains is one of the most robust and adaptable forms found in nature: the tensegrity. The same mechanisms of tension and compression, found within the individual cells of almost every living organism, and are used to maintain the integrity of the cellular structure through the processes of division and reproduction.

As noted above (see Section 6.3), the human body has also been described as a tensegrity, comprised as it is of a careful balancing of forces between muscles, bones and fascia. The anthropomorphic ideas of the harmonious Vitruvian man can be expressed through tensegrities and applied to architecture, using their flexible, shape-shifting structures as a vessel into which the metaphor of our corporeal bodies can be transferred.

Figure 96. Testing strut arrangement configuration.

Figure 97. Body tensegrity.

The project employs mechanized tensegrities that change shape, mobilize using SMAs and self-assemble using electromagnets to form various larger arrangements and structures. As a result, it displays the ability to form an aggregate structure in the manner discussed in Section 5.3. This ability of the constituent parts of eMotive to self-assemble into larger aggregations, and transform into a larger “organism,” resembles the characteristics of the human body and its constituent cells that assemble and disassemble (see Section 6.3). In this way, it reflects the many “selves” that we “transform” and “assemble” our bodies into when we extend our bodies with our various prosthetics (as discussed in Section 3.3).

Figure 98. Physical model deformation and emergent behaviour studies. See Appendix A.

Figure 99. Tensegrity activation mechanisms and computational system. The kinect sensor captures the movements of the user and process them using a computer running an arduino script and a skeleton tracker plug-in. This information was then used in different models to generate motion in the tendons or struts of the tensegrity to demonstrate a response to the user's emotion.

7.1.2.ADDRESSING THE EMOTIONAL MODEL

The art of painting was selected as the means to explore the idea of emotion in architecture in this design exploration. A canvas provides a two-dimensional space on which we attempt to capture and depict our inner visions and emotions in a three-dimensional space; a monument to our conception of the world and how we wish to see it. The paintings that I have created (see Figure 100) reflect my unique impression of several types of spaces created using the eMotive assembly that would evoke certain specific moods for me. They seek to project, through the emotionally conducive prosthetic of painting, my emotional reactions to particular time and place. In this way, each picture tries to convey my emotional experience at a specific moment (or “slice”) in time. Like a language (written, architectural, etc.) it is open to interpretation. Different people will have different feelings, make different assumptions about what happened before and what will come next. This reflects the ideas discussed in Section 4.5 that the same architecture may generate different emotions in different people.

Figure 100. Emotional impressions.

In this way, architecture speaks to each of us, as Mallgrave notes, viscerally, in our guts, through emotions and feeling. It speaks directly to our bodies before we even process it consciously. In response, we speak back to architecture through our bodies, crouching in low spaces, standing tall and relaxed in open spaces, etc.

In order to reinforce the emotional relationship between the phenomenology of our bodily, intuitive experiences with architecture, we must provide the structure with the means to engage in a visceral, emotional exchange with the user. Note that this is not the same thing as a static instance of architecture being designed to elicit an emotional response in its users (e.g., awe, safety, fear, etc.) as discussed at length in Section 4.5, but the capability to engage in a real-time emotional dialogue with the user. In order for the built space to speak to our bodies in real-time, it must be imbued not only with the anthropomorphic qualities described previously (i.e., flexibility, motility, form-finding, etc.), but also with the ability to observe our body language, the primal means of how we project our corporeal bodies onto and through the world around us and the extension of our prosthetics.

Observing, however, is meaningless without recognition. eMotile seeks to emulate recognition by incorporating an intuitive or instinctual understanding of human movement. In other words, eMotile is “hardwired” to “see” how we carry ourselves. The project makes use of sensors, like the Xbox® Kinect, to monitor the orientation, configuration (i.e., positioning of the limbs) and distance of the user, so as to enable it to decode the body language of the user in an effort to attribute a statistical likelihood of the user experiencing a particular emotion (e.g., happy, sad, fearful, comfortable, etc.)

Figure 101. Parameter of body volume.

The emotions that we feel are telegraphed through our bodies and projected outward for others (including the eMotive assembly) to see and interpret them. For example, when we are in a positive frame of mind, the volume of space that we occupy increases as we extend our limbs outward and stand tall. Conversely, when we are in a negative frame of mind, we occupy less volume as we withdraw our limbs, lower our gaze and turn inward.

