A R C H I T E C T U R E C I V I L E N G I N E E R I N G E N V I R O N M E N T
The Silesian University of Technology No. 3/2010

PATTERN ANALYSIS. STUDY ON COMPOSITION STRUCTURE IN MUSIC AND ARCHITECTURE

Jan SŁYK*

* Dr.; Faculty of Architecture, Warsaw University of Technology, ul. Koszykowa 55; 00-659 Warszawa; Poland
E-mail address: *j.slyk@fpa.pl*

Received: 20.06.2010; Revised: 14.09.2010; Accepted: 30.09.2010

Abstract

Researching generative processes in design leads one towards theory of architecture. Evaluation of created forms demands exact instruments. In the engineering field mathematical models could be implemented as well as rules derived from laws of physics. Parametric description of aesthetical solution requires rules we do not have. Art object needs calibration accordingly to algorithmic criteria. Is it possible? Architectural debate focuses on holistic aspects of reality. Building, design project, concept exists as completed subject. Researching architectural molecules we prefer global, arbitrary definitions much more to micro-scale analysis. Experiments described in this paper illustrate efforts made to discover and understand elementary architectural tissue. Juliusz Żórawski's idea, introduced far before Christopher Alexander's algorithmic methodology, constitutes foundation for evaluation as well as for creation processes. Data acquisition, differently than procedures present in generative concepts, relies on rational analysis of space. Structural optimization as well as individual/accidental/chaotic parameters are taken into account with secondary importance.
Authors aim to research whether architectural argument can benefit from elementary analysis of patterns as proved on the field of contemporary music. If yes – can we implement discovered rules for generative form-creation processes?

Streszczenie

Refleksja nad użytecznością generatywnych metod projektowania wiedzie ku teorii architektury. Dokonywanie oceny efektów twórczej działalności wymaga precyzyjnych narzędzi. W obszarze technicznym – dostarczają ich matematyczne modele procesów oraz reguły wywiedzione z praw fizyki. Chcąc parametrycznie opisać estetykę rozwiązania – musimy ściśle sformułować zasady, czyli ustalić kryteria ewaluacji odpowiadające logice algorytmicznej. Czy jest to możliwe? Opis architektoniczny posługuje się nader często ogólnym postrzeganiem rzeczywistości. Projekt, budynek, jednostkowa idea traktowane są w nim jak zamknięte i skończone podmioty wywodu. Analiza w mikroskali, poszukiwania struktury najdrobniejszych elementów składowych i reguł ich wiążących ustępują miejsca definicjom stylów, ograniczonych niekiedy do produktów wąskiej grupy twórców. Przedstawione w artykule eksperymenty dążą ku poznaniu struktury architektonicznej na poziomie elementarnym. Koncepcja Juliusza Żórawskiego, wyprzedzająca algorytmiczne podejście do analizy przestrzennej znane z prac Christophera Alexandra staje się podstawą dla dokonywania oceny i generowania form architektonicznych. W odróżnieniu do wielu współczesnych koncepcji, źródłem informacji o powstającym obiekcie nie jest zespół przypadkowo pozyskanych danych oraz rezultat optymalizacji strukturalnej. Autor próbuje zbadać, czy podobnie jak w analogicznych studiach nad kompozycją muzyczną, akwizycja informacji architektonicznej może odbywać się na gruncie racjonalnej analizy uporządkowań. Jeśli tak – czy reguły wywiedzione z modelu teoretycznego posłużyć mogą do konstruowania nowych rozwiązań?

Keywords: **Pattern; Perception; Form; Genetic algorithm; Shape grammar.**

1. INTRODUCTION

Development of information technology brings new impulse to theory of architecture. Taking into account numerous variables – computer became strong architect's ally. We are able now, to describe in numbers external and internal conditions. Digitally controlled spatial navigation allows to explain sensual impressions as sequence of vector images. Proportions, formal structure, rhythm, color, articulation – all architectural characteristics achieved parametric status. However, demands for precise reasoning grew. While exploring architecture algorithmically, one expects to find certain rules. It is easy to come across them in material world. Much harder – on the field of pure art. Referring to Vitruvius's trinity of architectural universals – a useful and durable building could be described through certain parameters. Researching existing structures, samples, projects and simulations architects measure geometry, quantify physical features, compare results with expectations.

