14 del 2 al 5 de Diciembre de 2008
CONVENCIÓN CIENTÍFICA
DE INGENIERÍA Y ARQUITECTURA

44 ANIVERSARIO cujae 2008

Congreso SIGraDi Cuba 2008
Gráfica Digital
Integración y Desarrollo
La Habana 1 al 5 Diciembre 2008

Top down and bottom up – using BIM to merge these two design strategies

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Abstract. **Our current research is focused on the optimization and evaluation of the architectural building design (gestalt), related and in balance to the inner organization of a building, the floorplan layout. This paper is focused on the impact of Space Layout Planning supported by Information and Communication Technologies (ICT) applied to Architectural Design. We present an overview and wide description of the „architectural design“, the classical definition and methods; and its evolution in practice since the ICT tools impact of the last forty years. Definition such as space program, space relationships, space function are wide discussed to understand the phenomena of architectural layout design, the parameters, variables, constraints and goals of each design. Second we present the state of the art and the current techniques and approaches (optimization, generative systems, artificial intelligence, genetic algorithms, physically based modeling, etc), a classification structure is generated to visualize the areas of impact and use of each technique (different areas from architectural design). Finally we described a complete framework to research and develop our own methodologies based on a specific case of architectural design, the current CAD tools and the possible develop of new tools using the impact of BIM systems.**

Keywords. Space layout planning, computer aided design, functional planning, architectural floor layout, design methodologies, simulation and evaluation

I. Introduction

After 50 years of research in the field of Space Planning and lots of solutions, prototypes, tests, depth programming, optimization formulas embedded into the architectural field, publications with big promises for the future. After all that work (and invested/spent money) we, the architects and designers, have nothing in our desk to support our daily task in the office.

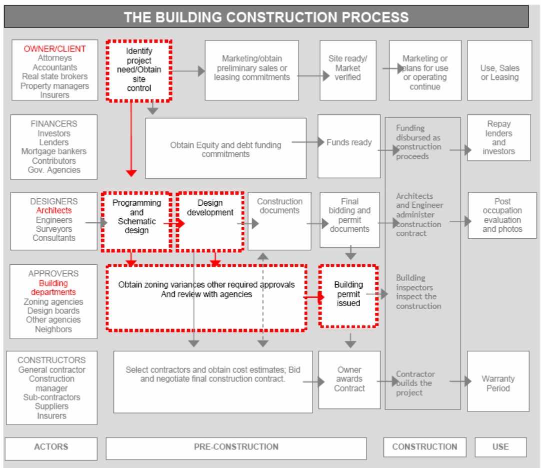
Maybe is not possible for any digital tool to create a floorplan? Maybe is possible but the solution is not an “architectural” one? Maybe the researchers are not architects? Maybe they really don´t know the problem as we know it? Have they designed a floorplan for anybody any time? We will see.

The main division relies on the “desired research environment” because the researcher will trend to bring the problem into his/her field of knowledge (because of obvious reasons) in this step a lot of information, variables, and know-how from architecture is lost. So we can hope at he end (as it happens now) that the solution will be “adequate” to the possibilities of the new field, in this case we are talking to move from architectural design process (an ill-defined task) to engineering process (a complete defined task).

No matter how fast, optimal, automated, parameterized, is the solution, architects don’t use them, and it will never satisfies/fit the large list of architectural criteria like “composition and aesthetic factors in Architecture lead to goals as functionality, habitability, balance, beauty, etc, which are in many cases subjective and hard to turn into parameters“ (Cidoncha et all,2006). Why this phenomenon happens? Some clues and some results.

II. Architects and Architectural Layout

The design of a floor plan is a stage during the architectural design process that takes place between the "schematic design" phase and the "design development" phase (see table1)



It consists in a drawing that contains the location of the different areas and rooms required by the client, as well as the sizes, names, walls and floor limits. This must be made for each story of our building and "should" met (depends on the type of building: schools, hotels, sports, residential, etc) the original space program of the clients. Under this criterion seems easy to run the design only collecting the rooms in areas, and then the areas together should "look" like a building. But of course this is process will generate amorphous shapes, orthogonal spaces, repetitive, boring and ugly results, and we don´t need to be architects to understand it. So we discard the way of placing the rooms next to each other and create a building as adding of spaces.

Loemker 2006 states that there are hundred of design methods, nevertheless the building as an object that "contains" rooms is/has been always the trend in architecture. In one hand the architect read the space program of the client (keeping it in mind and processing it) and in the other desires to design a "beautiful" form, into which he put later the rooms. This can be observed for example in some examples of three most famous architects in the history: Le Corbusier, Mies Van der Rohe and Frank Lloyd Wright (see image1) and in the current results of international competitions Norman foster, Zaha Hadid, Rem Koolhaas and Frank Ghery.

image1

How to put rooms into a shape is something seldom described in architecture, nor during the studies. The teachers of Architectural Design subjects react to a result of the students and make some suggestions (move this room, delete this room, bigger, smaller, etc) in a process known as "critique sessions" and the books show final results, not the process. A famous sentence in architecture says "form follows function". Only Francis Ching and Neufert have made a big (and famous) efforts to explain some "techniques" but not steps, to distribute the rooms into a shape. We could/must conclude that this process is still a blackbox: the result appears suddenly, like magic.

