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Paper '**Flows of movement: intensities, singularities and attractors as event generators**'

The aim of this research is to analyze the built fabric under the effect of extreme conditions using pedestrian movement, organization of flows, agent based modeling and event occurrence and generation.

Extreme conditions are defined as 'events' taking place within the urban fabric that create intense density fluctuation, social interaction that affects decision making and peoples' aggregation. An event is a temporal phenomenon, a singularity that occurs in time, an 'emergent phenomena' that causes disturbances and irregularities.

The built environment is understood as a complex adaptive system (CAS) and is governed by all their properties. As all CAS, spatial systems are best examined when under 'critical conditions' reach their limits. In every organism there needs to be a 'critical point' in order for the system to become unstable, bifurcate and evolve into a new state of equilibrium.

Pedestrian movement, whether on open urban spaces such as squares and pedestrian ways, or in a micro-scale of a building, such as a museum, shopping mall, or transport station plays a key role in the way the space is occupied and determine the way it should be designed.

In order to analyse pedestrian movement under tension, agent based modeling is introduced. The aim is to create a system that self-organises itself according to the generation of events. More events are introduced and act as attractors to pedestrian interest and movement in order to stabilise the system and to enhance social interaction.

The proposed analysis inserts a choreography of movements, flows and generic events within a simplified grid, at first, and onwards to a promenade within central Athens thus creating a continuously evolving homeostatic event space.

Topic: Architecture

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The proposed model is composed of attractors and unities within a simplified grid and is defined by the level of attraction (1-6) and the number of unities (more than 3 in each cell constitutes an 'event' within the grid at any given time). When an event occurs, the system tries to find a way for relief. This can be achieved by generating more events through new attractors in order to 'attract' unities from the 'event' space and re-establish equilibrium.
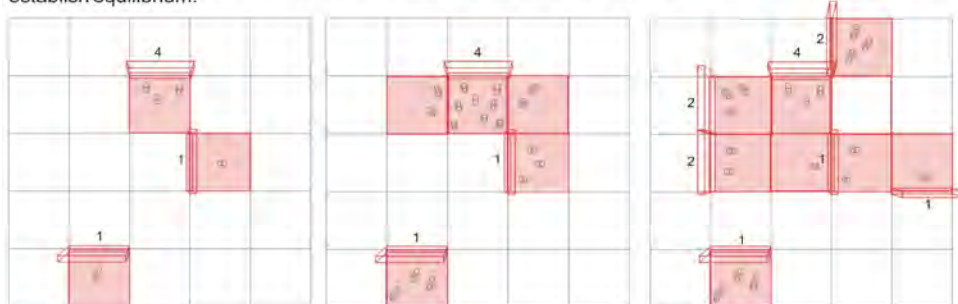
1. State of equilibrium
- attractors have an allocated value
- unities are less than 3 in each attractor

2. State of event
- unities are more than 3 in each attractor - system becomes unstable and needs to reconfigure

3. State of new organization of flows
- new attractors are set in order to establish order
- unities are dispersed into more attractors - system stable again

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Keywords:
Generic events, extreme conditions, agent based modelling, pedestrian movement

Flows of movement: singularities, intensities and attractors as event generators

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Abstract

The aim of this research is to conceptualise on the built form under the spectrum of extreme conditions using notions of movement, organization of flows, agent based theories and event occurrence and generation.

Extreme conditions are defined as 'events' taking place within spatial configurations of form that create intense density and movement fluctuation, social interaction that affects decision making and peoples' aggregation. An event is a temporal phenomenon, a singularity that occurs in time, an 'emergent phenomena' that causes disturbances and irregularities. [5]

The built environment is understood as a complex adaptive system (CAS) and is governed by all their properties. As all CAS, spatial systems are best understood when under 'critical conditions' reach their limits. In every organism there needs to be a 'critical point' in order for the system to become unstable, bifurcate and evolve into a new state of equilibrium.

Movement, whether on open urban spaces such as squares and pedestrian ways, or in a micro-scale of a building, such as a museum, shopping mall, or transport station plays a key role in the way the space is occupied and determine the way it should be designed.

The goal is to visualise a system that self-organises in form and activity according to the generation of events. More events are introduced and act as attractors to pedestrian interest and movement in order to stabilise the system and to enhance social interaction.

The proposed analysis intends to insert a choreography of movements, flows and generic events within a simplified grid, thus creating a continuously evolving homeostatic event space.

1. Form as Dynamic System

Architectural concepts and values are constantly redefined according to the contemporary cultural and social envelopes through which they evolve.

