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Research

Dynamics of Urban Centre and Concepts of Symmetry: Centroid and Weighted Mean

Presented at Nexus 2010: Relationships Between Architecture and Mathematics, Porto, 13-15 June 2010.

Abstract. The city is a kind of complex system being capable of auto-organization of its programs and adapts a principle of economy in its form generating process. A new concept of dynamic centre in urban system, called "the programmatic moving centre", can be used to represent the successive appearances of various programs based on collective facilities and their potential values. The absolute central point is substituted by a magnetic field composed of several interactions among the collective facilities and also by the changing value of programs through time. The center moves continually into this interactive field. Consequently, we introduce mathematical methods of analysis such as "the centroid" and "the weighted mean" to calculate and visualize the dynamics of the urban centre. These methods heavily depend upon symmetry. We will describe and establish the moving centre from a point of view of symmetric optimization that answers the question of the evolution and successive equilibrium of the city. In order to explain and represent dynamic transformations in urban area, we tested this programmatic moving center in unstable and new urban environments such as agglomeration areas around Lausanne in Switzerland.

Introduction

We consider the urban situation as unstable and the urban form as dynamic. Until today, the analysis of urban morphology was done in a static way, not allowing to follow the evolution nor the successive equilibrium of the city. Beside the general evolutionary form of the city, urban centers are particularly sensitive places of diverse dynamics: they admit more material exchanges or information by concentrating public buildings and places.

We develop and define an interactive and autonomous city system. This enables us to reconstitute the structure of another scale of the city. This "urban system" can develop a new concept of centre[1] by integrating diverse programs.

The concept of the urban system evolves from that of *quartier*, or district. This allows us to re-qualify the evolution and the transformation of the urban centre. Let us define the initial characteristics of the urban system from the point of view of morphogenesis:[2]

- System composed by the various interactive elements
- System as process
- System of the dynamic and mixed centre

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The centre transforms continually and displace in an interactive field. The dynamic centre mainly characterizes the evolutionary urban system.

Thus, we focus on three issues about the dynamic centre:

- **Higher geometry complexity** (the complex form of magnetic field by many facilities laid out)
- **Changing value** (the value of programs changes in times following different needs of society)
- **Coordination x, y** (the localization of programs and moving centre)

The *centroid* and the *weighted mean* based on the concept of symmetry are newly proposed to advance these issues in this paper. These mathematical notions integrate into the new urban organization system to identify and represent the dynamic centre.

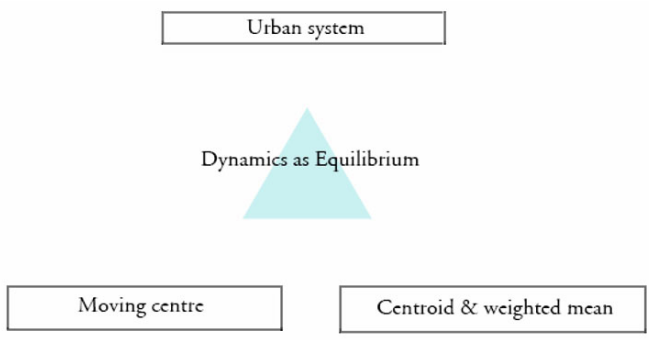


Fig. 1. Three main subjects and dynamics as equilibrium

"Urban system" and "programmatic moving centre"

An urban system of complexity

We suppose that the urban system consists of basic elements, such as habitation or activity groups, public spaces and equipment.[3] The system could be characterized by the appearance of its interactive elements in a perimeter (fig. 2a). In addition, the centre of the system can move in condition (fig. 2b).

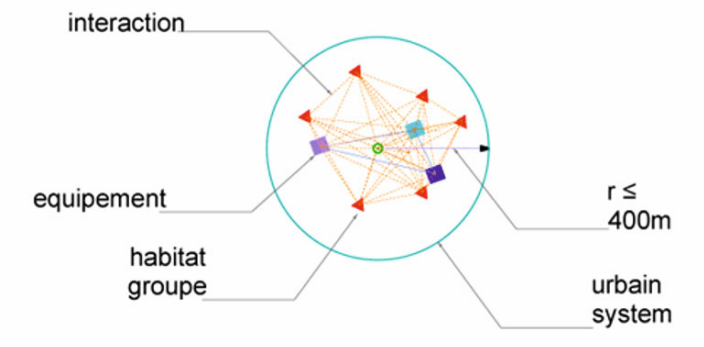


Fig. 2a. Configuration of the urban system. Drawn by the author

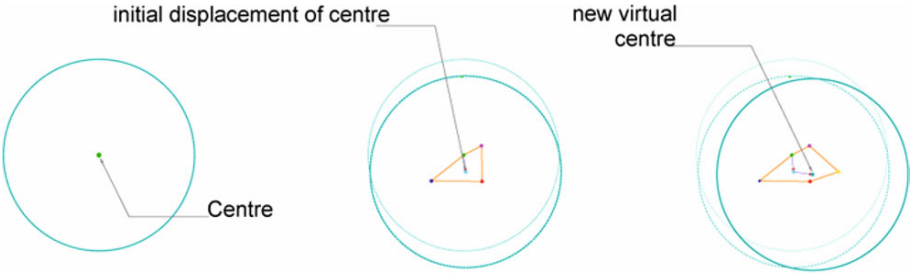


Fig. 2b. The dynamic centre. Drawn by the author

And so, an urban system can be defined by the following formula:

$$US = PS * E * GH * GA = \{PS_{m|m\geq 1}, E_{N|n\geq 1}, GH_{p|p\geq 1}, GA_{p|p\geq 0}\},$$

where n, m and p are the numbers of elements; PS is the subset of public spaces, i.e., plaza, street or park that is often characterized by an important flow of people and that gives public life and activities; E is the subset of equipment, i.e., collective facilities (administration, education (school, university), health (health care centre, hospital), culture (theatre, cinema), religion (church, mosque) etc.); GH is the subset of habitation groups (house, housing); and GA is the subset of activity groups (factory, warehouse, atelier etc.).

In particular, we notice that the proximity becomes a significant measure of the urban system. All the elements influence on each other within a certain distance. The maximum distance from "home" (a habitation group) to a facility in an urban system is of 800 m. Thus, the rayon of interaction of a system is r=400 m. It is the general distance allowing the everyday life on foot, or by bicycle in the system. In addition, the appearance of diverse public equipments on the system impact significantly on the dynamics of the centre.

Dynamics of urban centre

We propose a new concept, "programmatic moving centre" which derives from dynamic centre of the urban system based on its evolutionary structure.

This programmatic moving centre also implies the concept of diversity (the phenomenon of growth generates more diverse programs) and of the changing value of programs.[4]

The centre is one of the phenomenological results of the city. It produces and distributes all kind of activities of the city. In fact, the concentration of buildings around public space induces more material exchanges, information, uses and social acts. The monument was often the most prestigious building entity symbolizing the centrality of district, village or city. It has an absolute symbolic value of the system created by and for the man. The absolutely fixed point of the centre by a monument can become dynamic in a field of attraction composed of several groups of the entities. We suppose that complex linkages between several public building entities generate different organization forms so that various types of central configuration can appear. In addition, the changing value of potential programs (according to the need and the change of society) modifies continuously and restructures its centrality.

In fact, the morphology of a city could be understood by its perpetual transformation at the urban system.

To determine the *programmatic moving centre*, several operations should be considered:

- Detection of the potential programs;
- Geometric linkage between these programs;
- Localization of the center by a given geometry;
- Establishment of the urban system in a ray of 400m from the centre of gravity;
- Revaluation of the center according to the structural evolution and changing value of building entities

Our statement is that certain mathematical concepts can be the key words to understand, explain and represent the dynamics based on the *programmatic moving centre* in contemporary cities.

Programmatic moving center and symmetric equilibrium: "Centroid" & "Weighted mean"

Nowadays, the urban area is unstable and it reveals more complex form by the phenomena of growth, sprawl and fragmentation. The urban centre could be considered no more as a static but as a dynamic one! We suggest applying certain mathematic languages such as "centroid" and "weighted mean" to calculate and to represent the dynamic evolution of the urban centre.

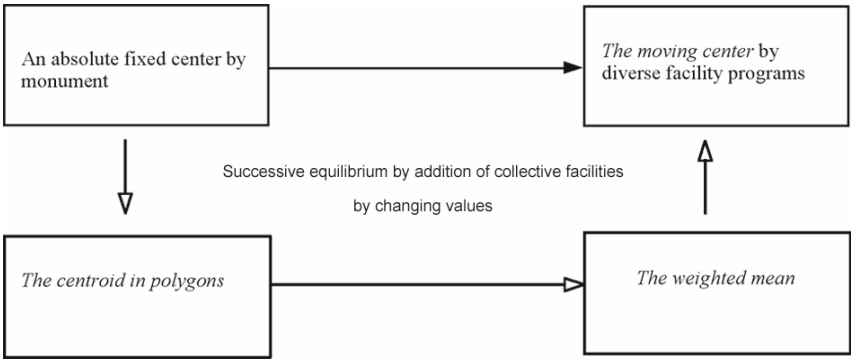


Fig. 3. From an absolute fixed center to the programmatic moving center by integrating "Centroid" and "Weighted mean"

Let us visualize the successive steps of transformation integrating the dynamics of the urban system beyond the static cent*re based on a fixed point by a monument* (fig. 4):

1. Appearance of a system with an historical centre composed of the symbolic building, and habitation groups;
2. Displacement of the centre of the system by adding another equipment;
3. New virtual center among the three equipments and growth of GH (group of habitation);
4. Virtual center reconstituted by different values (*1, 2, 3*) of the equipment;
5. Movement of urban system according to the various centre of gravity.

