

Smart Structures across the Voronoi diagram

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Abstract

Nowadays computational geometry plays a fundamental role in a large number of domains, it solves geometric problems by using algorithms through several parameters intricated between them; one of those domains is construction in view of its geometrical character but also its degree of increasing complexity and its willingness to offer intelligent and adaptable solutions to changing parameters in real time. The Voronoi algorithm represents one of the bases of computational geometry, it generates from known points a set of points which constitutes a cell or region which have certain geometrical characteristics, its association with the design of structures gives them a decision-making autonomy in real time to become a smart structure, this translates into the calculation of the influence zones of the vertical supports following their movements interactively.

Keyword: Smart structures, Computational geometry, Voronoi diagram, Construction adaptability.

1. Introduction

In the last decade, smart systems have grown in many areas, simplifying, improving and optimizing everyday functions. Architecture is not an exception to the rule and tries to integrate these new technologies into several components of the construction. These systems focus on providing comfort to the user such as the intelligent outer shell by improving the thermal efficiency, filling by providing a personalized atmosphere as shown on figure 1 ... nevertheless there remain essential parts in the building such as the structure that has so far been obsolete and archaic.



Figure 1. The Aegis Hyposurface dECOi (URL 1)

The term Smart represents the ultimate level of adaptability, certify Lelieveld 2013, that emphasizes the ability of the object to adapt, grow or shrink and learn from its environment, these three characteristics requires at first recognition of the environment of the object and its function to finally provide an answer, this constantly evolving with the help of feedbacks.

The classical design of the structures is based on the study of the load distribution by approaching it according to several combinations of constraints which does not integrate the notion of interaction with a changing and dynamic environment. As a result, it does not recognize its environment in the first place and therefore it cannot provide an adequate and optimal response to it.

1.1. Computational geometry

Since the dawn of civilization, man has always been fascinated by geometry, his Greek and Egyptian illustration is a masterpiece of applied mathematics, says Franco P.Preparata 2012, it was used to solve problems relating to property taxes but also as the main base of erection of buildings.

Geometry is a field of application of mathematics, it has been studied and developed for a long time, highlighting its primary notions and precise rules. It was not until the 1970s that the term computational geometry appeared in the body of mathematics (Mark de Berg 1997).

Computational geometry integrates the notion of algorithm, the latter represents the reflection body of all tasks, thus computational geometry represents the field of study of geometric problems by using and manipulating geometric objects using algorithms.

Computational geometry finds many application domains such as robotics, GIS "geographical information system", graphic processing, CAD .

In the field of construction, the latter is gaining momentum by using this approach as a design tool seeking through the mathematical logic of optimal shapes at given loadings.

1.2. Smart structures in the building

Smart structure is a structure or mechanism with sensory and reactive elements which, when activated or modified.



Figure 2. The tree a smart structure (URL 2).

In nature, the shape of a tree represents the history of the forces that were applied to it during its growth (Julian Vincent 2005) , the tree and its environment interact one of the main mechanisms of this interaction is feedback, the latter drives the tree to adapt rapidly and autonomously to the different loads that are applied to it during its life cycle, bringing it in search of its optimal shape at every moment. This adaptability is qualified as intelligent or smart.

According to Vincent 2005, "the ultimate smart structure should be designed by itself", so it has to integrate particular detection and actuation components to perform intelligent actions autonomously.

The basic components of an intelligent structure are summarized in five points:

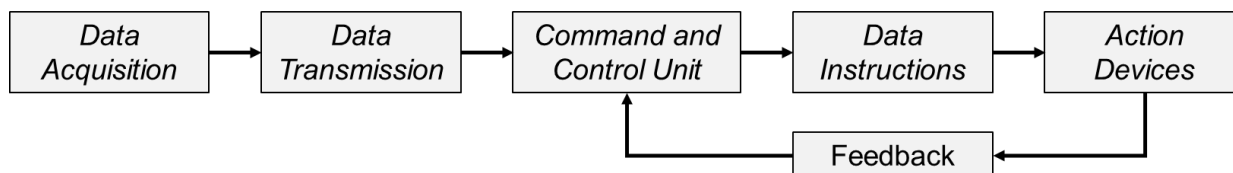


Figure 3. Components of a smart structure (Developed by Author)

Data Acquisition: The purpose of this component is to collect the raw data required for its decision making. Data Transmission: The purpose of this part is to transmit raw data to local and / or central control and control units. Command and Control Unit: The role of this unit is to manage and control the entire system by analyzing the data, reaching the appropriate conclusion and determining the required actions.

Data Instructions: The purpose of this part is to return the decisions and instructions associated with the members of the structure.

Action Devices: The purpose of this part is to act by triggering the devices / control units.

A sixth component can be added in order to satisfy the learning capacity which represents:

The feedback device: the purpose of this part and to retransmit the new data induced by the actuation to the control units in order to improve the response.

2. Methodology

2.1. The load distribution

In our research we consider a post and beam structure with a homogeneous floor.