The notions of movement, fluidity, transformation, and adaptability in architectural theory and their implementation in actual built form have always been fascinating. As early as Giovanni Batista Piranesi, examples of ambitious imaginary projects can be traced. From the beginning of the last century, artists, urban and social theorists,

philosophers, architects explored the notion of dynamic transient space. From Marcel Duchamp to the Cubists and from the Futurist movement to the Situationists were among the pioneers into the exploration of space and form as a transformable field of activities and forces. *Fig.1-6*

The work of the Futurists Boccioni and Sant Elia and of the Situationist Constant represented the idea of movement and flows in contrast to the static presence of actual form. There have been many ways of representing motion in the past. The introduction of a sequence of static models in different time instances and their superimposition was an approach followed by artists such as Marcel Duchamp and theorists as Singfried Giedion.
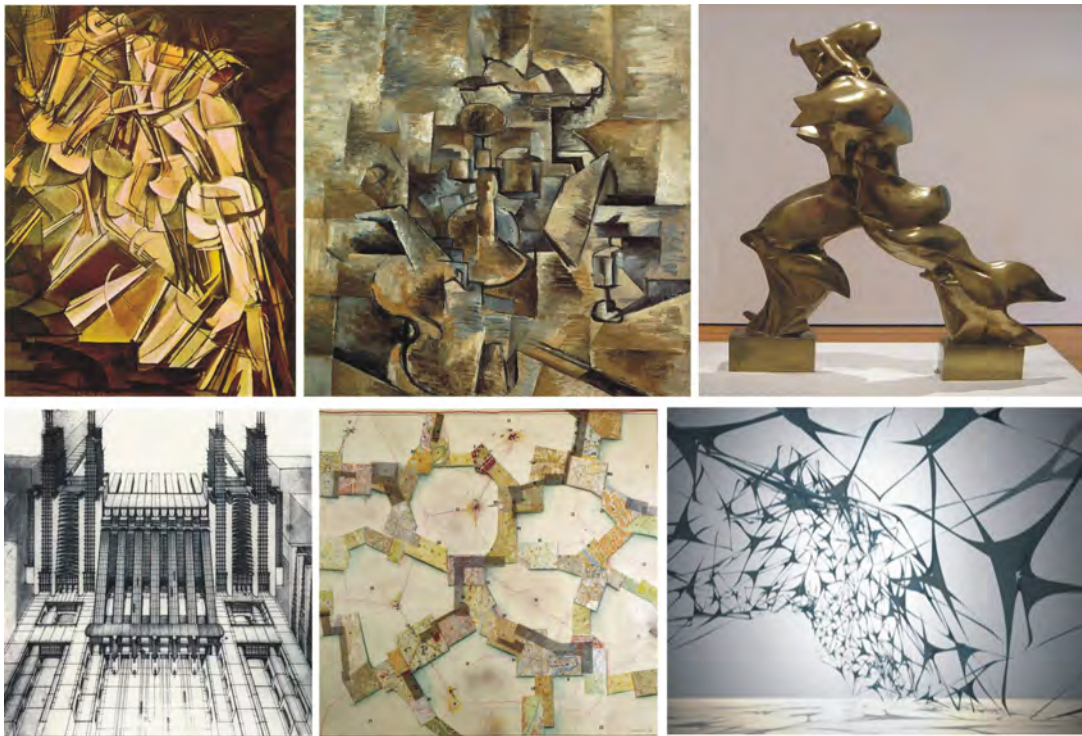
(Clockwise)
Fig 1 Marcel Duchamp, Nude descending a staircase, 1912.
Fig 2 Georges Braque , Violin and Candlestick, 1910.
Fig 3 Umberto Boccioni, Unique Forms of Continuity in Space, 1913.
Fig 4 Antonio Sant Elia's, La Nuova Cita, 1914.
Fig 5 Contant's New Babylon, 1969.
Fig 6 WWK, Generic Art, 2009.

In philosophy, 'movement and becoming' is key notion to the Deleuzian thinking of smooth, un-striated surfaces; architectures of fluid spaces, permanently moving in and out of shifting networks of relation.

The last few decades, in order to implement dynamism into the design process, theories of networks, complex systems, chaos, biological processes, evolution strategies, swarm intelligence, catastrophe theory, emergence, homeostasis, topology, fractals and other notions are being investigated.

Simple parameters like scale, volume and dimension are no longer adequate to define forms; multivalent and external or invisible forces such as pedestrian and automotive movement, environmental forces like wind and sun, urban views and alignments, intensities of views and occupation in time affect form of a dynamically conceived architecture [2].

The built environment is comprised of different, autonomous entities that interact together creating systems and sub-systems within a network, organising macroscopically complex behaviour. It is a self-organising complex system guided by the properties of emergence. It evolves, develops, learns and transforms, identifying each time and reacting to the variable and fluctuating needs by changing its behaviour accordingly for optimum solutions. A 'homeostatic' system, that is in continuous interchanging states of crisis, being governed by the superimposition of variable flows of energy, bodies, information, sounds, light, densities, social behaviour, and politics.

