Feather-inspired social media data processing for generating developable surfaces: Prototyping an affective architecture

Prototyping an affective architecture

Chenjun Liu¹, Tsung-Hsien Wang², Mark Meagher³, Chengzhi Peng⁴
¹,²,³,⁴ University of Sheffield
¹,²,³,⁴ {cliu57|tsung-hsien.wang|m.meagher|c.peng}@sheffield.ac.uk

This paper presents the development of an interactive installation intended as a prototype of experimental affective architecture connected with social media data processing. Social moods and emotions are now spread more widely and faster than ever before due to pervasive uses of social media platforms. We explore how data processing of users’ expressions and sharing of moods/emotions through social media can become a source of influences on shaping the form and behaviour of interactive architecture. The interactive prototyping method includes (1) a feather-inspired data-to-shape rule system together with the ShapeOp Library for generating strips as developable surfaces, (2) a physical computing platform built with Arduino micro-processor and shape memory alloy springs for actuation, and (3) physical model-making. As a prototype of social media aware affective architecture, an interactive installation design is proposed for a campus space where the actuation of the strip installation is linked to data processing of Twitter messages collated from users on campus. We reflect on the prototyping methodology and the implications of an architecture affected by people’s expression of moods/emotions through social media.

Keywords: social media data processing, developable surfaces, interactive prototyping, shape memory alloy, elastic morphing, ShapeOp

INTRODUCTION
Natural feathers found in birds are made with components of different forms and functions (Lovette and Fitzpatrick, 2016). In Plumology, the side branches of a feather vane are called barbs and are linked together by two types of microscopic filaments called barbules and hooklets. The upper barbules contain a series of hooklets catching the lower barbules of neighbouring barbs along the feather shaft. The barbs and barbules form strong flexible surfaces with the interlocking linkages, without which the barbs or hooklets may become separated from each other, losing their integrity. Feathers comprised of barbules and hooklets are termed “pennaceous”. Feather-
ers without barbules and hooklets, such as down feathers, are called “plumaceous”, which form layers of insulation next to the skin, trapping air to protect the bird from heat and cold. We observe in bird’s feathers that the existence of an element in the microscopic scale can control the form and function of an element in the macroscopic scale. In this paper, we present some rules derived from the organization of bird’s feathers and demonstrate how these pattern-forming rules can be applied to social media data processing that drives morphological transformation of datascapes into developable surfaces.

From the rule of the arrangement inside feather branches, the control points of the vane can be parametrically modelled as key points in the model space, mimicking the hooklets structure of feather. We then have a shape/form that can be transformed by these control points. The concept of ‘control points’ taken from the micro-structure of the single feathers is the barbs in the connection parts between barbules, which also control the density and morphology of entire single feathers because of its location and density. In our preliminary computational design experiment, a 2D grid is used to construct lines and intersections, and then set the number of the intersections and layout to control the density of lines. In this case, the 2D grid of different versions are applied with forces in Rhino-Grasshopper (Figure 1).

Extended to 3D modelling, triangles are introduced. The triangle allows changing the control points from (a) controlling two lines to (b) three control points controlling multiple lines, with reference to the stereoscopic model of feathers (Figure 2). In so doing, we see more changes and possibilities. In addition, the stability of the triangle is also used to make the model stay unchanged when the relative distance between the control points is fixed. Because a triangle may share an edge with another triangle in a solid space, the model of a triangular prism can be grown into a triangular polyhedral structure.

**SOCIAL MEDIA AND AFFECTIVE ARCHITECTURE**

The rapid rises of social media platforms and smartphone technologies have brought unprecedented changes in communication and information production/consumption. Contemporary uses of mass social media have also evidently affected how architecture is designed, reported, experienced, evaluated, and serviced (Hussien, 2014). We can argue that aspects of (re-)imagination, conception, construction and operation of architecture are increasingly conditioned by social media. The Rotterdam-based practice MVRDV is one of the forerunners of tapping into the potential of planning and design with social data. Indeed, “Datascapes” is identified as one of the key elements of their design philosophy (MVRDV, no date). As more sophisticated models and processing (min-
Twitter API objects value and its conditional relationship