What about beauty? Is there any constant foundation for aesthetical reflection?

This paper refers to experiments undertaken in CAAD studio, Warsaw Faculty of Architecture. Juliusz Żórawski's theory of architectural forms, Christopher Alexander's implication method and integrated CAD toolbox were implemented to achieve both: discover and create primary architectural genotype – pure spatial patterns. Universal rules derived from psychology of perception became a foundation of an algorithmic, decision-making process, described thereafter. Contrary to existing shape grammar experiences – implemented method rejects historical grounds. It does not rely on regularities found in relative information [1]. The only aspect taken into account in this experiment is human reaction and interpretation evoked by visual signals. Experiments engage research, as well as didactic activity. Studio work bases on tutor's interdisciplinary experience (IT knowledge, scripting, theory of art) and student's fresh approach.

2. BACKGROUND

Twenty-eight years before Christopher Alexander's "Pattern Language" [2] was published, a polish modernist – architect and professor – *Juliusz Żórawski* introduces a text concerning formalization of architectural reasoning [3]. His PhD thesis, defended during war in 1943, is now recognized as pioneer achievement in psychological aesthetics. *Rudolf Arnheim* [4] follows the same concept assuming there is a strong relation between human psychology and physical parameters of art individuals.

Design methodology based on "if...then" structure allows to evaluate solutions. In the way *Alexander* solves functional problems, *Żórawski* examines schemes, and 3D projections – trying to answer how visual sensations (of architecture) induce spatial impressions.

Author starts from describing so-called "tendencies". He assumes human being tends towards cohesive forms, geometrical patterns, limited numbers, etc. An interpretation of what we see is strongly dependent on psychological preferences – presented here idealistically – as constant within culture. Therefore, a structure of image is relevant for aesthetical judgments. Żórawski presents arguments useful for theoretical research as well as for design practice. Several rule types, formulated by *Żórawski*, help to establish language for space description:

- Axiomatic rules – define vocabulary of forms and patterns; e.g. "The form is an organization of parts" [5]
- Descriptive rules – illustrate statistically proved psychological effects of visual stimulation e.g. "All visual illusions result from inconsistency of partial forms that constitute global form bringing the illusion" [6]
- Parametric rules – measure previously defined interactions and impressions e.g. "Conformity of formal and functional guidelines creates more consistent patterns and forms" [7]
- Semantic rules – describe the role of locations and relations between forms constructing patterns e.g. "It is possible to define beginning and end of a consistent form" [8]

First part of Żórawski's work introduces tools for an interpretation of space. Author explains implementation of referred rules. Theoretical schemes illustrate examining techniques for spatial form evaluation and categorization .

Second part – brings architectural examples. *Żórawski* presents historical buildings and urban complexes in the way the interpretation of forms is facilitated. By utilizing symbolic sketches, real buildings are transformed into models. On that base author researches aesthetical meaning – describes space with help of formal language. Analogically to Alexander's patterns – abstract rules work much better in an algorithmic sense. Architectural context generates numerous interferences. Meeting Donald Knuth's [9] postulates demands to clarify the image. Żórawski's representations simplify spatial contexts and allow to figure out basic structural rules.

3. CASE STUDY

Although Żórawski's work is not a definite foundation for algorithm – it is one of the most formalized architectural descriptions. *David Cope*, starting his work on Experiments in Musical Intelligence based his research on both: examples of actual *J.S. Bach* music, and a theory of Baroque polyphony [10]. It is barely conceivable that one could compose inventions and fugues without these resources. Historical compositions contribute motives (words) and structure (grammar). Theory written by *Fux* [11], in extremely consistent, mathematical way – gave proper reference point for mutations and form creation. Efforts of architects studying algorithmic composition fall into two separate categories. Shape grammarians research historical patterns present in existing buildings or projects. Progressive designers develop skills of form creation by deriving tools from IT descended from their own aesthetical narration. Is there anything in-between?

