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Computer Aided Architecture: origins and development

Computer Aided Architecture: origini e sviluppo

The essay deals with the birth of CAD (Computer Aided Design) in relation to topics of architecture (Computer Aided Architectural Design). The close link between the themes of CAAD and future BIM (Building Information Modeling) can clarify the conditions that have made possible the spread of BIM as a reference standard. We shall both consider research by Charles Eastman in the 1970s, and describe relevant considerations concerning the history of computer graphics and the architectural design, by Ivan Sutherland, Steven Coons, Nicholas Negroponte, Christopher Alexander, Douglas Engelbart, William Mitchell, Warren Chalk, Mario Carpo, Jean Nouvel.
There are many systems that have anticipated the BIM, such as the Building Description System (BDS), the General Space Planner (GSP), the COPLANNER, the URBAN5, the Building Optimization Program (BOP), the BUILD.

Il saggio affronta la nascita del CAD (Computer Aided Design) in rapporto alle tematiche di carattere architettonico (Computer Aided Architectural Design). Lo stretto legame tra CAAD e futuro BIM (Building Information Modeling) consente di chiarire i presupposti che hanno reso possibile la diffusione del BIM come standard di riferimento. In particolare vengono analizzate alcune ricerche degli anni '70 di Charles Eastman, e presentate considerazioni di rilievo della storia dell'informatica grafica e dell'architettura, tra cui quelle di Ivan Sutherland, Steven Coons, Nicholas Negroponte, Christopher Alexander, Douglas Engelbart, William Mitchell, Warren Chalk, Mario Carpo, Jean Nouvel.
Sono poi citati alcuni sistemi che hanno anticipato il BIM, tra cui il Building Description System (BDS), lo General Space Planner (GSP), il COPLANNER, l'URBAN5, il Building Optimization Program (BOP), il BUILD.

Keywords: architecture, modeling, BIM, CAAD, drawing
Parole chiave: *architettura, modellazione, BIM, CAAD, disegno*

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ORIGINS

"Our premise was that a computer database could be developed that would allow the geometric, spatial, and property description of a very large number of physical elements, arranged in space and 'connected' as in an actual building. Conceptually, the model would be similar to a balsa wood model, but with far greater detail"[1]. With these laconic words it is synthesized one of the most interesting research hypotheses on the subject of the relations between architecture and computing, recorded in September 1974 at the Institute of Physical Planning of the Carnegie-Mellon University. It is the formulation of a description system for buildings (Building Description System, or BDS) from which started an experimentation that led to the current definition of the BIM protocol (Building Information Modeling). That report was written by a team led by Charles M. Eastman funded by the National Science Foundation and – as it often happened at the time – by A.R.P.A. (Advanced Research Projects Agency) of the Ministry of Defense of the United States. Architecture had applied the digital representation systems since the early 1960's, and the computerized drawing system called Sketchpad, developed by Ivan Sutherland in 1963[2] at the Massachusetts Institute of Technology (Fig. 1) was already using, in its three-dimensional formulation, some synthetic schemes of volumes of buildings[3]. However, in Eastman's report we find that, for the first time, the real potentiality of an integrated system of control of the design phase is acknowledged, a model that is centred on the mathematical/numerical model to which various information that amplify the potentiality of the object is associated.
The role of drawing, then, would soon change, in favor of a greater automation of the representation of the model: "Later – we read in the report – we expect to focus on automatic composition of high quality architectural drawings. Among the issues we plan to investigate are automatic methods of dimensioning and automatic determination of line width and type. It is anticipated that drawings will be generated not from a perspective view with the viewpoint set at infinity but from the cartesian coordinates of sections of the elements of interest" [4]. These researchers clearly aim at a dynamic, flexible, parametric drawing, very different from the traditional drawing outlined in pencil or

