

Between Thermal Efficiency and Formal Expression: Tropism as a Method for Layering Control in Generative Design

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ABSTRACT

The definition of architectonic features often requires negotiation between diverse classes of design conditions merging in particular elements. The use of encompassing concepts opens possible approaches for layering control between these assorted factors. This study presents a method for the implementation of tropism as a conceptual gathering procedure in social housing windows definition, aiming to enhance the relationship between building and context in terms of spatial comfort and formal expression.

KEYWORDS: tropism, generative architecture, diffusion limited aggregation, rhetorical structure theory, social housing.

Generative Process and Environment

A close relationship between environmental conditions and the development practices of a culture is a defining factor for the emergence of the rules that ensure the contextual fitness of vernacular architecture (Alexander, 1966, 28-45). However, this close connection is not persistent over time, disrupting a fundamental part of natural evolution of designs and causing the proliferation of inconsistent solutions (Steadman, 1979, 71-98).

In recent decades, with the rise of digital technologies and their potential to recreate complex natural phenomena in virtual space, new possibilities to reinforce this significant bond between artificial space and context became available, opening new prospects for the definition of form using the forces of environment (Lynn, 1999, 9-41).

Explorations with processes extracted from the organic world such as evolution (De Landa, 2002, 9-12), self-organization (Weinstock, 2006, 26-33) and morphogenesis (Roudavski, 2009, 345-374) aim to take advantage of the efficient adaptability of organisms towards novel formal definition methodologies. In this context tropism is a behavior that can change the morphological development of an individual in the search for convenience conditions, suggesting possible paths to pursue the persistent need of certain spatial conditions in architecture.

Tropism as an Encompassing Concept

The word tropism is morphologically composed by the lexeme trop- (Greek tropos, “turn; manner”) and the suffix *-ism* (Greek *ismos*, “process”). This behavioral process of turn is defined in botany as “a directional response of a plant’s organ to a directional stimulus of environment, usually through some form of differential growth” (Hart, 1990, 23). But this directional change may not be limited to the natural world, its presence as a concept manifests similes in several other areas such as serial music, geometry, ontology and linguistics. Towards an integration between this vectorial turn and its signification for space traversing, Verstegen established poetical connections between physical and metaphorical movement in animate architecture (Verstegen, 2001, 8-11). These conceptual explorations posit rhetorical signification to previous attempts to define form by the action of environmental forces, establishing possible connections with recent developments in shape generation using energetic-efficiency criteria (Caldas, & Nordford, 2003, 503-515).

After Verstegen’s approach seeking integration between physical and conceptual tropes, for the scope of this study tropism will be understood as the process of turn by which an object gains formal and energetic attitude in its relationship with context.

Tropism Models in Biology and Linguistics

There are a range of models whose aim is to reproduce the development of organisms in space, and to explore the rhetorical organization of discourse; this study will focus on diffusion-limited aggregation (DLA) regarding its ability to reproduce the distributive manifestation of biological tropism in a concrete context, and rhetorical structure theory (RST), an analysis tool aimed to reveal the presence of rhetorical connections as gathering properties between the elements of a major compound.

Biology: Diffusion-Limited Aggregation

In the natural world, organisms share the distinctive characteristic of having an attitude towards their surroundings. In botany the action of tropism results in a directional response to environmental stimuli such as gravity, sunlight or moisture, which implies a significant contribution to the plant's survival (Hart, 1990).

For the incorporation of biological tropes the proposed method uses DLA, a stochastic model in which several types of tree-like branching structures develop by aggregation of particles diffusing in space due to Brownian movement (Witten & Sander, 1981, 1400-1403). This theory describes the growth and distribution of systems in which particle diffusion is the main developmental strategy, such as corals, mosses and lichens (Fig. 1). Aggregations are formed by the collision of particles floating in space, establishing direct physical relationships between the organism and its surroundings (Pawliczek & Soltys, 2009). With the incorporation of DLA as generative constructor, the proposed method is expected to deliver formations that respond actively to the local conditions of a specific context, prompting direct connections between artificial space and environment.

Linguistics: Rhetorical Structure Theory

A linguistic trope is a rhetorical figure of speech, "a term in rhetoric for expressions with a transferable meaning, which can be understood as a substitute for a denotatively suitable

word" (Bussmann, 1996, 1227). In this sense it is a semantic substitution of the original signification used to persuade the reader/listener. Its main feature is the potential to change language, distorting meaning to produce an impression that a normal phrase cannot.

