Fuzzy Adaptive Intervention Plan

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Introduction

In this presentation we discuss the idea of a plan for the configuration of the built environment, which is generated in real time covering a wide range of scales and multiple users demands. The basic concern is in challenging traditional properties and tools that regard design as a static object which has to be completed all in once, before the realization of space [21], [43]. Another conventional practice wants the architect to have a unique authority on the design of individual architectural objects. But the reality of the city requires a more global and collective design that completes a dialogue among individual parts and the whole structure of the city [10], [13], [33]. We will present therefore an inference construction, which generates proposals for the configuration of space by reproducing a weighed expression of users' knowledge.

The plan is a Neuro-Fuzzy controller which can learn and reproduce, in general, relations of the form IF (original suggestions and intentions) …THEN (design actions and proposals), by redefining its knowledge through examples inserted from local sources. Its architecture and function are hybrid forms coming from the combination of different Neural Network and Fuzzy Controller models. The plan, which is called "Fuzzy Adaptive Intervention Plan" works in two diverse directions. The first refers to a procedure of condensing information so as to get spatial images that express multiple reasons but only one fuzzy object. This part of the plan is discussed further in detail, as it is the one on which we have concentrated our study. The second direction of the plan is focusing on the task of "defuzzication", the transformation of fuzzy proposals into clear actions and decisions for the nature, form and position of the architectural products.

For this subject we took as case study the Piraeus highway, which connects the center of Athens with the Port. Together with its neighborhoods constitutes a complex urban space with composite organization and mixed uses that has provoked the interest of state authorities, urban planners and architects.

Software Development and Function

The first part of the plan was realized as a piece of software based on the principles of the Adaptive Resonance Theory (A.R.T) and the Fuzzy A.R.T [17], [18], [19], [20], [26], [37], [47]. It is constructed on two layers. Examples formed in real time because of actual or potential changes of the built environment, are developed and represented in the first layer (Feature Layer). The second layer constitutes a field for the development of Knowledge and conclusions, outlining a "preceding-image" of real space-time. These two layers communicate through bi-directional connections: each result of the second layer is fed back into the first, in a procedure of a mutual absorption of characteristics among stored images and entering examples. After "resonance" is completed, the most significant characteristics of the first layer are presented intensified in relation with the activity of the second layer, so that the whole system is trained to learn and memorize the best possible relations among inputs and outputs. (Picture 1)

The benefit of this procedure is the development of proposals for the realization of space that attain the adaptation of local choices and demands to the whole of expressed choices and resolutions and vice-versa. In order to understand the function and the particular benefits of this program we introduce some crucial notions, terms and conditions.

Input vector (In): each choice or demand, must be expressed as a spatial object into a two-dimensional Euclidean space, even if this expression is approximate and refers to empirical data. Each Input must be considered to have a double identity as an act of transformation and its result.

Fuzzy Group: each choice entering the system is an action that transforms the previous choice towards a new object. The final object contains therefore in some degree the initial expression. The group of all choices that preserve an object unchangeable in a specific degree is the fuzzy group of the transformations of this object. Fuzzy group is a hybrid term that derives form the combination of the Group Theory and the idea of the Fuzzy Sets [32], [45], [52], [56]. We should note that the transformations mentioned above might refer to an initial object or to an object that constitutes the common section of all choices. We can also interpret the definition of the Fuzzy Group in a different way, as a group of transformations that each of them preserves unchangeable an object in a certain degree (in our case this degree is determined by "vigilance").

Containment Degree: the basic notion that outlines the function of the plan is that the whole of the expressed demands is contained in some degree in each individual choice. The Containment Degree designates the degree in which the Fuzzy Group of an object is contained in the given object and is measured in a scale from 0 to 1. Mathematically expressed: $0 \leq In \wedge W / In \vee W \leq 1$, where $\wedge$ is the min operator of fuzzy logic and $\vee$ is the max. [$In \wedge W= \min (In, W)$ and $In \vee W= \max (In, W)$].

Learning- Preceding-images: learning refers to the systematic change of weights that link artificial neurons with each other. Weights (W) store the connections among Inputs and Outputs, actions and reactions, organizing the "long-term memory" of the network. The adaptability of the plan is due to appropriate alteration of these weights. The weight vector W is updated according to the equation $W' = \beta(In \wedge W) + (1- \beta) W$, where $\beta \epsilon [0,1]$ is the learning rate parameter. In our study W is an $n \times m$ matrix where each element (ni, mj) is a number between 0 and 1.