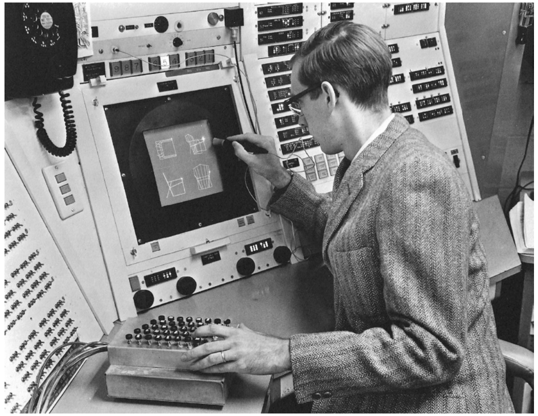

Fig. 1. Ivan E. Sutherland working with the drawing system called Sketchpad (c.a 1963); from Blau, Eve, Kaufman, Edward (eds.) (1989), p. 140.

ink on a sheet of paper. Behind these considerations, however, there is a agelong research on the assisted manipulation of architectural design. Eastman himself, in fact, had proposed few years before a system for space planning (General Space Planner, or GSP), which allowed to optimize the spatial distribution of housing units, thanks to the use of specific algorithms[5], that certainly help to develop the BDS system. On the other hand, however, many previous experiments intend to

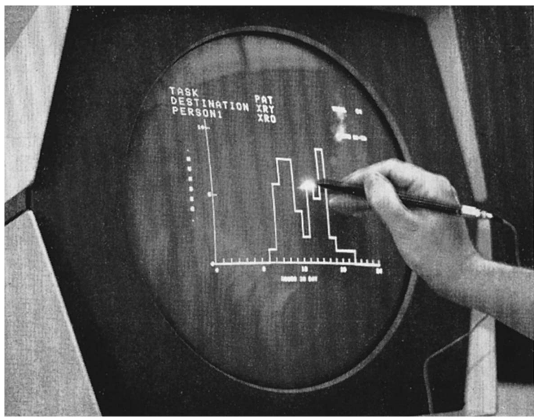

Fig. 2. Diagrams of analysis with COPLANNER software; from Souder, James J., Clark, Welden E., Elkind, Jerome I., Brown, Madison B. (1964), p. 141.

tackle the issue. An example is the COPLANNER[6] system, a method of Computer-Aided Planning based on functional distribution of hospitals, allowing to statistically and graphically control the space necessary to the design of hospitals. The work, coordinated by the architects James Souder and Welden Clark, was based on statistical information and flow charts to help the designer in the planimetric composition of the environments (Fig. 2).
Although the graphical representation was reduced to the essential aspect – the walls were drawn by the system without thickness and the internal distribution was even more simple, only described in dotted form –

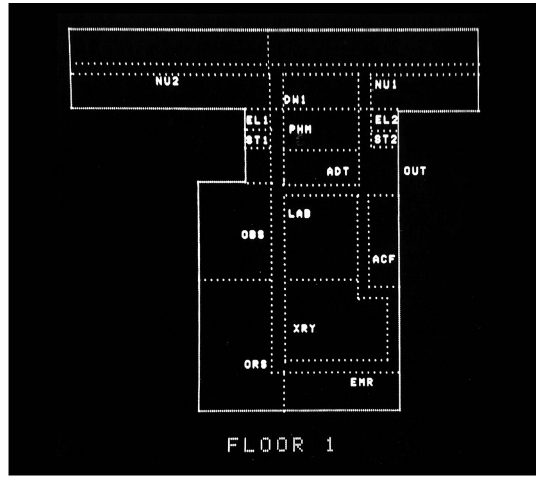

Fig. 3. Scheme of a typical floor with COPLANNER; from Souder, James J., Clark, Welden E., Elkind, Jerome I., Brown, Madison B. (1964), p. 148.

the efforts in using a computerized design system and the results achieved were without any doubt beyond all expectations (Fig. 3).
Then we have some other attempts to systematize the relationship between architectural design and computer. We must mention from David Campion's research[7] – meticulously describing all the tools available – to that of Nicholas Negroponte[8], who explores in an unsystematic way the most daring experimentation. The Architecture Machine Group that Negroponte activated at MIT in the late '60s recorded and proposed possible research paths directly involving architectural design

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Fig. 4. Architecture Machine Group, URBAN5 control and management system; from Negroponte, Nicholas (1972), p. 74.

and new tools of interaction, according to a symbiosis between the architect and the machine[9]. Among these we must mention the software URBAN5 provided for the control and the 3D reconstruction of an urban settlement, with the scope to interact with the model through the use of a control panel (Fig. 4). The essay by Joseph Licklider, entitled Man-Computer Symbiosis[10] in 1960 is certainly a landmark on critical thinking, widely referred to by authors on the same subject.