In this project, the tensegrity assembly can observe various aspects of the user's body and then use that information, as a person might use it, to intuit the emotional state of the user. Specifically, it observes, records and processes in near real time the following aspects of the user's body:

1. body volume (i.e., open vs. closed);
2. relationship between the parts (e.g., head and shoulder, spine and leg, arm and spine etc. Which can be measured by measuring the angle between the body parts);
3. proximity to the structure (close vs. far);
4. direction of movement (toward or away);
5. standard patterns of limb motion (e.g., limb walking pattern, the action

Figure 102. Parameter of body volume

Figure 103. Parameter of proximity.

of sitting, picking something up from a desk or from a floor, reaching for something high up, etc.);

6. motion intensity (restricted vs. rapid motion);

The information received from the Xbox® Kinect is used to assign a numerical value to each monitored aspect of the user's body, which are then aggregated and compared against set of standards and norms. For example, a user might have an openness score = 7 (vs. closeness=3), a motion intensity score = 7 (i.e., relatively active) and a proximity score = 6 (i.e., relatively close to the structure). Comparing these values to its internal database allows the system to infer that the user is in a "positive" frame of mind. Conversely, if the system had observed low numerical values for each of the above parameters, it might infer that the user was in a "negative" frame of mind.

Having labeled the user's behavior as being in a "positive" frame of mind, the eMotive could then respond with a range of "pre-programmed" postures or sequences of movements limited only by the structure's engineering and mechanical parameters. For example, it could assign itself an openness score = 8 (and, therefore, extend its compression elements to 80% of their maximum value), a motion intensity score = 9 (and begin reverberating at 90% of its capacity), and a proximity score = 6 to match the user's score

(and bends/warp itself toward the user by 60% of its maximum bending capacity.) Complex structural behaviour will emerge automatically from eMotive, as the rules that are built into it mechanical components as discussed above (e.g., if any of its tensile elements are shortened then the related compression elements will move toward the shortened element). This will lead to a complex, form-finding behaviour in the larger, aggregated eMotive structure that will enable the assembly to adjust to changes in the environment and seek a new equilibrium. Its overall, emergent behaviour (discussed in Section 5.1) will resemble swarm behaviour, as the “rules” built into each tensegrity unit affect their neighboring tensegrities and feedback on each other in a dynamic and reciprocating manner.

Figure 104 Parameter of motion intensity.

Figure 105. Parameter of motion intensity.

7.1.3.ADDRESSING THE LEARNING MODEL

In the relationship between the user and eMotive, each viscerally interprets the body language of the other. However, in order to make the system more than just responsive requires reinforcing the relationship between the body and architecture by giving the built space the power of “cognition.” By enabling eMotive to learn from its actions, like its human counter-part, the project can remember the outcome of its behavior on the user, determine the user’s preferences and adapt its responses to support or even challenge the user’s attitude. In this way, the project seeks to engage in a true “Paskian” conversation with the user and arrive at a negotiated position.

eMotive achieves this objective by integrating pervasive (i.e., ubiquitous) computing elements to collect the various sensory inputs and coordinate the tensegrity outputs, as well as to provide the tensegrities with a collective memory of the user’s preferences. If the user demonstrates a dislike for a particular configuration (as demonstrated through the user’s responsive body language), then the structure can record that fact and, using a genetic algorithm, generate alternate configurations. These, in turn, can be monitored for their impact on the user and remembered for future encounters.

For example, after the initial state of the user is assessed as being “positive” and eMotive responds the same way, then monitors the user to determine the effect its response had on the user. If the user’s score remains within the “positive” range, then the system uses a neural network-like system to strongly associate its response with the user’s initial behaviour. Conversely, if the response generates a very low score from the user (e.g. “negative”) then eMotive will record a weak correlation between the user’s initial “positive” behaviour and the system’s response and will likely avoid that behaviour in the future. In other words, it will learn what types of body language to avoid when the user is “positive”.

The system may be pre-programmed to generate positive scores from the user, and so will continue to change its responses and monitor the user in a constant feedback loop that attempts to maintain, or even improve, the user’s emotional state. Alternatively, if the user’s behavior has changed very little over time, the system may become “bored” and “challenge” the user by adopting a different or unexpected behaviour.

