

Memory Mesh: Conformationally Adaptive Solar Shading

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ABSTRACT

Innovative technologies that enable more efficient use of energy in the built environment contribute to the effectiveness of green building design, and to sustainable building practices. Digital fabrication can be used to unlock the inherent physical properties of common materials as a means to create solar shades which change shape in response to ambient conditions and user needs in a system which relies on extremely simple mechanical actuation. These conformationally adaptive solar shades take advantage of materials which can be deformed not only to occlude or permit the passage of light, but also to produce optimal angles for the maximization the interception of solar radiation of the surface of the device itself.

KEYWORDS: solar shading, materiality, sustainability, biomimicry, anisotropy.

Architects today are charged with building a world where the most insurmountable problem will soon be resource management. Sustainability is riding an unprecedented wave of popular culture, but many of the tools necessary for the job have been laid before us by previous generations. Building sustainably is simply good design, and always has been. The face of design, however, is changing. The explosion of digital techniques allows the use of conventional materials in unexpected ways, unconventional materials in unimaginable ways, and will devise new materials from improbable sources. At the core of this philosophy is the rejection of the ornamentation of normative building modes with sustainable “elements”. Instead, nature can be a model for a form of design which demands endless variation. The complex beauty of nature derives from a trial and error based problem solving. From the nano-structures on a gecko's foot, to the naturally ventilated termite mound, natural systems have evolved to solve all manner of architectural problems (Benyus, 1997). This arsenal of biological approaches can be hybridized with anthropocentric and ages-old passive design strategies as a baseline for building design which can be utilized to exploit inherent material properties for enhanced performance of the built environment. Additionally, long before architects began designing for natural light, cross ventilation, and solar efficiency, nature perfected the art of resource management through a highly localized

system of material deployment. This ad hoc material variation of natural constructions results in directional variations in strength, referred to as “anisotropy” (Oxman, 2010). Such structural directionality, as seen in the properties of wood grain for example, is the basis for much of the current thinking in architectural materials research. This research explores the use of deliberately effected weaknesses in common, sustainable materials as a means to produce spatial phenomena, material complexity, and building performance.

Solar shading is an essential component to passive energy design for buildings. Sun angles and building orientation are basic architectural considerations common to most regional architecture, and are commonly seen in such vernacular building formations as shotgun and dog-trot houses, or wrap-around porches (Haase, 1992). Traditionally, solar design has come in the form of static shading devices applied to building openings, or in building forms which accommodate such strategies in their basic shape and orientation. Conformationally determinate devices are limited in terms of on-demand adaptability. New technologies, however, have created adaptive solar shading which responds to lighting conditions, time of day, and the presence of building occupants. Active shading devices currently do exist and take the form of motorized metal fins and roll-down shades. These technologies rely on mechanical solutions to architectural problems. The most ad-

vanced of current dynamic shading systems such as the adaptive fritting case study performed by Hoberman Associates and Buro Happold INC (Drozdowski, 2009) are dynamically adaptable but are reliant on elaborate mechanical actuation in order to function, thus requiring expensive maintenance or in the famous case of the Institut Du Monde Arabe (Lublow, 2008), abandonment of the system entirely.

Rather than relying on complex mechanical actuation, a more efficient type of solar shading can be created which has the ability to change shape in response to solar demands and user needs. A novel material treatment is currently under development which relies on the properties of common materials to change shape while under strain, and return to their original shape when at rest. The behavior of this device is the result of deliberately introduced anisotropy in otherwise dimensionally stable composites of wood veneer, carbon fiber, metals, paper, fabric, or nearly any material with the ability to return to a baseline shape after deformation. As in the production of expanded metal meshes, alternating slits are introduced into the material allowing expansion in any selected direction. Unlike expanded metal mesh, however, the material memory of the selected materials results in the creation of what is essentially a flat spring, or memory mesh. When under tension, the device expands. When tension is released, the device returns to its resting state (Fig. 1).

By varying slotting patterns using parametric modeling techniques, digital means can be exploited to produce analog effects in architectural materials. Researcher Dustin Headly in his Expanded Topographies project (Kolarevic, 2008) showed that permanent structural and spatial effects could be obtained by using alternating slotting patterns in permanently expanded metal walls. Similarly, temporary spatial effects can

be obtained in memory mesh by using parametrically controlled curving patterns. Such spatial effects happen while the device is under tension, but when released the assembly returns to its resting state (Fig. 2).