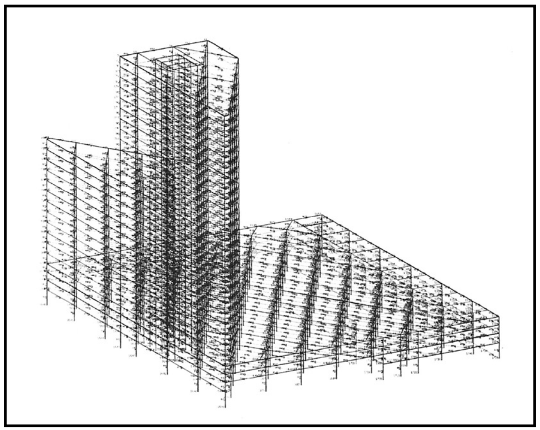

Fig. 5. Example of plot of a structural volume (C.F. Murphy Associates, progetto per Sheraton Hotel in Salt Lake City, Utah); from Blau, Eve, Kaufman, Edward (eds.) (1989), p. 145.

ARCHITECTURE AND COMPUTER

Beside this massive research on information technology applied to architecture we have the experiments of architects who, designing with traditional instruments, refer to electronic technology. Their reference is on a strictly evocative plan, conducted through the use of representations strongly characterized by conceptual abstraction. On the one hand the new digital plotting instruments showed the sharpness of free of shades lines (Fig. 5), on the other architectural firms such as Archigram and Superstudio generated equivalent drawings, although producted strictly by hand, also influenced by the graphic sign of comics.
Besides, communication media spread the information about new drawing processing tools, which became an integral part of the collective imagination about the future development of computer graphics, although the high cost of equipment did not allow architectural firms to adopt such instruments.
We must notice that the evocation was also often conducted on the edge of new housing types and not only on the figurative level. The *Computer City* Archigram was referred to a new proposal of settlement at the urban level based precisely on the intensive use of computing, as well as the *Home Capsule Project* by Warren Chalk, inserted into the *Plug-In City* (Fig. 6), proposes a way of living the domestic space in a high technological form, in which the conceptual idea undoubtedly refers to ergonomics and the modular efficiency of a space capsule.
And even some of the compositional schemes proposed by Superstudio – the histograms of Architecture, for example (Fig. 7) – refer to abstract representations similar to compositions' diagrams produced electronically by assembling mechanical parts. The same representations that they would use with their de-

