Maria Kerkidou

Paper: **SPATIAL FORMATIONS OF INTERACTING AGENTS**

Topic: Architecture

Authors:
Maria Kerkidou
University of National Technical University of Athens
www.ntua.gr
Anastasia Pechlivanidou-Liakata
University of National Technical University of Athens
www.ntua.gr

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Abstract:
In contemporary architecture, the problematic of architectural design has expanded, and reshaped its boundaries through strategies that digital technology victuals. As a result, architects are inclined to revise the design logic and explore the architectural object while trying not to use programs but to program architecture per se. The shift towards an algorithmic expression of the architectural problem derives from the designer's need to codify the problem through a series of finite steps[1]. This work involves the designation of algorithms to generate form from the rule-based logic inherent in architectural briefs, typologies, even behavioural patterns that affect the organization of space. The implementation deals with the design of public open-air spaces. As such, it leads to the choice of a method able to provide for the demands of diverse users. Looking into the body of work of alternative methods investigating multi-user spaces, the use of agents constitutes an interesting and promising approach which has been frequently tested as observation and simulation platform of social behaviour[2]. Additionally, it is related to self-organization and incorporates concepts that attempt to decipher natural and social complex phenomena which determine their own form and processes. Based on these premises, this implementation brings into play two swarms of agents acting in parallel and representing i) the building components of an open-air space, and ii) the users along with their activities. The implementation algorithm is based on M.Resnick's 'Ant' model in which agents behave like ants, whose goal is, while navigating, to trace food, which they achieve by leaving trails of pheromone behind for someone else to find before the chemical evaporates. The ants' nests constitute the conceptual metaphor of a space's structural components, representing the environment; whereas the ants signify the users whose behaviour differentiates according to their activities. The system incorporates repelling/attracting forces changing the system's state, offering various snapshots of spatial configurations. The goal of the experimentation is to create a generic platform in order to provide a sketching tool facilitating and amplifying design creativity and expressiveness.

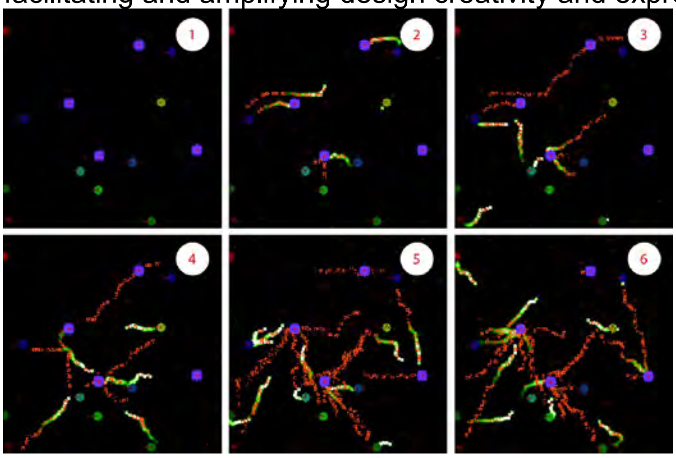

Image of agents' interaction: emergence of pheromone trails

Contact:
mkerkid@gmail.com

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Spatial formation of interacting agents

M. Kerkidou, BSc, MSc.
School of Architecture, National Technical University of Athens, Greece.
e-mail: mkerkid@gmail.com

Prof. Emeritus A. Pechlivanidou-Liakata, BSc, MSc.
School of Architecture, National Technical University of Athens, Greece.
e-mail:deste@central.ntua.gr

Abstract

In contemporary architecture, the cogitation on architectural design has expanded, and reshaped its boundaries through strategies that digital technology victuals. As a result, architects are inclined to revise the design logic and explore the architectural object while trying not to use programs but to program architecture per se.

The shift towards an algorithmic expression of the architectural problem derives from the designer's need to codify the problem through a series of finite steps. This work involves the designation of algorithms to generate form from the rule-based logic inherent in architectural briefs, typologies, even behavioural patterns that affect the organisation of space.