The load distribution is based on the path of the forces, the latter is evaluated in a standardized way, after having determined its values, the use of probabilistic combinations allows us to establish a dimensioning according to an ultimate limit state, thus the structure is designed to support maximum values throughout its entire life cycle, this approach to the structure highlights the non-optimized nature of this structure to respond to load loadings in real time much less important than the ultimate state determined later.

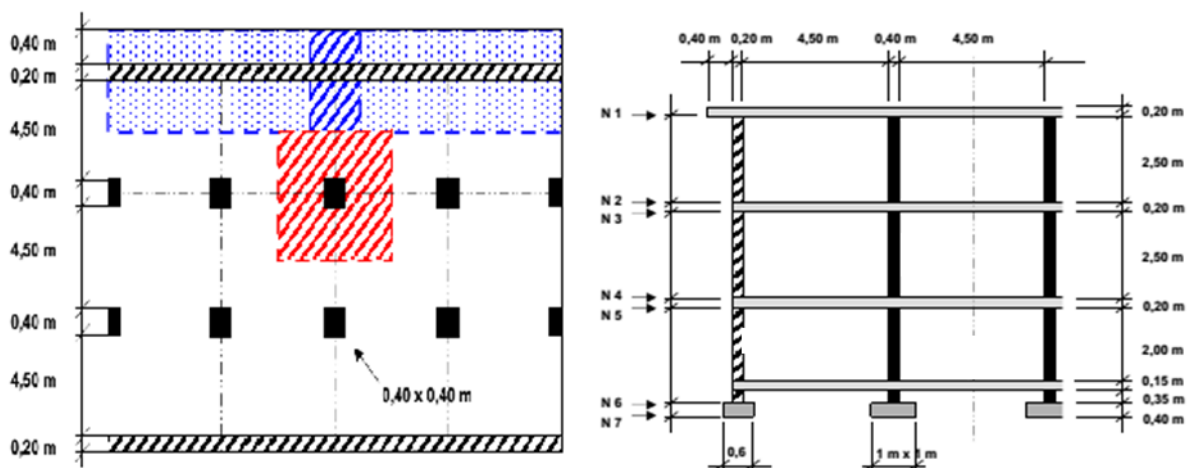


Figure 4 : load distribution (URL 3)

The ultimate optimization of the structure suggests an adaptation to the loadings and constraints imposed on it by redefining at each moment several parameters related to its resistance.

Therefore, the ultimate optimization of the dimensioning of the structure passes by the recognition of the environment of this one in real time, in this article we will study the load distribution on the vertical elements carrying in a structure with gantry. The vertical load-bearing elements support loads according to an area of influence, these areas of influence correspond to the sum of the half distance of the spans in the right and left directions to the latter.

To calculate these areas of influence we will use a mathematical approach based on the Voronoi diagram.

2.2. The Voronoi diagram

Let us give a space M and a set S of sites p in M , as well as a notion of the influence of a site p on a point x of M . The region of p consists of all the points x for which the influence of p is the strongest. Throughout this section we have a set of $n > 3$ point sites $p; q; r \dots$ in the plane. For points $p = (p_1; p_2)$ and $x = (x_1; x_2)$

$$d(p, x) = \sqrt{(p_1 - x_1)^2 + (p_2 - x_2)^2}$$

d denotes their Euclidean distance. By pq ,

For $p; q \in S$ let

$$B(p, q) = \{x \mid d(p, x) = d(q, x)\}$$

be the bisector of p and q . $B(p; q)$ is the perpendicular line through the center of the line segment pq . It separates the halfplane

$$D(p, q) = \{x \mid d(p, x) < d(q, x)\}$$

containing p from the halfplane $D(q; p)$ containing q . We call

$$VR(p, S) = \bigcap_{q \in S, q \neq p} D(p, q)$$

the Voronoi region of p with respect to S . Finally, the Voronoi diagram of S is defined by

$$V(S) = \bigcup_{p, q \in S, p \neq q} \overline{VR(q, S)} \cap \overline{VR(p, S)}$$

By definition, each Voronoi region $VR(p; S)$ is the intersection of $n-1$ open halfplanes containing the site p . Therefore, $VR(p, S)$ is open and convex. Different Voronoi regions are disjoint.

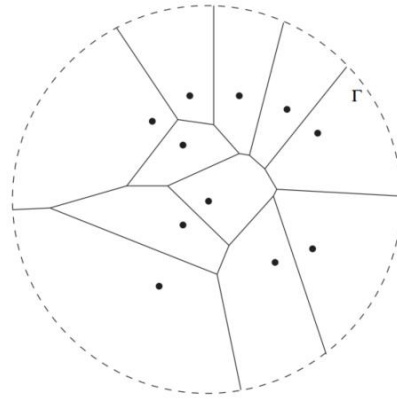


Figure 5 : Voronoi diagram of 11 points in the Euclidean plane (Aurenhammer, Voronoi diagrams and Delaunay triangulations, 2013, p 06)