III. Technical Description of the Problem

The creation of an architectural layout has been labeled under different names, following two traditions in architecture: to create always something new (even the name of the things) and to give a "overlapping and coming back" during the design process: not strict limits for each phase and the possibility of return to the beginning though we are on the end. Some names are: functional planning, space planning, schematic layout, floorplan development, floor layout, arrangement of rooms, room distribution, etc. All of them attempt to assign RELATIONSHIPS to a FUNCTION, this means: from the space program of the client (rooms and sizes) architects must decide which functions are connected (or not) to other through a relationship. This process, again, is not ruled in any book. If I want to design a house in which every room is a separated building and to move from one to other though the outer space is not forbidden. Only in some kind of building there are some "rules" for the relationships of some functions (hospitals, schools, etc). Neufert has made a great effort trying to describe in extend a wide range cases and making suggestions to architects.

When the client decides to have a house or a building, he/she presents the site to the architect and declares what does he/she needs there. This declaration of needs is called "Space Program", a transcription or a translation of the needs (human activities, see Table1) of the client into an architectural programmatic language, this means, words and numbers able to be interpreted by the architect into rooms, sizes and relationships. This listing of rooms is known under several names: Project Programm, Project Summary, Architectural Order, etc. However the term SPACE PROGRAM will be adopted because means to the USE and SIZE of these spatial requirements.

Table 1			
ACTIVITIES of human being	PLACE for the activities	ROOM for the activities	SIZES of activity (Out of our research field)
To work	Places to work	Office	Minimum for a desk, a chair and walk.
To sleep	Places to sleep	Sleeping room	Minimum for a bed, a closet, a night-lamp desk and walk.
To eat	Places to eat	Dinning Room	Minimum for a table, 1 chair and walk.
To meet and share with the family	Place to meet	Living Room	Minimum for a sofa and walk.

Here the spaces (NAMES) and their sizes (AREAS) must be named, listed and grouped in areas. In this moment begins the architectural design phenomenon: to put all these rooms into a 3dshape and to add functionality and orientation, it means specific "adjacency" relationship and "location" of the room about any criteria: sun path, wind, views, optimal paths, spiritual meanings (e.g.: FengShui), It describes in detail the whole functional features the type of building. This description will vary in accordance with the type of building (see table 2). From this step also a Total Area is obtained adding all of the space sizes listed in the Space Programm Schedule.

TABLE 2		
housing buildings	Theater	Office
type of tower	Hall	Hall
types of flats	Lobby	Lobby, Floors/Offices
outer parking	Main Room	Lifts/Stairs
building services	Stage	Cleaning rooms
green surfaces	Toilets	Corridors
undergrounds	Stairs	etc.
etc	Store rooms	
	Restaurant	
	etc.	

Other words for FUNCTION are related to the activities that will take place in the room: use, utility, functionality, space. Other words for RELATIONSHIP: order, structure, distribution, organization, scheme, arrangement, orientation

When the architect starts to refine and organize this Space Program he/she has some criteria to be fulfilled. Depending on each case, one criterion could be more important than other. Next we describe the most common grouped in RATIONAL criteria: possible to measure under rational criteria or procedures and GENERAL DESIGN criteria: not possible to measure under rational criteria or procedures.

RATIONAL criteria

1. Solar: To place the rooms in the optimum *place* and *orientation* about the SUN. Objective: To assure natural illumination to the mayor quantity of rooms of long stay
2. Views: To place the spaces in the optimum place and Orientation about the Views. Objective: To assure the best views from the long stay rooms to the landscape or surroundings.
3. Accessibility: Referred to the distance between the main street (or *street of access)* and the building´s entrance. Objective: To minimize the distance to access the building.
4. Related Functions: Some functions of the space program are *more* related than others. Objective: to establish which rooms are high, medium or low related. And which room is desired NOT to be closer to any other.
5. Minimum distance: Objective: Minimum distance between rooms to optimize the circulations spaces.
6. Efficiency (Circulation / Usable Ratio - Circulation): the result of comparing the circulations surface with the usable surface. Objective: to keep the most surface for use and fewer surfaces for circulation.
7. Efficiency (Volume/Usable): the result of comparing the volume of each space with the usable volume of it. Objective: to keep the most volume for use and less free volume. Other aspect like sun and ventilation could have an influence over this variable.

GENERAL DESIGN criteria

8. Geometric Composition: the rooms must be inside a mayor geometric form (square, circle, arc, rectangles, etc), sized and grouped following aesthetic intentions.
9. The Divine Proportion/Golden ratio: the wall distribution follows the sides of a rectangle and the lengths of both sides of the rectangle obey to a fix numerical relationship (1.6180339887). Possible to be measured.
10. 3d Shape to fill: Ching 1975[1] defines the possible configurations in space distributions: Linear, Central, Yard, U Shape, L Shape, Organic shape, Religious shapes.
11. Sustainable criteria: the space distribution should to met an optimum regarding to any sustainable criteria (minimal surface in perimeter walls, energy consumption, solar gain in surfaces, material quantification, room light load, etc).

All these variables must be considerate during the layout creation, so our problem now is to put together the rooms but following some of them. The problem is very complex, in a design is possible to fulfill only some of them. In those cases architects declare that the design is optimized for…(solar, views, etc.) they lack of tools to demonstrate it.

Some steps from this stage are represented by abstract methods: Matrix / Schemas / Topology (see image2)

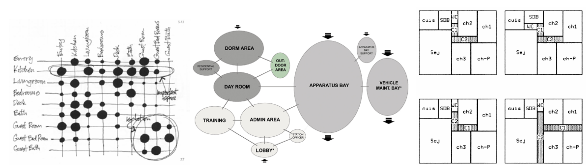


Image2

Finally the conversion from these abstract methods to a real design is neither clear, nor ruled and it still remains in the "black box" paradigm LYON (2005-2007).

