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MAPPING RESPONSIVE ENVELOPES

Material culture evolution and climatically responsive building facades



Sean Cullen
Queen's University Belfast, School of Natural and Built Environment
scullen05@qub.ac.uk



Professor Greg Keeffe
Queen's University Belfast, School of Natural and Built Environment
g.keeffe@qub.ac.uk



Dr Oliver Kinnane
Queen's University Belfast, School of Natural and Built Environment
o.kinnane@qub.ac.uk

ABSTRACT

This research paper proposes the transfer of biological evolutionary methods to the field of climatically responsive building facades. Through charting their trajectories and situating them across the physical and biological sciences, the paper will explore knowledge transfer, historical flows and the fate of information from a sustainable perspective.

Despite similarities to biological evolutionary processes, the application of biological methods does not directly correlate to responsive building facades. Through a database of precedents and projects, a hybridized method of mapping will be developed as a means towards understanding the genus of ideas, mutation, and selection within this process so as to establish to what degree it is similar to that of biological systems as well as Gould and Eldredge's (1972) theory of 'punctuated equilibrium'. 'Punctuated equilibrium' states that evolution within biological systems occurs in short, sharp bursts after long periods of inactivity, contradicting orthodoxy of evolution as a slow, gradual process. This theory proves correct for climatically responsive facades due to the convergence of technology with cultural awareness for environmentally conscious architecture. Temkin and Eldredge (2007), in their application of phylogenetic analysis on musical instruments, identified lateral exchange of information as the most significant factor in material culture systems.

Through developing a hybridized map of climatically responsive facades, this research will indicate characteristics, ideas, and historical flows of information as well as their subsequent fate. Within material culture there is considerable conservatism, pointing to selection by designers and manufacturers as an inhibitor of evolution. As a result, this process identifies new architectural connections and areas of focus where distinct innovation may occur.

KEYWORDS

History of facades; façade theory; material culture evolution; climatically adaptive; future trends; innovation

INTRODUCTION

Climatically responsive building facades have been well documented in recent years due to the emergence of design consciousness towards energy efficient architecture. Most sources catalogue projects according to their location, climate, or typology, like *Kinetic Architecture: Designs for Active Envelopes* by Russell Fortmeyer. However, none aims to establish their evolution or the impact of other industries on their form and function through the consideration of principles, techniques, objectives, and technologies. By defining these projects as 'material culture artifacts' and placing them in a wider context, their evolution can be charted. Material culture evolution refers to the study of tracing changes in physical form, the transmission of information, and the 'descent of modification' of cultural artifacts, or objects, over a period of time (Lycett, 2015). The process by which the evolution of climatically responsive facades is mapped will offer an insight into how designers and manufacturers borrow, share, and innovate in the digital age, with the hope of highlighting common ideas, themes, and concepts as well as patterns of innovation. Designers and makers must be aware of this network of information transmission in order to truly assess the value of current orthodoxy. In material culture, the danger exists whereby flawed concepts continue to be reproduced because of human presence within the system, despite how marketplace economics may limit the threat. In researching such evolutionary trends, and by identifying horizontal and vertical transmissions of knowledge, we become aware of the significance of inheritance in creative genius and ideas, which, according to some research, creates stability and conservatism in design and manufacturing. Through an overview of material culture theory, evaluating its application to contemporary, climatically responsive facades and applying a hybridized method of mapping knowledge transfer, historical flows, and the fate of information, it hopes to offer designers and makers a broad overview of this network which could lead to new and broader innovation.

