TAMING SMART MATERIALS:
A Workshop on Controlling Behavior with Geometries

ARCH 599, 2 units, Fall 2019, Wednesdays, 10-11:50am, Clipper Lab, Instructor: Doris Sung

COURSE DESCRIPTION

This workshop will be an in-depth study correlating the importance of geometry with the control of smart material behavior. We will meet once a week to develop dynamic movement and surfaces using three different phase changing materials: shape memory polymers, polystyrene and shape memory alloys (or thermobimetal)--most of which will be provided by the instructor or handmade by the students. After the initial introduction of the scientific nature of the three materials and studying selected group of precedents through diagramming and replication, students will begin to familiarize themselves with the natural behavior of the smart materials and develop effective geometries in two and three-dimensions as well as integrate structural strategies for a final installation with a self-supporting surface. By the end of the semester, each student will build a self-assembling device as a culmination of their earlier studies. The device may be a responsive surface or an operable product or piece of furniture. The final presentation with include drawings/diagrams and will be made public physically and digitally.

INTRODUCTION

By definition, 'smart materials' automatically transform without additional energy or control, when exposed to an outside stimulus. Because they inherently respond to changes in temperature, humidity, light, or other common intangible elements of our environment, these responsive materials can be useful in optimizing gradient systems, automatically. Rather than constricting the movement of materials in a building assembly, architects and researchers are now considering the changes in these materials as a benefit and understanding the inherent behavior of these materials as a requirement. This method of design combines both bottom-up and top-down strategies, mainly on a local level. Farshid Mousavi refers to this condition as transversal. "In a transversal system, a "base unit" assembles a variety of causes and concerns into a complex supramaterial whole—an amorphic rather than hylomorphic whole; that is, the way the elements combine is not subject to a predetermined system but is specific to those elements." It is where multiple inputs are very specifically combined to achieve a single output. In all of the projects discussed below, a transversal method of design contributed to the success of the final value or function in the various surfaces.

One such material is smart thermobimetal, used since the beginning of the industrial revolution. A lamination of two metals together with different thermal expansion coefficients, the material deforms when heated or cooled. As the temperature rises, one side of the laminated sheet expands more than the other. The result is a curl in the sheet material. P675R, the thermobimetal combination used for the following studies, has the highest amount of deflection in the temperature range of 0-120 degrees Fahrenheit. The low expansion material is called Invar, which is an alloy of iron and nickel, and the high expansion material a nickel manganese alloy. Made corrosion-resistant

by plating with nickel, chrome or copper, this material can be ordered at any desired thicknesses. The amount of deflection varies dependent on the size/shape of the pieces, the air temperature, the position of clamping and the thickness of the material.

In the development of responsive materials for building application, geometry plays a significant role on two levels: in the design of the four-dimensional operation, and in the alteration of the behavior of smart materials. These issues are specific to designing with shape-changing materials, and are additional to the standard problems of fabricating, tessellating, pattern-making, assembly sequencing, and making building façades performative. Rather than altering the various bonds, ingredients and characteristics of materials at a molecular level (a common task of the material scientist), the simple manipulations of the overall geometry of the raw material can provide enough control to change, negate, retard or enhance the natural behavior of that material.

For multidirectional smart materials, geometry plays a critical role in determining how the material behaves. Because the material's shape can deform in multiple directions when exposed to changes in the environment while using zero energy and no controls, the shape of that piece pre-determines the way that element will curl, shrink, inflate, deform or melt. When understanding the materials elemental structure or non-hierarchical grid-like molecular organizations, one can manipulate the behavior to exaggerate or dampen its inherent tendencies. This control can lead to the use of similar materials for architectural purposes such as shading, ventilating, propelling or structuring. For this reason, this course will introduce students to a new role for architects in the area of taming smart materials to behave.

REQUIRED READINGS

Each week, students are required to read the articles listed on the Schedule and be prepared to discuss the readings at the next meeting. Students should challenge the position of the author, the support given in the article and what this means culturally, scientifically, historically and personally. Reading assignments may change during the semester. Students will be notified via email at least on week in advance if there is a change. All readings will be available on Blackboard as downloadable PDFs.

PRECEDENT STUDIES AND DIAGRAMS

Each student will select five precedents to study in drawings and diagrams. A list of precedents will be provided to choose from. Or the student has the option of selecting on of his/her own with the instructor's approval. From the five, the student will be asked to translate two of the projects using any of the three smart materials. A field of at least nine units must be developed for class for review. A standard for diagramming these precedents will also be discussed in class and replicated throughout the semester.

PROJECTS 1, 2, 3

Referring to each of the three smart materials being studied in this course, each student will develop multiple units (see schedule for numbers) and patterns. Using shape memory polymers and alloys as well as polystyrene, students will be able to test various aspects of responsive design in both the operational phase or in the construction phase. These projects must be completed in both physical prototypes and drawings/diagrams. Format of drawings/diagrams will follow the standard developed for the precedents.