An important property of complex adaptive systems is self-organization and the emergence of organized order by individual local interactions. There are four main characteristics that define it [3]: simple initial rules, multiple local interactions, random organization, and decentralized control.

Organized macro-behaviours emerge from simple individual interactions. The theory of emergence explains the behaviour of many systems. The human consciousness that emerges from the acts of the individual neurones, being unaware of the overall result, the way ant colonies are structured, the single-cell organisms that evolve in clusters of interdependent cells for their survival (slime moulds), the world wide web, a traffic jam, the development of wealthy or poor urban areas, are just a few examples of emergent behaviour.

Greg Lynn, Neal Denari, Kas Oosterhuis, Lars Spuybroek and many other cutting edge architects use computational, bottom-up, generic methods in order to conceptualise on the speculative and explorative aspects of smooth, liquid, trans-formal architecture. Motion, force and direction contribute to the production of form and its potential transformation. In such a way architecture is not static but it takes part in the evolution of the form derived by dynamic flows [1]. Architectural form is defined as a derivative of time, motion and force that can be occupied in a multiplicity of ways and forms according to the different variables of inputs and outputs.

Dynamic configurations of fluid spatial models replace traditional static ones. The occupation and habitation of space and the activities that take place add dynamism to the frozen state of built structure.

2. Event

Event, a phenomenon or occurrence located at a single point in space-time and everything that comes about [4].

An event is a temporal phenomenon, a singularity that occurs in time, an 'emergent phenomena' that causes disturbances and irregularities [5].

Architects have been taught to reflect and design form according to programmatic and functional needs and towards an aesthetically pleasing result. Architectural form is traditionally regarded as a dimensional space of stasis defined by Cartesian

coordinates and linked to the notions of permanence, materiality, verticality, horizontality, gravity. Passivity and stasis characterize an architecture that remains indifferent to the movements and forces [16].

The way space is felt, occupied, inhabited, inside and outside, in all dimensions, is more crucial and interesting towards an understanding of spatial configuration. 'Architecture is as much about events that take place in spaces as about the spaces themselves' [6] .The one should inform the other in a generative process for optimum design.

Another characteristic of built form is its permanently allocated program. The relationship between functions within a building are considered fixed not taking into account the variability and flexibility of their relationship.

The moment in time; the singular that branches out to the infinite.

Singularities refer to those critical points or moments within a system when its qualities and quantities undergo a fundamental change [5].

The location of a new building, the insertion of a park within a dense urban grid, people flocking for a popular exhibition, an earthquake, a traffic jam, are all components and signifiers of a 'phase transition' within their system. Singularities in time, they are as much events in themselves as event generators in an infinite interplay between order and disorder, catastrophe and stability.

In any system, when the input is larger than the ability of absorption, disanalogous to the output, then the system tends to be in a situation of disorder. The breaking down of order into disorder or disaster is marked by a critical point, a point of transition where the system becomes unstable [2].

Critical points are necessary in order for the system to become unstable, bifurcate and evolve into a new state of equilibrium. At this singular moment of occurrence, throughout the crisis all the attributes are augmented. The full dynamism and potential of the system can be seen and analysed. This is a very interesting notion, that any organism is best understood when in crisis, it reaches its limits.

In order for complex systems to survive, they have to go through transition phases between stable and unstable states. In conditions 'far from equilibrium', non linear dynamics prevail and the system gradually becomes sensitive to external variations. Small fluctuations or disruptions lead to a chain reaction of immense scale. In situations like these, the system needs to find a way to balance again. As a consequence of this procedure, new forms of behaviour and new patterns emerge which lead to organization or catastrophe [7].

A complex system that reaches a transition phase between stable and unstable state follows these procedures in order to maintain equilibrium [8]:

1. The system self-organises into a new state.
2. From a chaotic situation emerges an ordered and structured system.
3. The system is in a state 'far from equilibrium' caused by external factor.
4. The movements of individual entities are unpredicted and uncontrolled and only at the exact instance of bifurcation the result is determined.
5. The system balances with many different ways and there multiple outcomes with the same parameters.
6. The fact that at the exact instance there is only one final outcome depends on preconceived notion that affects the evolution of the system.

7.   The homogeneity and symmetry of the system in equilibrium is broken.
8.   The individual entities, despite their random movement, behave in a consistent manner, which emerges from the interactions of the individual elements.

The rate of transmutation of the built fabric spans into long periods of time, consequently, the effect of the transformation is not visible in every day life. In particular, singular circumstances, such as events or crisis, the biorhythm of the built environment changes within a small time frame.

Events are defined by their ability to change the needs of the built structure directly and intensely, thus transforming it drastically, on a microscopic or macroscopic scale, to accommodate the multiple needs that occur.