Weights are considered to be the preceding-images of the plan as they construct an internal representation of real space and form the initial conditions to activate the system. Each preceding-image is constructed through a continuous procedure of redefinition regarding an initial choice (architectural object). This procedure designates a question regarding the degree in which the initial object preserves a stable identity or it gains a complex quality that can be interpreted in various ways. So, this procedure questions the degree of self-similarity that can be obtained [34].

Vigilance (ρ): there is a measurement that designates the degree in which a preceding-image can be considered to remain unchangeable after the introduction of a new Input. If the Input is a Fuzzy Subset of W and so meets the criterion of ρ ($In \wedge W / In \geq \rho$, $\rho \epsilon [0,1]$), then it is part of the Fuzzy Group of W and resonance occurs. Vigilance therefore is a precondition for resonance and indicates the degree in which the preceding-images are flexible to changes.

Output vector (Out): to each Input corresponds an Output ($n \times m$) where each of its elements is marked by a number between 0 and 1 that represents the containment degree of the whole of the preceding-images, to the local choice. So, we get a three-dimensional object where the two dimensions represent space and the third describes the containment degree.

For the interpretation of the result we should take into account some general remarks.

- When the containment degree reaches near 1, then the Input has been confirmed several times by different preceding-images and so it has a multiple identity. On the contrary, when the containment degree reaches near 0 then the Input has not been influenced by the preceding-images and so it keeps its initial character. In the first case we get a fuzzy proposal that is however well adapted to the whole structure of choices, while in the second case we get a clear proposal that is not tuned to the demands expressed through the preceding-images.
- Input and output should be interpreted in comparison. Input is set as a binary vector (0 or 1): if 1 corresponds to an entity "A", then 0 corresponds to its complement "not-A". Output though is an analog result and therefore tendency towards 1 may mark the confirmation of either "A" or "not-A". So what gets the support of the preceding-images can be either the one or the other.

Defuzzication operated by the second part of the Fuzzy Adaptive Intervention Plan is in fact the procedure that interprets the containment degree in terms of architectural qualities. It shapes rules regarding the actual position and nature of emerging forms through the exploitation of knowledge coming from multiple users. (Picture 2)

In general, the function of the program realized can be described as follows. Architectural choices are designed on a two-dimensional field of n x m pixels that each represents a number from 0 to 1 ($0 \le x \le 1$). Initially, some pixels are activated and some are not. Knowledge of the system is stored into nods created on the second layer. Each node contains a two-dimensional field of pixels activated in different degrees and receives the sum of common parts among Input and the preceding-images stored into the rest nods. Each nod therefore receives both the Input and the whole of images produced inside the system. If criterion ρ is met then weights of each nod are altered, if differently the weights are sustained. The result is the cumulative image of the changes. The Output is fed back into the system and is weighed again with the initial Input. The procedure continues repetitively as many times as we define.

The example

For the specific application in the Piraeus highway we have set as initial conditions three questions regarding two different levels of the city. The first concerns the wider body of the city and refers to the axis of Piraeus Rd. while the second refers to a specific block adjoined to the road.

These questions, as we have already mentioned, outline an action of redefinition that leads to an instant object. Images produced through this action work as rules or “competitors” for the local choices emerging from the story of the city. They define what we call internal representation of the system, the space where the examples that construct the intervention are evolving. We should note that each level of transformations that compose a preceding-image is corresponding to an “internal” or factual time that exists somehow independently from “real” time. This gives us the ability of developing a different descriptive quality regarding time.

Our questions are registered as “degree of deviation”, “degree of interconnection” and “degree of centralization”. Because of the lack of efficient and detailed information, the definition of the problem of Piraeus area, as well as the formulation of the questions, was made through plainly empirical observations. What we had in hand were local examples via which we tried to discover and simulate hidden knowledge about the description of space.

In general the questions are described as following: the “degree of declination” refers to the degree in which the area of Piraeus is open to the entire city or it has a self- referring function. The “degree of interconnection” defines the degree in which different units that characterize the place are tuned. Finally, the “degree of centralization” expresses the degree in which actions and events are accumulated.

In the following pages we present a sample of this application. We are not presenting the whole thinking about resolving the problem of Piraeus highway nor we are explaining our specific architectural choices. We only try to clarify the function and procedures followed for the activation of the plan.

