EMBEDDED ARCHITECTURE
ADA, DRIVEN BY HUMANS, POWERED BY AI

JENNY E. SABIN
JENNY SABIN STUDIO / CORNELL UNIVERSITY
JOHN HILLA
JENNY SABIN STUDIO
DILLON PRANGER
JENNY SABIN STUDIO / CORNELL UNIVERSITY
CLAYTON BINKLEY
ARUP / ODD LOT DESIGN
JEREMY BILOTTI
JENNY SABIN STUDIO / MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Introduction

Named after the polymath, mathematician, first computer programmer, and early innovator of the computer age, Ada Lovelace, Ada is a collaborative project by Jenny Sabin Studio for the Artists in Residence Program at Microsoft Research, 2018-2019. The first architectural pavilion project to incorporate AI, Ada is a lightweight knitted pavilion structure designed with Microsoft Research which embodies performance, material innovation, human-centred adaptive architecture and emerging technologies, including artificial intelligence and affective computing. An external rigid experimental shell structure assembled from a compressive network of 895 unique 3D-printed nylon nodes and fibreglass rods holds Ada’s form in continuous tension. Working with researchers and engineers at Microsoft Research, Ada is driven by individual and collective sentiment data collected and housed within the Microsoft Research Building 99. A network of sensors and cameras located throughout the building offers multiple opportunities for visitors and participants to engage, interact with, and drive the project. The data include facial patterns, voice tones and sound that are processed by AI algorithms and correlated with sentiment. Three scales of responsive and graduated lighting, including a network of addressable LEDs, a custom fibre optic central tensility cone, and five external PAR lights respond in real time to continuous streams of sentiment data. These data are correlated with climes, spatial zones within the project, and responsive materials.

An important aim of the project was to expand and inspire human engagement. While artificial intelligence powers the project through the precise narrowing and statistical averaging of data collected from individual and collective facial patterns and voice tones, the architecture of Ada augments emotion through aesthetic experience, thereby opening the range of possible human emotional engagement. In turn, the project opens new pathways for fundamental research on the use of AI to correlate connections between human sentiment and local environment. Ada will be used as a platform for researchers to test their data and machine learning algorithms at Microsoft Research.

Suspended from three points and hovering above the ground floor of the atrium, Ada is a socially and environmentally responsive structure that is interactive and transformative. This environment offers spaces for
curiosity and wonder, individual and collective exchange, and rigorous research experimentation as the pavilion filters light, casts dynamic shadows, and changes in response to participants’ input.

Background

The history of modern computing may be traced back to an uncanny meeting between two disparate inventions that were simultaneously emerging: the punch cards that mechanised the Jacquard loom through stored memory, and Babbage’s steam-driven calculator, the Analytical Engine. The Analytical Engine weaves algebraic patterns, computation, and architecture. The history of modern computing may be traced back to Lovelace, 1843. In this project, the textile as an active and evolving overlay of spatial information.

Methods

Generative Design and Structural Analysis

The design of Ada commenced with a series of collaborative conversations between Jenny Sabin and Microsoft Research on topics spanning artificial intelligence, adaptive and embedded architecture, affective computing and personalisation. Initial design studies were later informed by a 3D-scanned representation of the site. A series of ellipsoidal and spherical 3D models were generated in Rhinoceros as precision modelling within a detailed and accurate structural concept of Ada builds upon 13 years of design development referred to as windows and cones respectively.

In this project, the textile as an information mediating surface architecture builds upon this history with forward-looking integration of digital fabrication, bio-inspired design, and light. Photo: John Brecher for Microsoft.

The size and density of the cells in this network were manipulated according to the geometry of the exoskeleton: specifically the angles of curvature in the concave shapes that make up this surface were generated using parametric computational tools developed as Grasshopper definitions that are based on graph theory. The process of form finding was based on particle spring systems and implemented via Rhinoceros, Grasshopper and plug-in Kangaroo developed by Daniel Piker. The NURBS surfaces were discretised into the mesh network M1 with defined grid spacing and grid shape based on the final digital knitting fabrication process. The grid mesh triangular faces are considered as particles connected by edges which are calculated as elastic springs. We input mechanical properties of the fabric by assigning axial stiffness and a damping coefficient to the geometry of the exoskeleton. The form found mesh M2 is then generated from the node coordinates and their connectivity. From mesh M2, we used the dual graph method to reconstruct a new mesh representation M3 which is tessellated by polygonal cells and cones.