In an architectural application, memory mesh can change shape in response to ambient conditions and user needs in a system which relies on extremely simple mechanical actuation to create shading which is able to stretch, bend, and twist to adapt to lighting needs, passive energy strategies, and for the enrichment of architectural space. Such sunshades would contribute to the creation of a materially-rich architectural environment, while still accommodating building performance and occupant needs. The proposed construct will take advantage of a novel and patent pending system which can be deformed not only to occlude or permit the passage of light, but also to produce optimal angles for the maximizing the interception of solar radiation of the surface of the device itself. The actuation of the device is extremely simple. In one example, when pulled perpendicular to cuts in the surface, the device expands. As it expands, the blades turn as the material deforms to accommodate the movement (Fig. 3). This permits efficient use of active solar technologies such as flexible photovoltaic cells applied to the surface. Optimal angles and opacities can also be created to shade buildings and building openings to allow the passage of diffuse light while blocking direct light, or to allow visibility through the screen from selective angles. Digital controls systems can be programmed to actively respond to solar angles, geographic location, and user preferences. When fully closed, the device can be made sufficiently strong to resist the damaging effects of hurricanes and major wind storms, to block sunlight, or to provide privacy. When fully open, the device can allow the passage of natural light and breezes, and to provide views to the outdoors.

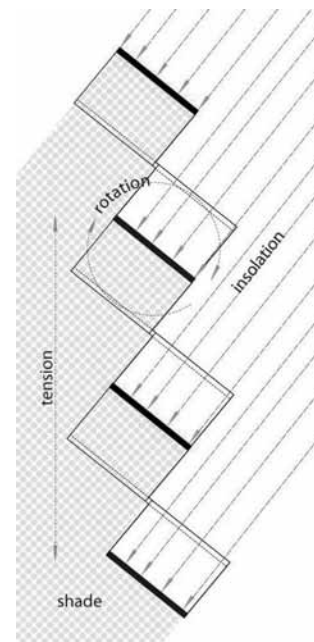
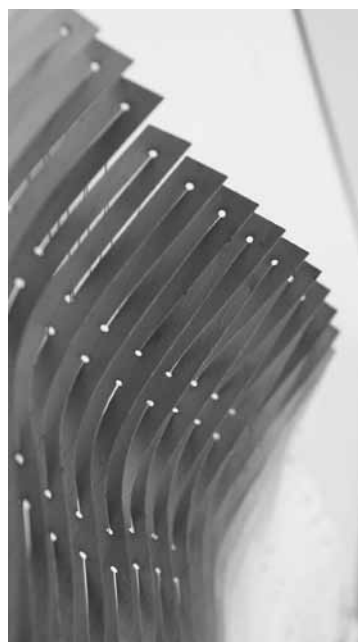
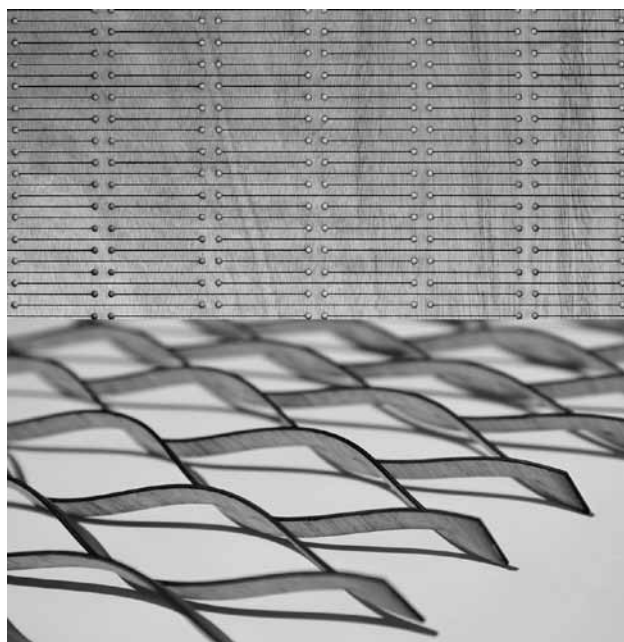


Fig. 1 Resting state; expanded state. / Fig. 2 Mesh under tension. / Fig. 3 Blade deformation to accommodate movement

Further research combines the memory mesh concept with the natural anisotropic properties of wood with respect to humidity. In the presence of humidity, wood expands more perpendicular to its grain than in parallel to it. By producing a hybrid slotting pattern in memory mesh, a surface can be created which opens and closes passively in response to humidity, actively in response to mechanical actuation, or both (Fig 4). A passive-active humidity gate is under development for use in experimental building skin systems which would take advantage of the heat of evaporation of deliberately introduced moisture to reduce cooling loads on buildings in warm climates.