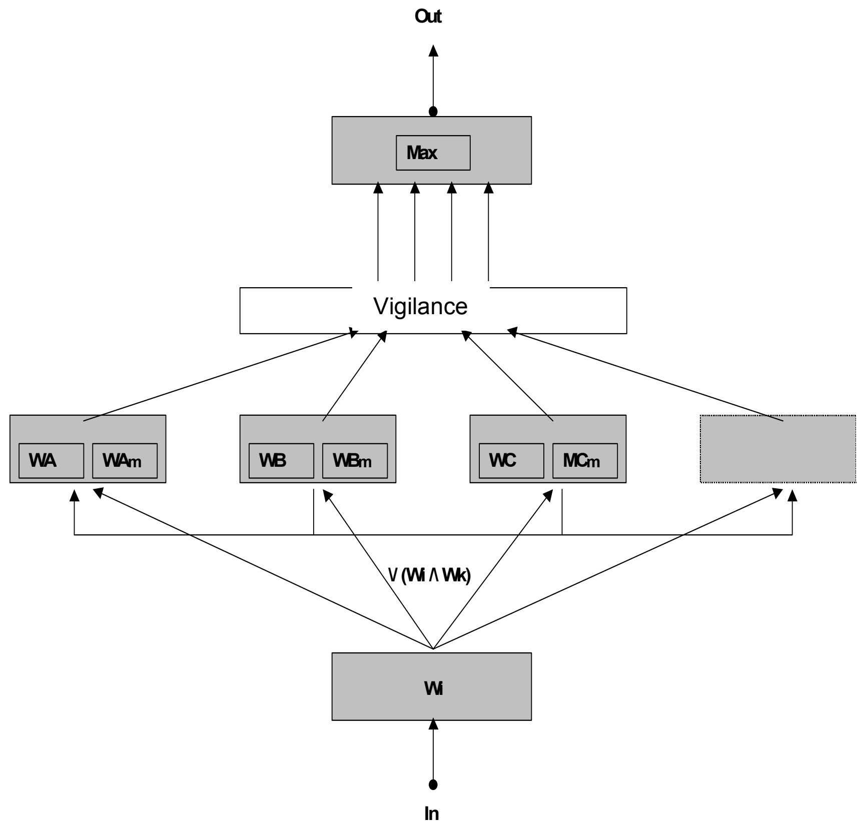
Conclusion

It is difficult to make a complete evaluation of this plan, since we have only materialized a part of the whole construction. Moreover, because of the lack of technical means and technical knowledge we haven’t achieved the real participation of different users. All data were manually introduced after a preliminary study upon history and particular characteristics of the area of Piraeus Rd.

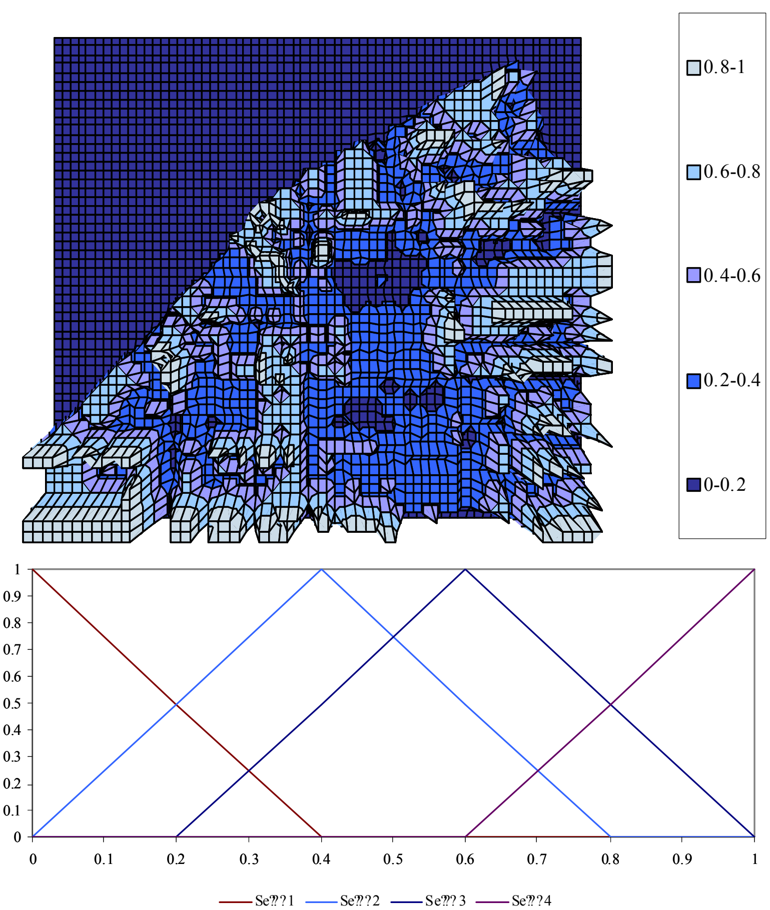
However, it seems that techniques deriving from the field of Smart Computation and Fuzzy Logic can be very effective for the design of an inference construction. What is the most beneficial characteristic of neural networks is their ability to get trained through experience (in real time) and not through a standardization or programmatic procedure. Moreover they offer the possibility of recognizing and reproducing arbitrary, non-linear relations and empirically formulated choices. In our case a mechanism of fast learning- slow recoding, qualifies the plan with the ability to gain new knowledge fast, without cancelling the previous knowledge inserted in the system.