Fold; surface of instability for deformation/transformation to occur

Intensity defines the characteristics of the event. Where singularity is the moment of bifurcation, the critical point of instability, the moment in time, intensity has qualitative and quantative attributes. Scales, use, activities within a new building or park, attraction factor of an exhibition, strength of an earthquake are all intensities of event.

Events can be seen in a microscopic or macroscopic scale. For example, overcrowding in an exhibition or a traffic jam has a beginning, duration and an end throughout a limited time period. An earthquake, while sudden and fierce has long time after effects. The urbanization of a rural area or the immigration of population to a different country develops into even more slow pace.

Dynamical systems cannot be understood by their spatial relations of configuration alone, but only through the events and qualities-transitions of phase and state-produced as a result of the flows of energy and the informational gradients that move through them [5].

Temporal stability; space in-between

Attractors are the points or phases of stability. All dynamic systems in the long run settle down to an attractor that acts as a state of repose [9]. *Fig.7*
For example, in an exhibition space, the exhibits act as attractors. The flow of movement paces down and even stops in front of the exhibit.
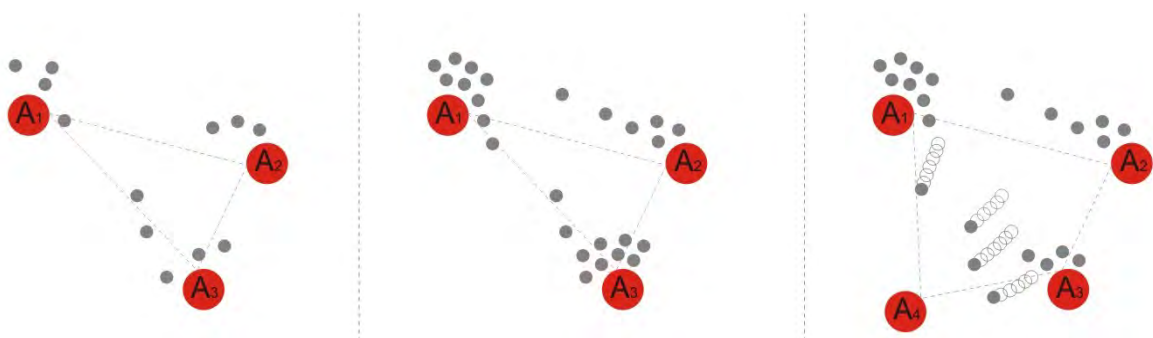

Fig.7 Attractors as stabilisers

Events; generators of events.

The continuous interplay of form and activities becomes a generator in itself of new events. A new building or the exhibits become event, attractor, and generator through alternating states.
An earthquake is a singular event in time of variable intensity. Furthermore, it is the generator of a multitude of events, of movement, and density shifts between people, of traffic jams, of large number concentration, of social behaviour.

Events cause constant fluctuation to a system that keeps reinventing itself, thus being in a continuous generative process of adaptation and optimization.

3. Flows of movement

As already defined, built space is as much static form as the flows of movement that activate it. There has been a lot of research in the way people occupy and move through space, in their physical, psychological and social presence through analytic and simulation techniques.
Crowd behaviour has the principles of a complex adaptive system. An ordered behaviour emerges from the individual movements of each unit. Crowds under tension engage in spontaneous, collective behaviour and have the tendency to form clusters / swarms. The crowd, in other words, is a collective being, formed under a given set of circumstances that is always more than the sum of its parts. [10]
There have been three main approaches into modelling crowd movement: [15]
1. Fluids have similar dynamics as crowd movement.
2. Cellular automata act as discrete, dynamic, systems, which model a lattice of
cells and base the state of a cell on the states of the immediately surrounding
cells.
3. Agent based modeling considers each pedestrian as an individual entity
and the interactions between it and the other pedestrians are individually
modeled according to physical or social laws.

Flocks of birds, schools of fish, herds of animals, crowds of people exhibit similar patterns of movement and swarming. They are made of discrete particles yet their overall motion seems fluid; it is simple in concept yet is so visually complex, it seems randomly arrayed and yet is magnificently synchronised. Perhaps the most puzzling is the strong impression of intentional, centralised control. Yet all evidence indicates that flock motion must be merely the aggregate result of the actions of individuals, each acting solely on the basis of its own local perception of the world [11]. Fig.8
Craig Reynolds was the first to simulate flocking creatures, that he called boids. Their behaviour was governed by three rules:
1. Separation: steer to avoid crowding local flock mates
2. Alignment: steer towards the average heading of local flock mates
3. Cohesion: steer to move toward the average position of local flock mates
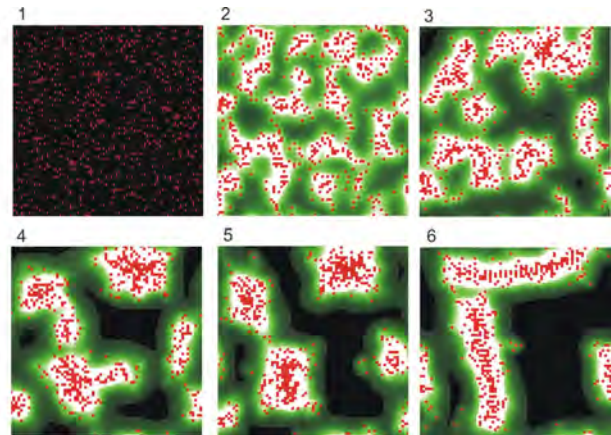
Fig 8 Boids