BACKGROUND

The application of phylogenetic analysis to material culture artifacts has become a common theme in recent years with the aim of identifying cultural transmission and knowledge transfer. Phylogenetic analysis is the reconstruction of evolutionary history which studies the patterns of relationships in physical and genetic characteristics between organisms, generally conveyed through evolutionary trees. Previous attempts to apply this area of study to material artifacts have included cornets and Baltic psalteries (Temkin & Eldredge, 2007), ornament patterns of Turkmen textiles, (Tehrani & Collard, 2002) and skateboards (Prentiss et al., 2011) where a cultural transmission thrives. As a result of this work, key similarities and differences between material culture evolution and biological evolution have been highlighted. One of the most interesting similarities, first noted in biological systems by Eldredge and Gould (1972), explains why biological systems, and later material artifacts, experience rapid changes and development followed by long periods of dormancy and stagnation. 'Punctuated equilibrium' proposed that evolution is not a gradual process, but one which occurs in short, sharp bursts of rapid change. Despite this, obvious differences occur. Within the biological realm, lineage occurs, creating "vertical transmission of genetically-ensconced information (meaning parent to offspring)" (Temkin & Eldredge, 2007). For this reason, mapping of biological lineages develops a neatness and compartmentalization. Evolution takes place in a restricted framework dependent on adaptation and mutation if organisms are to survive in the fight for resources. In contrast, material culture artifacts can be described as networks which link historical information while indicating idea theft, 'directed variation', 'selection' and horizontal transmission of knowledge (Barnet, 2004). Arguably, these are the most important dynamics within material culture systems because networks proliferate as knowledge and technological transfer from outside industries increases. Vital to this process is the human presence – a maker or designer.

Identification of these dynamics in material culture evolution primarily considers morphology of the 'artifact' or object, as seen in the indicated studies, despite human presence within the system, which plays a critical factor. At the heart of conscious design is what Eldredge refers to as 'directed variation' (Wertheim, 2004). The maker mimics concepts, components or models because of their perceived benefits, either in manufacturing or in performance. Despite this, there is still an evident conservatism within material culture artifacts even though no genetic constraints exist. 'Selection' is the reason for this and it exists for two reasons. The role of manufacturers accounts for the first. As makers, they are aware of all possibilities within the design framework but the expense of resources to manufacture – tooling and machinery for example – restricts the design scope to a selected number, primarily based on marketability and demand. Within this framework of manufacturing and selling, as Eldredge explains, the design, or 'type', remains fundamentally similar throughout time and individual exemplars, or 'tokens', "are more-or-less faithfully rendered versions of the types" (Barnet, 2004). The second form of 'selection' is due to the demand by clients for the same 'model/type' as others while demanding uniformity and consistency in product quality and price. These restrictions in production and fabrication result in limited variation of the artifact when considering its morphology. In contrast, understanding the network of social interaction and learning provides insight into why conservatism exists in human-made objects.

The dynamics of human makers are identified as social learning mechanisms, which foster and enhance horizontal knowledge transfer, as well as 'idea theft'. Social learning can be defined as "learning that is influenced by observation of, or interaction with, another animal or its products" (Heyes, 1994). Lycett (2015) labels social learning as an umbrella term for various mechanisms through which information is inherited or shared amongst individuals. Such mechanisms can range in complexity but are generally defined by four distinct characteristics: stimulus enhancement, emulation, imitation, and teaching (Lycett, 2015). Stimulus enhancement refers to the effect one individual has on another's behavior through exposure to a particular stimulus. This takes place either through the process of making or with the material itself, not with the aim to directly copy, but to enforce behavioral adjustments (Heyes, 1994; Lycett, 2015). Emulation, as Lycett defines it, is similar to Eldredge's term 'selection'. It refers to copying of objects formed by an individual without replicating the demonstrator's exact actions. Within the field of climatically responsive facades, this form of social learning is observed in the proliferation of shading devices through simple vertical elements copied globally, without applying the exact same mechanisms. Imitation differs from emulation as it is the 'direct copying of the precise actions of a demonstrator which could bring about the same effects or results (Lycett, 2015; Whiten et al., 2004). Architecture has been a very specific focus of material culture studies because it is rooted in location and context. It is a work of art as well as a device or machine, which adds layers of complexity. "It is both a work of art and a tool for living, combining aesthetic with utilitarian drives at a variety of conceptual levels" (Prown, 1982). All these conditions, particularly since the development of digital technologies and communications, have made social learning easier and more accessible. As a result, these mechanisms generate a significant network of information and knowledge sharing, far more complex than biological systems.