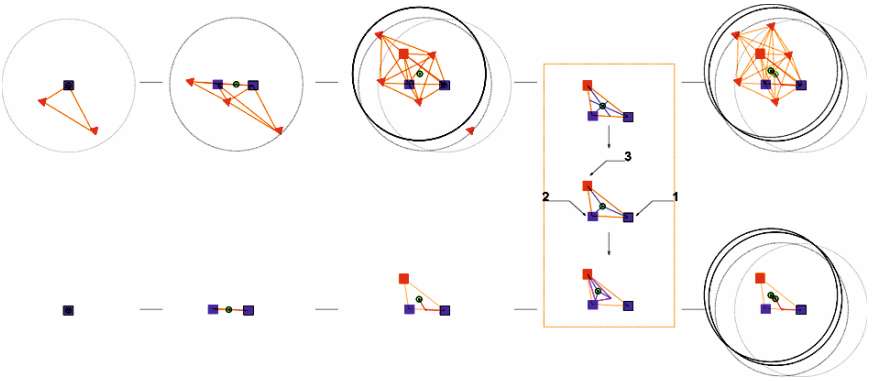


Fig. 4. Dynamics of urban system based on the evolution of gravity, drawn by the author
Legend: △ (in red) - group of habitation, □ (in blue) – equipment (facility), o (in green) - centre of system

In particular, at steps 3, 4 and 5, we start to realize the form of interactive field that can show higher geometry complexity by adding more facility programs. Also, it describes the displacement of point of *centroid* based on the changing value of programs.

Then, let us apply the mathematical formula that makes it possible to obtain the centre of polygonal organization. In the 1st image in the *figure 5* below, the pentagon connecting 5 entities could be broken up into five triangles and each one has its *centroid*. So, the *pentagon centroid* ($\vec{G}$) can be described below:

$$A_1 = \frac{x_1 y_2 - x_2 y_1}{2}$$

$$G_1 = \left\{ \Sigma \frac{(x_1 + x_2)}{3}, \Sigma \frac{(y_1 + y_2)}{3} \right\}$$

$$\vec{G} = \frac{\Sigma A_i \vec{G}_i}{A} = \left\{ \Sigma \frac{(x_i + x_{i+1})(x_i y_{i+1} - x_{i+1} y_i)}{6A}, \Sigma \frac{(y_i + y_{i+1})(x_i y_{i+1} - x_{i+1} y_i)}{6A} \right\}$$

where A is the surface; G is the centre of gravity; and $\vec{G}$ is the centre of gravity in the polygon.

Look at the images in fig. 5, which show the establishment of the centre by the *polygonal centroid*. It shows that the centre moves by applying different values (for example *1*,*2* and *3*) in pentagonal geometry at the third step.

At the present time, the interaction among the equipments associated with historical buildings in an urban centre, which was represented by a triangle or a simple polygon, will be geometrically much more complex. In addition, the application of the changing value in different time can require more sophisticated calculation. Thus, the *polygonal centroid* above is not sufficient to explain and to represent more complex urban centers.

By considering also the problem of geographic coordination, we could resume the three following problems below:

- Problem of more complex geometries (many facility services laid out);
- Problem of the value of the facilities (values in different times);
- Problem of coordination x, y (localization of programs).

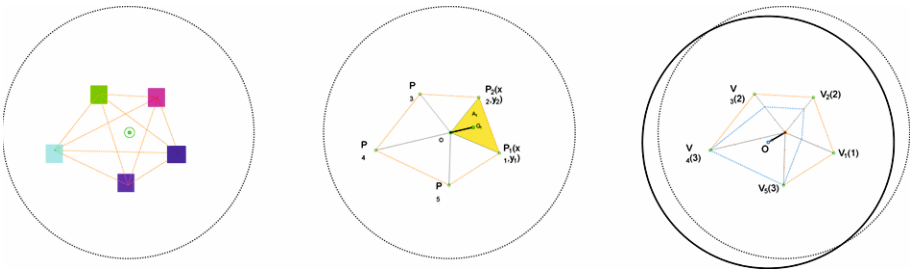


Fig. 5. Establishment of centroid in complex form and displacement of centroid by the changing value of programs in pentagonal organization, drawn the author
Legend: ☐-facilities, P- coordination of facilities, V- value, O – centre of urban system

The theory of Alain Schärlig for the best localization[5] based on the minimum F (*frais totaux*) helps the understanding and the calculation of the dynamic centre of urban system focused on the facility programs in the research. The concept of the localization theory is based on the equilibrium point that repositions constantly between the components. We also suppose that application of the equilibrium notion is effective to obtain an optimal organization of the dynamic urban system.

Let us propose that the concept of "weighted mean"[6] is appropriate to the determination of *the programmatic moving center* by solving the three problems above through the transformation in time (…, t_{-1}, t_0, t_{+1}, …).