The method for varying the system’s responses will be based on genetic algorithm that will randomly vary (i.e., mutate) some of the initial response parameters and then monitor the user to determine if the modified behaviours were “successful”. Those that are successful will be strengthened in memory, while those that are “unsuccessful” will be weakened. In future encounters, the structure will “remember” the user’s preferred response to “successful” “mutations” and will attempt to use those responses again from the outset.

Figure 106. eMotive challenging the user versus improving the emotional state.

In other words, its behavior will develop an approach to architecture that possesses an adaptive and evolutionary response relative to changing phenomena of the user.

7.1.4.ADDRESSING THE SELF-ASSEMBLY MODEL

eMotive can change its shape by autonomously re-configuring its individual tensegrity units to alter the form and density of the aggregate structure. The changes are conditional on pre-programmed criteria that are, in turn, based on the behaviour of the user(s) (e.g., the degree of intensity of the communication between users). eMotive uses its Kinect sensor to monitor the movement and positioning of the user(s) in the same way as was previously described above. However, in this case, it then uses the input values from the sensors to determine if the necessary criteria have been triggered to self-assemble into a new form. If the criteria have been met then the individual tensegrity units are instructed

to adjust their relative positioning so as to generate the necessary change in the form and density of the applicable portions of the overall structure. Each unit, being aware of its own position relative to the overall structure, mobilizes itself in the necessary direction to achieve the desired result, but without the benefit of an overarching “master plan.” The units couple and decouple themselves from each other using the electromagnets, LED lights, sensors and actuators attached to the ends of their compression elements (see Figure 108, Figure 109).

Figure 107. Proposed motion pattern and layout map.

Figure 108. eMotive physical model.

Figure 109. Tensegrity unit assembly diagram.

Figure 110. Tensegrity assembly, method 1.

Figure 111. Tensegrity assembly, method 2.

Figure 112. Tensegrity assembly layout, method 1.

Figure 113. Tensegrity assembly layout, method 2.

Once decoupled, a unit is free to ambulate in the required direction to achieve the larger goal, by moving over other units or “walking” directly to the desired location and then re-coupling electro-magnetically to the other units and “climbing” up them. (see Figure 110, Figure 111)

For example, if eMotive senses that the intensity of interactions (intensity = the number of interactions for predetermined area) between users increases, then the unit will determine that it needs to modify its form and density in the vicinity of the users who are deemed to be actively communicating. The central processing unit will then direct individual tensegrity units to autonomously make their way toward/or away from the active users in order to re-aggregate/or aggregate structure in the area of those users. Each unit will then decide on the best path toward its goal, evaluating its progress in real-time as it proceeds along its path, and re-evaluating and re-calculating its route relative to neighbouring units and the overall structure, as it progresses.

The eMotive exploration focused on designing behaviors that the system could exhibit based on its interactions with the user. Through the process of physical and digital modelling, it became possible to distinguish its individual parts that, like the fragmented organs of the body, combined together to form the “whole”. As a next step, it followed that these constituent parts needed to undergo a “metamorphosis” of sorts and be assembled, in a holistic manner, into a complete structure, capable of enveloping and fully interacting with the user (see Section 7.2).

7.2. DESIGN EXPLORATION 2: THE POD: FORMATION OF AN ARCHITECTURAL PROSTHETIC BODY

Having explored a tensegrity assembly with the eMotive experiment, further consideration was given to envisaging the current technological implications of the digital age and ubiquitous computing. In a manner similar to the radical ideas of the Archigram group (see Section 3.3.4) this design exploration examined how architecture can contribute to the discourse, encouraging the decoupling of ourselves from our current preconceptions about technology and the directions it may be taking. The Pod project stepped outside of

Figure 114. Prosthetic bodies.

the realism of currently achievable implementation and speculated, instead, on an imagined reality profoundly different from our own (although grounded in today) where body and emotionally intelligent prostheses “evolve” to coexist in a structurally coupled dialogue. This conjecture provides a means to engage in a dialogue about the current conditions in architecture and to consider differently where changes in technology may be leading.

The project then further imagined a social construct within this fantasy world as a means to provide a view to contextualize the project (i.e., a speculation within a speculation). In so doing, it positions the project within a discourse of investigations that sets the stage for future contributions through a larger discourse.

