Elliptic Paraboloids in Circumpolar Vernacular Architecture

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Abstract

This workshop employs mathematics to explore characteristics of elliptic paraboloid forms common to tradition-based country buildings from distinct regions of the circumpolar north. To begin, short videos show full-scale reconstructions of three dwelling types from Indigenous peoples' tradition: Sápmi goahti (birch-framed turf-clad dwellings from northern Scandinavia), Inuvialuit qaluurvik (willow-framed skin-and-moss clad dwellings from the western Canadian Arctic), and Inuinnait iglu (snow block dwellings from the high Arctic of North America). Workshop participants then build scale models of the three types. Participants' models, combined with dimensional information about the full-scale reconstructions, facilitate mathematical analysis of the vernacular structures. Conical frusta and second-order polynomials integrated in applicable dimensions describe the shapes and calculate their interior volumes. Efficiencies are calculated and compared both qualitatively and quantitatively: mass of materials required to build each vernacular structure, energy expended during construction, and potential for passive heating in the basic form and detailed design. Discussions will address bio-mathematics, including the natural strengths of certain forms, whether made of bent wood or stacked snow blocks; ecological advantages of the housing types; on-going usefulness of reconstructed vernacular architecture as places for teaching and survival shelters; comparisons with "formal" architecture, including Antoni Gaudi; and the value of long-resident peoples' architectural knowledge.

Introduction: the research

In the high Arctic, subsistence hunters and fishers have learned, through countless generations of experimentation, to rapidly construct shelters from available materials so they can survive inclement weather while harvesting food. Now, as extreme weather events become more intense and unpredictable alongside accelerating climate change, long-resident Indigenous communities and scientists may benefit from adapting tradition-based dwellings of the north – Arctic vernacular architecture – for modern use as adaptable, temporary structures. Research into vernacular dwelling types, and their potential for on-going usefulness, was undertaken over a 10 year period in several high Arctic communities in the circumpolar region. Full-sized reconstructions of tradition-based structures were built with guidance of Indigenous knowledge-holders and involvement of students in each community. These reconstructions were intended to share traditional architectural knowledge across generations, to function as places for story-telling, and to be shelters for recreation and/ or emergency use. Surprisingly, several of the reconstructed vernacular structures had a similar elliptic paraboloid shape, despite different cultural contexts, bio-geographic conditions, materials, and methods of building. Elliptic paraboloid structures in this research include Inuvialuit qaluurvik (willow-framed skin-and-moss clad dwellings from the western Canadian Arctic) (fig. 1), Sápmi goahti (birch-framed turf-clad dwellings from northern Scandinavia) (fig. 2), and Inuinnait iglus (snow-block dwellings from the North American high Arctic) (fig. 3). The range of sizes of all three dwelling types was also similar, although overall dimensions varied depending on the number of people housed within, according to local knowledge holders.

Figure 1: *students constructing a qaluurvik, or willow frame house, in the western Canadian Arctic.*

Figure 2: *A gamme or goahti (birch-framed turf-clad dwelling) in northern Norway.*

Figure 3: *A two-person iglu built by Inuk knowledge-holder Attima Hadlari glows with lighting in Cambridge Bay, Nunavut, Canada. Mark Hadlari photo*

The Bridges 2016 workshop

The "Mathematics in Circumpolar Vernacular Architecture" workshop invites participants to construct scale models of three elliptic paraboloid structures from circumpolar architectural vernacular, and then undertake mathematical analysis of these works to quantify functionality, environmental characteristics, and design similarities. Participants will be encouraged to work in small cross-disciplinary teams, with each team taking on a different structure and tasks.

The workshop will begin with short videos and a presentation depicting the reconstruction of full-sized tradition-based country structures that have an approximately elliptic paraboloid form. After watching the videos and presentations, workshop participants will receive model-making materials, including model bases, branches of willow, birch, moss, skins, and modeling clay. Although the basic form of each dwelling will be an elliptic paraboloid, participants will be welcome to experiment with the materials and combine them in different ways, recognizing that vernacular architecture, like other traditional knowledge, characteristically underwent many adaptations depending on the experience and ingenuity of the builders [1]. Previous model-building sessions at conferences and universities displayed considerable ingenuity depending on each builder's background, experience, and interpretation (fig. 4).

Figure 4: *model-making workshops undertaken by Mackin in 2015 (clockwise from top left): Lisbon workshop; a student builds a half paraboloid in Lisbon; young iglu builders in Nunavut, Canada; Dr. Mackin with qaluurvit models during workshop in Copenhagen.*

The models produced by Bridges 2016 workshop participants, combined with dimensional details and drawings of the full-scaled reconstructions, will facilitate mathematical descriptions of each structure. Interior volumes will be derived from a series of stacked conical frusta (for the iglu, which is made is a series of spirals gradually tapering towards the peak) [Cambridge Bay Elder Attima Hadlari pers. comm.], [2], or alternatively by fitting a second-order polynomial and integrating it in each applicable dimension (for the goahti and qaluurvik, which have a continuous curvature because of their bent wood form). It may be noted that the willow and birch branches may bend in a catenary rather than hyperbolic arch, but for the purposes of the workshop elliptic paraboloid is assumed to have a sufficient fit.

Combining mathematical analysis of participants' models with drawings and statistics provided for the full-scale reconstructions (derived from primary research and from [2], [3], [4]), workshop participants will evaluate each of the three building types for thermal performance, wind- and snow-load resistance, and approximate mass of structure per person living in the dwelling. Efficiencies will be calculated and compared both qualitatively and quantitatively. Participants can choose to mathematically model and/ or graphically illustrate the mass of materials required to build each vernacular structure, energy expended by people during construction, and/or potential for passive heating in the basic form and detailed design.

After modeling and evaluations are complete, applications will be discussed. Topics will address bio-mathematics, including the natural strengths of certain forms, whether made of bent wood or stacked snow blocks; ecological advantages and applications of the housing types; on-going usefulness of reconstructed vernacular architecture as places for teaching and survival shelters; and the value of long-resident peoples' architectural knowledge. The mathematical analysis and hands-on model building will facilitate comparisons with other vernacular and "formal" architecture, including the three-dimensional experiments of Catalan architect Antoni Gaudi, who used weighted string to describe the strongest and most natural form of arch [5]. Finally, working in cross-disciplinary teams will enable participants to experience different approaches within their individual disciplines. Like the circumpolar vernacular structures themselves, this workshop finds similarities in seemingly dissimilar fields of knowledge, thereby fostering communications across academic and cultural boundaries.

References

[1] Nancy J. Turner, *Ancient Pathways, Ancestral Knowledge: Ethnobotany and Ecological Wisdom of Indigenous Peoples of Northwestern North America*, Montreal: McGill Queens University Press. 2014.

[2] G. Peter Kershaw, Peter A. Scott, and Harold E. Welch, "The Shelter Characteristics of Traditional Inuit-Styled Snow Houses", Arctic Vol. 49 No. 4 Dec. 1996, pp. 328-338. 1996.

[3] Molly Lee and Gregory Reinhardt, *Eskimo Architecture: Dwelling and Structure in the early historic period*, Fairbanks: University of Alaska Press. 2003.

[4] Inuvialuit Elders with Robert Bandringa, *Inuvialuit Nautchiangit: Relationships between people and plants*, Inuvik: Inuvialuit Cultural Resource Centre. 2010.

[5] Santiago Huera, "Structural Design in the Work of Gaudi", *Architectural Science Review* Volume 49.4, pp 324-339. http://oa.upm.es/703/1/Huerta_Art_002.pdf. 2006.