We believe that study on these techniques has a lot of benefits to offer regarding all aspects of architectural design, from decision- making to the design of buildings.

Picture 1

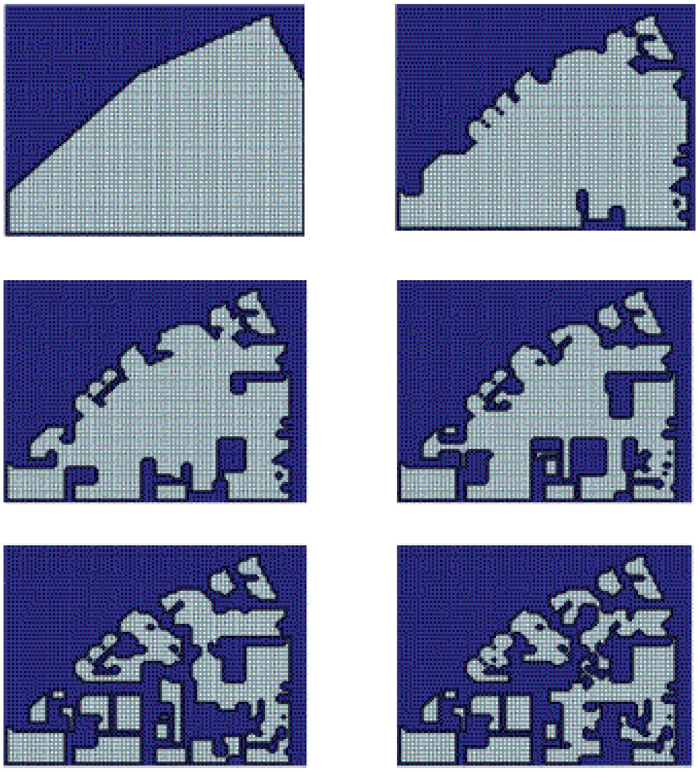


Picture 2



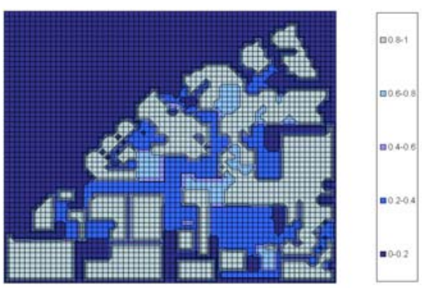
In this diagram the colors indicate different qualities of architectural objects.

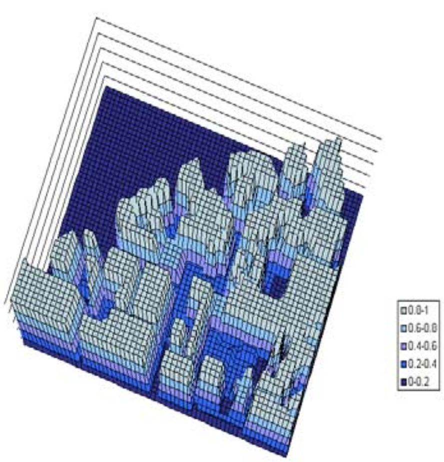
Example for the development of the Preceding images: The development of Declination



The maps depict choices for the configuration of a specific block trying to investigate the question about the degree in which the whole of the city penetrates in the block. We actually depict a procedure where the block is gradually corrupted from the inflow of a space that can be regarded external and that works as a plane for the connection and coordination of the broader area. We can say that there is a progressive transformation leading from private to public. In fact, we interpret this course as a redefining process regarding the fronts of the block. The fronts are composing an external envelope, which is fractionated in a continuous way.