IV. Brief History of Research in Space Planning and Highlights

The lack of tools to make space planning research in the architectural field has leaded to search in other fields like Engineering to find solutions to the problem. As it was declared when we shift to other discipline we lost some variables and we gain some new.

In the last 50 years there have been many rapprochements to different fields, mainly on engineering. One similar approach is founded in the "Floor Planning" sub-field and here we can find some areas that use this techniques and related concepts:

1. Computers Design: i.e.: driven layout and floor planning of electronic devices and systems.

2. Electrical and Electronics Engineers (IEEE): i.e.: automatic layout generators for I/O cells.
3. Vision systems - Computer vision-Sensor array: i.e.: Automated camera layout to satisfy task-specific and floor plan-specific coverage requirements.
4. Plant Design, Engineering and Operations Research, etc.

The oldest approach used to face the problem is "Floorplan design for industry" (Cidoncha et all, 2006) in which we can find these stages: definition of products and production process, location of industrial plant, Industrial plant project, Building and Facilities. The study of methodologies was carried out intensively in the fifties (Immer and Buffa), then SLP (Systematic Layout Planning) by Muther in 1961 in which the flow of material and works for every kind of floorplan is included, no matter the kind of building (offices, schools, etc). Not other important researches were carried out in this field due to the wide acceptance of this method. The last years the researches have gone deeply into layout generation and solution optimization, two steps of this process.

But of coarse that many other authors have tried to use other approaches, next a small list/history of authors that have research this field of Space Planning:

Author	Title	Publication/Reference
Buffa, E.S., Armour, G.L., Vollman, T.E.	*Allocating Facilities with Craft*	Harvard Business Review, 1964
Johnson, T.E., Weinzapfel, G.E., Perkins, J. I., et al.	*IMAGE: An Interactive Graphics-Based Computer System for Multi-Constrained Spatial Synthesis.*	M.I.T., 1970
Mitchell, W.J.:	*A Computer-Aided Approach to Complex Building Layout Problems*	EDRA2 Conference, 1970
Miller, W.R.	*Computer-Aided Space Planning*	Workshop on Design Automation, 1970
Eastman, C.E.	*A System for Computer Assisted Space Planning*	Workshop on Design Automation, 1971
Al Banna, S. and Spillers, W.R.:	*An Interactive Computer Graphics Space Allocation*	Workshop on Design Automation,1972
Mitchell, W.J. and Dillon, R.	*A Polynomial Assembly Procedure for Architectural Floor Planning*	Third Environmental Design Research Association Conference, 1972
Krawczyk, R.J.	*SPACE PLAN: a User Oriented Package for the Evaluation and the Generation of Spatial Inter-Relationship*	10th Design Automation Workshop, 1973
Gero, J. S.	*A System FOR Computer-Aided Design in Architecture*	Principles of Computer-Aided Design, 1973
Teicholz, E.	*The Computer in the Space Planning Process*	12thDesign Automation Conference, 1975
Gero, J. S	*Computer Aids to Design And Architecture*	N. Negroponte (ed.),1975
Weinzapfel, G., Negroponte, N.	*Architecture-by-yourself. An Experiment with Computer Graphics for House Design*	Siggraph 1976
Fortin, G.	*BUBBLE: Relationship Diagram using Iterative Vector Approximation*	15th Design Automation Conference 1978
Ruch, J.	*Interactive Space Layout: A Graphic Theoretical Approach*	Conference on Design Automation, 1978
Shaviv, E.	*Automatic Generation of Optimal or Quasioptimal Building Layout*	CAADFutures1985

A. State-of-the-art review

1) Research and Prototypes

We started reviewing the last ten years. The first interesting point founded here is that many names are given to this field of research:

Names	Author (Year)
Automated Layout	Hassett, 1982
Automated Floor Plan Generation	Chichian, 1996
Space Layout Planning	Arvin and House, 1999
Floor Layout problem	Li, Frazer and Tang, 2000
Autonomous Layout Design	Epstein, 2001
Space Planning *Space Planning Methods*	Hsu, 2000 Hsu and Krawczyck, 2003
Space Allocation *Floor Space Relocation*	Al and Spillers,1972 Loemker, 2006
Architectural Layout Design	Michalek, Choudhary and Papalambros, 2002 Nilkaew, 2006 Keatruangkamala and Sinapiromsaran, 2005

The second is the descriptive survey of each approach, they will be described: Author (year), techniques utilized, Procedures description, finally an evaluation of each one (pros and cons).

1. Arvin and House (1999). *Physically Based Modeling Techniques*

Forces and elastic band concepts applied to a functional space program. Use of "Dynamic Physic Simulation". Adjacency is modeled as a spring (elastic) connection. It transform the designer's "intention" of "to move an space" into forces.

Pros: Objective design vs. constrained design comparison. Allows users interaction like in "real world". Detailed description of implementation.

Cons: Complex definition for relationship between spaces/mass and vice-versa.

2. Hsu (2000). *Constraint Based*

Creates a Data base with relationships between spaces and the surrounding (site, sun, light, wind). Features:
Autocad + LISP. Several options generation. Use of colors and 3d Diagrams. It generates a 3d wall model

Pros: It considers architectural input for the DataBase like relationships, site and natural conditions. The application follows these restrictions (constraints). It work in a well-known environment (AutoCAD)

Cons: No description of implementation (just the language: AutoLISP + AutoCAD). No use for non-rectangular shapes. No accurate in spatial orientation. Difficult to check spatial relationships.

