Conference Paper

Hybrid Environmental-Media Facades

Jules Moloney*, Anastasia Globa, and Rui Wang

IDeEA lab, School of Architecture and Built Environment, Deakin University, Geelong, Australia

Abstract

There is significant potential for responsive sun screening systems to improve the energy performance of large scale public and commercial buildings. However there has been minimal uptake, primarily due to the capital and maintenance costs. We propose that these costs can be offset by providing added value in three ways. (1) Development of a finer grained control interface for occupants to enhance individual comfort, which has been shown to improve worker productivity. (2) With a high granularity of panels and a control system that enables individual movement of each panel, the system can be re-purposed as a low resolution media screen to foster social interactions in urban settings. (3) Enabling a new movement-aesthetic for architecture of indeterminate states that coalesce and shift during the daily and seasonal cycles, thus enlivening the public face of architecture. To evaluate the feasibility of such hybrid responsive facades we are developing physical prototypes calibrated to real time simulation and control software. A initial proof-of-concept design explores the optimal configuration and geometry of the kinetic panels to enable the granularity required for a range of graphic and textural information, along with development of the actuator. We document progress to date on this research into hybrid environmental-media façades'.

Keywords: Responsive sun screens, media facades, architectural aesthetics

Corresponding Author: Jules Moloney; email: destech@deakin.edu.au

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1 Introduction: challenges and opportunities

There has been growing research in what has been variously termed "intelligent, "adaptive" or "responsive" architectural facades [1]. Each of these fields have different points of focus, but the commonality is the premise that if the external façade can be adjusted in response to changing weather patterns and the requirements of users, then performance can be increased. The primary driver for the research is the need to reduce the energy footprint of building, which accounts for 40% of global energy and one third of global greenhouse gas emissions [2]. The building envelop (comprising facades and roof) has been calculated to be responsible for 42% of a commercial building's operating energy, of which a significant portion is attributed to the impact of sunlight and daylight. Various studies have demonstrated automated sun shades that track the position of the sun to shade or reflect sunlight through windows, improve energy performance and internal comfort levels [3]. Recently, a simulation undertaken in California calculated that incorporating solar panels with sun shades would enable a zero energy commercial building without any other additional measures [4]. However,

despite the growing recognition that tuning the performance of facades through adjustment of sun shading systems contributes to energy savings, there has been minimal uptake. The reasons for this are multiple: high capital cost, the reliability of actuators and moving parts, poor control systems and aesthetics.

The proposition explored in our research is that responsive sunscreens will always be more expensive and that to generate more uptake, there is a need to explore ways to add value beyond energy savings. We have identified three ways in which this can occur. First is the potential to provide a finer grained control interface for occupants to enhance individual comfort, which has been shown to improve worker productivity [5]. To achieve this, we argue that the individual building occupant must be part of the control loop, with the capacity to create the micro climate that suits particular tasks and personal preferences. While human factors has been central to product design and human-computer-interfaces, at the scale of public and commercial buildings the capacity for an individual to adjust micro climates has been constrained by centralized control systems. The electric room thermostat was invented in 1883, yet this typically is still the sole means of individual input to building environmental control systems. The enabling of individual control of external sun shading to provide personalized sunlight or shading in work environments provides one opportunity to add value.

The second approach to adding value lies in a parallel field of research, that of media facades at the urban scale. Typically these take the form of media content displayed via LED screens or projection embedded into the surface of a façade. Alternatively, external and internal lighting can be programmed to generate dynamic lighting of buildings and low resolution patterns or information. The agenda for such urban media facades is to facilitate public participation and foster social interactions in urban settings [6]. We propose that if a responsive sun shading system has a high granularity of panels and a control system that allows individual movement of each panel, the façade can be conceived as a low resolution media screen. In daylight conditions, panels can be designed to provide a graduation of shadow, while in overcast or night conditions, embedded lighting can accentuate the individual 'panel-pixels'. This would allow a range of content and use scenarios to be considered. As explored within media facade research these include: public service, news and community media application; public art and urban games content; and the capacity to generate income through advertising.