fig 9 Star Logo's simulation of slime moulds

The interpretation of swarm behaviour is also evident in the simulations of slime mould, in Star Logo a Cellular Automata environment, showing that creatures can aggregate into clusters using a decentralized strategy, without any "leader" involved. In this example, each creature drops a chemical pheromone (shown in green). The creatures also "sniff" ahead, trying to follow the gradient of the chemical. Meanwhile, the patches diffuse and evaporate the chemical. Following these simple, decentralized rules, the creatures aggregate into clusters. Similar principles apply in people gathering into clusters. [12] *Fig.9*

In the research of L.F. Henderson, he observed phase transitions in pedestrian movement, brought about in a manner analogous to liquefying a gas by compressing it. Later on, D. Helbing considered that although crowd movement was similar to fluid dynamics, the motivation of individuals had to be incorporated in order to create complex patterns. He proposed that the movement of an individual is conditioned by two influences: internal, or personal aims and interests, and external, or perception of the situation and environment. Often these will conflict. External influences on behaviour are caused by interactions with others. According to Horney, such interactions resemble forces of attraction and repulsion. Furthermore, Hughes introduced the 'thinking fluid', in terms of the relationship of fluid dynamics and cognitive characteristics of human movement. [13]
Helbing went on to observe many collective patterns of self organised motion such as the corridor and the intersection examples. *Fig.10-11*
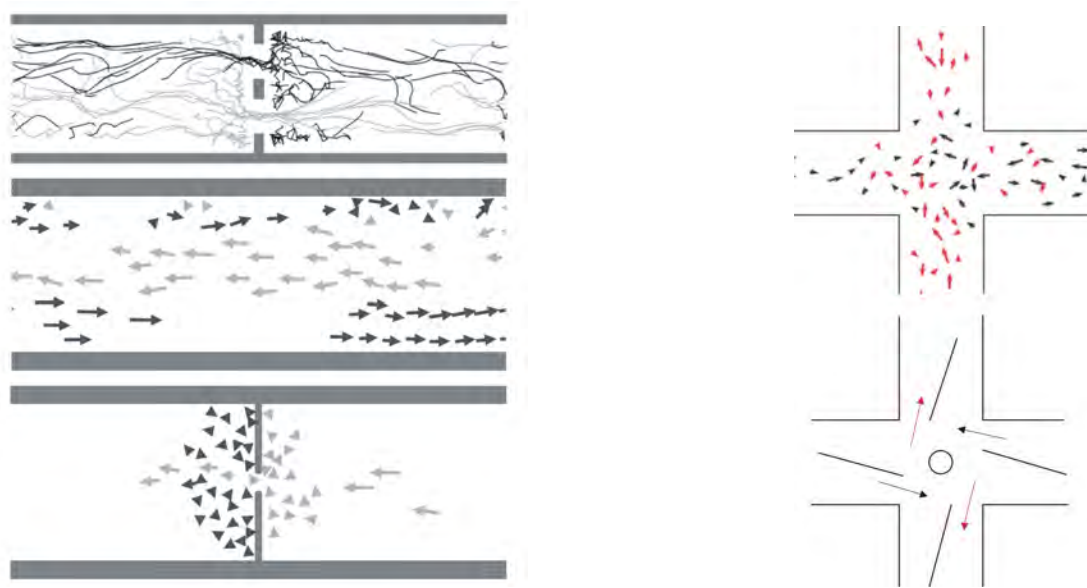
Fig 10 -11 Corridor and Intersection Paradigms (src: [14])

By simulating movement in an axial way within an enclosed space of one entrance and exit, he concluded that people self organise in streams according to the direction of motion. Also, he suggested that at the point of entrance-exit, movement seems to slow down and congestion appears. By introducing another opening, movement is achieved without clustering as one stream of direction flows from one opening and the other flows to the second opening.