3. Elezkurtaj and Franck (1999-2002) *Algorithmic Support*

System that supports architectural floor plan design interactively. Approach: New AI (Artificial Intelligence), Evolutionary Strategy (ES) and Genetic Algorithm (GA). It deals with task of define the function in architecture, allowing some proportions for the room and some topological relationship between them. When the solution is created by GA it allows the user to modify the result and see the new solution in real time.

Pros: Wide description of GA function and optimal, how to search the optimum. Description of mathematical operations. Interface emulating architectural design environments, simple use, allows easy and intuitive interaction with the user with a fast answer in real time. Result is really acceptable in terms of architectural design . Description and critics of AI, New AI, Shape grammars and GA.

Cons: No description of implementation. Images are not clear. No real case of study (only from students). There is no a fix room list. It doesn´t considerate specific cases (standard cases). Missing links to web in papers. Use of boundary is not clear.

4. Li, Frazer and Thang (2000) *Constraint Based Generative System*

Non Linear Programming that provides multiple solutions. LINGO Non Linear Solver mixed with: SLP (Successive Linear Programming) and GRG (Generalized Reduce Gradient Alg.). Visual implementation in Microstation.10 solutions in 4 minutes. Optimal and sub-optimal solutions for giving designers "other inspiration".

Pros: Constrained Based Approach similar to the architectural practice. It is a "real" solution using "real" data. Deep explanation of implementation and techniques(SLP and GRG).

Cons: irregular boundaries are not included. Complex mix of implementation solvers SLP and GRG for non-experts users.

5. Michalek, Choudhary and Papalambros (2002) *Gradient Based and Evolutionary Algorithms*

Optimization Model and a method for integrating Mathematical Opt. and Subjective Decision during Conceptual design. Use of Gradient Based Algorithms and Evolutionary Algorithms for discrete decisions and global search. Define the available space as a set of GRID squares and use an Alg. to allocate each square to a room activity

Pros: It takes into consideration the Aesthetic and other subjective aspects of design. Mathematical optimization allows the user to interact in the design process without to be worry about the background complex operations through an "object-oriented representation" of it

Cons: Very complex description of how each variable response to another. The language of the process is not related to an architectural environment.

6. Hsu and Krawczyk (2003-2004). *Computer Aided Design In Space Planning Methods*

It presents the State-of-the-art of CAD in Space Planning, description of techniques: Neighbor Searching techniques, Switching techniques, Random techniques, Zoning Clustering, Virtual Grid Searching Methods, Bubble Diagram simulation, Interactive Space Layout, Physically Based Space modification. Finally it shows the SPDA tool: Space Planning Design Assistant (Hsu, 2003)

Pros: Qualification of spatial character in residential, firms, banks, theater. Division between fragmental and solid forms.

Cons: It doesn´t considerate the volume or shape that the architects use. Complex description of how to use the application. It doesn´t describes which is the input from the user.

7. Duarte (2003) *Discursive Grammar*

Process for mass customizing housing based on computer-aided design and production systems. Development of an interactive system for generating solutions on the Web based on a "discursive grammar" (programming grammar and a designing grammar). Provides the rules for generating designs in a particular style. Describes the designing grammar using Siza´s houses at Malagueira as a case study.

Pros: The use of computer driven shape grammars came close to passing an architectural Turing test (in Elezkurtaj and Frank, 2002)

Cons: Plans are meaningful only if they are well formed, which means that the elements are defined in a clear-cut way and manipulated according to syntactical rules (in Elezkurtaj and Frank, 1999). Architectural design cannot be reduced to producing graphics and imitating styles (in Elezkurtaj and Frank, 2002)

8. Keatruangkamala and Sinapiromsaram (2005) *Mixed Integer Programming*

Several Houses design with 4,5,6,7 and 8 rooms. Use of solvers: GLPK, CPLEX, DICOPT. Definition of variables and parameters: functional, constraints dimension. Constraint and objectives functions: minimize the distance among rooms and maximize room spaces. Use of GLPK (GNU Linear programming Kit) from Moscow Aviation Institute (Russia)

Pros: Clear interface, fast and promise the optimal layout solution with multi-objectives. It continues the stream from Frazer.

Cons: Complex geometry description instead of goals and multi-objectives. No test with architects. Complex understanding of formulae for non-experts

9. Loemker (2006) *Operations Research: Allocation Techniques + Scheduling Algorithms*

Architectural Layout Planning is described in the form of mathematical rules. Demonstrate that "design" is in principle a combinatorial problem, i.e. a constraint-based search for an overall optimal solution of a design problem. Applied to the design of new buildings, as well as the revitalization of existing buildings. Planning task approach from Operations Research is taken to prepare optimal decisions by the use of mathematical methods, where the understanding of design is in terms of searching for solutions that fulfill specific criteria. Use of scheduling algorithms. It allows Non-destructive optimization of existing floor plans.

Pros: it allows distributing a space program into an existing building. The use of non-rectangular boundary is allowed. 10 results are obtained in a few minutes. The "Non-destructive" approach contributes to create a "Sustainable Renovation of Buildings" concept.

Cons: Adaptation of Operation Research approach to resolve the re-allocation is complex for non-expert users. Interface and user interaction (input and constraints) is not clear.