The structural concept of Ada builds upon previous work by Jenny Sabin Studio, with engineering design by Arup, where structures display the balance of tensile and compressive forces as a means for generating lightweight
The design was how to create a convex surface (an ‘ovaloid’) and expressive forms. The generative question for the 5
and when fully elastically prestressed was entered into the process. The circumference of each of the cells when slack
layer (a ‘cable net’ of nylon webbing), connected together by tension elements (the digitally knitted ‘pores’). The prestress in the weaving net applies a uniform load to the grid shell which stabilises it against deformation that would lead to elastic buckling. The capacity and stability of the structure was confirmed via explicit finite element analysis, accounting for non-linear geometric effects using the analysis software ABAQUS.

When the net form-finding process was complete, each cell andcone received a unique ID that followed each cell and cone. The capacity and stability of the structure was confirmed via explicit finite element analysis, accounting for non-linear geometric effects using the analysis software ABAQUS.

The free edge of the hybrid grid shell was stiffened using a custom fabricated aluminium edge ring that also serves to transfer tensile and compressive reactions between the weaving net and outer exoskeleton. Over the flattest part of the shell edge, the ring splits into two pieces which creates a more expressive separation between the tensile and compressive surfaces, but also results in a stiffer element to resist out-of-plane buckling at this location with low inherent geometric stiffness. Working in conjunction with the exoskeleton, the upper and lower metal rings were designed to establish terminal conditions. This provided both structural stability and weight, and a framework for establishing key points of attachment for the exoskeleton at the top and bottom of the installation.

3D-printed Nylon Nodes and Exoskeleton

The complex composition of cellular units that aggregate to make up the exterior surface of Ada required an exoskeleton that can synchronously define both the shape of each cell and overall geometric form. This network contains an irregular combination of convex polygons that have between four and seven edges. We were interested in further exploring the use of pultruded fibreplugs that connect the inner surface to the outer surface, behaving as springs. Courtesy Jenny Sakkis Studio.

The LED network nests in the fold of the fabric sleeve. Light from these diodes is transmitted across the vertical length of the cone to connect a series of diodes and bright emissions through curated breaks in the surface of the fibres. The central tensegrity cone is a cable net forming a simple tensegrity cone is an independent structure that was designed to showcase additional innovation in a lightweight response material that is able to respond to a variety of digital and mechanical stimuli to absorb electromagnetic radiation from, for instance, the sun or UV lights. This causes the light emission or glowing effect across the fabric structures.

The central tensegrity cone comprises a finely tuned steel structure wrapped in a photoluminescent fabric that is embedded with fibre optics. The sleeve contains panels of the fibre optic fabric that were designed to conform to the dimensions of the central tensegrity cone and sewn and finished together with alternating strips of elastic material. A zipper that runs the vertical height of the cone is sewn into the fabric as a means of joining the two ends of the sleeve. Several programmable LED strips run the vertical length of the cone to connect a series of diodes directly to bundles of fibre optic strands within the fabric sleeves. Light from these diodes is transmitted across the struts and is visible through a subtle glow of the fibres and bright emissions through curated breaks in the surface of the fibres.

Brain Ring Hardware

Ada’s Brain Ring is a bespoke yet simple assembly of laser-cut stainless steel parts with strategic voids for ventilation and channels for wiring. It accommodates

a symmetrical, there are 895 nodes due to the variable patterning and size gradient of the mesh. For this reason, mass-customisation via 3D printing was an obvious fabrication choice. A node typology was developed by generating a tubular and lifting each end of the three rods into a node and then meshing together. In order to allow for the assembly of the structure, a number of the nodes were split along the mid-surface and clamped together using stainless steel cable ties. Each node was required to transfer compression and tension between all the rods coming into it. Interference fits, aided by the pre-compression in the shell, created these positive connections between the nodes and rods without use of adhesive. Several materials were considered for these nodes, including FLA, ABS, and nylon. After mechanical testing, according to ASTM D638-14 standard methodologies on an Intron (5500 Series Universal Testing Instrument, Multi-Jet Fusion) printing in nylon was determined to have the most appropriate performance characteristics for handling the significant bending forces created by the rods at each node. MJF by BigPrint is a new technology that heat fuses parts at the voxel (volumetric-pixel) level, resulting in rapidly manufactured parts with both superior finishes and mechanical strength.