In the case of the intersection example, motion seems to settle into temporary roundabout stream. The efficiency of pedestrian flow could be increased considerably by putting an obstacle in the center of the intersection, because this favors the smooth roundabout traffic compared with the competing, inefficient patterns of motion. [14]

According to Bill Hillier and the Space Syntax team there is a logic, a syntax in the way people relate to and navigate space. [13]

Pedestrians rely on sight in order to decide which way to go. The calculation of vision fields, lines of sight and 'shortest routes' makes possible to measure the pedestrian flow in a complex building or a city and to predict the best entrance and exit in case of crisis [2].   Visibility Graph Analysis was introduced by Turner et al in order to evaluate visibility of individuals. The VGA method reveals properties of the interconnectedness of visual fields.

Using this technique on Tate Gallery in London, very interesting conclusions were observed concerning the way people experience space. *Fig.12*

Visitors in the museum in the simulation and in real life, tended to circulate towards the left of the gallery's main axis, rather than the right one. The conclusions showed that this behaviour didn't have anything to do with the attraction factor of each room rather than with the spatial layout of the building.
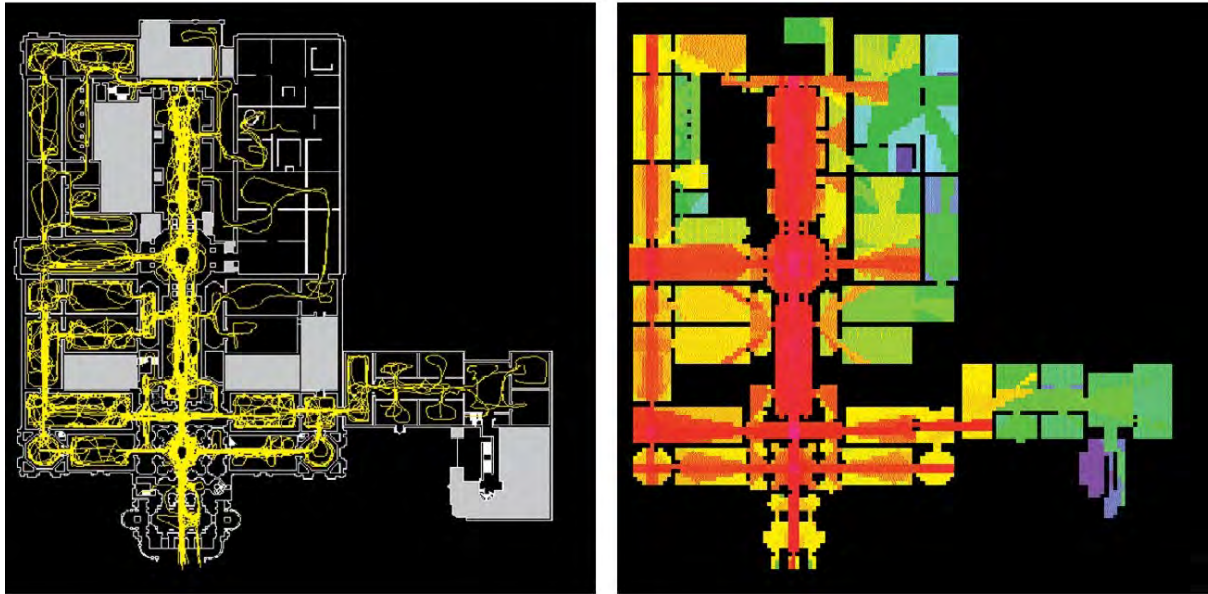
*Fig. 12 **Tate** Gallery. Movement Traces and Visibility Graph Analysis. The thermal image indicates the visual fields of visitors. (src.: Hillier, 2004, Hillier and Tzortzi, 2006)*

Examples like the Tate Gallery showed that the way space is occupied and the movement within it directly influences the design process.

4. Ongoing study

The ongoing study is focused onto the implementation of the theory of event and flows of movement into a generic process of form and layout optimization.
The aim is to create a system that self-stabilises according to the input and output of data, the fluctuations of movement and density.

At this stage, the effort is to distinguish which methodology will work out best.
The proposed model is composed of attractors and unities within a simplified grid and is defined by the level of attraction (1-6) and the number of unities (more than 3 in each cell constitutes an 'event' within the grid at any given time). When an event occurs, the system tries to find a way for relief.