10. Nilkaew (2006) *Genetic Algorithm*

It studies the House Design problem. Analysis Process: Room SPACE → Room RELATION. Qualitative: Topological (Architectural Space and Relations) and Quantitative: alternate schematic plan options. Made by GA process and computational optimization algorithms

Pros: Easy understanding of concepts: mix of qualitative and quantitative variables. It brings a real logical way of thinking from architects. It captures information from architectural knowledge: function schemes, sizes, and relationships. Generates several solutions that fit this knowledge

Cons: No use of boundary. No more shapes (only rectangles). No more data about GA implementation and objective function. No description of time consumption.

11. Doulgerakis (2007) *Genetic Programming + Unfolding Embryology*

Implementation of computational methods for the generation and the optimization of floor plans, considering the spatial configuration and the assignment of activities. Co-operative system was created, which is composed of a Genetic Programming algorithm and an agent-based unfolding embryology procedure that assigns activities to the spaces generated by the GP algorithm. Ranking Sum Fitness evaluation method is proposed and applied for the achievement of multi-objective optimization

Pros: It gives a complete literature review and classification of Space Layout Planning. A co-operative system (Genetic Programming algorithm + agent-based unfolding embryology procedure) assigns activities to the spaces generated by the GP algorithm in a natural way for designers.

Cons: Arbitrary mix of the layout’s social and cultural generative forces with evolutionary systems.
the Ranking Sum Fitness evaluation method could be not closer to architectural practices

12. Medjoub and Yannou (2001) *Topological Level and Heuristic Algorithms*

Space planning application that uses Topological solution and graphs. Applies Heuristics Algorithms for Space Ordering and allows constraints. It resolves topological aspects without presuming dimensions. It is possible to define relationships, orientation, minimum sizes.

Pros: Space Planning, Topological Solutions, Heuristics, Space Ordering, Constraint based. Argues the validity of Constraint Programming. Argues that in preliminary design topology is more important than geometry (in critic to shape grammars, expert systems and others). Clear explanation of variables and constraints. Complete description of searching mechanisms and results. Not presuming dimensions at the beginning. The space program is handled in a “architectural” way.

Cons: It mentions constraint and restriction equations, but doesn´t give names or descriptions. It is tested with architects and other users, but not tabulated. Long time of searching in first steps. Complex resolutions in terms of an architectural context but necessary for the expected solution.

Third we made a classification schedule. The criterions are:

1. Science: from which they come from.
2. Approach: trend or stream within the science field.
3. Implementation: techniques used in the resolution of the problem.
4. Boundary use: to distribute the space program (yes or not)

Science	1	2	3	4	5	6	7	8	9	10	11	12
Engineering			√	√		√		√		√		
Mathematics							√					
Physics	√											
Medicine												
Architecture		√	√	√		√	√			√		

Approach	1	2	3	4	5	6	7	8	9	10	11	12
Genetic Algorithm			√							√		
Constraint Based		√		√		√		√				√
Evolutionary Algorithms			√									
Physically Based	√											
Shape Grammars							√					
Mixed Approach			√									

Implementation	1	2	3	4	5	6	7	8	9	10	11	12
Linear Programming								√				
Non Linear Programming				√								
Gradient Based Algorithms												
Genetic Algorithms			√							√		
Integer Programming								√				
Differential Equations	√											
Mathematical Equations						√						√
Drawing techniques						√						

Boundary use	1	2	3	4	5	6	7	8	9	10	11	12
Yes			√	√			√		√		√	√
Not	√	√			√	√		√		√		

Summary and conclusions for research and prototypes

Basically all of them produce a floorplan design; this consists in a border shape that contains other interior shapes, which represents functions and sizes for human activities. Following Del Rio (2007) the common stages in all the approaches are:

- *Analysis stage:* consists of the preparation of the information, the listing of requisites, the definition of goals, the planning of needs. Known among authors as: architectonic design, intention, architectonic diagnose, functional level.
- *Synthesis stage:* the one in which solutions are generated. Current authors call it: search for the architectonic object by graphic simulation, planning, layout schematic design, topological level…
- *Evaluation stage:* the different designs are compared and the appropriate one chosen.

2) Commercial software review

Next we present some digital tools from the software companies that are/where available in the market.

13. ALBERTI (acadGraph, 1998)

A German company that developed a complete package solution for the automatic generation of architectural room layouts. It needs several „real“ inputs like: building stories structure, name of the rooms, orientation of rooms (north, south, etc), relationships between them (strong, week, medium). Finally the algorithm produces about one hundred solutions in some seconds and chose the best that fits with the criterions.

Pros: the definition of the rooms and variables to considerate is similar to the real architectural practice in a very clear and simple interface. It works with a real boundary for the building.

Cons: the solutions generated by the software were never accepted because it gave a non-artistic floor plan design and also a lot of "empty" new spaces were generated to fulfill the boundary. Creation of "non-sense" floor plans (see image 3).

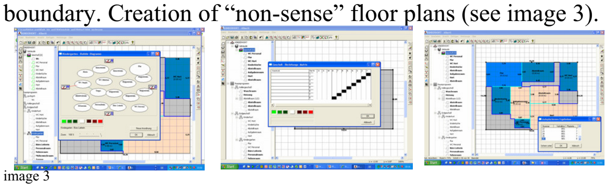


image 3

14. VECTORWORKS10(Nemetscheck, 2004)

The tool was included only in one version of Vectorworks under the name of „space Planning Tools". It consisted in three steps: 1. Definition of the space program (rooms, names, sizes and relationship between them), 2. Import schedule to the software, 3. Creation of space arrangements by the software

Pros: the relationships between spaces are defined in a classical way, so every architect will understand the interface. It shows a small evaluation 2d band for space surface comparison.