7.2.1. THE POD

The pod was envisaged as being an emotionally intelligent prosthetic (as discussed in Section 4.5) with the kinetic attributes of the body, capable of recognizing, responding to, and learning from the emotions of its inhabitants. It also seeks to adopt an anthropomorphic model (see Part I) that emulates the flesh and bone of the human body and, in so doing, projects the metaphor of our corporeal selves to its logical conclusion by imbuing the structure with its own bodily form. It does this by incorporating our own physical qualities of flexibility and motility directly into its tensegrity elements, thereby adopting the same mechanisms of tension and compression utilized by the human body and that can be found in many biological systems. (see Section 6.3)

Figure 115. Pod clusters. Plan.

Similar to the aggregate eMotive assembly, the pod can employ its various sensors to observe the body language of its inhabitant, as displayed through their face, limbs, heart rate, respiration and body temperature. The pod shares the ability of its dweller to innately recognize the basic human emotions (as discussed in Section 4.5) and is also capable of learning cultural displays of emotions that depend on context and experience. It does this through the application of a sophisticated artificial intelligence that allows it to process the actions of its dwellers and, over time, correctly identify their moods, preferences and predispositions (as was explored in Section 7.1). As a result, the pod is able to engage in a dynamic feedback loop of communication with its inhabitant, in which the body language of the one is interpreted and responded to by the other.

In this “Deluzian” dance of the inhabitant/wasp and the pod/orchid, the movements and expressions of the one change and shape the other as, together, they engage in a second order cybernetic conversation that drives them toward a mutual equilibrium of understanding. (see Section 5.2) Each pod is a prosthetic extension of the physical embodiment of its individual inhabitant. Rather than representing the image of the idealized Vitruvian man (see Section 2.1) or some standardized or normative body (see Section 2.2), each pod reflects the unique physical and psychological needs of its inhabitant’s mind and body. The inhabitant communicates and interfaces with its pod through body language and gesticulations, thereby enabling the manifestation of a uniquely personal environment to reflect the particular physiological and emotional requirements of the user at that moment in time.

The tentacles are located on the outside surface of the pod and serve a range of uses. They provide structural support for the unit, acting simultaneously as scaffolding,

Figure 116. Front section. Side elevation. Transverse section.

platform and tensioning cables. The tentacles are also sensitive appendages of the pod itself, enabling it to sense and interact with its external environment, probe other pods and interconnect with them to form larger aggregations to accommodate multiple inhabitants. Like the eMotive assembly, the changes in the pods leading them to form aggregations are based on the behaviour of the user(s). In this way, each pod unit, being aware of its own position relative to the other pods, mobilizes itself in the necessary direction to achieve the desired aggregate structure, but without the benefit of an overarching master plan. The tentacles also provide the pods with a form of mobility, limited only by its structural constraints, allowing them to ambulate in the proximity of their dweller and move over and under neighboring pods.

As noted, the pods are capable of monitoring the body language and emotions of their inhabitant. The pod is constantly “looking” at its inhabitant to gauge the inhabitant’s disposition and then seeks to respond appropriately. Over time, through an extended process

Figure 117. Pods connecting to aggregate into larger structures.

Figure 118. Pod perspective view.

of communicating through body language, trial and error, the pod learns its inhabitant's preferred responses. The pod adjusts its position in space and its shape around its inhabitant and the number and size of openings in response to its user's preferences; like a favourite pet molding itself into its owner's lap to soothe them, or stretching downward and wagging its tail and becoming animated to encourage play, or laying down next to them and extending a paw just to touch them and comfort them and provide a point of contact.

Each pod also looks at the other pods in its community and learns to identify them and their individual dwellers over time. Pods share a protocol for communicating with other pods wirelessly. In this way, pods are able to move around, over and under one another without disturbing their occupants. Pods also share a common basic body language for communicating with each other and notice how other pods in their community move and change shape in response to their individual inhabitants. In this way, pods learn about their communities and the goings-on in their vicinity.

Figure 119. Pods connecting to create larger aggregations.

Figure 120. Pod in play.

Figure 121. Pod in play.

Figure 122. Pod world.