The progression of the relation among private and public as well as the fraction of the fronts, is the result of illegal building and use of space but is also the result of the uncommon organizational form of industrial installations and storehouses. The big undefined free spaces are functionally necessary for storage and for the movement of big trucks. The lack of determined and legible limits and the complexity of the environment make a self-referring space.



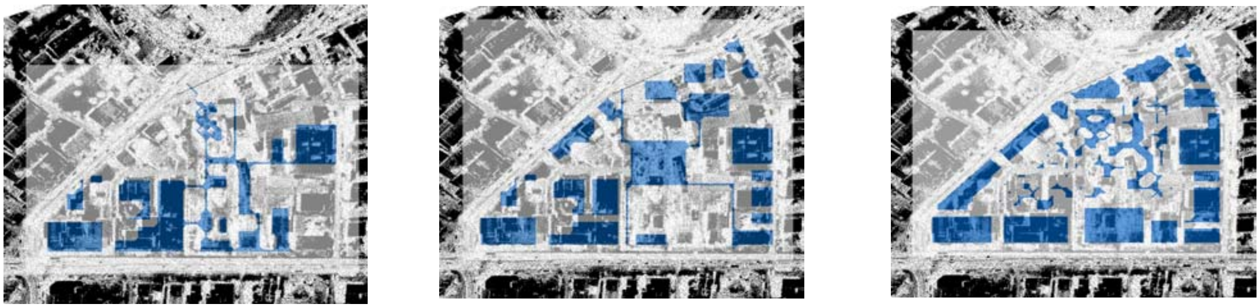


The maps on the left represent an initial condition for the evolution of space. This condition is based on the degree in which the whole of the interpretations regarding the distribution of areas with open character (external space-time) and areas with an autonomous function (internal space-time), participate in the minimum declination of these alternatives. Areas that tend near 1 represent architectural entities that have been confirmed several times from the whole images expressing the division of internal and external.

We can notice that towards the perimeter of the block the fronts are separated abruptly. On the contrary, changes are more progressive in the center of the block. Likewise, the inflow of external space is organized in long intervals so the alternation rhythm from internal to external is slow. In general we can say that we get the image of a block with a strong frond, even though in the perimeter there are fractions that allow the inflow of public space. Towards the center of the block these fractions are transformed into wider complicated spaces. The fronds are less strong there and they define a network of spaces with a gradual quality.

Example for the formation of results

Inputs

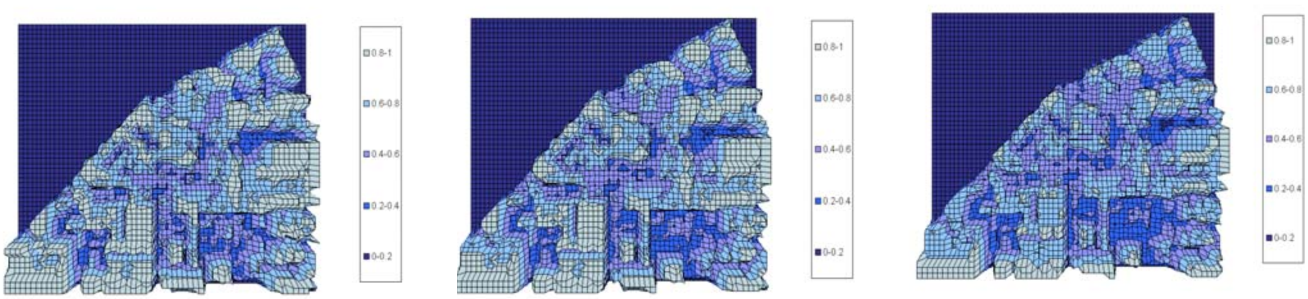


The first map is the abstract expression of a casual choice for the organization, form and use of the block. The given buildings and the open space referring to an abandoned industry now owned by the state, are used for the generation of a local center. This place has a public character and use but it also covers the functional demands of neighboring buildings.