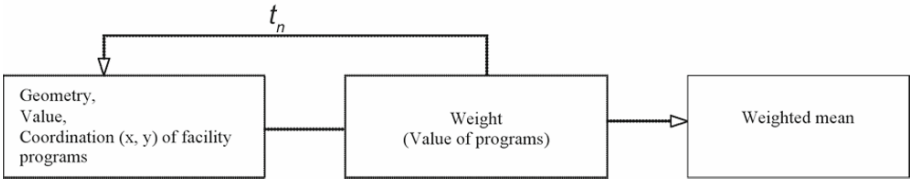


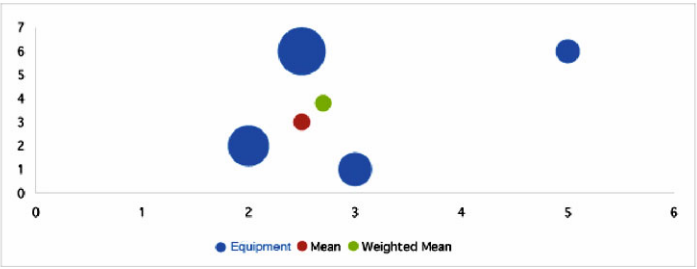
Fig. 6. The problem of programmatic moving centre and weighted mean

We reinterpreted this mathematical law (*the weighted mean*) by integrating it into *the programmatic moving centre*. Then, each facility is considered as a mass that includes geographic coordinates (x, y) with "actual weight" (*the value of the program*).

Here, we determine the application of *weighted mean* to the *programmatic moving center* by weighting the values[7] and by calculating the coordinates (x, y)[8] of the various equipments below:

In Table and graph 7, the value of commercial programs (market and hypermarket) has been amplified (from 1 to 5) like that of school (from 2 to 4). And the appearance of the library and its changing value have made an influence to the dynamic centre. The value of the other programs (church and administration building has been weakened in reverse. In fact, the dynamics of centre (*Point in red→ Point in green→ Point in yellow*) was illustrated by calculating the equipments' positions (x_i,y_i) and those values in different times (t-1→t 0). It showed us the more effective result by applying the *weighted mean*. We will experiment three real cases of the West Lausanne,[9] Switzerland: the center of *Bussigny*, *Prilly* and *Ecublens* to understand the dynamics of the urban systems in agglomeration area (Table and graphs 8-10).

item no.	name	x position	y position	weight		weight * x	weight * y
1	church	2.5	6	4		10	24
2	commune	2	2	3		6	6
3	school	3	1	2		6	2
4	maket	5	6	1		5	6
5							
	sum	12.5	15	10		27	38
	mean	2.5	3		weighted mean	2.7	3.8
					formula =	(w1 * x1 + w2 * x2 + w3 * x3) / (w1+w2+w3)	



item no.	name	x position	y position	weight		weight * x	weight * y
1	church	2.5	6	1		2.5	6
2	commune	2	2	2		4	4
3	library	5	3	3		15	9
4	school	3	1	4		12	4
5	hypermarket	5	6	5		25	30
	sum	17.5	18	15		58.5	53
	mean	3.5	3.6		weighted mean	3.9	3.53333333
					formula =	(w1 * x1 + w2 * x2 + w3 * x3) / (w1+w2+w3)	

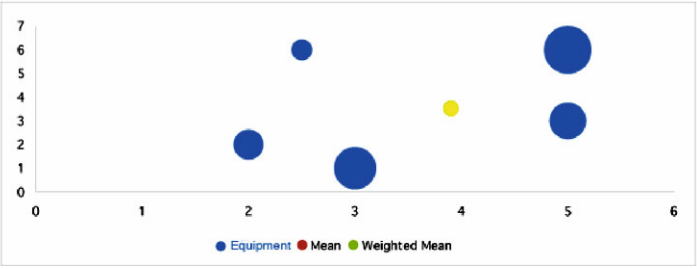
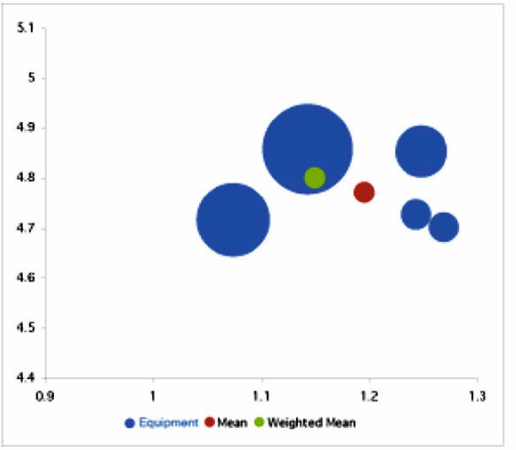


Table and graph 7. t_{-1} to t_0, by various programs and change of value, the moving centre is found on different points as equilibrium

We observe the following:

- The appearance of new equipments (school 2, church 2, market 3 and administration in several directions is less effective to displace the ancient centre.
- The appearance of new equipment (school 2) with its potential value (v=9) can displace easily the centre.
- The appearance of a group of new equipment with potential values on the opposite side of old ones is more effective to displace the centre of the system.