7.2.2. THE POD WORLD

In the pod world, the intensely personal space afforded by a user's private capsule is balanced by the resurgence of communal spaces. The private/autonomous space of the pods provides a customized reflection of the individual. It is based, in large part, on the unique physical and emotional attributes of the user, making the pod an emotionally intelligent prosthesis tailored to that one person. As a result, bringing someone into one's pod is like bringing them inside a part of oneself. While this might bear some similarities

Figure 123. Pod community.

Figure 124. Pods matrix.

Figure 125. Accentuating and highlighting some of the autonomous and independent components that make up the Pod

Figure 126. Pod physical model.

Figure 127. Pod physical model.

to inviting person into any personal space, the pod is distinguished by the fact that it is constantly in communication with the user and changing and adapting itself in real time. This makes for an extremely intimate and enclosed space. To offset the highly personalized and secluded nature of the pods, a social construct is imagined in which users have made the areas outside of their pods into more public/interdependent forums. It is suggested that, in the pod world, three areas of activity have been given heightened social and cultural importance; bathing, eating and excreting.

Figure 128. Bathing facilities. Perspective view.

Bathing, once considered to be a purely social activity in Roman and other times throughout human history, became an increasingly solitary activity with the advent of indoor plumbing, modernist attempts at making the built space sterile/hygienic and cultural shaming of the body. Pods, as the evolution of the metaphorical prosthetic projection of the individual's body into the physical world, allow the user to look elsewhere for the projection of the communal body into a corporeal architecture. The return of the bathhouses of yore provides a renewed focal point for matters of the body centered around the community and social interaction.

Figure 129. Excretion facilities.

Figure 130. Excretion facilities.

Figure 131. Bathing facilities.

Figure 132. Bathing facilities.

Figure 133. Bathing facilities.

Figure 134. Bathing facilities.

Figure 135. Bathing facilities.

Figure 136. Bathing facilities.

Excretion facilities have also become fully public spaces again. Defecating activities have been put on a “pedestal” in celebration of the body and its naturally periodic functions. The semi-open elevated space emphasizes the need to intermixing, with companions and bystanders, your own miasma with those of others. Giant, glass vessels below serve to collect and display the bodily discharge from inside the physical bodies of the individuals, as it is collected and transformed into fertilizer and fuel. This “exhibition” allows us to re-connect to the interior of our bodies and reminds us the important role we play within the larger ecosystem. It also emphasizes the manner in which our bodies directly affect the environment and vice versa, in a dynamic and reciprocating feedback loop. This connection between the “inside” and “outside” is reflective of the divide that emerged in the Middle Ages (see Section 3.1) between the idealized Vitruvian man (see Section 2.1),

Figure 137. Excretion facilities.

which focused almost exclusively on the exterior body, and the fragmented body, that arose in response to a growing appreciation at the time for the relationship between the “parts” and the “whole” (see Sections 3.1-3.3). The social spaces in the pod world seek to restore the connection between the inner and outer and between our fragmented, individualized, unique bodies, and the holistic body of the community.

The bathing and excretion spaces in the pod society, like the altered spaces demonstrated by Abramovic and Yula (see Section 3.5), cause us to re-evaluate our concepts of nakedness and hygiene. In so doing, they communicate powerful bodily signals about the important role that each individual (i.e., each “part” or “fragment”) plays in society, and welcomes them for their unique contribution and connectedness to the whole.

Figure 138. Excretion facilities. Perspective.

Figure 139. Transparent excrement collectors.

Figure 140. Excretion facilities. Plan.

Figure 141. Excretion facilities. Perspective.

Figure 142. Excretion facilities. Perspective.

Figure 143. Excretion facilities. Perspective.

Figure 144. Excretion facilities.

Figure 145. Excretion facilities.

Food preparation, once the focal point of many personal residences, is no longer done in private. Instead, communal kitchens are the preference, with neighbours gathering regularly throughout the day to nourish their bodies. Semi-open canteens, where some food is grown, and animals are slaughtered and prepared, dot the landscape to form social venues and provide an alternative to the private/independent space of the pod's interior. In these eateries, people come together to cook and feed and partake in the cycle of life. They witness the bodies of other organisms (e.g., plants, fungi and animals) that have been

Figure 146. Nourishment facilities.

grown through a biological process of self-assembly, disassembled into parts and, in the case of livestock, organs for the purpose of consumption by the patrons. Those who are preparing and eating the food are witness to the parts being ingested into the bodies of the diners, in preparation for their eventual excretion in the facilities described above. By partaking in the larger social constructs of food and culture, each individual is reminded of their place in the food chain and of the importance of their participation in the care, feeding and harvesting of their food sources. Their attention is also drawn to the role that the bodies

Figure 147. Nourishment facilities.