<table>
<thead>
<tr>
<th>DATA VALUE</th>
<th>DESCRIPTION</th>
<th>TYPE</th>
<th>RELATIONSHIP</th>
<th>CONDITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>created_at (time)</td>
<td>The UTC datetime that the user account was created on Twitter.</td>
<td>String</td>
<td>Time</td>
<td>Range / Length</td>
</tr>
<tr>
<td>text</td>
<td>The actual UTF-8 text of the status update.</td>
<td>String</td>
<td>Characteristic</td>
<td>Keyword</td>
</tr>
<tr>
<td>protected</td>
<td>Protected Tweets may only be visible to your Twitter followers.User will receive a request when new people want to follow.</td>
<td>Boolean</td>
<td>Privacy</td>
<td>Boolean</td>
</tr>
<tr>
<td>followers_count</td>
<td>The number of followers this account currently has.</td>
<td>Int</td>
<td>Activity level</td>
<td>Amount</td>
</tr>
<tr>
<td>verified</td>
<td>When true, indicates that the user has a verified account.</td>
<td>Boolean</td>
<td>Safety</td>
<td>Boolean</td>
</tr>
<tr>
<td>friends_count</td>
<td>The number of users this account is following.</td>
<td>Int</td>
<td>Activity level</td>
<td>Amount</td>
</tr>
<tr>
<td>listed_count</td>
<td>The number of public lists that this user is a member of.</td>
<td>Int</td>
<td>Activity level</td>
<td>Publicity</td>
</tr>
<tr>
<td>coordinates</td>
<td>Represents the geographic location of this Tweet as reported by the user or client application. The inner coordinates array is formatted as geoJSON (longitude,latitude).</td>
<td>Coordinates</td>
<td>Density</td>
<td>Location/Range</td>
</tr>
<tr>
<td>hashtags</td>
<td>Represents hashtags which have been parsed out of the Tweet text.</td>
<td>Array of Object</td>
<td>Characteristic</td>
<td>Keyword/Boolean</td>
</tr>
<tr>
<td>lang/language</td>
<td>The BCP 47 code for the user’s self-declared user interface language.</td>
<td>String</td>
<td>Characteristic</td>
<td>Keyword/Boolean</td>
</tr>
<tr>
<td>favourites_count</td>
<td>The number of Tweets this user has liked in the account’s lifetime.</td>
<td>Int</td>
<td>Activity level</td>
<td>Amount</td>
</tr>
<tr>
<td>statuses_count</td>
<td>The number of Tweets (including retweets) issued by the user.</td>
<td>Int</td>
<td>Activity level</td>
<td>Amount</td>
</tr>
<tr>
<td>place_type</td>
<td>The type of location represented by this place.</td>
<td>String</td>
<td>Function</td>
<td>Keyword</td>
</tr>
<tr>
<td>withheld_scope</td>
<td>When present, indicates whether the content being withheld is the “status” or a “user.”</td>
<td>String</td>
<td>Privacy</td>
<td>Boolean</td>
</tr>
<tr>
<td>filter_level</td>
<td>Indicates the maximum value of the filter_level parameter which may be used and still stream this Tweet. So a value of noFilter will be streamed on none, T1w, and T2w streams.</td>
<td>String</td>
<td>Interactive Level</td>
<td>Boolean</td>
</tr>
<tr>
<td>retweet_count</td>
<td>The number of times this tweet had been retweeted at the time the tweet was harvested.</td>
<td>Int</td>
<td>Interactive Level</td>
<td>Amount</td>
</tr>
</tbody>
</table>

Figure 3
Twitter API objects value and its conditional relationship

Figure 4
The system diagram of ‘data-to-shape’ process

Methods are being developed and applied to social media data (in particular, to location-aware social media), we propose a definition of social media conditioned affective architecture—the performativity of an architecture that is intrinsically linked to the fluxes of social media data analytics reflecting social moods/emotions in real-time. Social media conditioned affective architecture can be as large as a city or as small as a bench in a neighborhood park. The temporal dimension of the conditioning (sustained linking) can also be varying - from seconds to decades. The manifestation of such architecture can be virtual, physical, or overlay of virtual and physical.

The complex social networks define our experience of the urban environment in addition to the physical architecture (Christian and Liang, 2011). Its framework represents the macro- and micro-simulation of social data through different locative data analyses. The foreground displays classified characteristic information at a local level, while the timer contexts provides the other dimensional comparison. Social data status can explore the immersive space that may respond to or contradict the physical architecture, even allows for the real-time streaming data analysis (Christian and Liang, 2011).
The freeform surface will transform to the shape of hills and valleys under the feather-inspired rule which represent the areas with high or low densities or other characteristics of social data as it be accrued. The outcome will be on a coordinates surface reflecting space attributes and activity over time (Christian and Liang, 2011).

According to the Twitter streaming connection process diagram, it receives streamed Tweets as they occur, performs processing and stores results, which means that we can collect real-time space users’ characteristic, or we can store it over a specific period of time to conduct a cumulative study of a space through time.

In the proposed ‘data-to-shape’ process (Figure 4), we use 3 elements—amount, keywords, Boolean as the data characteristic to classify its coordinates, and input it to the other control condition—time to define the location in the period of time. Therefore, a virtual space can be shaped to show its interactive level or other characteristic in a period of time or act as a movable shape related to its real-time data.