item no.	name	x position	y position		weight		weight * x	weight * y
1	church	1.248	4.853		3		3.744	14.559
2	commune	1.074	4.716		6		6.444	28.296
3	school 1	1.143	4.858		9		10.287	43.722
4	market1	1.243	4.727		1		1.243	4.727
5	market2	1.269	4.701		1		1.269	4.701
6								
7								
8								
9								
	sum	5.977	23.855		20		22.987	96.005
	mean	1.1954	4.771			weighted mean	1.14935	4.80025



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3	school 1	1.143	4.858		9		10.287	43.722
4	market1	1.243	4.727		1		1.243	4.727
5	market2	1.269	4.701		1		1.269	4.701
6	school 2	1.195	4.784		9		10.755	43.056
7	churchi2	1.031	5.065		3		3.093	15.195
8	marcket3	1.184	4.436		6		7.104	26.616
9	administration	1.003	4.696		3		3.009	14.088
	sum	10.39	42.836		41		46.948	194.96
	mean	1.154444444	4.759555556			weighted mean	1.145073171	4.755121951

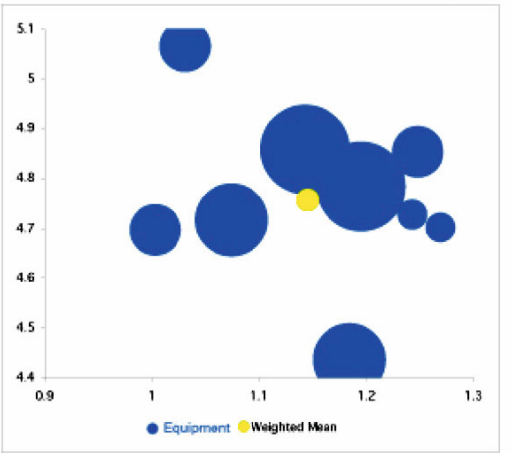
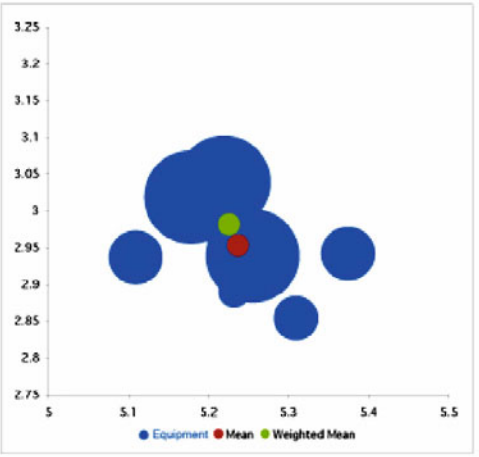


Table and graph 8: t_{-1} to t_0, displacement of the center (1. P in rouge on top → 2. P in green on top →3. P in yellow on bottom), Bussigny

item no.	name	x position	y position		weight		weight * x	weight * y
1	church	5.374	2.942		3		16.122	8.826
2	commune	5.216	3.006		6		31.296	18.036
3	commerce	5.255	2.939		9		47.295	26.451
4	police	5.109	2.937		3		15.327	8.811
5	resturant	5.309	2.854		2		10.618	5.708
6	school	5.178	3.019		9		46.602	27.171
7	nersury	5.219	3.039		9		46.971	27.351
8	marcket1	5.232	2.89		1		5.232	2.89
9							0	0
	sum	41.892	23.626		42		219.463	125.244
	mean	5.2365	2.95325			weighted mean	5.225309524	2.982



item no.	name	x position	y position		weight		weight * x	weight * y
1	church	5.374	2.942		3		16.122	8.826
2	commune	5.216	3.006		6		31.296	18.036
3	commerce	5.255	2.939		9		47.295	26.451
4	police	5.109	2.937		3		15.327	8.811
5	resturant	5.309	2.854		2		10.618	5.708
6	school	5.178	3.019		9		46.602	27.171
7	nersury	5.219	3.039		9		46.971	27.351
8	marcket1	5.232	2.89		1		5.232	2.89
9	school2	5.309	3.19		9		47.781	28.71
	sum	47.201	26.816		51		267.244	153.954
	mean	5.244555556	2.979555556			weighted mean	5.240078431	3.018705882

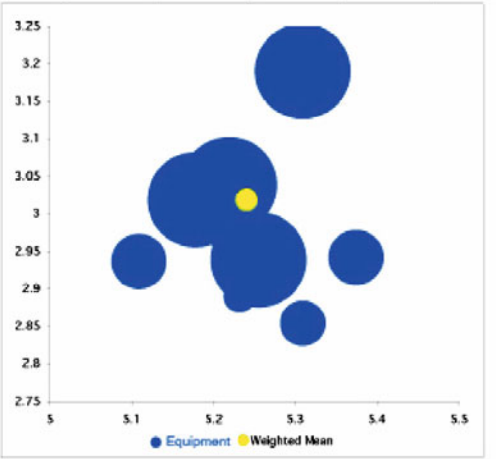
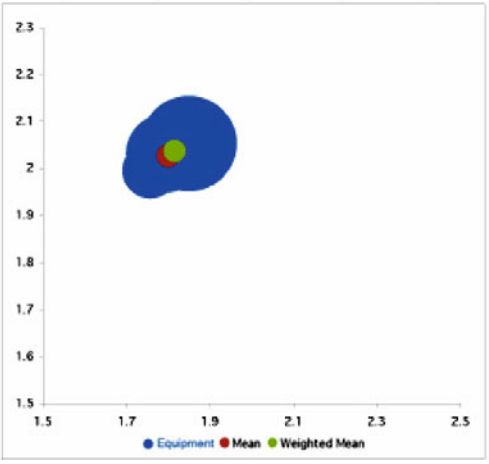