Figure 148. Nourishment facilities.

Figure 149. Nourishment facilities.

Figure 150. Nourishment facilities.

Figure 151. Nourishment facilities.

Figure 152. Nourishment facilities.

Figure 153. Nourishment facilities.

Figure 154. Nourishment facilities.

of the other organisms play in building the bodies of those that consume them, and they are made more cognizant of the impact on their communal facilities.

Around local bathhouses, pods wait as temporary, private shelters should they be desired. Pods climb onto one another to create multi-storied units and provide a scenic view of the panorama and the collective activities below, where users congregate. There, outside of their pods, individuals exchange gossip and news using the oldest of mediums; body; enjoying live music, theatre and dance, and partake in locavore activities.

In this world, pods and the people who inhabit them, establish themselves around these three previously described activities: bathing, excreting and nourishment. The pods set themselves up with their inhabitants so that everyone can gaze into any direction and see the celebration of being reunited with the physicality of the body. These re-imagined

Figure 155. View from inside.

practices of how we clean, care and feed ourselves, are intended to bring us closer to our unique selves and to other bodies, as distinguished from the “normative” ideal created cultural systems throughout the generations in the form of the anthropomorphic man (i.e., Vitruvian man), the standardized body (i.e., the measured man) and the photo-shopped body (i.e., the digital man). This approach allows us to revive a positive image of ourselves and to consider our own body complex issues in appreciation of the complexity of our bodies.

As the pods and their dwellers become the prosthetic extensions of each other, and as they shape and change one another through ongoing communications in the universal language of emotion, each becomes the organs of the other and, together, form a more complete body within a larger construct.

Figure 156. View inside the Pod.

Figure 157. Pod world.

8. CONCLUSION

Architecture has changed us. Such is the human condition: we shape our tools and they, in turn, shape us. The same has always been true of our relationship with the prosthetic of architecture. The spaces we build are informed by our physical and emotional needs, while those same spaces (house, temple, office tower, Igloo, spacesuit, etc.) impact and alter our bodies and pattern our minds. They are the product of our ideas, fashions, societies and cultures, but over time and in an integrated and reciprocal manner, our structures feed back into those same social constructs and impact them. Prior to the Industrial Revolution, the process was relatively slow and incremental. Vestiges of the past are still to be found everywhere, in our tools, writings and architecture. But the age of automation and mass production accelerated the process greatly. Our tools began to change profoundly, vesting our bodies with great physical capabilities. The digital revolution followed, freeing our minds to encircle the globe and reach out across continents and oceans of data. Communication and information became the order of the day. An ever expanding digital network began to envelope the world, forming an electronic nervous system that connected every person and device. The age of The Internet of Things had begun.

Architecture forms part of this vast multiplicity, but while continuous advances have enabled individuals to become ever more closely bound to their technologies, the built environment has lagged behind. Architecture forms an essential part of our experiences, defining the structures and spaces in which we live, work and socialize. But while we have become accustomed to having emotional connections with our devices (project onto, form with, and demand of), our relationship with architecture has remained relatively static in comparison. The lack of emotional integration with our built environment threatens

Figure 158. Pod world.

to create a digital divide between structures and the networked world experienced by its users. Phenomenology and cybernetic systems provide the conceptual means to advance the relationship between the body and the prosthetic of architecture and to close the gap. To do so, a dynamic and reciprocating communication loop demonstrating emotional intelligence and adaptability is required between the two systems. In this way, they become structurally coupled and begin to physically change and alter the cognitive elements of one another.

In order for our structures to be able to exercise emotional intelligence and communicate in emotive terms, they must first be imbued with a bodily form. Nature provides a guide for the principles that might underlie such a body in the form of the tensegrity. Found throughout living systems at all scales, the tensegrity seems to be an ideal structure for replicating some of the expressive qualities of the human body. Through a combination of tension and compression elements, it is able to demonstrate flexibility and motility that is similar to our own bodies. The next step is to give the architectural body emotional intelligence. This requires that the architecture be: (i) imbued with an understanding of body language, (ii) capable of cognition (i.e., the ability to learn and adapt based on its responses to the behavior of the user); and (iii) possess the ability to coordinate a bodily response (i.e., to make its body communicate emotionally). Once it possesses all of the foregoing attributes, the built space can communicate in emotional terms with the user and, in so doing, become an emotionally intelligent prosthetic of the user.