The following section presents experiments undertaken in order to investigate how we could benefit from implementing traditional architectural theory. First study aims of discovering formal structure of architectural objects – rejecting individualism, focusing on physical aspects. Second study examines automatic procedure of evaluating shapes. In the place *David Cope* used Fux's theory of voice movement – we put Żórawski's Theory of Form.

3.1. Process #1 (reading patterns)

Seminar carried out in Warsaw Faculty of Architecture [12] aims at introducing methodology of rational interpretation. Through understanding regularities in different aspects of human creation (music, grammar, forming space) we try to discover communication mechanisms on the field of art. Researching two minutes of chosen music composition starts the case study. Linear character of sample and focused ear perception allows to introduce grammatical listening comprehension. Only rational filters are in use during interpretation. Although it is not possible to exclude individual perception factor, we strived for objective description. The aim is realized in three steps: (1) filtering (defining leyers: eg. frequency, rhythm, harmony, sound), (2) producing geometrical schemes for each layer, (3) discovering regularities (patterns) within layers and between them.

Summarized study, presented on the chart concludes first part of seminar. Since we base on not professional reading – graphic representation is implemented instead of real score. We apply computer tools as well as traditional research to collect observations.

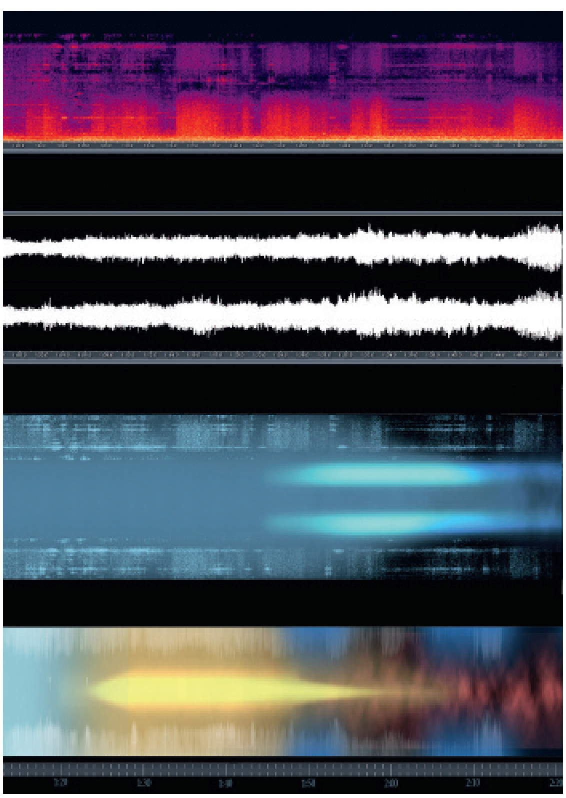

Figure 1.
Ahasverus "Oneironosia" – music interpretation; diagrams prepared with the use of computer processing tools seminar work; auth. stud.: A. Bobynko

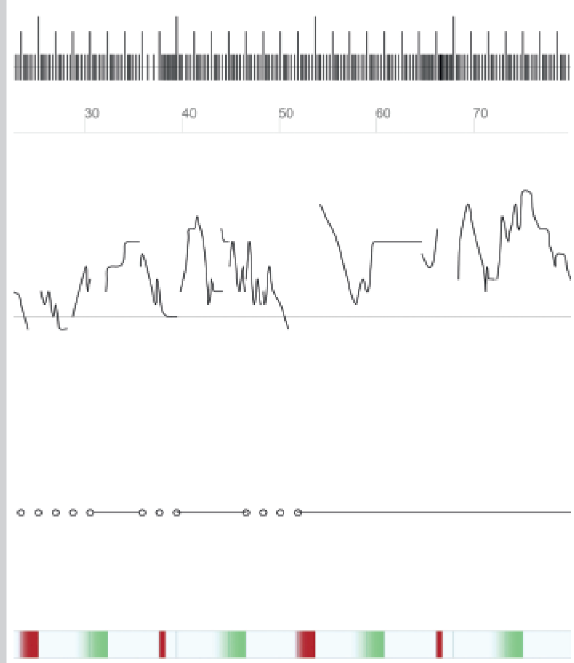

Figure 2.
"La Folia" L'Arpeggiata – music interpretation; diagrams based on traditional analysis seminar work; auth. stud.: K. Kantorowicz

Resulting diagrams depend on chosen method. Software outputs (fig. 1) represent physical, measurable features: spectral and acoustic dynamics, space/stereophony, harmonic complexity. Multicolor graph describes role of sound elements located within music space. Clouds refer to acoustic events: blue – choir chords, yellow – concentrated electronic theme, red – ambient not defined sounds, dark blue – rumbling bass. Color density and shape reflects music texture.