The third and not the least of the opportunities afforded by a hybrid environmental-media sunscreen system, is the opportunity for a new form of architectural composition. In previous work we have explored in depth the poetic potential for architectural design, based on precedent within kinetic art and thousands of algorithmically generated animations that map the theoretical range of composition for a facade of 400 panels. Analysis of these animations led to the development of 'State Change' - a framework for architectural composition based on morphology of movement, which includes nomenclature for describing the wide variety of design permutations [7]. State Change shifts the focus of composition from the design of a static object to the design

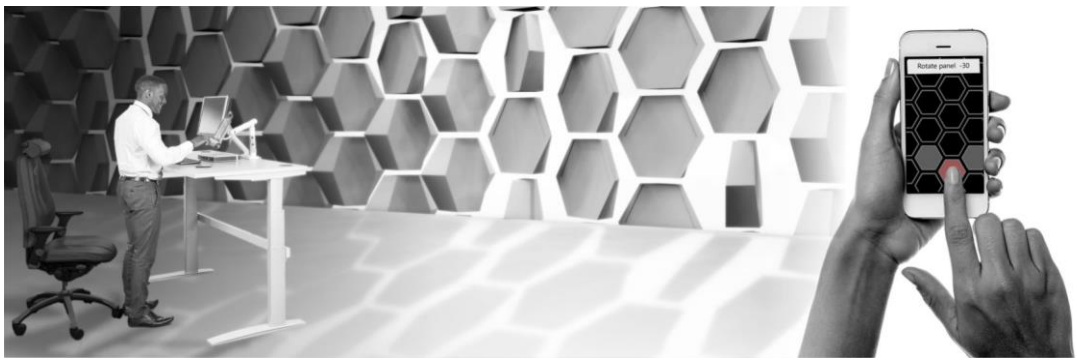

Figure 1: MICRO-ENVIRONMENT CONTROL BALANCED AGAINST FAADE OPTIMIZATION.

of a process, involving the specification of input-control-output systems that results in an aesthetic of "movement itself" [8]. This new movement aesthetic of indeterminate states that coalesce and shift during the daily and seasonal cycles, has the potential to transform facade composition and in the process enliven the public face of architecture.

The added value of these three alternate applications of responsive sunscreens – individual micro climates, media facades and a new form of architectural composition – are illustrated in the following sections to provide the basis for our research agenda on hybrid facades. Following this we report progress on a simulation and a partial working prototype of a hybrid façade system. The article concludes with an outline of further work.

2 Adding value

2.1 Microclimate control

A key issue for the uptake of responsive sun screens is to enable individual users to tune the operation of the screens. This would involve developing control systems that are intelligent enough to balance a percentage of individual settings against daily energy optimization targets. As illustrated in Figure 1, it is envisaged that users would be able to adjust external screens to suit individual preferences for sunlight, daylight and views over the course of the day via a smartphone application. Research is required to model the impact of individual operation on overall building performance to determine the percentage of screens and the time constraints by which individual can opt out of the overall façade optimization.

2.2 Embedded media

If there is sufficient granularity to the façade and individual control of each panel, then images and text can be embedded within the movement of the façade to in effect pro-

Figure 2: MEDIA FAÇADE APPLICATIONS: ART & GAMES; INFORMATION; ADVERTISING.

duce a large scale urban screen. Previous research based on 400 panels in a 4:3 proportion provide sufficient granularity to produce engaging content. This would enable the sun shade system to be repurposed when not required for environmental control. As illustrated below this can facilitate public service and community information, public art projects and urban games, and has the potential to generate advertising revenue. Shadow casting when the screens are in direct sunlight would provide a 'grey scale' reading of content, which could be supplemented by façade lighting during overcast days and at night.

2.3 Architectural composition

We have undertaken a comprehensive study of how a responsive façade can facilitate a new form of architectural composition. Critique of theory and practice in architecture, inspiration from kinetic art of the 1960's and the design parameters of kinetics were examined. From this, animations were generated to explore the theoretical range of this new form of architectural composition. By classifying the animations, a theory of kinetic form 'State Change' was developed. The aesthetic of such facades can be distinguished by a characteristic spatial form or *shape*, and secondly in terms of temporal behavior or *dynamic*. Kinetic shape and dynamic enable the identification of three states – wave, fold, field – and the transitions between these – stratifying, swelling, atomizing, ribboning, aggregation, interweaving [7].

