Proposal for the ACSA Brick Education Prize 2024

Title: **B.AR**- **Bricklaying in Augmented Reality**
Format: Seminar, lab
Credit: 3 cr
Expected enrollment: 12

Department of Architecture, The Pennsylvania State University
Instructor: Orsolya Gaspar

Offered as a Supporting course in the undergraduate and graduate curriculum, as ARCH497 Special Topics. It primarily targets architect- and architectural engineering majors, but motivated students from other related areas, including, but not limited to, art history or civil engineering, are also welcome.

Description

The course explores the theory, history, and best practices of fired brick masonry construction. High-level theoretical understanding is reinforced through hands-on exercises and seminar-style discussions. The course culminates in a collaborative design-build pavilion project, where participants utilize Augmented Reality (AR) to explore and showcase its potential in brick masonry construction.

The brick—a small rectangular prism—is the ultimate building block, both figuratively and practically. This course begins with the premise that understanding bricks requires an understanding of patterns. From the abstract, geometry-driven world of patterns, students transition to discussions on masonry materials, structural strength, and how these factors should influence the geometry (both global and local) of brick structures. The history of brick construction offers illustrative examples of how material, form, and pattern serve as tools for spatial design in the hands of a skilled designer. Theoretical discussions are reinforced through practical assignments that develop students' computational design skills. The design-build cumulative experience at the end highlights that bricklaying relies on tactile feedback, requires skill, and must deal with the element of impromptu. Due to its size, brick can quickly adapt to various forms; however, bricklaying remains labor-intensive. More complex tasks require a high level of expertise or craft from the builder. Traditional brick-building practices are evaluated and contrasted with current standard approaches and forward-looking methods in terms of sustainability, economy, and circularity potential. The promises and limitations (as of now) of emerging technologies (e.g., automation in brick construction) are discussed in more detail, arriving at augmented reality-supported construction. The pavilion assignment showcases how

AR can enhance the craft of bricklaying by adapting to its inherently design-on-the-go nature and enabling the realization of complex patterns.
Complex patterns are not only decorative: they can enhance the structural properties of masonry construction, which can facilitate the circular use of bricks (compensating for the material uncertainties). The final assignment emphasizes the need for minimizing supporting structure (i.e., formwork and scaffolding) and the trade-offs of using traditional, non-cementitious mortars to allow the reuse of the bricks. The pavilion is assigned a different theme each time the course is offered (such as Reclaimed Brick, Balancing the Nubian Vaulting, Un-Cut), which is aligned with the planned public B.AR lectures (featuring an invited expert on the theme). Hence, each pavilion will highlight a different characteristic of brick construction. It also assists with the long-term sustainability of the course: different topics can mobilize different industry partners whose support could greatly benefit the construction process.

Instruction
Instruction combines frontal, collaborative, and lab-like formats. The assignments are group assignments (see Schematic schedule): time is allocated in class for students to start working on their assignments and discuss challenges.

Software and hardware requirements
Rhino 7 or higher, Grasshopper – *some experience is strongly recommended*
Bring-your-own-laptop and hand-held device *(mobile or tablet, Android or Mac)*
Fologram plugin and app – *provided (by the Department) at no cost for the duration of the course; no prior experience required*
MS HoloLens2 headset – *provided at no cost for the duration of the course; no prior experience required*

Goals and Educational Outcomes
The course expands students' knowledge of patterns and brick masonry construction and enhances their computational design skills. It educates future architects about the potential of brick construction and promotes sustainable and circular building practices. The course offers a deeper understanding of AR-assisted brick construction, as it aligns well with and can elevate the hands-on craft of bricklaying. The pavilion project aims to reach a wider audience, raising public awareness about the versatility of this well-known yet often underestimated building material while offering hands-on brick construction experience for the students.

After successfully completing the course, students will:
- Be familiar with the basic concepts and terminology of tilings on flat and curved surfaces
- Be familiar with the construction history of brick masonry and vaulting
- Understand the basics of mechanics of brick masonry
- Understand the potentials and challenges of bricks as circular building materials
- Understand the potentials and limitations of cutting-edge masonry construction techniques
- Be able to implement a simple form-finding algorithm using an existing physics simulation engine (Kangaroo2) into the CAD workflow
- Be able to develop a simple, parametric brick patterning algorithm using Grasshopper
- Be able to operate the Fologram MR app on a mobile device and the HoloLens2.
- Be able to contribute to the collaborative development of a custom, paperless design-to-construction workflow of a brick structure using Grasshopper and Fologram.

Schematic timeline (16-week semester, 1 week break)

Foundational period (9 weeks)

Tilings and patterns // Fologram basics

3 weeks //Assignment 01 – Tessellating the plane (*Fologram: placement of model, basic operations (non-parametric), hand gestures. Theory: Tilings, notations, basic concepts, architectural applications, past and present. XR notations, basic concepts. Output: AR assisted Penrose-puzzle-assembly app)* // Readings: Grünbaum & Shephard: Tilings and patterns, Ch. 1., Steinhardt: The Second kind of impossible pp 40-60

Mechanics and material properties of masonry + Form Finding // Kangaroo basics

2 weeks // *Digital twin best-fit with Kangaroo2 of a simple, hanging cloth model. Theory: Mechanics of masonry, Form-finding for no-tension materials. Output: Inverted hanging cloth as: physical model + digital twin best fit*// Readings: Huerta: Mechanics of Masonry Vault*, Heyman: The masonry arch,* Adrienssens et al.: Shell Structures for Architecture, Ch.1.

Brick patterns and construction history // advanced Fologram

3 weeks //Assignment 02 – Tessellating curved surfaces *(Fologram: parametric operations, hand tracking, scanning + custom brick patterning script. Theory: Stereotomy and masonry mechanics, Brick construction techniques, Scaffold-free construction. Output: AR-assisted bricklaying app for simple vault (dome, barrel) construction)* // Readings: Fathy: Architecture for the poor, Ochsendorf: Guastavino Vaulting, *Boni et al (2021), Addis: 3000 years of building, Cathedrals*

Contemporary bricklaying and sustainability of bricks

1 week // *Theory: Automation in brick construction. Reusing bricks – challenges and advances.* // Readings: Bruun et al. (2024), Mitterberger et al. (2020).

(Readings in Italic are suggested only)

Design and construction phase (6 weeks)

Design 3 weeks (*assisted by a graduate student TA as needed*)

Construction 3 weeks (*includes a mason-assisted building workshop during the last week*)

6 weeks // Assignment 03 - Design-build *(Output: brick pavilion + AR-assisted bricklaying app with progress tracking (automatic updates))*