Central Tensegrity Cone

The central tensegrity cone is a cable net forming a simple tensegrity cone is an independent structure that was designed to showcase additional innovation in a lightweight response material that is able to respond to a variety of digital and mechanical stimuli to absorb electromagnetic radiation from, for instance, the sun or UV lights. This causes the light emission or glowing effect across the fabric structures.

The central tensegrity cone is a cable net forming a simple tensegrity cone is an independent structure that was designed to showcase additional innovation in a lightweight response material that is able to respond to a variety of digital and mechanical stimuli to absorb electromagnetic radiation from, for instance, the sun or UV lights. This causes the light emission or glowing effect across the fabric structures.

The central tensegrity cone is a cable net forming a simple tensegrity cone is an independent structure that was designed to showcase additional innovation in a lightweight response material that is able to respond to a variety of digital and mechanical stimuli to absorb electromagnetic radiation from, for instance, the sun or UV lights. This causes the light emission or glowing effect across the fabric structures.
attribute. The animation occurs at an interval of 3 seconds, animation frames which update each pixel’s colour.

Elation SIXPAR PAR lights. When data are received, the structure through a local network connecting Raspberry Ethernet Switches, power supplies, and ethernet and modulation) addressable LED control, Ubiquiti 10X PCBs (printed circuit boards) for PWM (pulse width modulation) addressable LED control, Ubiquiti 10X Ethernet Switchet, power supply, and power cables. Working collaboratively, Jenny Sabin and Studio, Microsoft Research designed and programmed the software architecture for two programs which allow Ada to interface with human sentiment in her environment: a program running on the PC, and a program running on each Raspberry Pi in the BrainRing.

PC & Raspberry Pi Software

The PC software continually queries data from the network of 182 unique lengths that composed the entire network. 10. (left) Illumination of the elements was desirable for easier fabrication and behaviour and elasticity. Additionally, standardisation of elements was desirable for easier fabrication and assembly which required that 3D forms in the Rhinoceros environment (Sabin et al., 2018). Through ten built projects commencing with the myThread pavilion in 2012 and, most recently, with Lumen for MoMA and MoMA PS1 YAP 2017, Jenny Sabin and her team have explored generative design and digital fabrication in knit and woven structures through multi-sensory responsive environments. Drawing synergies with current work at the intersection of data-driven cyber-physical assemblies, digitally knit structures, and textile architecture, Ada celebrates, integrates, and materialises AI, affective computing, responsiveness, and performance as much as it can, even when touched and pushed by inhabitants.

Fabric Structure and Base/Upper Ring

Due to the high level of precision needed for the key structural connections to be produced in the base ring.

Conclusion

Acknowledgements

This platform would not have been possible without the unique collaboration with Microsoft Research. Unlike the pioneering work of Mark Sagor, such as his BabyX project that seeks to humanise stretch factor associated with non-rigid materials or accounted for within established tolerances. the exoskeleton, in co-action with several other key elements in the project, is a major contributor to the structural infrastructure of Ada. Moreover, these characteristics added an interactive haptic feature to Ada that mainkne, rigged and suspended when touched and pushed by inhabitants.
AI through ‘more symbiotic relationships between humans and machines’. Ada does not apply literally (Vassos, 2017). Instead, Ada offers subtle and abstract interactions with humans through space, material and form to augment and expand our emotional range in a specific context - an office environment - which, in turn, affects the probable sentiment data being collected as specific context – an office environment – which, in turn, interacts with humans through space, material and physical and social context inform one another as a result of a rigorous design process in which materials, data and variable tolerances and the precise transfer of forces are programmed. Installation challenges, due to the architecture that we inhabit and encounter.