3 Proof of Concept Prototype

3.1 Hardware and software

To evaluate the feasibility of hybrid environmental-media facades, we are developing physical prototypes calibrated to real time visualization and performance simulation. We are using the Unity game engine as the software environment to enable fast pro-

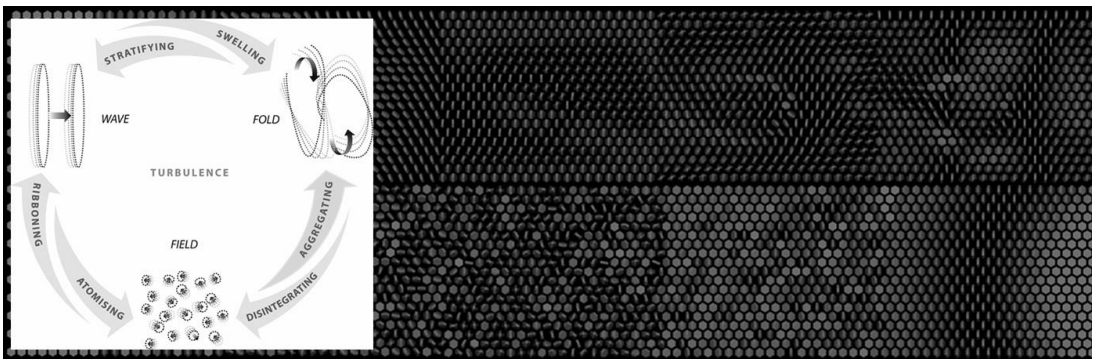

Figure 3: STATE CHANGE: AN AESTHETIC OF MOVEMENT FOR ARCHITECTURAL FACADES.

Figure 4: CONTROL SOFTWARE NETWORKED TO MICROCONTROLLERS AND SERVOS.

totyping and testing of interactive controls. These include an accurate sun tracking system, an image translation utility that maps grey scale value to rotational movement and a smart phone application that enables parts of the facade to be controlled independently (mimicking microclimate control). The software simulation is networked to an Arduino microcontroller that wirelessly communicates to 5 servo controllers we have designed and fabricated, each of which drives 9 servos.

3.2 Panel and actuator development

A physical prototype has been designed that explores the optimal configuration and geometry of the kinetic panels, to enable the granularity required for a range of graphic and textural information. Experiments with configurations demonstrated that rotation within a hexagonal grid provided the best combination of edge detection and contrast between shaded areas (the two factors that affect human perception of movement) [9]. However when shifting from animation to a physical prototype, it became clear that the hexagonal grid was too visually dominant for the hybrid role of media facade. Our design development shifted to refining the geometry of the individual part. The breakthrough in the design iterations was the realization that the depth and shape of the edge provided a subtle deformation of the hexagonal grid when rotated. This