The implementation deals with the design of public open-air spaces. As such, it leads to the choice of a method able to provide for the demands of diverse users. Looking into the body of work of alternative methods investigating multi-user spaces, the use of agents constitutes an interesting and promising approach which has been frequently tested as observation and simulation platform of social behaviour.

Additionally, it is related to self-organisation and incorporates concepts that attempt to decipher natural and social complex phenomena which determine their own form and processes. Based on these premises, this implementation brings into play two swarms of agents acting in parallel and representing i) the building components of an open-air space, and ii) the users along with their activities.

The implementation algorithm is based on ant foraging models in which agents behave like ants, whose goal is, while navigating, to trace food, which they achieve by leaving trails of pheromone behind for someone else to find before the chemical evaporates.

The ants' nests, the food-sources retrieved and the nodes constitute the conceptual metaphor of a space's structural components, representing the environment; whereas the ants signify the users whose behaviour differentiates according to their activities.

The system incorporates repelling/attracting forces changing the system's state, offering various snapshots of spatial configurations. The goal of the experimentation is to create a generic platform in order to provide a sketching tool facilitating and amplifying design creativity and expressiveness.

1. Introduction

The application of computers in architecture has been confined so far within the boundaries of design and representational tools in architectural projects. Contemporary computer techniques offer the possibility of developing and handling new adaptive strategies embodied within the architectural process. Thus, this work refers to an enriched type of design that is bent on an adaptable version of architectural spaces and forms which respond not only to contextual parameters, but also to elements stressed out by the activities to be accommodated, within the frameworks of adaptive architecture.

The method which is chosen for the spatial formation stems from swarm intelligence systems and the computer model that has been developed is being based on relatively simple rules, resulting to a rather complex product compared to its initial elements. In spite of the inchoative structure of the model's system the final result can many times assist with problems of contradictory criteria.

Existing research on application of similar models has presented their analytical as well as generative aspect in terms of spatial tools and methods. Within the framework of this paper, both of the aforementioned aspects are schematically implemented and presented according to the current stage of the model-under-development allows.

This is part of an ongoing study developing a method which employs one swarm of agents as the building components of an open-air space (mobile or fixed) and another one as the users and their activities. There is interchange of data between the two swarms; namely, one group responds dynamically in every alteration of the other's state. The organisation of such a system integrates a mechanism of interaction which is based on a set of interrelations among its components.

2. Spatial interpretations and fluctuations

2.1 Spatial practice

Bill Hillier analyses explicitly that space should not be seen as the "inert background" of human's material subsistence. "Space is more than a neutral framework for social and cultural forms. It is built into those very forms. Human behaviour does not simply happen in space. It has its own spatial forms. Encountering, congregating, avoiding, interacting, dwelling, teaching, eating, conferring are not just activities that happen in space. In themselves they constitute spatial patterns" [1].

As Hillier suggests, the relation between space and act of living depends on the relations between configurations of people and configurations of space. Additionally, as Ireland puts it, the aforementioned spatial patterns are “not attributes of individuals, but patterns or configurations, formed by groups or collections of people” [2].

Doreen Massey’s work theorizes about the abstraction of space and contrives to present its attributes through the following considerations:

1. Space can be recognized as the product of interrelations: “as constituted through interactions, from the immensity of the global to the intimately tiny” [3].

2. Space can be understood as the sphere of the possibility of the existence of multiplicity in the sense of contemporaneous plurality: “as the sphere in which distinct trajectories coexist; as the sphere therefore of coexisting heterogeneity. Without space, no multiplicity; without multiplicity, no space. If space is indeed the product of interrelations, then it must be predicated upon the existence of plurality. Multiplicity and space as co-constitutive” [3].

3. Space can be identified as continuously under construction: “Precisely because space is a product of relations-between, relations which are necessarily embedded material practices which have to be carried out, it is always in the process of being made. It is never finished; never closed. Perhaps we could imagine space as a simultaneity of stories-so-far” [3].

Extending this analytical approach, De Certeau’s notion of space is introduced as the composition of mobile elements’ intersections. “A space exists when one takes into consideration vectors of direction, velocities, and time variables. Thus space is composed of intersections of mobile elements. It is in a sense actuated by the ensemble of movements deployed within it. Space occurs as the effect produced by the operations that orient it, situate it, temporalize it, and make it function in a polyvalent unity of conflictual programs or contractual proximities. Space is a practiced place [4].