For analyzing the appearance of linguistic-like trope properties, the proposed method uses RST, a theory aimed to characterize organization and coherence of natural text. RST was proposed in the context of linguistic computer generation to declare the hierarchical order and the nature of the relationships between argumentative blocks (objects) of a given text (context). In general terms, it works by dividing a document into independent meaning components, or text spans, for a posterior identification of the rhetorical relationships between them and the ultimate generation of a tree-like blueprint that denotes the hierarchical organization of the discourse (Fig. 2). The characteristics of the significance bonds between two or more text blocks denotes the specific nature of those connections, making available the identification of rhetorical relationships in the argument (Mann & Thompson, 1987). The proposed method takes advantage of the analytical features of RST, surveying abstract expressiveness characteristics by scanning the directional growth of DLA configurations.

Case Study: Chilean Social Housing

To explore the possibilities of biological and linguistic tropes in a real scenario, they are applied as generative rules for apertures definitions in Chilean social housing, pursuing coherence between their role as spatial quality regulators and formal expression elements.

Chilean social housing is defined by a tightly constrained framework of public-legal regulations (basic standards) and private-economical interests (minimal cost). This scheme produces typologies that traditionally exhibit plain similarities, driven by a constant development of both sides of the problem. Except for some cases, the resulting architecture now distilled in the emergence of a grammar that generates a set of proven solutions over which each architect has limited im-

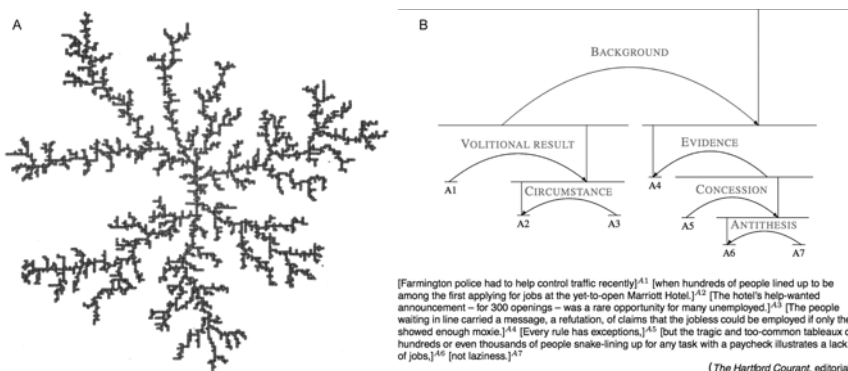


Figure 1. Diffusion-limited aggregation. Source: Witten & Sander (1981)

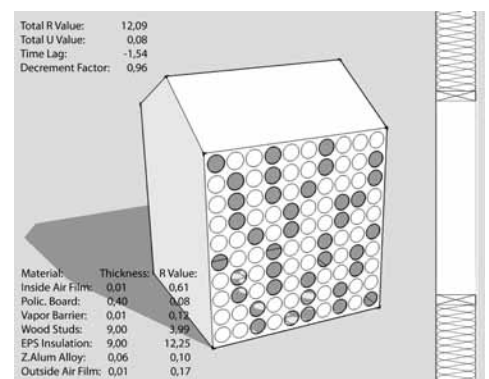


Figure 2. Rhetorical structure theory. Source: Mann & Thompson (1987)

pact, being in most of the cases non-context sensitive, hence bringing important problems to the thermal quality of spaces.

The development of basic social housing in Chile is regulated by the *Fondo Solidario de la Vivienda* (Chile, 2005), which defines the involved laws, normative and roles of several public and private agents in their gestation, design and construction. It promotes the involvement of private companies by establishing financial incentives and defines a counterpart in the public system as supervising authority. Among others, some of the outlined basic standards are the program, room size and distance between units, leaving to the *reglamentación térmica* (Chile, 1992, art. 4.1.10) the definition of general requirements for features such as envelope's insulation and maximal percentage of windows. This regulation takes account of energetic issues based on local climatic conditions, leaving to the designer the definition of other important features such as the distribution and orientation of apertures.

In recent years, this typology has been the subject of intense research regarding its responsibility for an integration of vulnerable members of society into the benefits of a growing Chilean economy. New governmental initiatives aim to boost the development and reconditioning of solutions, promoting energetic efficiency (Chile, 2006) because of its immediate benefits to inhabitants and its consequent advantages for the country's social sustainability (Bustamante et al., 2009). In this context, the incorporation of tropisms in the design process opens possible paths for layering control between a range of abstract aesthetic aspirations (formal expression) and site-specific environmental requirements (thermal comfort).