METHOD

The consequence of this complexity requires a hybridized method of analysis and interpretation when mapping contemporary responsive building envelopes by establishing a data sample of real buildings, research prototypes, and speculative designs. A descriptive process of each project was then undertaken and finally mapped through cladistic and phenetic interfaces. Firstly, this paper considers contemporary, climatically responsive facades as a starting point, but is not limited to this, and in some cases encompasses the holistic, broader interpretation of the term responsive, including media facades. A database of projects (Fig.1) was established which offers varying project 'types' in order to portray a cross-section of designs, from Jean Nouvelle's Arab Institute (9), built in Paris in 1987, to concepts, like Building Integrated Concentrating Solar Façade (44) by Centre for Architecture, Science and Ecology (CASE). As a result, the examples have been exposed to varying degrees of holistic architectural application, which include client approval, budgets and schedules.

Subsequently, the database underwent an objective analysis based on three stages - description, deduction, and speculation (Prown, 1982). All steps are vital in ensuring the perspectives and experiences of the investigator do not distort the analysis of the artifact. The description records the object itself through internal evidence – drawings, images, and models – to highlight dimensions and materiality for example. Deduction allows the investigator to engage intellectually and sensorily as well as determining an emotional response to each of the projects. Here, some allowance for interpretation exists as it contributes to alternative approaches to understanding a very specific field and set of artifacts. Speculation allows for the formulation of hypotheses aimed at exposing effects noted by the investigator. It also accommodates a 'program of research', which exposes external data and information. External evidence supports findings and allows for a continual readjustment of hypotheses and ideas, discussed through the findings. The output of these stages (Fig.1) notes the projects according to object (A), purpose (B), aim (C), technique (D), and movement (E) pattern. Unlike biological systems, which use analytics of DNA, presenting black and white information, design relies on interpretation and inference on the part of the observer. Drawings, patents and images infer connections in idea genus while designers and makers indicate human and social relationships, which affect 'selection' and social learning mechanisms as discussed earlier. The method required the development of unique approaches to 'historical interfaces' when considering the evolution of climatically responsive facades. In order to visualize the fate of information and knowledge transfer in the design of contemporary, climatically responsive facades, phyletic interfaces were used as a basis to develop two alternate network maps. Simple phyletic methods - branch structures - were used, namely phenetic and cladistics approaches, in order to initiate the mapping process. Phenetics attempts to classify organisms based on their similarities and differences without regard for evolutionary relationships. This involves the description of the organisms, qualitatively and quantitatively, the evaluation of their similarity, and the identification of clusters. Morphological similarities generate groups of organisms that form a network of relationships but do not necessarily share the same evolutionary histories (Fig. 2). On the other hand, cladistics can be defined as the study of pathways of evolution. The network created expresses ancestor-descendant relationships, which exemplifies evolutionary modifications over time. Cladistic mapping used a smaller sample set, indicated by dots (Fig. 1), and demonstrates interconnection of concepts, ideas and knowledge from one project to another over time (Fig. 3).