While reflecting on the aggregation of the above theories, one discerns the importance of space’s aptitude to transform, not being identified as the object space but as the spatial formulation articulated through movement, activity, habitation and interaction [5].

2.2 Spatial production

In terms of design, a multitude of parameters must be integrated and embodied through the form-finding process. Additionally, the design of space requires the incorporation of complex organisational and functional necessities; and therefore “constitutes a recurrent negotiation of analyzing existing and requisite conditions as well as generating and evaluating possible responses” [6].

Further to this recognition, M. Hensel and A. Menges enhance architectural design with the properties of versatility and vicissitude; versatility dealing with “the notion of the behaviour and performance of an organism or artifact within its specific context, while addressing both the object and the subject", and vicissitude entailing "the differentiation of the object and the dynamic of the environment" [7].

Moreover, from the aspect of the design process, the parameters that compose the design problem of space, in spite of the conventions and abstractions of representation, acquires the properties of space, and thus, inherits its complexity. Thereupon, the articulation of the functions that outline the architectural program is also complex. It is corroborated that space being defined through the -soon to be assigned- utility and hence, activity, shows evidence of organisational dynamic characteristics.

Such an approach argues that diverse social interactions are ascribed by the "motile, mutable and feedback-based relations between habitat and inhabitants", for which the articulation of the built environment acts as a supporting layer with catalytic features. Subsequently, inhabitants' activities can be identified as emergent equivalents of "individual and collective itineraries, with provisions made and conditions yielded by highly differentiated spatial organisation and material systems" [7].

3. Synthesis of space through agents

The intention of this research is the development of a method that bridges the perception of space and the deployment of architectural design. In order to define the notion of space within the framework of habitation, interaction and activity, it is aspired to assemble the emerging attributes through computational methods that invoke interpretations and approaches of natural systems as an attempt to translate information into object. It is not intended to simulate human behaviour, but to investigate how behavioural patterns of usage and habituation of space can be produced through simple interaction among discrete entities and how this systemic structure can compose a morphogenetic matrix of spatial articulations and configurations.

According to Asquith [8], spatial behaviour allocates perpetually changeable features depending on the general context, resembling the rules conditioning social insects' behaviour, whose local interactions expedite emerging behaviours of global range; thus, stressing out the aptitude of self-organisation systems.

"The specificities of space are a product of interrelations -connections and disconnections- and their (combinatory) effects" [9]. Assembling the characteristics of space one can discern the reasons for which the agent based approach is chosen for this implementation.

Agent based modeling comprises a theoretical basis along with practical instruments which combined can offer an interesting aspect of natural and urban phenomena as a collective dynamics of interacting components. Agents facilitate the investigation of the individual's behaviour in micro-level associated to the patterns that emerge through the interplay of numerous individuals in macro-level [10].

Specifically, this work implements a simulation using swarm intelligence. The definition of swarm intelligence would describe the attempt to design algorithms or distributed problem-solving mechanisms that collect information from the collective behaviour of social insects, offering an alternative way of creating intelligent systems [11].

Swarm intelligence is based on two fundamental concepts: self-organisation and stigmergy. Self-organisation constitutes a process during which the global tuning of the system rises through local interactions among its components. Stigmergy complements self-organisation, describing the way of communication and interaction between the components of the system.

Extending this to artificial intelligence entails that agents can respond to disturbances without being programmed to manage the specific disturbance [11]. As James Adam describes, “the simple building behaviours of each individual, acting alone, combine together and result in the construction of coherent, functional structure”. There is no activity coordinator as a unit, but rather a collective intelligence expressing the aggregate of the colony [12].

As a result, while the individual actions of each insect can be described very simply, emergent behaviour appears, that is, when many individuals are working simultaneously in the same environment, the behaviour of the system as a single entity is seen to the construction of a complex structure. This behaviour stems from the individual actions of each insect [12].