Traditional analysis (Fig. 2) allow to interpret abstract, intellectual aspects: rhythm, melody, articulation, harmony. All schemes are coordinated with use of time factor. Comparing vertically – one can find regularities throughout composition. Realizing particular layer contributions allow to clarify development of form, points of changes, periodic structure.

Entering architectural chapter we benefit from methodology of music study. First experience helped to interpret architectural object "as we interact with it". Professional analysis, we tend to, bases on geometrical projections (plans elevations…). Since recipient of architecture rarely realizes orthogonal views – our experiment had to reject them as well. Perspective projection in our eye constitute primary visual sensation and coming through it spatial impression. Adding time factor to the process we are able to collect fundamental samples – sequence of images + consciousness of viewer location in space.

Experiment starts from discovering crucial viewpoints. Opposite to linear music perception – architectural interpretation depends on exploration scenarios. *Kazimierz Wejchert* illustrates urban perception using "impression diagram" models [13]. Determined viewer path generates determined impression value function (strong contrasts invoke curve extremes). Our case is even more complex. Viewer interacts with single architectural object researching space. Consciousness growths as following data completes psychical image of real object. Getting new information demands relocating viewpoints repetitively. Some observations have to be verified. Real viewer paths (examined during seminar) are extremely irregular unique and unexpected. How is this described by navigation map within architec-

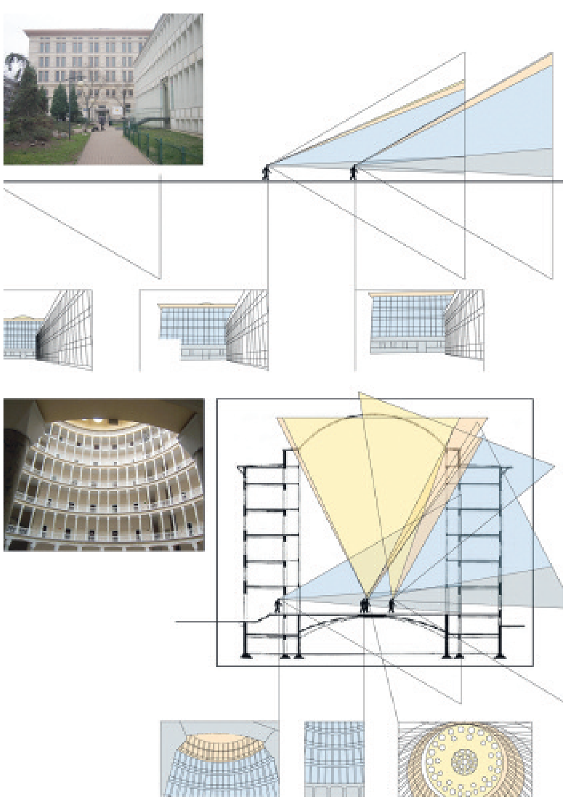

Figure 3.
M Leykam – Presidium building, Warsaw – study of viewpoint sequences auth. stud.: M. Tamoń