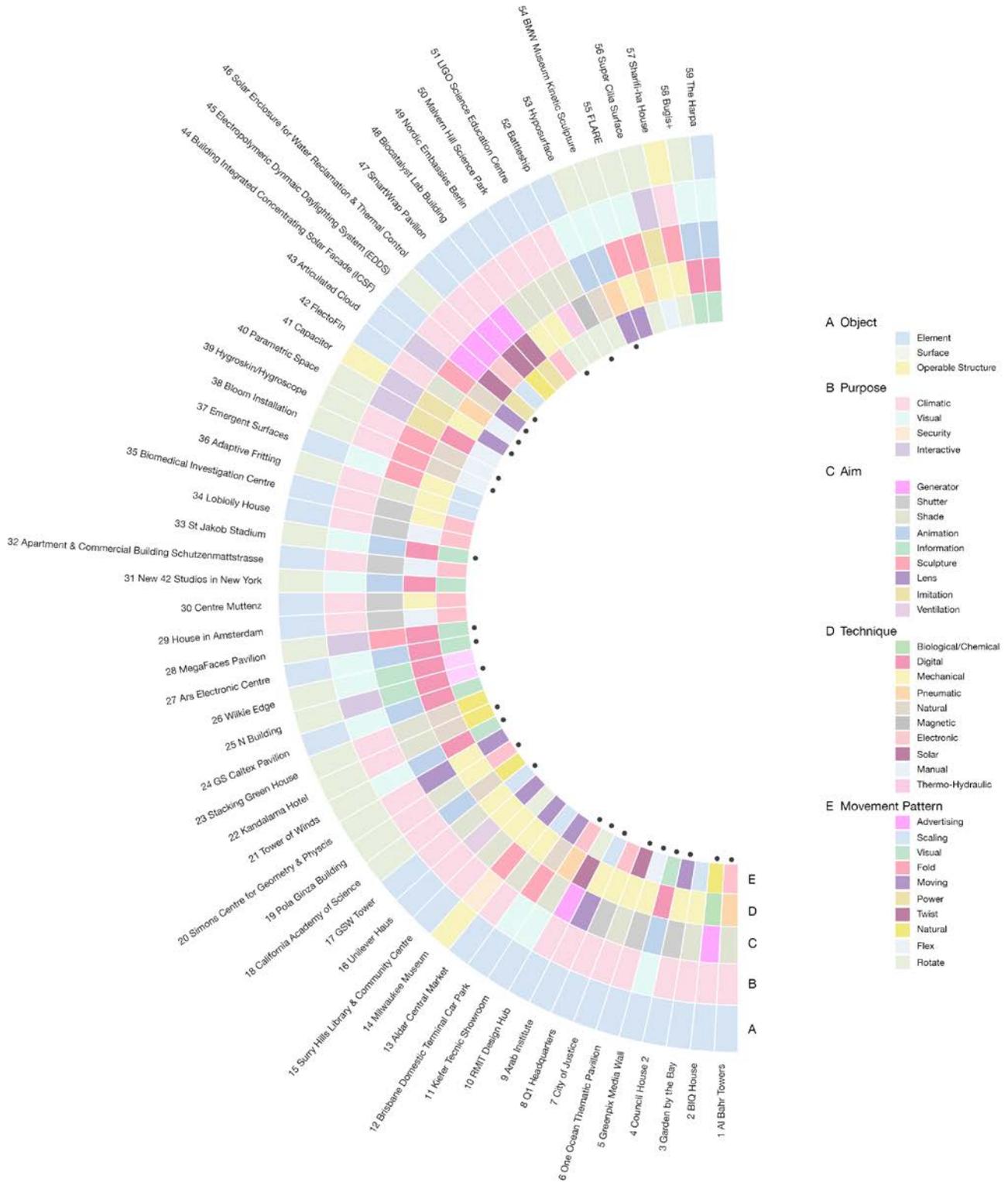


Figure 1: List of projects, precedents and prototypes used in this paper to track responsive façade design. Each was analyzed within the categories listed.