4. Design problem and method

The implementation presented is addressing the design problem of open-air multi-use space such as a park. The programmatic demands deal with the fact that this kind of space addresses a broad spectrum of users from diverse backgrounds.

Principal goal is to assign to space transformative features as response to the continuously changing conditions that affect open-air spaces (e.g. weather conditions), as well as to the diverse demands of the users (e.g. sight-seeing visitors or everyday visitors).

The platform used for this implementation is NetLogo which constitutes a multi-agent programmable modeling environment (fig. 1). It offers the ability to model complex systems unfolding through time easily and effectively, along with the use of numerous agents that act independently, enabling the study of micro-behaviour of individuals as well as the macro-patterns emerging from their interaction [13].

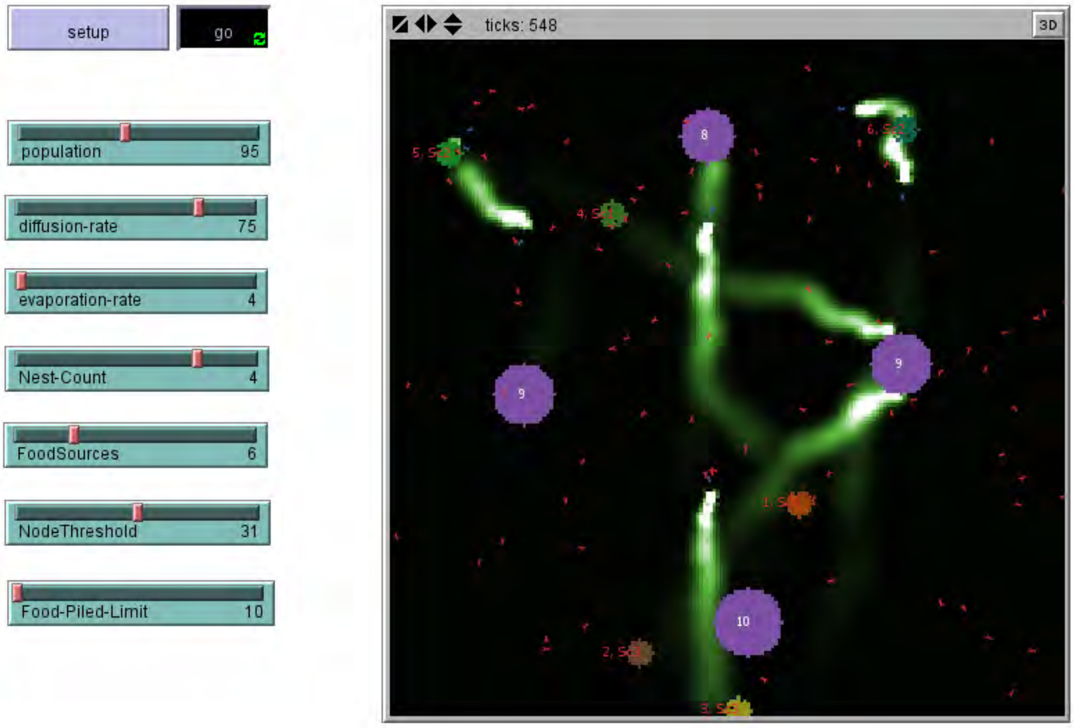

Figure 1: Model interface.

The model incorporates two groups of agents that act in parallel. The one group represents the users of space/pedestrians (ants) while the second one the environment (patches: surface units of the 'wolrd') (fig. 2).