Cons: the creation of the schedule can be made inside or outside the software, but then the import step has some complications related to the excel extensions and versions. The result is a planar and non-overlapping distribution of the rooms on the screen, the architect must manually re-locate all the rooms following any criterion (see image 4).

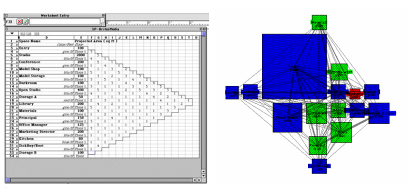


image 4

15. AFFINITY 5.0 (Trelligence, 2006-2007)

Created to support the architectural business process of a building (plan, design, construction). Allows working to different teams in the early stages: programming and schematic design. It consists in different steps: capture of space program: within the software or outside using spreadsheets, project settings: building site, use, budget and costs to met, rooms and areas settings: (sizes, numbers, relationships), schematic design: manual distribution from browser to the screen of each room, 3d visualization: it enables a GDL technology for the real-time 3d views of the rooms (as 3d blocks), evaluation and report: the solution generated is compared to the original requirements of the project and easy comparison can me made (red color when it doesn´t met).

Pros: it is possible to set some variables of the spaces and areas in a digital format, it allows to re-use this information or bring it from another applications. The report is very accurate and refers to real needs data for the client and other players. It has a wide library of types of rooms and room stuff, as well as several templates for building types (house, offices, health, etc)

Cons: it doesn´t create a solution. Architects must manually move and place the spaces along each story. The setting phase, previous to design, is very long and difficult (if we think in non-expert users) and is completely far from the "3d way" of thinking of architects. The 3d visualization is poor compared to the current tools used by architects (AutoCAD, 3dsmax, SketchUp, Archicad, etc). Pluggins for Revit and Archicad only evaluate after to take the decisions but don´t generate solutions (see image5).

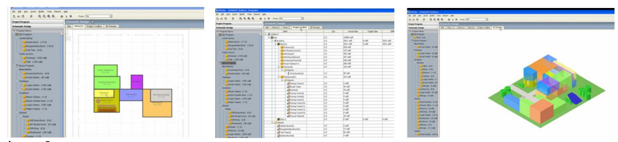


image5

<u>BIM and space planning</u>

In the architectural BIM (Building Information Modeling) software there also some tools for working in space planning. We describe some cases:

16. *Archicad 9.0:* The ZONE tool allows describing in a deep way the space contained within walls (name, number, story, area, perimeter, etc). It allows color and 3d visualization for the space (without walls and others). It must be done after the design of walls.

17. *Revit2008:* the "Room/Area" tool allows scheduling the spaces within walls and creating a color legend for each story, this allows visualizing in a customizable way the spaces-rooms-areas in each floor plan. Easy creation of reports for each story. Must be done after the design of walls.

18. *Bentley Architecture* (Microstation v8): Room and component schedules, quantity and cost calculation, specifications. After design.

19. *Allplan BIM 2008:* it is possible to create a room element (using the Room tool to define its boundaries) or the Auto-Room tool, to create rooms automatically within a specified area (it will detect all the spatial enclosures and create individual rooms within them). It allows the creation of floor space calculations and color-filled plans based on various criteria for space planning and facilities management. All possible after design.

Charles Eastman, in his last book mentions other commercial software that don´t support neither the creation, nor the selection of a solution, like *Visio Space Planner*, *Family Composer* (Army Corps of Engineering), *Solibri* (Space Program Validation for GSA), *ANSI-BOMA standard for Area Calculation*. All these tools and his evaluation of BIM tools are related to evaluation of "previous" made decisions.

Summary and conclusions

For commercial software: There is no commercial application that supports the creation of an architectural floorplan layout. The closer approach to our needs is Alberti, because it really creates solutions but they are not acceptable. Others like Affinity describe in detail the schematic layout but don´t generate one. Vectorworks is also a good approach because generates a solutions, but this is not a layout, here are the spaces together and then we need to mode them.

For research and prototypes: we have some point to enrich the future discussion about the problem. Under the engineering point of view:

- They are successful approaches in the field of engineering, they satisfied criteria of this field.
- Floor Planning is a Mathematical Problem (Rectangular Polynomial Arrangement, Gero 1977).
- Space Layout is a Engineering problem resolved and framed since a long time (*Sequence Analysis* Buffa,1955) and now some sub-steps are being improved every year.
- Optimal or Sub-Optimal results have been achieved (Michalek, Choudhary and Papalambros, 2002) (Li, Frazer and Tang, 2000).
- They follow complex constraints and relationships.
- They resolve the problem for engineers.

Under the architect’s point of view:

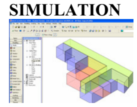
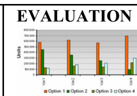
- They have failed
- Has any architect used them in a real design project?
- Have they been implemented in Architectural Practice? (except Vectorworks10 and Alberti)
- What happens with interface?
- Bad Conception and Misunderstanding of the problem?
- Are the researchers/authors architects?
- Do architects use optimal?