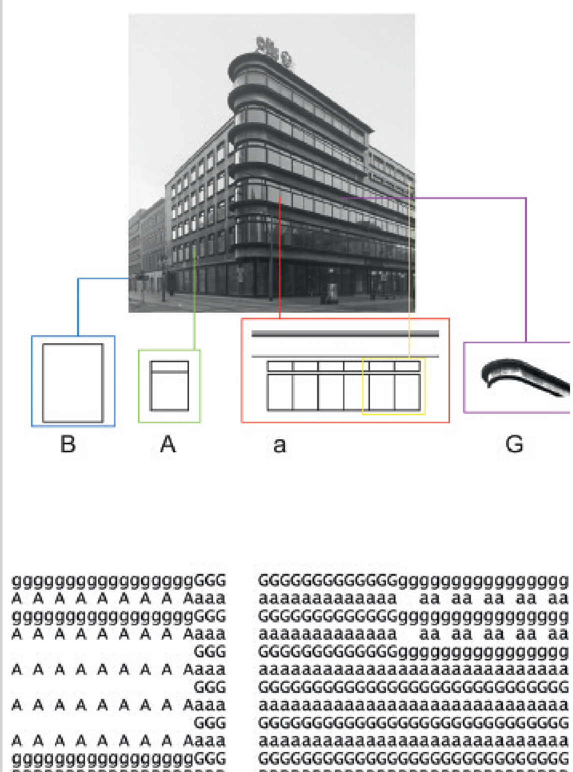

Figure 4.
E. Mendelsohn – Petersdorff department store, Wrocław – study of the skin elements. auth. stud.: P. Gniewek, J. Kamiński

tural environment? Considering Żórawski's method we assumed that perception depends on the object. Particular locations outside and inside the building offer better opportunities to collect valuable data.

Single perspective view could be described as a multilayer information container. Different containers offer different information structure. For example: looking from the long distance – we observe global relations and standing at the door, we can discover interior – exterior interaction. Complete perception demands: collecting critical mass of containers and getting coordination knowledge. Coordination depends on clear layer definition. Getting new information container the viewer interprets its contents: the base of column (detail: slab + torus) is linked with principal parent element (column) and localized (second from the left).

Diagram describing individual matrix of viewpoints, prepared by students, (Fig. 3) refers to building structure. The cone of visibility is subdivided proportionally to area covered by distinguished objects projections (grey – ground floor, blue – the body, orange – the crown, yellow – the dome). Several viewpoints generate impressions dominated by grey+blue elements. The others focus mainly on orange+yellow zone. Changes of impressions during walk through contribute knowledge and evoke curiosity.

In the second part of experiment – students researched individual layer structure of the building. Spatial elements were categorized as well as relations between them. Global composition image came into being differently than music interpretation. Music offers detailed and incomplete information in the real time. Architecture – complete and not detailed. Studying architecture is like building puzzle – started from several points, blurred at the beginning with no right sequence for getting the conclusion. Some puzzle zone are easier to recognize. The phenomenon results from internal relations we are able to find (two eyes + nose + mouth = face). These relations exist in architecture as well. Described by *Żórawski* rules let us recognize regular rhythms easier, concentrate on strong objects, tend towards balanced patterns. Erich Mendelssohn's facade study (Fig. 4) illustrate student's effort to convert complex architectural physiognomy into symbolic matrix. Four letters were assigned to indicated objects (windows, panes etc.). Chains of letters and spaces, read horizontally and vertically correspond with real wall. Elevation have been coded and represented in pure, abstract form – ready do analyze.

At the end – music and architecture interpretations were compared. Previously prepared diagrams allowed to overview composition. We tried to describe elements as well as relations. Several techniques helped to illustrate correlations and hierarchy. Grammatical models based on Chomsky method [14], formal logic, matrix mapping and others were very effective for both: music and architecture study.

3.2. Process #2 (creating patterns)

It seems unproblematic to find regularities, hierarchy and structure in existing architectural objects. Here we will describe further steps, taken in Warsaw Faculty CAAD studio [15], to research creation possibilities based on theoretical grounds. Is it possible to generate patterns meeting harmony criterions? Where should we start?

The initial part of experiment concentrates on researching programming tools. We aspire to evaluate patterns according to the tendencies described at the beginning of Żórawski's work. We decided, no specific circumstances should be considered at the beginning. Postulate of getting the solution "from nothing but theory" was realized through procedures starting from chaos and evaluating. *Gareth Loy* [16] describes analogical procedure in algorithmic music. *David Cope* demonstrates spectacular expertise executing computer programs while creating musical patterns. Theory of polyphony helps him to set the frame rules. After that – sequencing process repeatedly recombine sound chains to meet proper harmony.

Transposing experiences of music we decided to implement a heuristic procedure. The method examines 2D scheme the way humans examine a visual impression. Elements of the scheme have been purposely reduced to homogenous structure of points, which represent an architectural pattern. Generative procedure has been written in Java-based programming language – Processing.