Through the integration of responsive materials and algorithms and affective computing, Ada’s form, software functionality, and relationship to its physical and social context inform one another as a result of a rigorous design process in which materials, data and light are programmed. Installation challenges, due to variable tolerances and the precise transfer of forces across the complex structural system of Ada, present productive areas to refine for future projects. The introduction of fibre optics and linear scale manipulation and programming of a 3-tined lighting system also present important leaps and openings for future permanent projects featuring embedded architectural systems. Finally, Ada opens up dialogue among important and pressing issues concerning personal data acquisition and privacy as well as vulnerable concerns with Ada. Ada is a project that celebrates AI, an architecture that is ‘happy to see you’ and ‘smiles back at you’.

Ada’s form, software functionality, and relationship to its physical and social context inform one another as a result of a rigorous design process in which materials, data and light are programmed. Installation challenges, due to variable tolerances and the precise transfer of forces across the complex structural system of Ada, present productive areas to refine for future projects. The introduction of fibre optics and linear scale manipulation and programming of a 3-tined lighting system also present important leaps and openings for future permanent projects featuring embedded architectural systems. Finally, Ada opens up dialogue among important and pressing issues concerning personal data acquisition and privacy as well as vulnerable concerns with Ada. Ada is a project that celebrates AI, an architecture that is ‘happy to see you’ and ‘smiles back at you’. 

Acknowledgments and Credits

Jenny Sabin Studio Team
Jenny S. Sabin – Architectural Designer and Artist
Dillon Pranger – Project Manager
John Mila – Jenny’s Advisor
William Gan – Design, Production, Installations
Clayton Brinley and Judy Guo – Grey – Design Engineer

Fabrication and Manufacturing

Grafik, Makers of Fiber in Digital Images, AcuFab

Microsoft Research Ada Core

Technical Fellow and Director Eckhard Körnicke
Director of Mixed Special Projects: Badiar Durr
Principal Research Designer/Educational Researcher: Aline Rosillowky
Principal Designer/Developer: Werner Cohle
Principal Designer/Developer: Jonathan Leister
Principal Researcher David McNuff
Partner/Designer: Carlos Motta

Special Thanks to Alixson Linn, Kiea Clayton, John Roach, Ada Brecher, Connor and Terry Ding, Aline Rosillowky, Christopher DDow, Abdel Udub, Gregory Lea, Nathaniel Wolff, Shiflett, Vishwanath Raghaug, Lex, Rob, Andrea, Natalia, Mary, Tracey Tion, The Bagel, Jo Arnt, Nicolas, Chris, Tyler Lovett, and the Blank Family. Thanks also to Jane Bury for her insightful input on this paper.

References


Acknowledgments and Credits

Jenny Sabin Studio Team
Jenny S. Sabin – Architectural Designer and Artist
Dillon Pranger – Project Manager
John Mila – Jenny’s Advisor
William Gan – Design, Production, Installations
Clayton Brinley and Judy Guo – Grey – Design Engineer

Fabrication and Manufacturing

Grafik, Makers of Fiber in Digital Images, AcuFab

Microsoft Research Ada Core

Technical Fellow and Director Eckhard Körnicke
Director of Mixed Special Projects: Badiar Durr
Principal Research Designer/Educational Researcher: Aline Rosillowky
Principal Designer/Developer: Werner Cohle
Principal Designer/Developer: Jonathan Leister
Principal Researcher David McNuff
Partner/Designer: Carlos Motta

Special Thanks to Alixson Linn, Kiea Clayton, John Roach, Ada Brecher, Connor and Terry Ding, Aline Rosillowky, Christopher DDow, Abdel Udub, Gregory Lea, Nathaniel Wolff, Shiflett, Vishwanath Raghaug, Lex, Rob, Andrea, Natalia, Mary, Tracey Tion, The Bagel, Jo Arnt, Nicolas, Chris, Tyler Lovett, and the Blank Family. Thanks also to Jane Bury for her insightful input on this paper.

References