3. Results et discussion

A gantry structure with a homogeneous floor composed of 20 support points that can move freely in the XOY plane

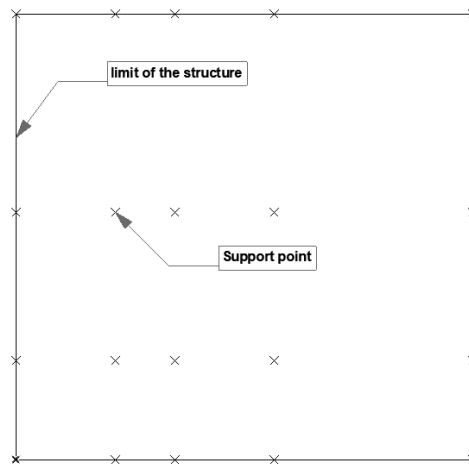


Figure 6 : Structure defined by 20 support points and its limit (Developed by Author)

Each point of this structure represents an element of support, this last one develops an area of influence which according to its displacement in the XOY plane grows or shrinks and because of this its loading changes.

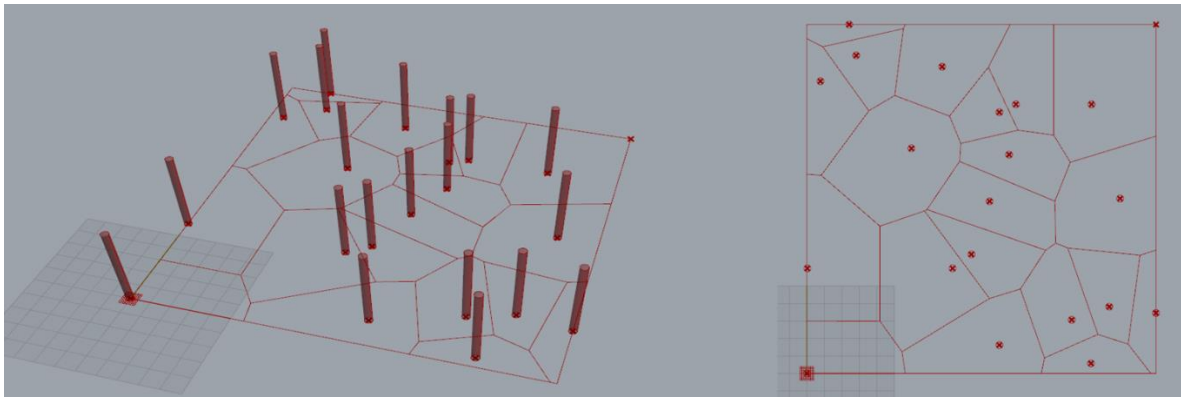


Figure 7 : Implémentation du diagramme de Voronoi aux éléments porteurs (Developed by Author)

Through the implementation of the Voronoi diagram within the structure, more precisely on the vertical elements, the latter assimilate their environments, this assimilation highlights two essential points:

- Acquisition of the data of loadings of the posts
- Updating the influence areas according to the displacement of the supporting elements interactively

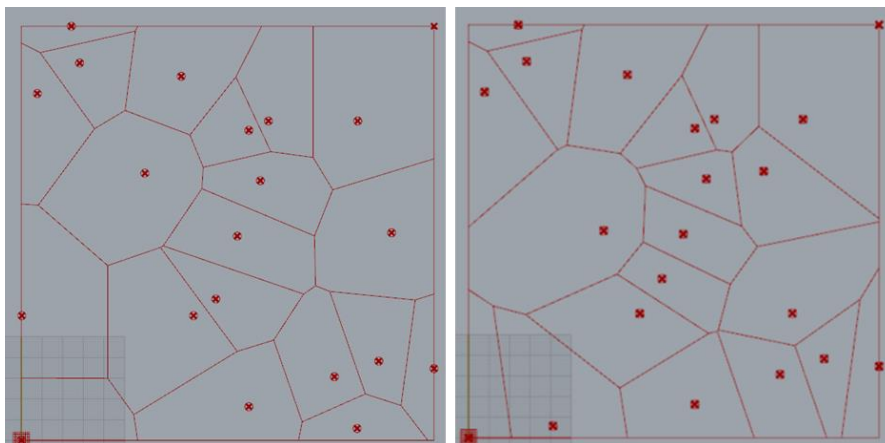


Figure 8: Implementation of the Voronoi diagram to the supporting elements (Developed by Author)

This real-time recognition of the structure of its environment satisfies the first component of a smart structure that is data acquisition.

4. Conclusion

The structure is an essential component that conditions the degree of adaptability of a construction, it is apprehended in a rigid way that obscures its environment, the integration of computational

geometry in the design process of this one makes it possible to improve its structure. level of adaptability to join that of smart structure.

The smart structure must apprehend and acquire the data relating to its environment in order to respond to it optimally, the implementation of the Voronoi diagram to a gantry structure offers the latter the ability to recognize its environment by determining the areas of influences of the columns interactively and thus deduce the load assigned to it.

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