Table and graph 9: t_{-1} to t_0, displacement of the center (1. P in rouge on top→ 2. P in green on top →3. Not in yellow on bottom), Prilly

item no.	name	x position	y position		weight		weight * x	weight * y
1	church	1.849	2.053		9		16.641	18.477
2	commune	1.793	2.032		6		10.758	12.192
3	Restaurant	1.757	1.995		3		5.271	5.985
4								
5								
6								
7								
8								
9								
	sum	5.399	6.08		18		32.67	36.654
	mean	1.799666667	2.026666667			weighted mean	1.815	2.036333333



item no.	name	x position	y position		weight		weight * x	weight * y
1	church	1.849	2.053		3		5.547	6.159
2	commune	1.793	2.032		6		10.758	12.192
3	Restaurant	1.757	1.995		3		5.271	5.985
4	administration	1.661	1.761		3		4.983	5.283
5	school	1.77	1.729		9		15.93	15.561
6								
7								
8								
9								
	sum	8.83	9.57		24		42.489	45.18
	mean	1.766	1.914			weighted mean	1.770375	1.8825

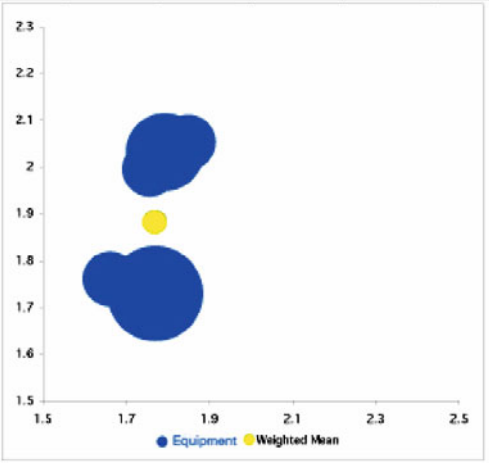


Table and graph 10: t_{-1} to t_0, displacement of the center (1. P in rouge on top→ 2. P in green on top →3. P in green on bottom), Ecublens

Urban morphogenesis representation of West Lausanne

The *urban morphogenesis representation* shows the moving centre in West-Lausanne based on the notion of *centroid* and of *weighted mean*. The magnetic field of urban system has been configured as various geometries from a point to the complex polygon (•→ -- → △→□→★). The numerous equipments and their changing values in times have resulted in urban dynamics. Therefore, the centre moves.