In the final analysis, this thesis draws no specific conclusions about the future of emotionally intelligent architecture. Instead, it establishes a platform, through investigation, experimentation and speculation (and speculation within speculation) intended to drive a dialogue amongst architects as to what form they think the future might take. It invites them to consider their own roles in shaping the future of emotionally intelligent architecture and encourages them to consider the social and cultural implications of such designs.

9.APPENDICES

The appendices below set out some of the design explorations undertaken over the course of preparing this thesis. The physical modelling was conducted to investigate the kinetic properties of tensegrities in order to gain an understanding of their form finding abilities and to determine which configurations were uniformly stable. Research was also conducted to understand the impact of varying certain attributes of the tensegrities, such as elasticity of the tension elements and length of the compression struts. Studies were also made on the effects of aggregating individual tensegrities into larger tensegrity assemblies. These studies served to better understand how the tensegrity could act as a proxy for the human form and replicate aspects of its flexibility and motility. The digital modelling examined the relationship between sensors and computer models of tensegrities to investigate the emergent behavior of tensegrity models where the human body is an instigator of the conversation. Physical modelling and digital modelling were then combined to determine how physical elements, such as shape memory alloys (SMAs) could be used to imbue tensegrities with the ability to actuate and ambulate in response to human initiated behavior and inputs. Other experiments were conducted to explore the design elements of the notation of space through a combination of light, movement and painting.

9.1. APPENDIX A: DESIGN EXPLORATIONS THROUGH PHYSICAL MODELING

Initial assembly of tensegrity models to study the robustness of structures with a varied number of strut elements. Tensegrities with smaller number of struts exhibit greater stability compared to tensegrities with larger number of struts. Also, tensegrities with six struts, as a result of their enclosing geometry (icosahedron geometry based on 20 equilateral triangles) demonstrated uniform stability and mobility throughout the structure.

The anthropomorphic model studies metaphorical dynamics of the emergent behavior between the human body parts and the body as a whole in a context of tensegrity structures. The length and weight of the struts inform the diameter and elasticity requirements for the cables. This, in turn, affect the response time for specified stimuli.

Figure 159. (Top right). Six and eight strut assemblies.

Figure 160. (Bottom right). Physical model deformation and emergent behaviour studies.

Figure 161. Interior and exterior systems.

Physical models as illustrated in Figure 162 were intended to explore the effects produced by introducing membrane elements onto the tensegrity structure in a single and aggregated assembly. Membranes of various densities and elasticities were tested with intent to:

- a) Investigate the spatial, visual and lighting effects with different materials;
and
- b) Test the elasticity of the materials for options to replace cable components with membrane components.

Figure 162. Six strut tensegrity with polyester membrane.

Tensegrity assemblage was built to explore spatial and lighting effects during the deformation of the structure. Various options of the aggregated structure were considered with varied layerings and morphologies.

Figure 163. Three strut tensegrity aggregation. Hand painted.

Figure 164. Three strut tensegrity aggregation. Hand painted.

Smart Memory Alloys (SMAs) such as Nitinol springs and Flexinol wires (both are nitinol titanium alloys) were tested to explore their elasticity and thermal shape memory behavior.

Flexinol wire was attached to the ends of the struts to substitute the tensile components. When electricity was passed through the wire, it contracted, causing the ends of the struts to move towards each other, resulting in overall form deformation.

Nitinol springs were installed in a similar manner. Although, the springs had to be initially deformed/stretched prior to “activation” which could be done manually or by counteracting forces of other tensile components.

After repeated applications of an electrical current, the Flexinol wire lost some of its thermal shape memory behavior at a greater rate, as compared to Nitinol spring.

In order to make a fair conclusion, further tests would require comparing Flexinol Springs and Nitinol Springs.

Figure 165. Testing thermal shape memory behaviour in Smart Memory Alloys.