There are two proposals for stabilising the system:
1. Attractors/Panels are variable components and increase or decrease in number according to unities fluctuation. Through a continuum of event generation, unities/agent movement and attraction, equilibrium is re-established by optimum spatial configurations, only to collapse again in a process that keeps on alternating between order and disorder. *Fig.13 -14*
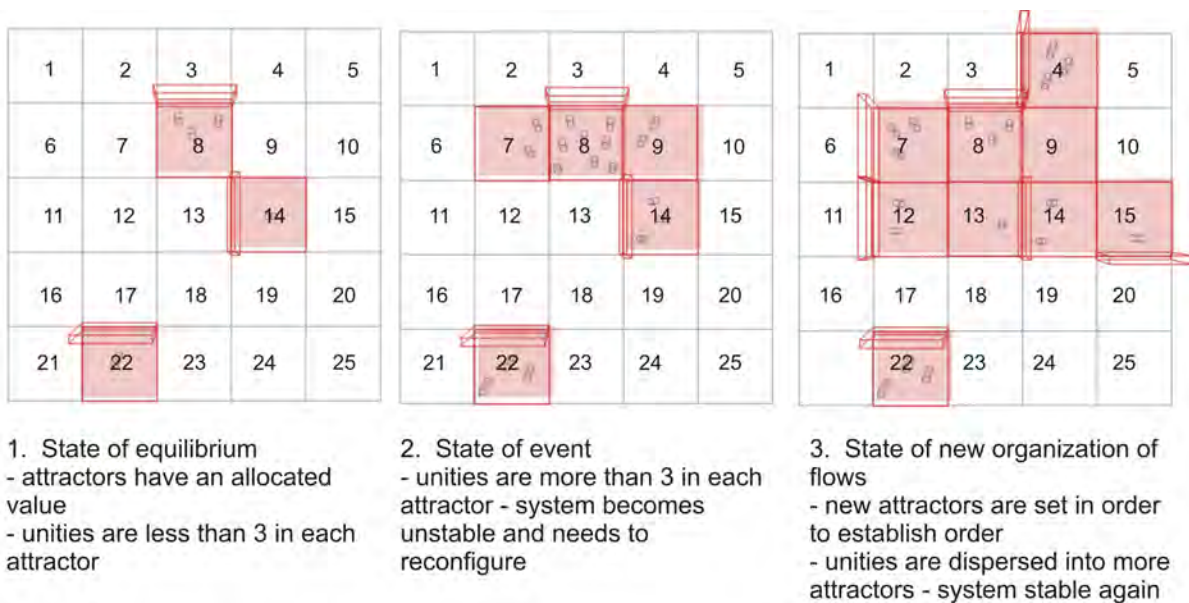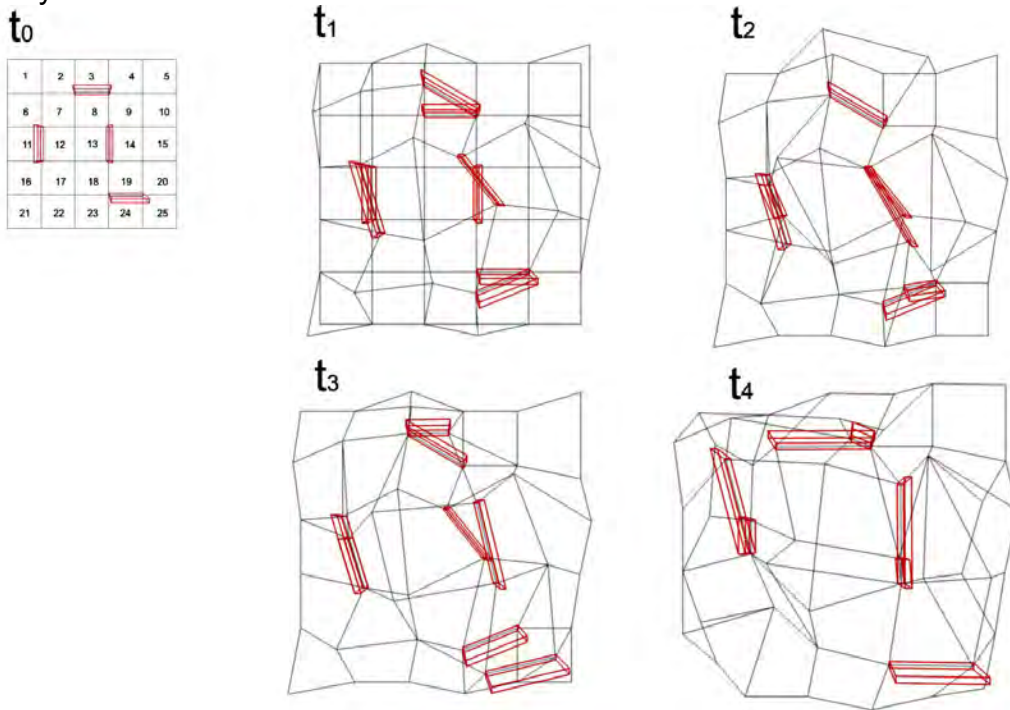
1. State of equilibrium
- attractors have an allocated value
- unities are less than 3 in each attractor

2. State of event
- unities are more than 3 in each attractor - system becomes unstable and needs to reconfigure

3. State of new organization of flows
- new attractors are set in order to establish order
- unities are dispersed into more attractors - system stable again

Fig.13 Diagram of Generic distribution of attractors and agents

In order to create a generic spatial configuration, the squares of the grid are codified into alternating true and false states, like a cellular automata environment. According to the finite number of unities and attraction of the panels, stabilisation states can be predicted. A similar codification is introduced in 'Design Code' by Jan Oliver Kunze and Jorg Kramer.