Tropism Model for Generative Facades

Addressing this twofold condition of facade apertures requires delicate interactions between measurable and non-measurable aspects of form definition. Aiming for an optimized approach to window configurations, the first explorations introduced geometrical limits as a compositional factor in an algorithmic search for performance (Radford & Gero, 1979). A straightforward inclusion of these abstract features as design intentions required the reduction of some of the architect's aesthetic preferences to sets of compositional rules. Then the quantifiable side of the problem could be carried out under that scheme with the incorporation of simulation software and generative procedures (Caldas & Rocha, 2001).

In the proposed method design intentions are reduced to a constrictive framework, leaving the emergence of actual configurations to the action of tropes. Different types of tropisms imply different advantages and drawbacks for the generative process; hence the main algorithm consists in a dual progression: possibilities production and selection filters. DLA's main aim is to reproduce the emergence of configurations in space, and is therefore applied as a formal definition factor for the emergence of a range of possible compositions. RST is an ana-

lytical system, and consequently serves as relationship evaluator, which rates the links between individual parts of the main arrangements. Under this layout, both empirical and speculative conditions are reduced to a constricted set of rules, coexisting under a controlled framework.

The implementation's general setup consists of a low-cost constructive solution for façades: a perforated EPS slab covered by an exterior layer of zinc aluminum alloy, and polycarbonate interior. Over this surface, a virtual grid of 10 x 10 apertures is disposed as general layout for the placement, evaluation and simulation of all possible arrangements (Fig. 3). The aperture definition algorithm (Table 1) starts with the production of a range of possible solutions delivered by a linear DLA algorithm, inside which several degrees of tropism are tested randomly (Fig. 4). The possible arrangements are then simulated for a specific location in Chile and scored in base of their closeness to ideal thermal comfort conditions.

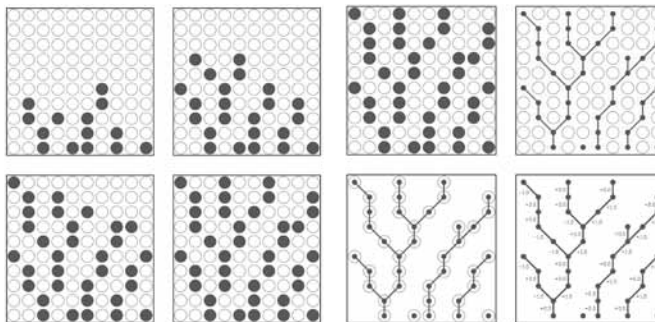


Figure 3. Low-cost constructive solution for facades /

Figure 4. DLA aperture generation (upper row) and RST analysis (lower row)

```
function <objective(x,y)>; // directional objective
function <trope(%factor)>; // tropism factor assigner
candidates = input // number of candidates
n = 1;
control = true;

while (control = true)
  while (candidates > n) // generate alternatives
    do DLA_Generation <trope(%factor)>;
    get DLA_2dArray
    do Simulation; // simulate
    do Comfort_Analysis;
    do score01; // assign thermal score
    do RST_Analysis <objective(x,y)>;
    do score02; // assign formal score
    get Score_Average; // merge scores
    n = n+1;
  end while
  if (score_average = true)
    get Best_Score = façade; // select best
    display façade; // display result
    control = false;
  end if
end while
```

Table 1. Pseudo code, proposed generative algorithm

The next main step, or second generative filter, regards the formal expression of the resulting geometric configurations. The procedure acts by defining lineal connections between the center of the different apertures and their immediate step neighbors. The resulting branching structures display the directional development of the compositions over time, revealing their growth orientation. A second score is assigned regarding their vectorial correspondence with a predefined objective (Fig. 3). The final step consists of the evaluation of the results for the selection of the best candidate, which becomes the actual facade.

Conclusions

Buildings' form definitions claim constant negotiation between diverse architectonic features merging in particular elements. This is a critical problem for the development of fit solutions in generative design; the emergence of adequate settings requires control procedures to assemble divergent components under organized configurations. A method for the implementation of tropism offers a possible approach to tackle this problem, establishing an integrative framework for the definition of form under a single encompassing criterion. Both context-specific and abstract conditions can coexist in a manageable structure, suggesting possible approaches to engage this dual condition of architectonic practice. This merging capacity of conceptual tropism is flexible enough to be applied in strongly constrained contexts, offering possible developmental paths for typologies where any improvement in this negotiation can have major consequences for the users and their social environment.

Further work is required to fully implement the method and to adjust the relative relevance of tropisms in the algorithmic process. Additional development of a complete results analysis system will deliver a deeper understanding of the real potential of this implementation. The existence and particularities of several other types of tropes opens further explorations in related models.

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