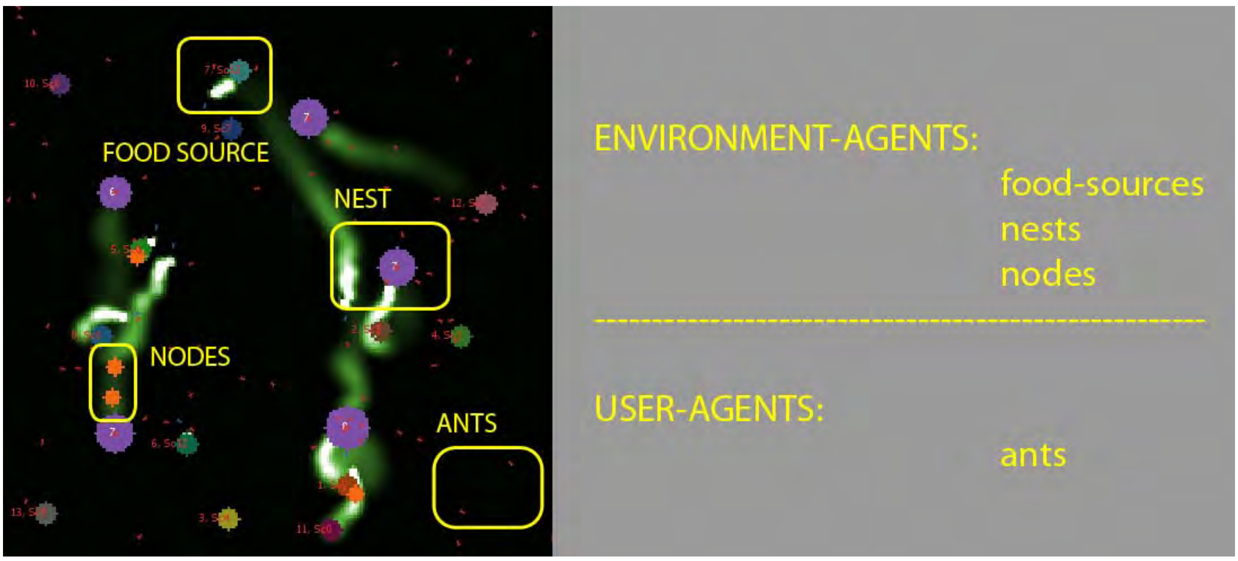

Figure 2: Environment-agents in various forms (food-sources, birth-nests, nodes) surrounded by user-agents (ants in red and blue according to their quest status) navigating the 'world'.

Collective behaviour is achieved through the application of chemical substance release (pheromone), which is used to indicate destinations. Destinations conform to each ant's food preference and constitute diverse food sources, whose discovery signals the release of pheromone, marking a trail.

The existence of the trail gradually deteriorates through evaporation, while the rest of the ants that share the same food-preferences (hence, interest in reaching the same destinations) will follow towards the location pointed by the trail. During their journey back to their birth-place (nest of route's initiation), ants become at some point aware of the nest's location inside the 'world' of patches. In actual ant behaviour this is achieved through the recognition of landmarks via comprehension of polarized light, whereas in this simulation model, it is achieved through scent emission by the nests throughout the 'world' in a gradient intensity. In this case, birth-nests as well as food-sources represent activities that engage the agents and therefore, cause their movement or lingering around the reason of attraction. Their location is set on random coordinates of the 'world', subject to the restriction not to approximate each other more than a certain number of patches.

Food-sources are labeled in order to indicate their identity to the observer, which is consistent to their 'scent'. This scent belongs either to a list of the food-sources that attract an agent (Attract List), or to the list of those that repel him (Repel List). The agents define their direction based on the scents and chemicals that are possibly stored at their neighboring patches' log. Scents originate from nests and food-sources, while chemicals derive from trails of other agents. Therefore, agents' communication is achieved indirectly, through the interaction among the patches and the agents who are located in short range.

Upon the discovery of an interesting patch, the agent, apart from examining thoroughly whether there are scents that belong or not to his list of preferences, he also calculates whether a scent's intensity outweighs the rest of the traced elements. If the indicative values show that a repeller surpasses an attractor or there are only repelling forces, then the agent ignores the stimulating source; if the attractor surpasses the repeller or there are only attracting forces, then the agent acquires heading towards the attracting source. In a similar way, the agent is checking the adjacent patches left, right and ahead in order to grasp where exactly the alert comes from and whether it is valid.

Once the food-source is traced, the agent subtracts a food-unit from the source's stock and starts to release pheromone starting his journey from the food-source to the birth-nest. Eventually, this process leads to the obliteration of food-sources which, as an integrated metaphor of the model, represents the activities (disguised as food-sources) of a specific duration which in due course, stop existing.