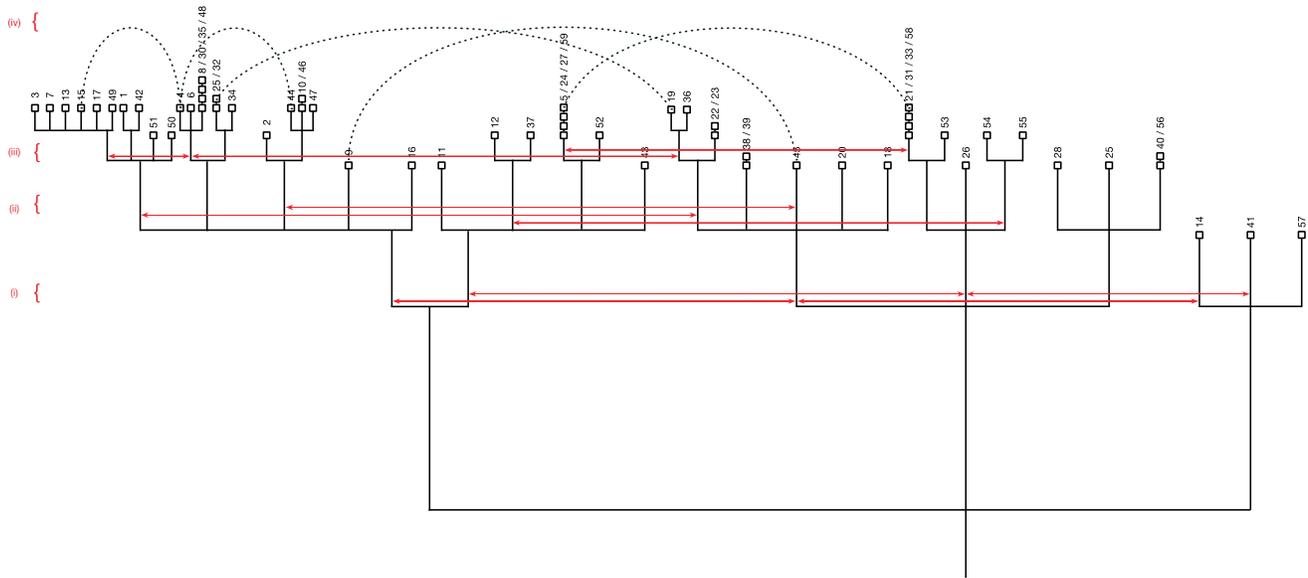


Figure 2: Interface based on a phenetic approach. Numbers correspond to projects as listed (Fig. 1). Red arrows – (i) purpose; (ii) aim; (iii) technique – and arched lines – (iv) movement pattern – indicate characteristic connection. Note groupings of projects that carry identical traits indicating areas ‘selection’ and conservatism.