Fig.14 States of Attraction and Density

2. The grid becomes fluid surface and the attractors move and transform according to density.

Cell Alteration Table :

t0	Agents	Area
1	<10	1.0
2	<10	1.0
3	<10	1.0
4	<10	1.0
5	<10	1.0
6	<10	1.0
7	<10	1.0
8	<10	1.0
9	<10	1.0
10	<10	1.0
11	<10	1.0
12	<10	1.0
13	<10	1.0
14	<10	1.0
15	<10	1.0
16	<10	1.0
17	<10	1.0
18	<10	1.0
19	<10	1.0
20	<10	1.0
21	<10	1.0
22	<10	1.0
23	<10	1.0
24	<10	1.0
25	<10	1.0

t1	Agents	Area
1	<10	0.7
2	<10	0.8
3	<10	0.9
4	<10	1.0
5	16	1.6
6	12	1.2
7	<10	1.0
8	<10	0.7
9	<10	0.5
10	<10	0.7
11	<10	1.0
12	<10	1.5
13	20	2
14	14	1.4
15	13	1.3
16	<10	1.0
17	11	1.1
18	12	1.2
19	15	1.5
20	<10	1.0
21	<10	1.0
22	<10	1.0
23	<10	0.8
24	<10	1.0
25	<10	1.0

t2	Agents	Area
1	<10	0.7
2	<10	0.8
3	15	1.5
4	<10	0.8
5	16	1.6
6	11	1.1
7	<10	0.7
8	11	1.1
9	<10	0.5
10	<10	0.7
11	<10	0.8
12	<10	0.6
13	27	2.7
14	13	1.3
15	21	2.1
16	13	1.3
17	15	1.5
18	12	1.2
19	<10	0.4
20	<10	0.8
21	<10	1.0
22	<10	1.0
23	12	1.2
24	<10	0.8
25	<10	1.0

Fi

g.15 Grid and attractors' deformations

This process allocates area according to density. If a panel has a high attraction value, then the allocated area on the grid becomes bigger to accommodate more agents. Constant density in any grid cell is established through the deformation of the grid. Panels are not increasing or decreasing in number as in proposal 1, rather they go through various stages of deformation, in and out of stability.

The two proposals could be combined in creating a system that self organises in terms of multiplication and deformation. The aim is to achieve optimum configurations according to density and movement throughout events.

These methodologies could potentially be applied in actual designs, for example exhibition spaces, temporary or multi-purpose usage spaces, or even for crowd control and movement orientation. *Fig.16-17*
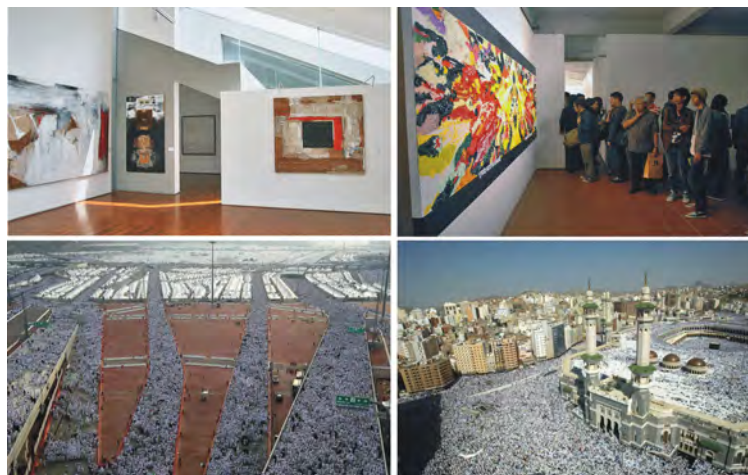

Fig. 16 Exhibition Space
Fig. 17 Mecca Hajj – D. Helbing's proposal of distributing crowds

5. Conclusion

This paper deals with the notions of movement, fluidity, transformation, and adaptability in form under the theoretical spectrum of events, complex adaptive systems and collective behaviours as a bottom up procedure. It is suggested that they take an integral part in the way people experience space as well as part of the design process itself.

 'Architecture is as much about events that take place in spaces as about the spaces themselves' [6] has triggered research on people's movement either as a theoretical background or as the creation of fluid dynamics paradigms, cellular automata and agent based modelling.

This is a proposition in transition, still at diagrammatic state. Future work includes encoding generic processes and implementing them into real spaces.

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