**FEATHER-INSPIRED TWITTER (FIT) DATA PROCESSING**

Following the SMCA proposition, we explore how Twitter data can be processed to produce ‘datscapes’ through the feather-inspired modelling method presented in Section 2. In general, social media data can be modelled through characteristic data points with multi-factor controls. An intermediate method is required if the interest is to generate 3D form from 1D or 2D data points (sets) as in the case of typical Twitter data. We explore such a transformation rule mimicking the micro-organization of bird’s feathers: the generative interlocking structure with a varying density which could allow changes in the control points in response to a changing environment.

We tested one type of spindle control points leading to stepwise progressive solutions, but they also correspond to each other. The design challenge here is how to extract the key elements from the natural feather-form studied and how they might be converted to 3D models. A Python script was developed to extract Twitter data (tweepy) into Excel, and then into Rhino-Grasshopper, turning the coordinate data into x, y. In our project, tweepy contains user geo location, user gender, keywords, mood, and other characteristics data. These features also provide the basis to determine the attributes and control levels of the control points (Figure 5). We also used other characteristics data as inputs to different control point levels, so linking the model to the Tweeter data feed. In doing so, we can have different states of control points: controlled, random, semi-random and other states. Triangles are used to connect the

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Figure 5
Processing Twitter sample data with a feather-inspired pattern generation system
Figure 6
Space forming in the same place defined by different time zones and characteristics

X and Y axes, and they are stretched with Kangaroo, so that the user location density is reflected on the Z axis.

The trend of these points suggest an axis as the main control line, and the intersection points on both planes which are found on the main control axis. The triangle network is to play as the second level of control points, so these will be like a feather main branch. Location data can also be used to control the form of dependent variables filtered by gender or a selected keyword which would be more like the organizational form of ‘down feathers’ that lack of balanced control, leading to a uncontrollable or free form. Through these processes on transforming, it will show the different virtual spaces which is depends on different time zones and characteristics (Figure 6). It can help us understand the situation of existing building and benefit to create a new way to design or upgrade architecture.

Figure 7
Virtual Strip surfaces related to the social moods data on site

PROTOTYPING AN INTERACTIVE INSTALLATION AS AFFECTIVE ARCHITECTURE

We applied the feather-inspired social media data processing to a studio design project that aims to produce a prototype of an urban transformable furniture for a University campus site. Sampled Twitter data was used to generate the initial 3D form which was inserted into the site. We are exploring two possibilities: (1) Augmented Reality Furniture (AR-F) exists in an augmented reality application (Figure 7); and (2) Real World Furniture (RW-F) to be realized in the real physical world (Figure 8).

STRIP AS A DEVELOPABLE SURFACE

Our RW-F scenario suggests a strip-based architecture that flows through the spatial-user context as a bench-shelter-pavilion installation. By modeling the strip, we could develop the surface elements

BIOMIMICRY - Volume 1 - eCAADe 35 | 185
into ‘controllable’ and ‘uncontrollable’ panels. The ground-up portion of the furniture body is controlled in accordance with a specific function, such as a seat changed by the shape of the human body, while the sky-down portion can be perceived to change in accordance with the pedestrian flow which the installation has no control. Modern architecture employs different kinds of geometric primitives when segmenting a freeform shape into simple parts for the purpose of building fabrication and construction. (Pottmann et al., 2008). The next stage of this project is to approximate the initial conceptual surface into discrete fabricable strips—namely single curved developable surfaces.

We use ShapeOp (Deuss et al., 2015) for shape rationalization and consider constraints such as mesh face planarity, vertex closeness and Laplacian fairing to explore the final output. The relationship between each group of points is controlled by a series type of constraints like the rule of the FIT-processed pattern. We then tried different combination of these constrains to explore a suitable shape optimization on the freeform strip surfaces, leading to developable surfaces that can be digitally fabricated.

**GEOMETRIC DISCRETIZATION OF FREEFORM STRIPS**

A simple definition of a developable surface is a surface can be flattened onto a plane without distortion. We use the quad-dominant with planar faces under the feather-inspired pattern to produce a developable strip surfaces. D-strip models as semi-discrete surfaces can be applied to form PQ meshes (i.e., Quad meshes with planar faces) (Liu et al., 2006): the intersection of the row and column polygons produces a smooth curve network that leads the entire mesh converge to a D-strip surface. It is also shown that a semi-discrete representation of a series of conjugate curve network in a surface can provide a computational model to the fabrication of strip surfaces (Pottmann et al., 2008). We use ShapeOp to reconstruct the FIT-generated freeform surface such that each face of the quad-mesh is driven to be planar us-
ing the plane constraint, satisfying the semi-discrete rule as limits of discrete models (Figure 9). And another constraint is the closeness constraint that constraints each vertex to its initial position to maintain the shape of the mesh (Deuss et al., 2015).