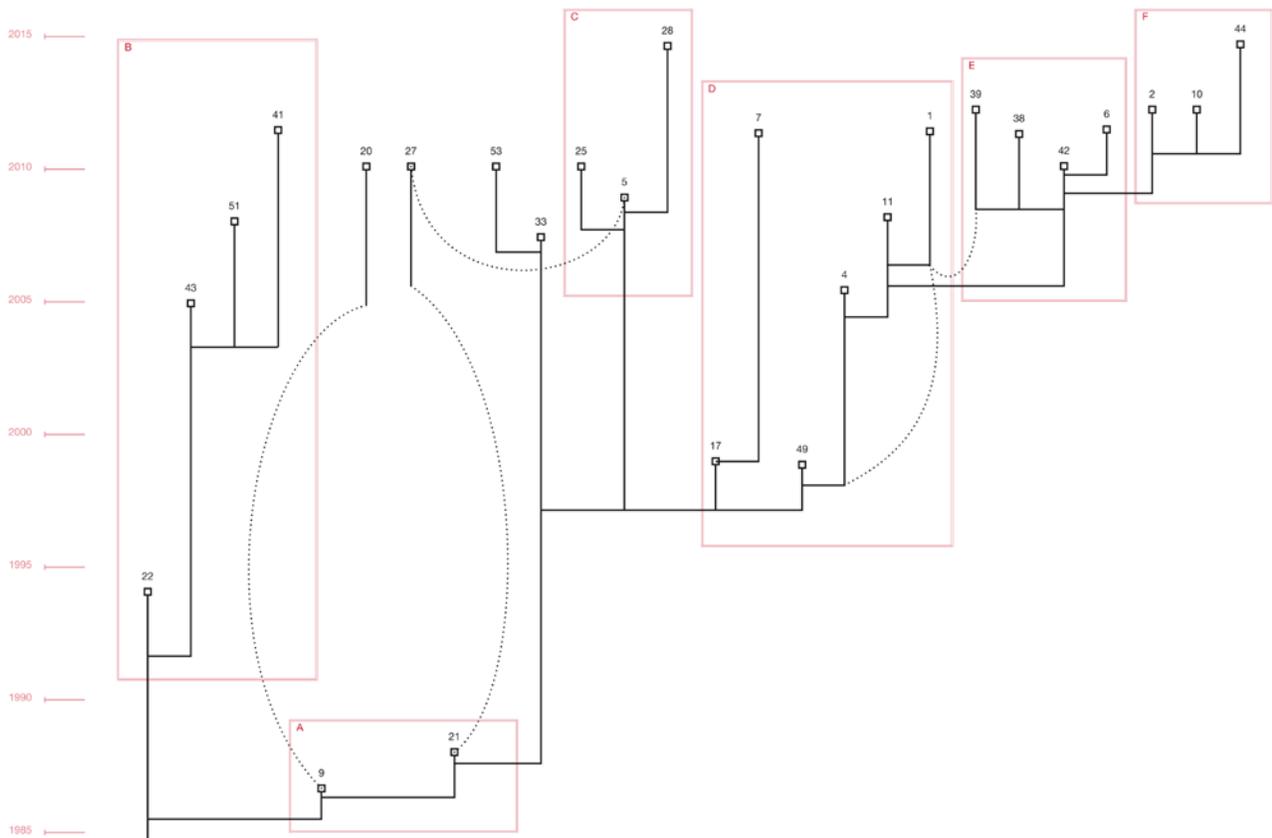


Figure 3: Network map based on cladistics interface of climatically responsive building facades. Numbers correspond to project as listed (Fig. 1). Arched lines indicate transfer of certain technological innovations, tracking the fate of information and knowledge rather than the morphological characteristics of the projects.

FINDINGS & DISCUSSION

The database and network maps identify certain characteristics while highlighting interesting aspects to the form, development, and evolution of responsive facades. The phenetic interface (Fig. 2) does not depict the morphological evolution of a certain model, but instead charts the fate of information and concepts through the development of responsive building facades. It results in projects, which, on the surface, appear completely unrelated but adopt extremely similar design principles. An example of this is the Al Bahr Tower (1), by AEDAS, and FlectoFin (42), by Institute for Building Structures and Structural Design (ITKE), which only vary in the movement pattern applied; all other principles are identical. Projects, which do appear similar, result in close proximity. Of particular note is Bloom Installation (38), by DO|SU Architects, and Hygroscope/Hygroskin (39), by Institute for Computational Design (ICD). In both cases they use material responses to climatic conditions to open and close, allowing light and ventilation. Interestingly, a number of clusters of projects occur while there is significant sharing of characteristics, despite vastly differing morphologies as indicated through various parameters shown by the red arrows - purpose (i), aim (ii), technique (iii) – and arched lines – movement pattern (iv). In contrast, the cladistics interface traces projects over time and is ancestor dependent. This is because of the obvious social learning mechanisms at work, which allows for idea theft, imitation and emulation to occur. The structure reflects ‘areas’ of conceptual understanding and implementation, identified as: (A) pioneers; (B) interpretation of nature’s role; (C) interpretation of digital and media; (D) climatic control; (E) methodological impact; and, (F) façade as producer. Arched lines indicate non-vertical instances of information transfer.