Figure 166. Testing thermal shape memory behaviour in Smart Memory Alloys.

Figure 167. Testing thermal shape memory behaviour in Smart Memory Alloys.

9.2. APPENDIX B: DESIGN EXPLORATIONS THROUGH DIGITAL MODELING

Digital simulations explored the communication between Kinect sensor and digital tensegrity models. Strut length and elasticity of cables were set as parameters to investigate the emergent behavior of tensegrity models where the human body is an instigator of the conversation.

Figure 168. Initial Arduino setup and digital simulation.

Figure 169. Digital model behaviour studies.

Similar to cellular automata behavior, the behavior of the digital models through cell subdivision relies on the innate (pre-programmed) behavior of the individual cells, geometric constraints and environmental parameters.

Initial geometry and environmental parameters for the growth process of the models A and B were set to be identical. Innate behavior of the cells of each model differentiate in the initial number of active cells which results in varied number of cell units at termination. Geometry adjusts continuously in the course of the formation of the model. Design of space does not rely on preconceived notions but on the character of the affecting agencies.

Figure 170. Growth pattern through cell subdivision testing.

9.3. APPENDIX C: DESIGN EXPLORATIONS THROUGH PHYSICAL MODELING

The following set of experiments was designed to test the effectiveness of replicating bodily gestures through Smart Memory Alloys (SMAs) (Figure 171, Figure 172, Figure 173) and servo motors (Figure 174). Various configurations of SMAs (linear, woven and spring) were considered. In the linear set-up, two ends of the SMA wire were attached to the ends of struts (compression elements) as a replacement for rubber bands (tension elements). In the woven set-up, Smart Memory Alloy (SMA) wire was woven into the stretched fabric with an attempt to re-distribute tensile forces and to have control over more than two compression elements per dimensioned fabric element. SMA wire performed best when it was coiled into a spring, as it was able to “flex” over a larger distance, setting the entire structure in motion toward its neutral balanced state.

The body parts were mapped out onto a Kinect skeleton tracker. When a specific body position was detected the signal was transferred through an Arduino micro-controller to perform premeditated actions: one or more of the SMA wires would contract to change the position of the tensegrity structure to a desired position.

During the test with servo motors, the length of the struts was set to be adjustable and followed a similar set up as in the test with the SMAs. Servo motors added a lot of weight to the structure and made it very difficult to work with.

Figure 171. Actuator studies. Test 1.

Figure 172. Actuator studies. Test 2.

Figure 173. Actuator studies. Test 3.

Figure 174. Actuator studies. Test 4.

9.4. APPENDIX D: DESIGN EXPLORATIONS: IMMERSING INTO MEDIA

Light painting was explored as a mechanism for notation of experiential space by extending the body through the prosthesis of fire and light.

The temporality of the fire dictated the longevity of the engagement between the body and its prosthesis throughout the process of burning. The interplay between the body and fire exhibits the stages of a metaphorical conversation from the initial interaction, through the heated discussion, to winding down of the dialogue and disengagement. The temporary conditions of the installation.

Figure 175. Light painting. Body as a medium studies.

Figure 176. Light painting. Body as a medium studies

Using glow sticks and flashlights denoted a metaphorical space that was controllable and somewhat predictable. Duration of the captured engagement rather depended on the recording prosthesis.

Figure 177. *Light painting. Body as a medium studies.*

Figure 178. Light painting. Body as a medium studies.

The dance video explored the concepts of body language as communicated by the movements and gestures of the dancer. The video of the choreographed performance combined with animated sequences of digital tensegrity models demonstrates the reciprocating communication between dancer and structure. It depicts a relationship between the notional space outlined by the performer and the corresponding spaces created through self-assembly by the prosthetic architecture. In the scene, the emotionally intelligent architecture recognizes and responds to the physical expressions of the human body, drawing the two into a higher order conversation.

Figure 179-180. Anastasija Dudnyakova performance.

Painting on water investigated the qualities of the engagement with the medium used. The medium (water) challenges the body to adapt to its sporadic behavior. The transparency of water establishes an intricate conversation where the quality of transparency incapacitates the ability to “look at” and compels to see through it. You simultaneously can look at the painted surface of the water and behind it, provokes imagination. The final image is always unpredictable.

Figure 181. Painting on water.

Figure 182. Painting on water.

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