**ACTUATION OF INTERACTIVE STRIPS BY SHAPE MEMORY ALLOYS**

Apart from being a developable surface, the strips in our prototyping installation design need to be actuated through social media data processing. The generic Feather-inspired Twitter (FIT) morphing system contains four stages: collection, molding, analysis and actuation (Figure 10).

It is connected by social data route under the feather-inspired rule and performs automatically to reveal the relationship between space/location and social elements (i.e., words expressing moods/emootions). The collection stage is operated using real-time tweedy streaming Python code on the Jupiter-Notebook platform presented in Section 2. And the molding step which transforms the data list to strip surfaces under the feather-inspired principle in Rhino-Grasshopper is presented in Section 3. The step of conditional statement for the stage of anal-
Figure 13
Form property of SMA is stretchable by applied force related to data type

Figure 14
3-Pins controllable simulation unit framework

Figure 15
Deformation of SMA springs occurred when heated by different electric ending stimuli
ysis (Figure 11) is organized in Rhino-Grasshopper by the conditional code using Python script. After the step of conditional choose (Figure 11), the output data list will be send to the “Uno Write” component of Grasshopper-Firefly, and then upload to the Arduino board from computer through the Firefly code in Arduino.

![Interactive strips controlled by an array of SMA springs](image1)

The actuation system of conditional controllable circuit consists of two parts - external power system and Arduino conditional control system (Figure 12), connected by a multiply-relay. In the external power system, the power is come from alternating current transformer. Then the power is separated to multiply current routes to transform again by regulators to reach the needed current that leads to thermal effect of electric current. In this step, we can control the parameter of regulator to control the current which leads to different levels on actuation and kinetic transformation. Next, we input the multiply current into multiply relays to make the choices which pin it would be lead to (T/F, G is ground) (Figure 12). In the Arduino conditional control system, we input the social data from excel file into grasshopper, and write the conditional code to make choices automatically transforming the characteristic data to True (T) or False (F) signal, then upload these signals to Arduino Board through FireFly (Figure 13). Finally, we connect the Arduino Board to the multiply-relay that send these T/F signals to the Decision maker. Therefore, the multiply current could controlled by these multiply characteristic data, then flow the shape of shape memory alloy and developable strip surfaces (Figure 14).

For the actuation morphing module, we use shape memory alloy (SMA) as the main deformation material. They are usually shaped as wires or springs that could return to ‘memorised’ states when they are heated over the ‘transform’ temperature (60°C) (Figure 15). When programmed, the SMA-driven actuation system can pull the strip surfaces up or down. The thermal effect of the electric current offers the needed ‘transform’ temperature on the SMA components. We use 5V for a 3A current to heat the SMA springs to trigger elastic morphing lasting about 7-8 seconds. Figure 16 shows the use of regulators to control the ampere of current flow through a series of SMA springs. This process performs a dynamic range such that the SMA spring wires expand and contract in line with social data flows (Figure 17). Therefore, the SMA-based actuation design aims to perform in the prototype simulation for reliability, flexible and safety (Khoo et al., 2011).
CONCLUSION AND FUTURE WORK

In this study we use public social media data to generate dynamic architectural form and behaviour as manifested in prototyping an interactive installation design. The social media data processing produces inputs to a feather-inspired form generation system which in turn generates freeform strips. We employ the ShapeOp Library to transform the freeform strips into developable surfaces such that they can be digitally fabricated. Movements of the developable strips can be actuated with a Shape Memory Alloy (SMA) driven kinetic framework. We close the loop by linking the social media data processing to the actuation control mechanism implemented on the SMA framework. The outcome from this study suggests a new proposition of affective architecture - an architecture capable of being affected by the moods/emotions expressed among social media users who also share relational experiences with that architecture. The implication is that future architecture can perhaps become more reflective of users’ social awareness or consciousness of state of affairs or conditions such as well-being or sustainability. It will be no longer a person sitting in the control room who manages the building, but those living in the building or walking in the city, who use social media to show their moods, emotions and other things.

Architecture has always been an important boundary to define space. With the development of information technology, people develop virtual social boundaries with reference to physical spaces, and also endow the original space with a rich array of spatial attributes. Our digital design experiment explores new possibilities for social media data processing for form and behaviour finding. A series of design tasks were carried out using various technologies of collecting and analyzing social media data, 3D modelling under a new rule-based system, conditional scripting and electrical morphing module making. The design experiment also points to possibilities of future buildings built with an elastic morphing module plugged into to social media networks for occupants to change the space they live in. Future work will include further experiments to test the real-time morphing module using live social media data feed as a site-specific development.

REFERENCES


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