The application of material culture theory to climatically responsive building envelopes supports the concept of ‘punctuated equilibrium’, highlighted by conservatism amongst designers, makers, and clients (Fig. 2) while it also demonstrates areas of conceptual focus, exposing approaches and social networks that have the potential to encourage speciation (Fig. 3). Firstly, it is notable that the concept developed by Eldredge and Gould (1972) of ‘punctuated equilibrium’ is applicable to the case of responsive building facades. Although building facades have always acted in a responsive manner, in recent years, primarily through the rapid development of technology, the field is experiencing a period of sharp, and potentially short, burst of change. The Oil Crisis of the 1970s fostered green, energy efficient building envelopes, driving design and manufacturing towards high performance envelopes, which are intelligent and reactive to weather, climate, and use. In conjunction with the boom of digital technologies, enhanced communications, and fabrication, it has allowed for significant diversity and development in the last 25 years. This is notable in the number of projects that sit alone on strands. Increasingly, however, certain ‘types’ are becoming standard as selection and closer social learning takes place. Multiple projects along a strand indicate such ‘types’, like 8, 30, 35 and 40 representing folded mechanical shutters (Fig. 2). Stagnation and conservatism are becoming more common for various reasons. Increased connectivity through global, digital communications offers leads to more conventional designs representing ‘tokens’ of a ‘type’. The impact of closer social learning mechanisms sees slight iterations of previously established examples because there is demand from clients and it is safe for designers and contractors. As stated previously, clients generally seek products that are similar to others and demand a stable price. Projects, viewed holistically, are ‘tokens’ rather than ‘types’, where branches signify principles and concepts, which are similar, not necessarily morphologically. Therefore, it may lead to the proliferation of ‘poor’ design and idea genus. In traditional material culture artifacts, like the cornet or skateboard, ‘types’ become successful because of marketplace demand, as users appreciate their design and/or cost. This leads to famous or notable models of artifacts. With regard to façade design, ‘types’, which exist at the level of conceptual design and component specification, thrive because of their perceived success and benefits. Double skin facades and kinetic shading devices represent the ‘types’ most prevalent today. Even though some designs appear significantly different, they are merely ‘tokens’ of the ‘type’. At a more detailed level, there is a tendency for designers to select standardized components, which manufacturers produce in high quality and quantity for a considerably lower cost. This leads to vastly differing costs and quality of product and, generally speaking, distinct branching in evolutionary development. However, it is at a conceptual level, and the specific function or aim of climatically responsive facades, where stagnation and stasis occur. The ‘lock-in’ effect limits the choice for designers, manufacturers, and clients due to tooling, resources, and the costs required to break molds. On the other hand, charting these projects in a cladistics process highlights what potential future developments and evolutionary processes that encourage speciation. It allowed projects to be clustered according to similar traits despite varying evolutionary histories. Two distinct clusters are notable, indicating current research focus and drive, which break near-market products and ‘types’; methodological impact (E) and façade as producer (F). Here, conceptual applications to the design of climatically responsive facades are occurring which go beyond responding to marketplace demands – an obvious form of selection. In order to drive advancement of new approaches to climatically responsive architecture, these areas need to be exploited due to their independence from marketplace demands. Each area relies heavily on advanced social learning afforded by global, digital communications.

CONCLUSION

Through the evolutionary mapping process, it is clear that the current development of climatically responsive architecture relies on a global network of designers and makers. Information and design knowledge are shared and borrowed which, in many cases, leads to only slight iterations of an overriding concept or idea, the most obvious of which is the moveable, mechanical solar shade and the double skin façade. As a result, these concepts have created major stability and conservatism in the field. This is due to what could be considered the 'lock-in' effect, seen in various global technologies and industries, a good example of which is the car. Driven by market forces, manufacturers and designers focus on certain processes in design and production in order to function profitably – a 'selection' which inhibits innovation. Currently, major innovation occurs in research institutes, where focus is on the development of specific prototypes, technologies, and/or methodologies rather than considering a holistic view of the field, which includes marketability and wholesale manufacturing. These organizations, including CASE, ICD, ITKE and Hoberman Associates, utilize revolutionary design methodologies and manufacturing techniques. They generally apply the greatest degree of knowledge transfer from other industries but struggle to bridge the gap to full-scale application, due to economic costs, or undergo the rigor of holistic architectural application – including budgets, schedules, and building codes. However, this exemplifies the extreme potential for advancement in the evolutionary process as the use of design ideas, methodologies, and technologies from alternate industries allows for rapid change, dynamism, and, key to climatically intelligent architecture, speciation.

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