MTRL 466: 2013
Adaptive Architectural Building Facades

As there is a strong demand for architects to incorporate natural light into interior spaces, there is the increasing use of windows in architectural design. This causes some challenges, however, as large windowed areas are more difficult to thermally control, meaning that while they let light in they also tend to lead to large temperature rise during the day. In hot environments (e.g. the southern United States) this heating can lead to significant challenges and often requires increased use of air conditioning to maintain heating. A recent example of the challenges of trying to accommodate natural light into public spaces is given by the Dallas Museum Tower scandal (see e.g. http://www.bloomberg.com/news/2013-08-20/dallas-tower-dithers-as-glass-roasts-museum-masterpieces.html)

There is a need for new technologies that can behave autonomously so as to allow natural light into architectural spaces when temperatures are not too high (e.g. during mornings and evenings) and block direct sunlight when it causes too much of a temperature rise inside.

We have developed a concept for a modular window shading system that (ideally) would be fully passive –it would respond to variations of temperature to control a set of "blinds" that would open or close without the need for any direct human intervention thanks to the use of adaptive materials. The design is based on a simple frame that is actuated either by bi-material hinges or through the use of shape memory materials connected to a light sensor. The former would be preferred, as it would allow for completely autonomous operation, though the later may need to be used in order to provide the minimum degree of control needed.

The figure below shows architectural drawings of the target (hypothetical) location as a 'test bed' for this technology. The project is a single story ranch house (no basement) located in Austin, Texas. On the plan shown below, the orientation is north meaning that the short face of the house faces south. Bedrooms are on the north end with a high ceiling to the east. Living spaces are on the south end of the house with a high ceiling on the west.

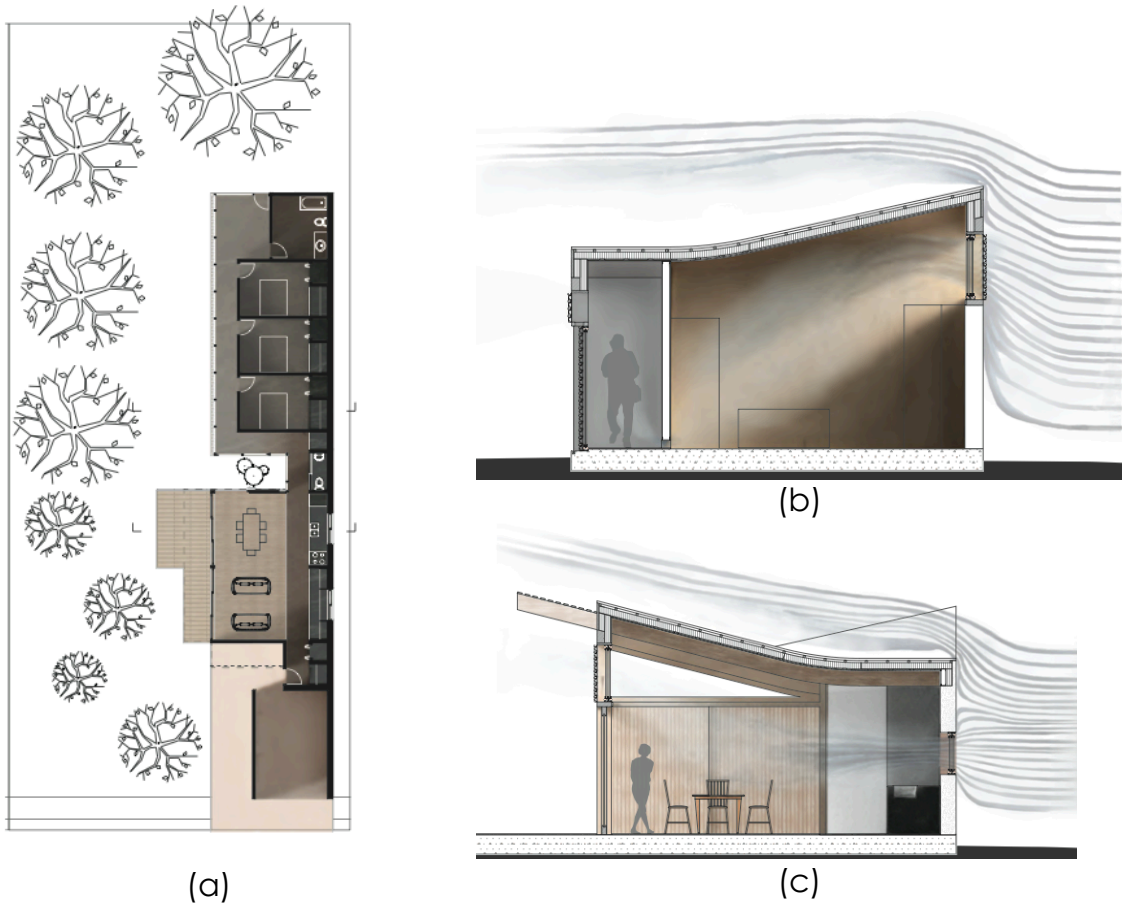

Fig. 1: Layout of hypothetical family home in Austin Texas.

The concept that we have developed is just that – it is only conceptual. We are therefore approaching you to help us to embody this concept with the aim of preparing a prospectus for investors. One of our key marketing strategies will be to argue the environmental benefits and cost savings accrued from having a fully passive system for controlling shading of space.

As noted above, two concepts have been retained to this point, one using bi-material strip to provide actuation, the other shape memory materials. We would like to evaluate these two options in parallel and, at the end, to evaluate which of the two is likely to be a more successful option. With our stated desire for the system to be as autonomous as possible, our preference at the moment would be for bi-material

actuation, though shape memory actuation may provide much needed control that the bi-material solution can't provide.

There are many tasks that must be accomplished to reach our goal in this project. Below I outline the most important of these tasks.

1. Evaluate the basic concept that we have proposed and critique its strengths and weaknesses from an engineering point of view
2. Identify, and be prepared to support your selection of, candidate materials for the inert portion of the shade (the frame and covering material) as well as for the actuating material (biomaterial or shape memory).
3. Basic engineering functionality must be obtainable.
    a. The actuators must be strong enough to be able to lift the weight of the structure.
    b. The structure must both extend and retract (in most shape memory materials the shape change is one way)
    c. The shape change must be able to occur in the temperature range experienced in the room
    d. Ideally, we would like to be able to control the temperature range over which the actuation can occur (so, for example, to allow parts of the shade to open while others remain all or partially closed to control light)
    e. Options for providing control of the actuation may be desirable. For example, can we have a Boolean response (open or closed) versus a gradual opening and closing with the degree of 'openness' depending on the temperature.
4. We want a basic thermal analysis that would let us know how much change in temperature to expect for the target room and what the costs would be to regulate this temperature using conventional HVAC solutions
5. Following on 4 we would like to do a simple life cycle analysis to show what life cycle energy savings could be accrued from this system relative to having no shades on the surface. This must include the energy costs associated with the materials in the shading system
6. Following on 4 and 5 we would like to have some economic information that would allow us to know a rough cost for our solution and what the potential cost savings to the consumer would be for installing one of these shading systems.

The deliverable for this project should be a report (two reports, one per group) which concludes as to the feasibility of the proposed concepts in terms of the 6 above points.