An option for the development of Piraeus area in general and for the specific block as well, is the creation of commercial stores referring to a wider public. In the second map is presented a typological option for the establishment of a discount super market: a big volume is set distant from the road leaving a parking lot at the front.

A different alternative entering the system designates the collection of various uses at the perimeter of the block. On the third map these uses shape a strong frond to the road, trying to exploit its public character. In the heart of the block an open undefined space is generated.

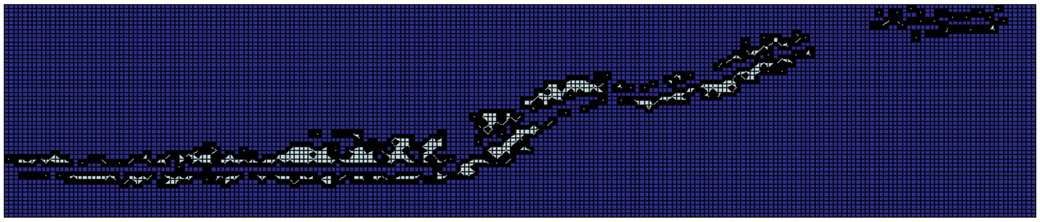
Outputs



These maps represent the degree in which all the preceding-images participate in the common part of the images and the choices expressed through the Inputs. In general the evolution of results shows a tendency to more ambiguous spaces. Differences are smooth and the containment degree is low in the whole area. This is something that we have been expecting, since we have introduced quite different alternatives. Moreover the low value of vigilance facilitated the absorption of new characteristics and therefore created images with multiple identities. The different options work together without necessarily confirming one another. We can notice that the largest part of the options preserved is orientated towards the Piraeus Rd. and that the corruption of the block is generally maintained. What is interesting is that in the space in the core of the block although it does not appear having a strong character, it has empowered its position.

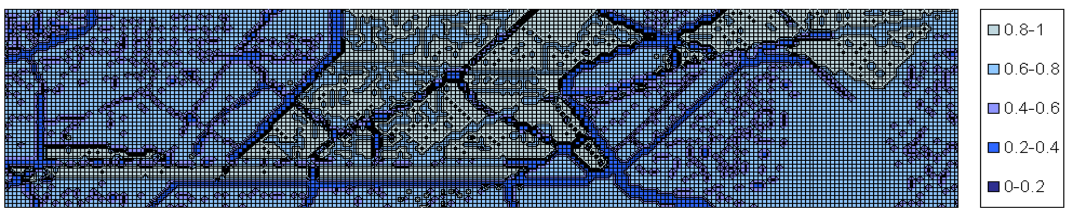
Example for the formation of results

Input



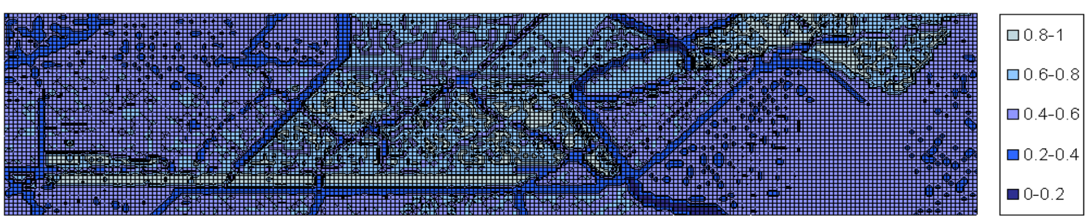
Given that Piraeus Rd. is an axis that connects different districts, the gathering of commercial activities around it arises as a possible alternative. This logic emphasizes the importance and the linear form of the axis by strengthening the fronds on both sides of the road.

Test 1



Both maps have been created through the interaction of the Input with the preceding-images of the plan, in order to mold a total object for the description of the city. They present a temporary result for the containment degree of the whole of preceding-images to an image that represents the common parts of these images with the above alternative. So tendency towards 1 denotes areas where commercial uses determine in a great degree the internal representation of the plan. In comparison with the Input, tendency towards 1 confirms either the presence of the commercial uses or their absence.

Test 2



In the bright colored areas commercial uses dominate the characteristic of space. In other areas where the degree is lower these uses are more diffused. In the first test, vigilance was high so the spatial distribution of commerce is more adapted to the initial entities. It reaches therefore a more stable image. In the second test, the low value of vigilance gave a high flexibility to the preceding-images. So the plan is trained to preserve the alternative of gathered commercial uses along Piraeus, giving a more completed image of the initial Input.

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