Generative processing is relevant for solving uncertain problems concerning spatial composition. Combined procedures imitate natural evolution in the cycle of three basic steps:

1. Random process – distributes initial portion of elements within generation of samples (simulation of primary chaos)
2. Fitness process – evaluates samples according to given set of objectives (simulates natural selection)
3. Reproduction process – produces new generation of samples inheriting features of parent solutions

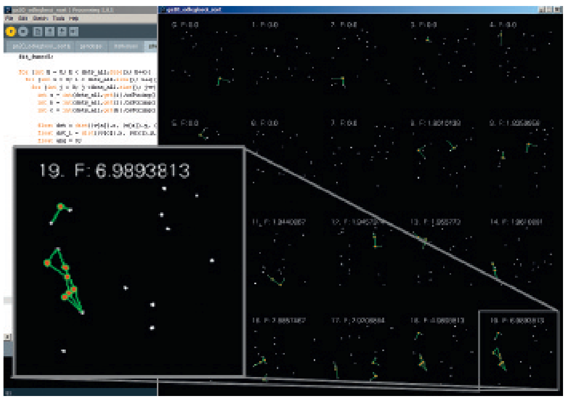

Figure 5.
Generation 5 – random deployment of points

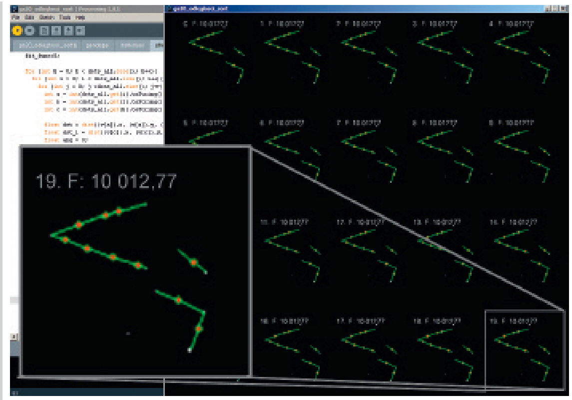

Figure 6.
Generation 1624 – ordered scheme

selected in step 2 (simulates genetic recombination, mutation and natural adaptation)

Genetic algorithm involved processes population of twenty samples. First generation represents set of chaotic distributions based on a pseudo-random number generation – linear congruential algorithm [17]. Second function searches for conclusions matching four objectives resulting from Żórawski's theory: (1) preference for objects forming straight lines (2) right angles favouring (3) recognition limited to five element groups (4) tendency to focus on strong elements.

At the beginning process analyzes space to find elements which are placed in round or right angles in relation to each other (with 2° of approximation):

```
if(dst < des_dist && dst_1  < des_dist && a !=b  && c!=a && c!=b){
pushMatrix();
translate((v[c]).x, (v[c]).y);
v[a] = new PVector ((v[a]).x - (v[c]).x, (v[a]).y - (v[c]).y);
v[b] = new PVector ((v[b]).x - (v[c]).x, (v[b]).y - (v[c]).y);

ang = degrees(PVector.angleBetween(v[a], v[b]));
v[a] = new PVector ((v[a]).x + (v[c]).x, (v[a]).y + (v[c]).y);
v[b] = new PVector ((v[b]).x + (v[c]).x, (v[b]).y + (v[c]).y);
 popMatrix();
if((ang>178 && ang<182) || (ang>88 && ang<92)){
if(centers.contains(v[c]) == false){
        centers.add(v[c]);
      }
    }
```

Throughout the generations the points features encoded in the genetic information are undergoing a crossover and a mutation processes, thus aiming to improve the overall performance of the artificial population of forms. Breaded forms are assessed and sorted in ascending order – the best individual in each generation is placed in the last position of the array.

```
Individual breed(Individual a, Individual b){
 Individual c = new Individual();
c.m_genotype = crossover (a.m_genotype, b.m_genotype);
c.m_genotype.mutate();
c.m_phenotype = new Phenotype(c.m_genotype);
 return c;
 }
```

Pairs of parents for the new individual in every generation are chosen using tournament selection method – two individuals are chosen at random with the higher probability to select higher ranked individuals.

```
Individual select(){
int which = floor((ind_num-0.00001)*(1.0-sq(random(0,1))));
 return m_pop[which];
 }
```

Result visualized on diagrams (Fig. 5 and Fig. 6) describes practical sense of the process. We start from random point clouds in population 5. Twenty possible deployments present no regularity and no geometric order. Although some points could be preferred by procedure for their potential value. Red dots visualize favored locations, green lines – relations that results from implemented geometrical rules.