Trails are formed following the agents' released chemical substance which slowly evaporates and spreads out to the neighboring patches. Numerically, the diffusion and evaporation rates are defined by the program user. Throughout the program's application, nodes appear in the form of orange aggregates of patches.

Nodes constitute a response of the context to increased concentration of pheromone indicating much frequented sections of paths or junctions of many paths. The appearance of nodes is of short duration, unless reappearance occurs due to heavy traffic in trails. Their signification refers to possible places hosting new activities that can be linked with peak hours of circulation.

Another feature suggesting adaptability to the system's alterations is the nests' expanding growth, which is analogous to the food imported by the ants of the respective nest. The size of the nest changes within predefined limits, manifesting the success rate of the ants' quest. In terms of design concept, the responsive nests signify the aggregation of activities and gathering of many users, suggesting more permanent locations for the tested hosting spaces (fig. 3).

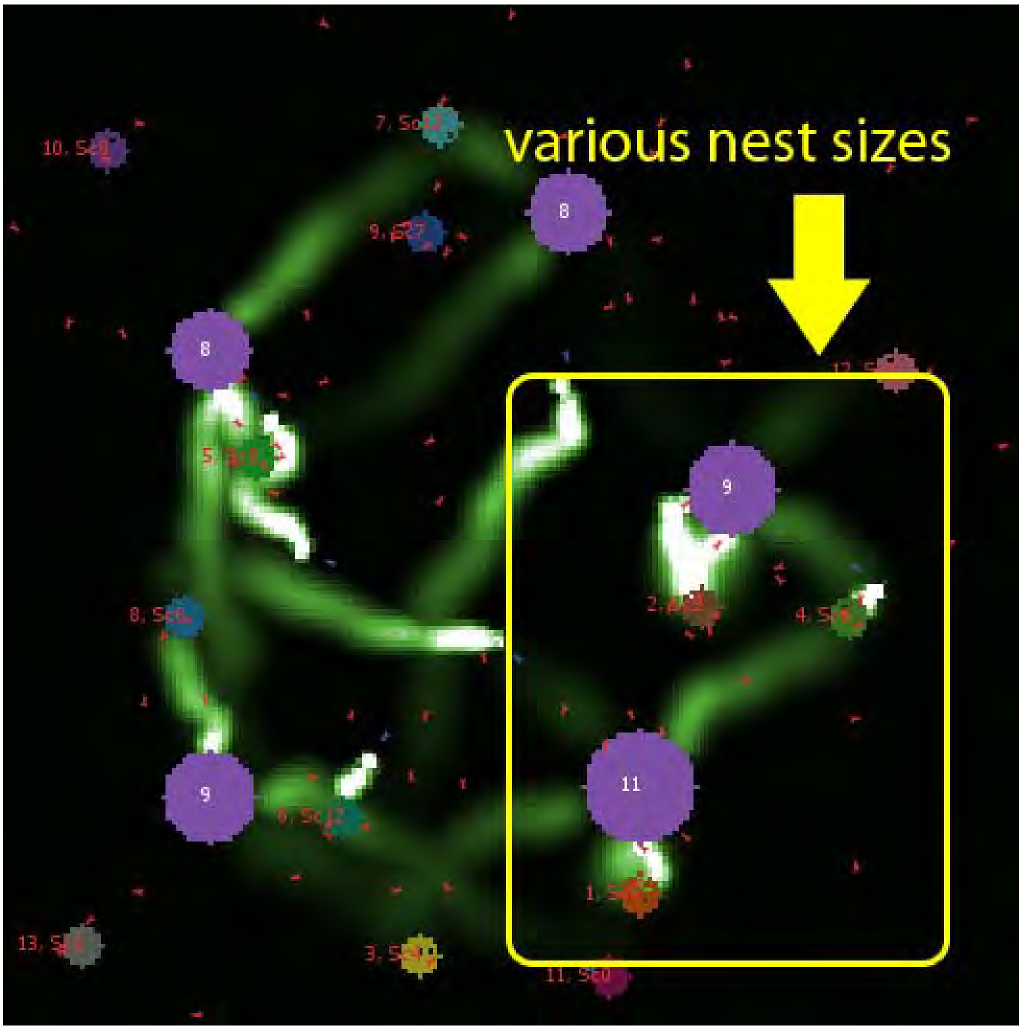

Figure 3: Gradual growth of nests based on the colony's success to trace and carry food back to the nest.