V. Our proposal

Then, based on the results of the descriptive stage, our background achieved in the architecture school and our own practical experience as architects, we elaborate our own criteria to be followed as a Computer Science Strategy for space planning tasks. It is based in the next observations:

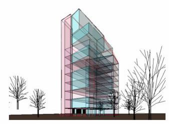
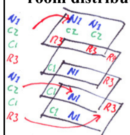
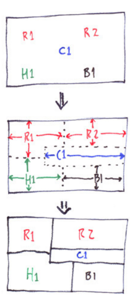
1. Functions have relationships.
2. The space program (set of functions) is flexible. In only requires a final sqm area (m2), during the process is possible to work with min/max.
3. The relationship between functions is not ruled in architecture. In engineering is based in Linear Sequence process.
4. The relation between room and function is not mandatory. Functions in architecture are not defined as a rule (neither in the law, nor in the books), only suggested or like intuitive knowledge. Only some specific cases have constraints (Low-income houses, hospitals, etc).
5. Thirty years of Space Layout research had/has no impact in real practice for architects.
6. The optimal design of a floor layout is not always/necessary the best for architects. In the case of Elezkurtaj and Frank, after the optimization process, they allow the architect to change manually the result.
7. While the architect designs with sketches there is a constant conflict of non-respected sizes (and that doesn´t matter: only are important form, proportions, function, beauty, etc), but in a defined algorithm this can not happen, because, the size restriction is never met during the process. It is not possible to write an algorithm to find something that one doesn´t knows at the beginning.

As a result of these points, we present framework based on SIMULATION and EVALUATION loop:

SIMULATION 	Author references	**EVALUATION**  	Author references
Spaces (3d rooms)	Doulgerakis (2007) Hsu and Krawczyk (2004)	Flexible criteria for specific case	Del Rio-Cidoncha et all (2003) Elezkurtaj and Franck (2000) Loemker (2006)
not final 2d Layout	Our thesis Hsu and Krawczyk (2004)	Report generation	Our thesis Elezkurtaj and Franck (2000)
Not Optimal Layout (architects don´t need one optimal)	Del Rio-Cidoncha et all (2003) Hsu and Krawczyk (2004) Hsu (2000)	Optimal evaluation for any criteria	Del Rio-Cidoncha et all (2003) Li, Frazer and Tang M (2000) Hsu (2000) Medjoub and Yannou (2001)
Interaction with designer	Elezkurtaj and Franck (2000) Arvin and House (1999)	3d layout “estimated” for continue working	Hsu and Krawczyk (2004) Elezkurtaj and Franck (2000) Medjoub and Yannou (2001)
3d layout “estimated”	Hsu and Krawczyk (2004) Arvin and House (1999) Elezkurtaj and Franck (2000)	Topological Level	Medjoub and Yannou (2001) Elezkurtaj and Franck (2000)
Flexible criteria for specific case User can enter the study case	Del Rio-Cidoncha et all (2003) Li, Frazer and Tang M (2000) Loemker (2006) Medjoub and Yannou (2001)		

This will allow an input of certain information and then will generate the solution with minimum algorithm effort. The steps for this framework are:

Stage name	Description (SIMULATION/ EVALUATION)
1. Space Program and m2 	*Evaluation* of the needs of the client in a spreadsheet table and adding all the spaces to get the total area of the building. 3d block families are created with all the rooms possible sizes

2. Massing/Shape studies 	*Simulation* of the possible volumes allowed by the Zoning Planning in the site. Creation of 3dvolume and shape desired by architect within the mass. Creation of boundaries of each story of the building using slice floorplate techniques.
3. Verification stage 	*Evaluation* of Space Program area v/s Massing Study area
4. Semi-topological room distribution 	*Simulation* of a semi-topological layout. The architect drag manually only the „name" of the rooms into the boundary of each story. At the same time, without to know it, he/she is defining the high constraints of the spaces (location, room name, number, relationship, orientation)
5. Space filling 	*Simulation* of the possible layout. Starting from the names of spaces (and their hide range of possibilities), the algorithm search between all existing room sizes, those that fit with the boundaries and adjacent rooms.
6. Final Verification	*Evaluation* of initial Space Program v/s generated solutions (room areas)

The implementation of this new methodology is based in commercial BIM software (Autodesk Revit2009) because of his powerful interface, 3d modeling capabilities, the possibility of adding constraint to objects and the capability of store several sizes within a family object (see image6). Other projects of our chair are implemented here using Parametric Constraint and API (Advanced Programming Interface).

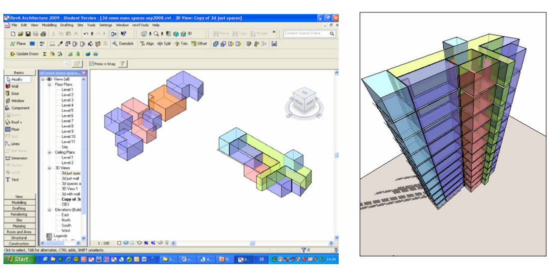


image6

VI. Conclusions

We have explained to non-architects the process of designing an architectural floorplan layout as part of the architectural design of a house and the applied the concepts to a building.

We have described in detail all the variables that must be taken into consideration when designing a floorplan layout, under the architecture point if view.

Facing the lack of methodologies in the architectural field, the trend in the last thirty years has been to take elements from engineering fields. All the researches and prototypes have a good evaluation under the engineering point of view, but not under the architectural one. The clearest proof of that is the absence of those results in our desktop, like available tools for the daily work.

Analyzing the paper and adding our architectural knowledge and background, and under the Simulation and Evaluation paradigm we have develop our own framework to develop a methodology in which the user participation is crucial to define constraints that, in other approaches, must be added by annoying medias. With this formula we decrease the dependence on a high-performance algorithm. It takes advantage of existing powerful BIM software and add a specific tool for architectural design.

It is crucial for the future that architecture students continue with the classical Design Courses but at the same time to be trained in programming tools and related courses. In this way they will resolve the problem of their area without losing the quality of the solution.