Through next regenerations best possible choices have been made and mutated to start new set of 20 solutions each time. In step 1650 every point of the set is related to others. Deployment consists mainly of preferred (red) locations. There are no points recognized as separate (outside the group). Relations (green lines) set the hierarchy of elements and groups meeting criteria of regularity taken from Żórawski's theory.

The scheme generation algorithm described above is an abstract representation of a three-dimensional architectural pattern design procedure. Schematic points can be translated into coordinates determining spatial decisions.

In the simplest case – dots represent "insertion points" of architectural elements (windows, panes, columns). Relation between points constitutes composition of elements at the surface. Procedure based on Żórawski's rules generationally assembles tissue of plan or façade.

4. CONCLUSIONS

Described experiments illustrate profile of research developed to combine traditional methodology and new electronic tools. History of two decades don't allow to portray clearly how information revolution influenced architecture. Is it only next chapter of evolution? Do we participate in so called "paradigm shift" – changing everything: from hierarchy of needs to social interactions and art? Fear of coming automatic architect, drawing human being out of creative activities, seems to become serious problem in contemporary debate. Is he really so dangerous?

Exploring the subject, we get more and more confidence that CAD offers unique, new possibilities. Several design concepts and buildings of last few years owe their success to computation only. Nevertheless – no valuable effects were achieved without strong intellectual contribution based on both: individual project analysis and theoretical foundation for the idea. Our studies aspire to support that aspect. We try to understand before we generate. We develop parametric processes benefit from real – time data acquisition as well as from theory. Hopefully – coming future will allow to integrate techniques even more. Not to substitute, but to equip the architect in the society of knowledge with new, powerful tools.

REFERENCES:

[1] *Stiny, G. & Gips, J.*; Shape grammars and Generative Specification of Painting and Sculpture. [in:] The Best Computer Papers of 1971. Philadelphia: Auerbach. 1972; p.125

[2] *Alexander, C., Ishikawa, S. & Silverstein, M.*; A pattern language which generates multi-service centers. Berkeley: CA: Center for Environmental Structure. 1968

[3] *Żórawski J.*; PhD thesis defended in 1943; all references related to last edition: Żórawski J., O budowie formy architektonicznej (About Structure of the Architectural Form), [in:] Wybór pism estetycznych Kraków (Choice of Aesthetic Writings): Universitas 2008 (in Polish)

[4] *Arnheim, R.*; Art and Visual Perception: A Psychology of the Creative Eye. Berkeley: University of California Press. 1954

[5] *Żórawski* op.cit., p.41(translated by auth.)

[6] op.cit., p.57

[7] op.cit., p.59

[8] op.cit., p.82

[9] *Knuth, D.E.*; The Art Of Computer Programming, VolI. Reading MA. 1997; p.17

[10] *Cope D.H.*; The Algorithmic Composer. Madison WI. 2000; p.25

[11] *Fux J.J.*; Steps to Parnassus: The Study of Counterpoint. New York: Norton. 1943; p.42

[12] based on the results of seminar "Interpretation in music and architecture" tutored by J. Slyk in 2009

[13] *Wejchert K.*; Elementy kompozycji urbanistycznej (Elements of the Urban Composition), Warszawa: Arkady 1984; p.173 (in Polish)

[14] *Chomsky N.*; Rules and representations. Columbia: Columbia University Press 2005

[15] based on research undertaken by J. Slyk an A. Guzik within CAAD Studio scientific, tools originally prepared by authors, script examples with explanation contributed by A. Guzik

[16] *Loy G.*; Musimathics vol.I Cambridge: MIT Press 2006; p.388

[17] *Knuth, D.E.*; The Art of Computer Programming: Seminumerical Algorithms Vol II. 3rd ed. Addison-Wesley 1997