FINAL PROJECT

Each student will be responsible to complete their studies in the form of a tessellation over the semester and culminate in a cohesive product. The final product may vary from a geodesic sphere to a wearable suit to a piece of furniture to a free-standing or hung artifact. Each part of the piece will be designed to be performative in some form or fashion either during assembly or after completion.

FINAL DOCUMENTATION

Each portion of the final project must be diagrammed in the same fashion developed for the precedent studies. The standard for these drawings will be uniform throughout the group. In addition, each student will develop line axonometric drawings with their final tessellation populating the overall installation geometry. Each axonometric drawing will be plotted on opaque Strathmore paper for display. Specific requirements will be discussed in class.

23 June 2019
This schedule will be updated every Friday (see date above).

Week 1 Aug 28
Activity: Introduction Shape Memory Polymers
Develop three 2D and three 3D units that can be multiplied in a pattern using the hand-made shape memory polymer. Consider trying various types of curls (uniform, twist, coil, reverse, etc.) as part of your strategy.

Week 2 Sept 04
Activity: Thermobimetals FIELD TRIP
Reading Due: Sung, Doris, "Smart Geometries for Smart Materials: Taming Thermobimetals to Behave", Journal of Architectural Education, 70:1, 96-106, DOI: 10.1080/10464883.2016.1122479, 2016.
Assignment: Develop two 2D and two 3D units that can be multiplied in a pattern using shape memory alloy. Consider trying various types of curls (uniform, twist, coil, reverse, etc.) as part of your strategy.

Week 3 Sept 11
Activity: Polystyrene
Reading Due: Picon, Antoine, "Reionventing the Meaning of Ornament", Ornament: The Politics of Architecture and Subjectivity, AD Primers, John Wiley & Sons, United Kingdom, 2013.
Assignment: Develop three individual units combining other materials that can be multiplied in a pattern using polystyrene. Because the material is a one-way operation and has compressive strength, consider combining this material with any of your choice for non-repeating motion.

Week 4 Sept 18
Activity: Replication of precedent
Reading Due: Moussavi, Farshid and Michael Kubo, "Introduction", The Function of Ornament, Actar, Barcelona, 2008.
Assignment: Select a precedent from nature, from other responsive systems, from art or from science. Replicate the behavior of the movement using one of the three smart materials. Bring 3-5 samples to class for discussion.

Week 5 Sept 25
Activity: Pattern-making
Reading Due: Pell, Ben, "Introduction", The Articulate Surface, Birkhauser, Basel, 2010.
Assignment: From the selected unit, develop three ways to multiply the system into a pattern.

Week 6 Oct 02
Activity: Tessellation for surface
Reading Due: Tibbets, Skylar, "Self-Assembly and Programmable Materials", Building Dynamics: Exploring Architecture of Change, Routledge, London, 2015.
Assignment: With the final selected pattern, use Grasshopper or digital methods to parametrically alter the tessellation of the surface into a self-structured form (hyperbolic paraboloid).

Week 7 Oct 09
Activity: Pin-up
Reading Due: Burry, Mark, "Geometry Working Beyond Effect", ed. George L. Legendre, Mathematics of Space, AD, July/August 2011.
Assignment: Eliminate any extraneous elements to your surface and engineer both the single unit and the complete field to the bare essentials. All geometries must have identifiable purpose with no extraneous or "ornamental" parts.

Week 8 Oct 16
Activity: Part to a Whole
Reading Due: Bonnemaison, Sarah, "The Skin of the "Sky Bubble" at Expo '67", On Growth and Form: Organic Architecture and Beyond, Tuns Press and Riverside Architectural Press, 2008.
Assignment: As a group, we will develop an overall geometry that can be broken down into specific forms. Students will be assigned a portion to complete for the final project. If necessary, a site will be selected in the school for the installation to be hung in tension or stand in compression.

Week 9 Oct 23
Activity: Crits
Reading Due: Kolarevic, Branko and Vera Parlac, "Adaptive Responsive Building Skins", Building Dynamics: Exploring Architecture of Change, Routledge, London, 2015.
Assignment: Production

Week 10 Oct 30
Activity: Crits
Reading Due: Baez, Manuel, “Phenomeno-Logical Garden: A Work in Morpho-Logical Process”, On Growth and Form: Organic Architecture and Beyond, Tuns Press and Riverside Architectural Press, 2008.
Assignment: Production

Week 11 Nov 06
Activity: Crits
Assignment: Production

Week 12 Nov 13
Activity: REVIEW: Final Installation
Assignment: Prepare drawings and diagrams.

Week 13 Nov 20
Activity: REVIEW: Final Installation
Assignment: Prepare drawings and diagrams.

Week 14 Nov 27
SCHOOL HOLIDAY
Thanksgiving Week

Week 15 Dec 04
Activity: Documentation
Assignment: Finalize drawings and diagrams.

FINAL EXAM PERIOD: Submission of final drawings/diagrams.