References

Arvin, S. and House, D. "Phisically Based Modeling Technique In Space Layout Planning", in *Proceedings of the Eighth International Conference on Computer Aided Architectural Design Futures*, Atlanta, 7-8 June 1999, pp. 245-262.

Ching, Frank. *Architecture: Form, Space & Order*. Van Nostrand Reinhold, New York, 1979.

Choudhary, R. and Michalek; J."Design Optimization in Computer-Aided Architectural Design" in *Proceedings of the 10th International Conference on Computer Aided Architectural Design Research in Asia*. New Delhi (India) 28-30 April 2005, vol. 2, pp. 149-159

Del Río-Cidoncha, M.G.; Iglesias , J.E. and Martínez-Palacios, J.. "A comparison of floorplan design strategies in architecture and engineering", in *Automation in Construction* 16 (2007), pp. 559–568.

Del Río-Cidoncha, M.G.; Iglesias , J.E. and Martínez-Palacios, J. "A multidisciplinary model for floorplan design" in *International Journal of Production Research*, print/ISSN 1366–588X online_2006 Taylor & Francis.

Del Río, M.G.; Martínez, J. ; Martín, A.; Bravo-Aranda, G. "Estudio Comparativo de las Estrategias para la Distribucion del Espacio en Planta en los Campos de la Arquitectura e Ingenieria" in *VII International Congress on Project Engineering*, Spain, 2003.

Donath, D.; Lobos, D. "Massing Study Support" in *Architecture in Computro [26th eCAADe Conference Proceedings]*, Antwerpen (Belgium) 17-20 September 2008, pp. 101-108.

Doulgerakis, A. "Genetic Programming + Unfolding Embryology in Automated Layout Planning". Thesis, Master of Science in Adaptive Architecture & Computation from the University Of London. Bartlett School of Graduate Studies University College London, 2007.

Duarte, J.P. "A Discursive Grammar For Customizing Mass Housing" in *Proceedings of eCAADe*,2003.

Eastman, C., Teicholz, P., Sacks, R. and Liston, K. *BIM Handbook. A guide to Building Information Modeling for Owners Managers, Designers , Engineers, and Contractors.* John Wiley and Sons, New Jersey, 2008.

Elezkurtaj, T. and Franck, G. "Algorithmic Support Of Creative Architectural Design" in ECAADE, 2000.

Elezkurtaj, T. and Franck, G. "Algorithmic Support of Creative Architectural Design" in Web page of Institute of Architectural Sciences IEMAR, Vienna University of Technology, 2002

Elezkurtaj, T. and Franck, G. "Genetic Algorithms in Support of Creative Architectural Design" in *Architectural Computing from Turing to 2000* eCAADe Conference Proceedings, Liverpool (UK) 15-17 September 1999, pp. 645-651.

Hsu, Y.-C. "Constraint Based Space Planning: A Case Study", ACADIA 2000, Quarterly, vol. 19, no. 3, pp. 2-3.

Hsu, Y.C. and Krawczyk, R.J."New Generation Of Computer Aided Design In Space Planning Methods – A Survey And A Proposal" in *Proceedings of the 8th International Conference on Computer Aided Architectural Design Research in Asia.* Bangkok Thailand 18-20 October 2003, pp. 101-116

Hsu, Y.C. and Krawczyk, R.J. "Form Development with Spatial Character Architecture in the Network Society" in *22nd eCAADe Conference Proceedings,* Copenhagen (Denmark) 15-18 September 2004, pp. 278-285.

Keatruangkamala, K. and Sinapiromsaram, K. "Optimizing Architectural Layout Via Mixed Integer Programming" in *Bob Martens and A. Brown (eds.), CAAD Futures*, The Netherlands , 2005, pp. 175-184.

Li, S.-P.; Frazer, J.H.; Tang M.-X. "A Constraint Based Generative System for Floor Layouts" in *Proceedings of the Fifth Conference on Computer Aided, Architectural Design Research in Asia*. Singapore 18-19, May 2000, pp. 441-450.

Lobos, D., "Diseño Plausible de Plantas de Piso. Una metodología asistida por IT Tools" in *Proceedings of the 10th Iberoamerican Congress of Digital Graphics (SIGRADI)*. Santiago de Chile, 2006, pp. 293-298.

Loemker, T. M. "Designing With Machines" in *Computing in Architecture / Re-Thinking the Discourse: The Second International Conference of the Arab Society for Computer Aided Architectural Design*, 25-27 April 2006, Sharjah, United Arab Emirates

Medjoub, B. and Yannou, B. "Dynamic space ordering at a topological level in space planning" in *Artificial Intelligence in Engineering* 15 (2001) 47-60.

Michalek, J.; Choudhary, R. and Papalambros, P. "Architectural Layout Design Optimization" in Taylor&Francis Group *Eng. Opt.*, 2002 Vol 34(5), pp. 461-484.

Michalek, J. and Papalambros, P. "Interactive Design Optimization of Architectural Layouts" in Taylor&Francis Group Eng. Opt., 2002 Vol 34(5), pp. 485-501.

Neufert, E.; Neufert, P.; Ed. Baiche, B.; Walliman, N. *Architects' Data.* Third English Edition, Blackwell Science Ltd, London, 2000.

Nilkaew, P. "Assistant Tool For Architectural Layout Design By Genetic Algorithm" in *Proceedings of the 11th Conference on Computer Aided, Architectural Design Research in Asia*, Japan. March 30th - April 2nd 2006, pp. 641-643.