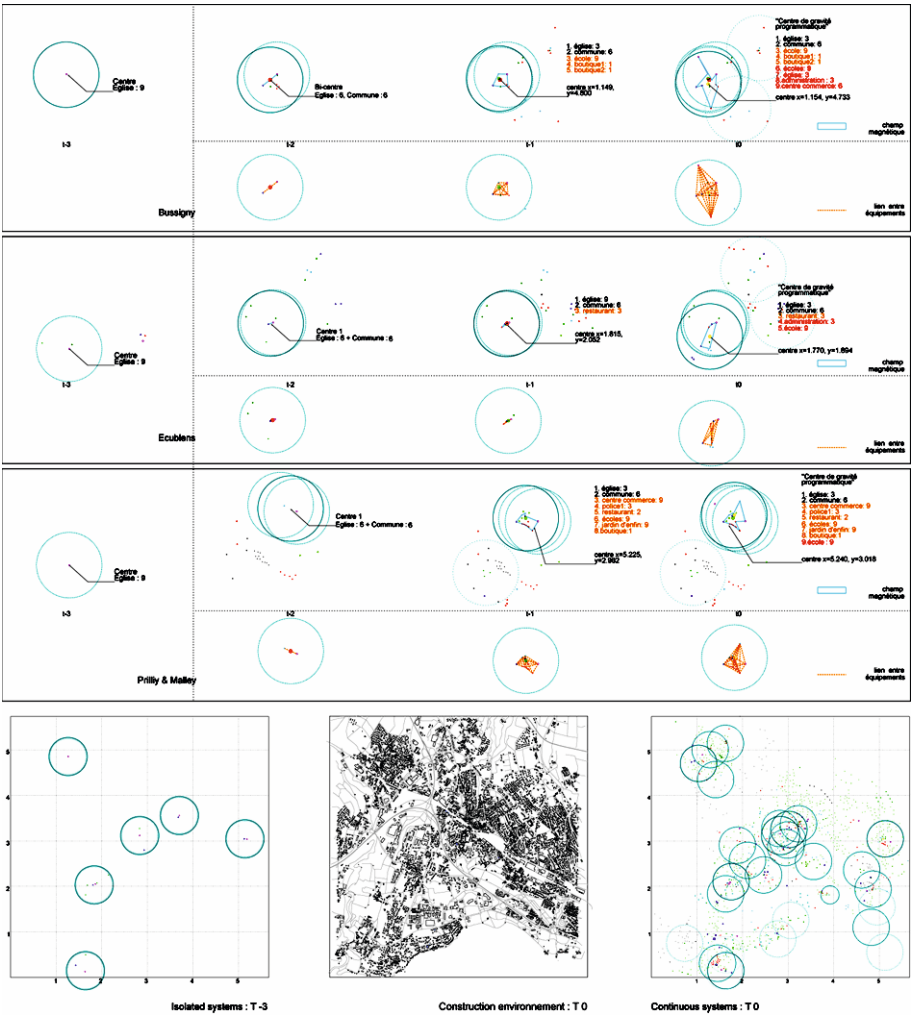


Fig. 11: Evolution of systems and programmatic moving centre: Bussigy, Ecublens and Prilly in West Lausanne, drawn by J-J.Park

Conclusion and discussion

The village or the *quartier* is newly defined as an urban system with its interactive elements: GH, GA, E, and EP as a whole. At this level of organization, the role of the equipments (facilities) revealed through their interaction and relative value is considerable.

The dynamic centre could characterize differently the urban system. The addition, the removal, the displacement of the collective programs and the changing values reinterpret the centrality. Therefore, the city adapts itself to its evolution (according to the needs and the transformation of society).

By developing the concept of the urban centre, it was important to identify and evaluate the existing urban elements and its evolution. Because we supposed that the unstable urban area could be organized more effectively as the indigenous and the new ones became a whole.

Thus, we worked on the *centroid* and the *weighted mean* to identify and evaluate the moving center based on the concept of symmetry. Furthermore, the *weighted mean* was very effective to represent the urban complexity and its centre around dense and mixed buildings. We also expect that these concepts will be useful to determine the localization of the grand equipment at a higher scale.

Three major questions could be asked concerning the dynamics of the urban systems:

- Which centrality is to be proposed for the contemporary city?
- What kind of method is the more useful in order to describe the change of urban state?
- Which kind of operation is appropriate for evaluating the new centrality?

The equilibrium can be explained as the organisms' unceasing act of optimization on growing up. With this process, the concept of symmetry could be applied in this paper in order to understand the contemporary city. It is interesting that the dynamics in urban area can be also understood as the act of unceasing optimal organization. The *centroid* and the *weighted mean*, that relate to the concept of symmetry profanely, allowed us describe and illustrate successive equilibrium of the unstable urban area.

So the dynamics of the centre in the urban system could be recognized by the effect of the equilibrium based on unceasing localization of divers collective programs.

The study can be extended to the two parameters that are decisive for a radical transformation of this equilibrium:

- *Strategic localization of the existing and new programs as collective facilities;*
- *Choice of effective programs according to their changing values.*

The localization of a certain program is already an act of perturbation that can provoke dynamics in the urban area. In addition, the synergy effect by the existing and new collective programs could be more considerable in dense and mixed contemporary city.

The dynamics are mainly influenced by growth and transformation of the facilities in the scale of the system. However, it should be well understood in totality including the dynamics of residence building groups in lower scale and the dynamics of the continuous systems in higher scale.

Otherwise, the automatic integration of evolutionary values to the GIS (Geographical Information System) remains a field to be developed for a forthcoming research about dynamic urban morphology.

Notes

1. In the Western European society, the urban centre (from village to metropolis) has often been established by historical buildings like the church or the town hall built around public places. As time goes by, public facility buildings have been built nearby and newly configured a dynamic urban central area.
2. Morphogenesis is the whole mechanisms explaining the reproducible appearance of structures and controlling their form. It is a fundamental question in all sciences of nature. Professor Patrick Berger (EPFL-IA-UTA) has applied this term to explain urban morphology. We apply this term for the dynamic morphology of contemporary cities. We consider here that the form is deduced by the interaction between the elements of the complex urban system. The pattern develops and become a total form with the process of interactions. The morphology of cities is dynamic while crossing its own transformation process (*urban morphogenesis*). It also could be understood as a result of economic optimization.
3. Normally, the equipment represents the whole of the installations, the networks, the buildings that make it possible to ensure the populations the collective services they need. Let us define the "equipment" as collective building units. These facilities become thus structuring elements of the urban system around the other central elements of the city.
4. It is a reflection on the urban centrality of today from the point of view of complex program. The centrality is found in the middle of various collective housing units including the old prestigious buildings e.g. the church or the town hall. The center, which was imposed by an absolute point of prestigious buildings, becomes the virtual and dynamic point in a magnetic field developed by the several housing units and collective equipments. The complex links between building units are created. This new central configuration can generate different form of fluidity, activities and urban life. Most of all, the urban centre transform by the evolution of the collective programs and their values through the time.
5. $\min F = \sum_{i=1}^{n} w_i r_i \sqrt{(X - X_i)^2 + (y - y_i)^2}$
   $w_i r_i = a_i$
6. One defines "*weighted mean*" as the average of a certain number of balanced values of coefficients. In statistics, considering a set of data, $X = \{x_1, x_2, \cdots, x_n\}$, and the corresponding non-negative weights, $W = \{w_1, w_2, \cdots, w_n\}$, the weighted mean $\bar{x}$ is calculated according to the formulae:

   The weighted mean is the quantity $\bar{x} = \frac{\sum_{i=1}^{n} wx_i}{\sum_{i=1}^{n} w_i}$ which means that

   $$\bar{x} = \frac{w_1 x_1 + w_2 x_2 + w_3 x_3 + \ldots + w_n x_n}{w_1 + w_2 + w_3 + \ldots + + w_n}$$

   (extracted from Wikipedia, http://en.wikipedia.org/wiki/Weighted_mean).
7. We abstracted the value of equipment from -3 to 10. The arbitrary evaluation of the value on the paper can be criticized but the changing value of the programs is one of the determinant factors to demonstrate the dynamic tendency of urban center.
8. The coordinates *x*: longitude, *y*: latitude. On the paper, we also abstracted the value of each coordinate (*x*, *y*) from 0 to 10 to describe and to explain more effectively.
9. We choose the West-Lausanne as a study area in which the urban dynamics has actually arisen from remarkable urban growth with construction in diverse and considerable transformation near Lausanne city.

References

ALEXANDER, Christopher. 2002-2005. *The nature of order*. 4 vols. Berkeley: Center for Environmental Structure.

ALLAIN, Rémy. 2004. *Morphologie urbaine: Géographie,aménagement et architecture de la ville*. Paris: Armand Colin.

BACRY, Henri. 2000. *La symétrie dans tous ses états*. Paris: Vuibert.

BASSAND, Michel. 2004. *La métropolisation de la Suisse.* Lausanne: PPUR.

BEJAN, Adrian. 2000. *Shape and structure, from engineering to nature*. Cambridge: Cambridge University Press.

BERGER, Patrick and Jean-Pierre NOUHAUD. 2004. F*ormes cachées, La ville*. Lausanne: PPUR.

BOURGINE, P. and A. LENSE., eds. 2006. *Morphogenèse*. Paris: Belin.

DARVAS, György. 2007. *Symmetry*. Basel: Birkhäuser.

DE CHIARA, Joseph, Julius PANERO and Martin ZELNIK. 1984. *Time saver standards for residential development*. New York : McGraw Hill.

FRIEDMAN, Yona. 2008. *L'ordre compliqé*. Paris: Editions De L'eclat.

JACOB, François. 1970. l*a logique du vivant, une histoire de l'hérédité*. Paris: Editions Gallimard.

LABORIT, Henri. 1971. l'*homme et la ville*. Paris: Flammarion.

LECUREUIL, Jacques. 2001. La programmation urbaine: nécessité et enjeux, méthode et application. Paris: Le moniteur.

MARSHALL, Stephen. 2009. *Cities, design & evolution*. NY: Routledge.

MERLEAU-PONTY, Maurice.1945. *Phénoménologie de la perception*. Paris : Gallimard.

MORIN, Edgar.1977. *La méthode: 1. La Nature de la Nature*. Paris: Seuil.

PLAZANET, Corinne, ed. 2008. Morphogenèse de la métropole. Master's thesis, Labo.UTA-INTER-EPFL École Polytechnique Fédérale de Lausanne.

ROSEN, Joe. 2008. *Symmetry rules: How science and nature are founded on symmetry*. Heidelberg: Springer.

SCHÄRLIG, Alain. 1973. *Où construire l'usine ?: la localisation optimale d'une activité industrielle dans la pratique*. Paris: DUNOD.

VERON, Jaques. 2006. *L'urbanisation du monde*. Paris: La découverte.

WEYL, Hermann.1952. S*ymmetry*. Princeton: Princeton University Press.

ZWIRN, Hervé P. 2006. *Les systèmes complexs: Mathématiques et biologie*. Paris: Odile Jacob.

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Jong-Jin Park, originally from the Republic of Korea, earned a Master's degree in Art and Architecture under the direction of Prof. Patrick Berger and Prof. Inès Lamunière at the École Polytechnique Fédérale de Lausanne (Thesis and Project: *une promenade vers un Paris insulaire*). He has participated in the architectural and urban design studio of Prof. P. Berger (EPFL) as a teaching assistant and with the thesis project "Morphogenesis" in the laboratory UTA from 2005. He is interested in urban morphogenesis and laws of symmetry to represent dynamic urban morphology. His Ph.D. thesis, "Contemporary City Morphogenesis: Multi-scale Model Experiment" was accepted in April 2010.