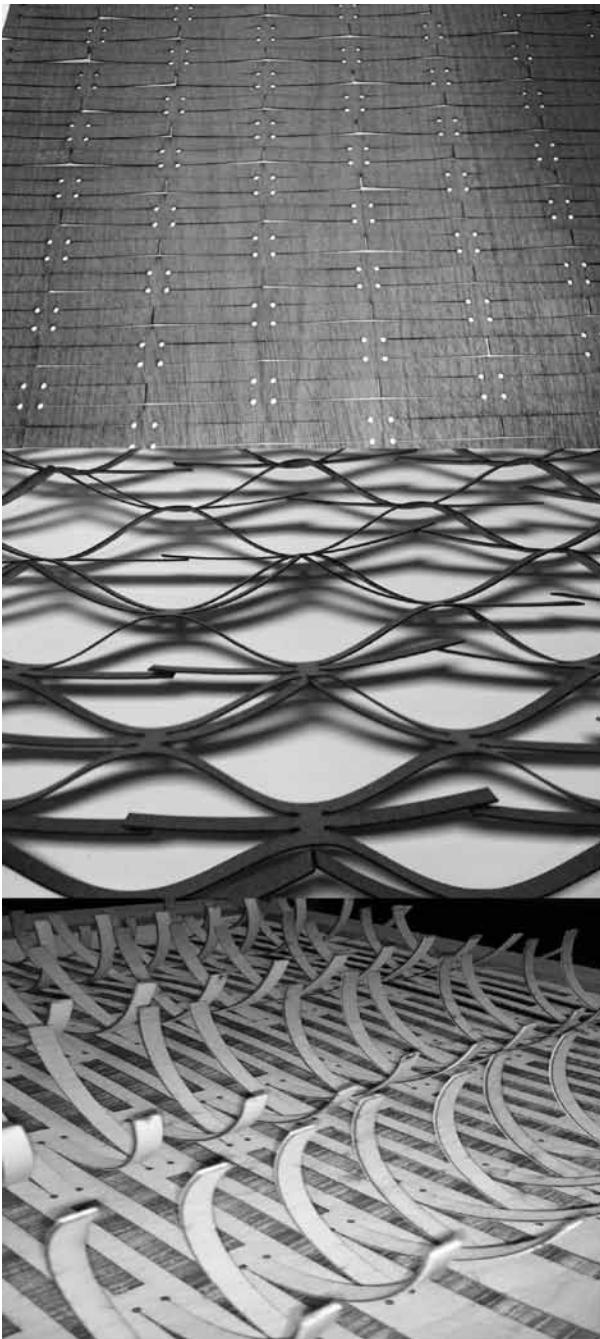


Fig. 4 Hybrid slotting pattern

Conclusions

The means and techniques for creating energy efficient buildings have been part of the architect's tool chest for decades. Architectural thinking in the 1970s saw much advancement in these realms, but energy in the form of cheap oil combined with social and political forces pushed this knowledge away from the public consciousness. The current green building trend is a positive step toward a sustainable future, one in which architects have an unprecedented opportunity to contribute to a more energy efficient world, and a responsibility to do so with a greater vision than ever before. Solar panels, shading devices, and other energy saving products have become readily available, accessible, and affordable while new technologies and manufacturing techniques are rapidly making these products more and more efficient (Kolarevic, 2003). It would be simple, therefore, to adorn normative buildings with green decorations in the name of social responsibility, and this trend can be seen worldwide. Architectural design, however, is rapidly changing in the face of new technologies. Advanced computational techniques allow for endless formal variation and performative specificity. Much the way leaves on a tree can vary in size and shape based on canopy height and available sunlight (Benyus, 1997), parametric modeling allows architectural design which is utterly unique to region and locality. These digital techniques can likewise be used to unlock the inherent physical properties of common materials to create simple passive machines. Furthermore, the use of digital control systems hybridized with analog material properties can create active devices which can be precisely tuned to maximize the performance of the built environment, as well as to create materially transcendent architectural space.

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