GRADING

15% Precedent Studies and Diagramming
10% Project 1
10% Project 2
10% Project 3
30% Final Project
15% Final Documentation
10% Attendance and Participation in discussions as part of completion of readings

All work must be done on time to receive full graded credit. Work not completed at time of due date will receive a drop of one full letter grade each day it is late.

ATTENDANCE

More than one absence will adversely affect the student's final grade by 1/3 letter. If additional absences are required for a personal illness/family emergency, preapproved academic reason/religious observance, the situation should be discussed and evaluated with the Instructor and Chair on a case-by-case basis. It is the student's responsibility to seek means (if possible) to make up work missed due to absences, not the instructor's, although such recourse is not always an option due to the nature of the material covered.

Any student not in class within the first 10 minutes is considered tardy, and any student absent (in any form including sleep, technological distraction, or by leaving mid class for a long bathroom/water break) for more than 1/3 of the class time can be considered fully absent. If arriving late, a student must be respectful of a class in session and do everything possible to minimize the disruption caused by a late arrival.

Being absent on the TWO days the Final Project is due can lead to an "F" for your final project (unless the Instructor concedes the reason is due to an excusable absence for personal illness/family emergency/religious observance). Review of the Final Project is to be treated the same as a final exam as outlined and expected by the University. If students are absent or tardy and miss their opportunity to present, this is considered equal to missing a final exam.

READING LIST

Baez, Manuel, "Phenomeno-Logical Garden: A Work in Morpho-Logical Process", On Growth and Form: Organic Architecture and Beyond, Tuns Press and Riverside Architectural Press, 2008.

Bonnemaison, Sarah, "The Skin of the "Sky Bubble" at Expo '67", On Growth and Form: Organic Architecture and Beyond, Tuns Press and Riverside Architectural Press, 2008.

Burry, Mark, "Geometry Working Beyond Effect", ed. George L. Legendre, Mathematics of Space, AD, July/August 2011.

Kolarevic, Branko and Vera Parlac, "Adaptive Responsive Building Skins", Building Dynamics: Exploring Architecture of Change, Routledge, London, 2015.

Moussavi, Farshid and Michael Kubo, "Introduction", The Function of Ornament, Actar, Barcelona, 2008.

Pell, Ben, "Introduction", The Articulate Surface, Birkhauser, Basel, 2010.

Picon, Antoine, "Reionventing the Meaning of Ornament", Ornament: The Politics of Architecture and Subjectivity, AD Primers, John Wiley & Sons, United Kingdom, 2013.

Sung, Doris, "Smart Geometries for Smart Materials: Taming Thermobimetals to Behave", Journal of Architectural Education, 70:1, 96-106, DOI: 10.1080/10464883.2016.1122479, 2016.

Tibbets, Skylar, "Self-Assembly and Programmable Materials", Building Dynamics: Exploring Architecture of Change, Routledge, London, 2015.

Thompson, Darcy Wentworth, On Growth and Form, 1917.

Statement on Academic Conduct and Support Systems

Academic Conduct:

Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in *SCampus* in Part B, Section 11, "Behavior Violating University Standards" policy.usc.edu/scampus-part-b. Other forms of academic dishonesty are equally unacceptable. See additional information in *SCampus* and university policies on scientific misconduct, http://policy.usc.edu/scientific-misconduct.

Support Systems:

Student Counseling Services (SCS) – (213) 740-7711 – 24/7 on call
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention. engemannshc.usc.edu/counseling

National Suicide Prevention Lifeline – 1 (800) 273-8255
Provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week. www.suicidepreventionlifeline.org

Relationship and Sexual Violence Prevention Services (RSVP) – (213) 740-4900 – 24/7 on call
Free and confidential therapy services, workshops, and training for situations related to gender-based harm. engemannshc.usc.edu/rsvp

Sexual Assault Resource Center
For more information about how to get help or help a survivor, rights, reporting options, and additional resources, visit the website: sarc.usc.edu

Office of Equity and Diversity (OED)/Title IX Compliance – (213) 740-5086
Works with faculty, staff, visitors, applicants, and students around issues of protected class. equity.usc.edu

Bias Assessment Response and Support
Incidents of bias, hate crimes and microaggressions need to be reported allowing for appropriate investigation and response. studentaffairs.usc.edu/bias-assessment-response-support

The Office of Disability Services and Programs
Provides certification for students with disabilities and helps arrange relevant accommodations. dsp.usc.edu

Student Support and Advocacy – (213) 821-4710
Assists students and families in resolving complex issues adversely affecting their success as a student EX: personal, financial, and academic. studentaffairs.usc.edu/ssa

Diversity at USC
Information on events, programs and training, the Diversity Task Force (including representatives for each school), chronology, participation, and various resources for students. diversity.usc.edu

USC Emergency Information
Provides safety and other updates, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible. emergency.usc.edu

USC Department of Public Safety – UPC: (213) 740-4321 – HSC: (323) 442-1000 – 24-hour emergency or to report a crime.
Provides overall safety to USC community. dps.usc.edu