The emergent trail network which is produced is based on the feedback relationship among pheromone, diffusion, evaporation and agents' behaviour.

The emission of pheromone by one agent affects many others that gravitate to the trail. Should their list of preferences coincide with the traced chemical, then additional pheromone release reinforces the trail.

Through diffusion, more agents become interested to certain paths, resulting to a route formation among food-sources and nests (fig. 4).

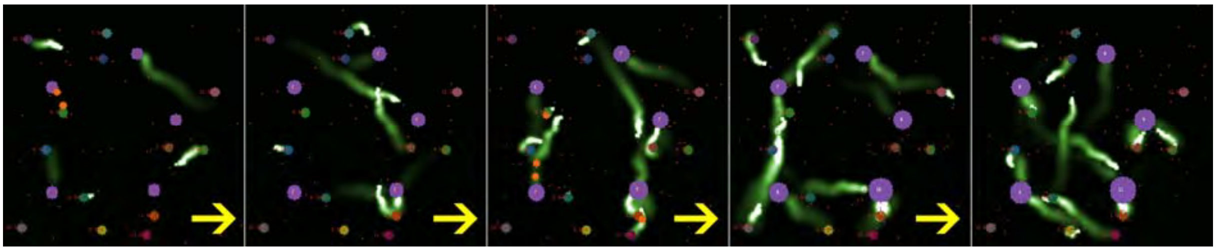

Figure 4: Sequence of time steps after the initiation of the model.

Linking those activity-imbued spaces, puts on the map their location and establishes, as time passes, stronger connections which surpass the predefined threshold of intensity being indicated by nodes [14].

The principle variables of the model manage the tuning of the system and its responsiveness according to:

1. number of agents which is defined by the population of ants; number of nests (Nest-Count)

2. diffusion-rate which specifies the amount of pheromone which is distributed from one patch to its neighboring ones

3. evaporation-rate which defines the amount of pheromone that patches drop at each time step

4. node threshold which defines the amount of pheromone that one patch must in order to become a node

As a result, a dynamic model gives rise to emergence stemming from agent interaction with the environment in adaptive terms. The fluctuation in the behaviour of the agents, exhibits great relevance respectively with the behaviour of biological systems, as in both cases self-organisation and emergence is achieved.

The results demonstrate a dynamic methodology towards the creation of spatial and route configurations whose network develops in several directions and thus, from an architectural point exhibits interesting spatial formations.

5. Conclusions

The model presented elaborates on the conceptual approach of architectural and spatial synthesis via agent based systems. Among the objects of research is to investigate whether spatial configurations can integrate diversity of behavioural singularities. The proposed method stems from a research in its schematic phase, and its structure is still under development in generic form allowing for additional features to be included in the future.

The model demonstrates a dynamic system whose flexibility and adaptability can be an asset if used in early stages of design process. User-agents circulate and stimulate their context causing alterations to the behaviour of environment-agents, promoting interaction and triggering a dynamic process to evolve. The system's state is modified as the local parameters, affected by movement, change the environment's configuration, forming paths among the several activities that endure or not in time. Successively, contextual stimulus causes alterations on other agents, who also respond at a subsequent time changing their movement; forming altogether a system in constant flux. The feedback process between user-agents and environment-agents is ongoing and gives rise to spatial configurations that emerge dynamically while being subject to the prevailing conditions of the environment.

The geometry of the model is abstract as it emerges from movement's traces, empty areas and spaces of activities, apt to be further ameliorated. In terms of representation, the model could also extend its geometrical vocabulary to architectural forms. This enhancement could also include a closer inspection of the interconnections among the system's components as to how this structure can be ascribed into spatial organisation. Development of the model towards purpose will entail the incorporation of further features; such features may comprise statistical data, classification of groups, exogenous perturbation factors etc.

Acknowledgments

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