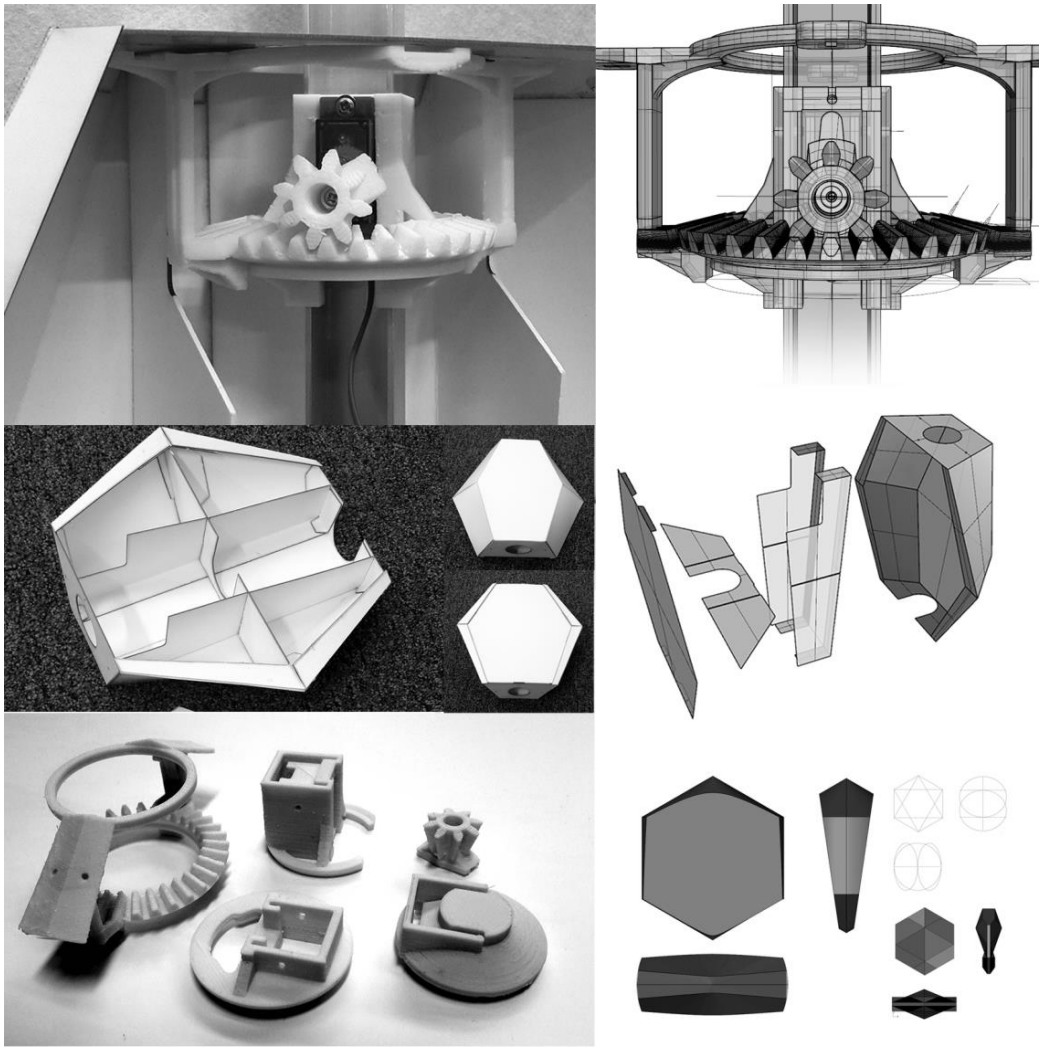

Figure 5: PANEL AND ACTUATOR DRIVE DEVELOPMENT.

had to be balanced against the need to allow light in and views out, which resulted in an asymmetric section with a curvilinear profile to the thickest edge. A key design parameter is the need to provide fine control over rotational speed, which is been explored through a 3D printed gear mechanism incorporated within the panel.

3.3 Calibration of panel with simulation

The physical prototype (45 panels) is been fabricated at the time of writing, after and fine tuning the software controls and the mechanics of the panel. This will enable calibration with superimposed large scale projection as illustrated to provide an interactive proof of concept that we will demonstrate during the conference.

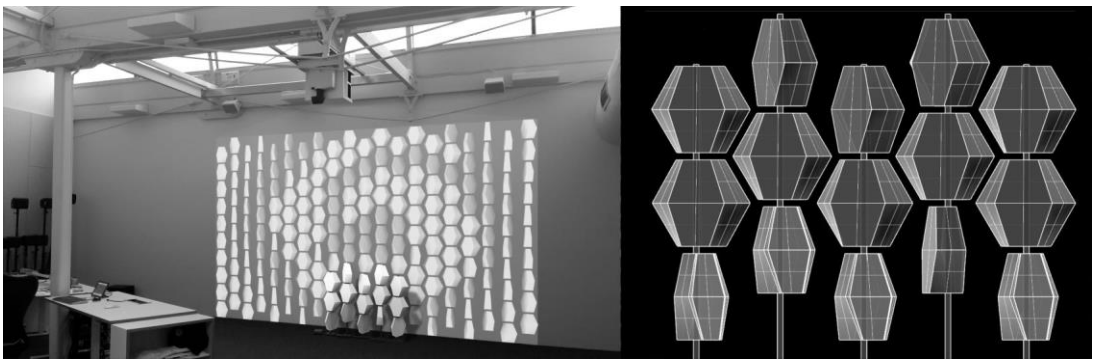

Figure 6: CALIBRATING PROTOTYPE WITH SIMULATION.

4 Further Work

We will refine the software controls, develop alternate panel-actuator designs and calculate energy performance for a range of building configurations [10]. The research will then shift to the design and fabrication of a solar powered autonomous panel, and research and testing of low maintenance actuators. The goal is to demonstrate the potential for a zero energy commercial building and in the process afford added value through micro-environment control, media display and movement aesthetics.

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