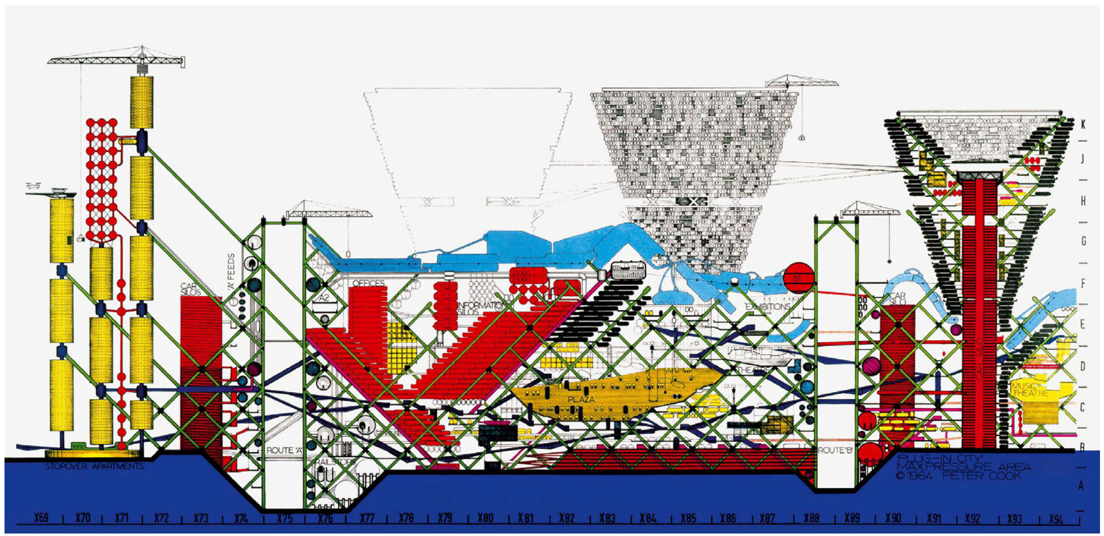

Fig. 6. Archigram, Plug-In City.

scriptive photomontages of one of the most famous and unprejudiced works: the Continuous Movement, with which they wrapped large cities like New York and Rome.
City and architecture are, therefore, in the form of complex combinations of mechanical shapes, arousing great concern and unease in those who would have to live in those spaces. It is not a coincidence that in a short text of November 1965 Chalk himself pointed at the harmfulness of these revolutionary ideas: "finally I would like to assure everyone that we are not monsters. We are not trying to make houses look like cars, cities like oil refineries, and even if we seem to be, this is certainly not the intention. Although this analogous imagery is very strong at this moment in time, it will, we contend, eventually be digested into a creative system, so that eventually a positive approach will emerge naturally"[11].
Surely the most significant research on the relationship between architecture and computers concerns theoretical previsions of the future that many computer science specialists have with extraordinary visionarity. Only in 1962 Douglas Engelbart – a leading figure in the history of electronics applied to drawing, and inventor of the 'mouse' device – had foreseen the figure of the 'augmented' architect, that is one who operates with new technologies: "Let us consider an augmented architect at work. He sits at a working station that has a visual display screen some three feet on a side; this is his working surface, and is controlled by a computer (his 'clerk') with which he can communicate by means of a small keyboard and various other devices. He is designing a building" [12]. Engelbart goes on describing all the phases of construction, from site survey, to the display of the excavation for foundations, to the construction of the walls, to the materials used, thanks to the help of the machine. Finally the computer makes the functional analysis of the work suggesting how to optimize the system. "All of this information – as the author writes – (the building design and its associated 'thought structure') can be stored on a tape to represent the design manual for the building. Loading this tape into his own clerk, another architect, a builder, or the client can maneuver within this design manual to pursue whatever details or insights are of interest to him – and can append special notes that are integrated into the design manual for his own or someone else's later benefit" [13].
In the same years Steven Coons, a professor at MIT, supervisor of the above-mentioned Sutherland's thesis, gives a similar vision of the architect, despite his training was on mechanical engineering and not on architecture: "We envisioned even the designer seated at a console, drawing a sketch of his proposed device on the screen of an oscilloscope tube with a 'light pen', modifying his sketch at will, and commanding the computer slave to refine the sketch into a perfect drawing, to perform various numerical analyses having to do with structural strength, clearances of adjacent parts, and other analyses as well. [...] In some cases the human operator might initiate an optimization procedure to be carried out entirely automatically by the computer" [14]. Coons ends the paragraph adding that "it is becoming increasingly clear that the combined intellectual potential of man and machine is greater than the sum of its parts" [15]. A close relationship is established between these two actors, the human agent and the technical tool, which, as Daniel Cardoso Llach writes, can have different forms: conceptual, procedural and rhetorical; and thanks to these considerations one particular idea is stated, as Cardoso Llach points out: "via the intervention of computer 'slaves', humans could devote themselves to a life of poetic contemplation" [16].
Also in those years Christopher Alexander offers his analytical methodologies of description of an architectural form, to be used in particular to classify and for project activity. Dedicated to the development of Design Methods, of which Alexander is a precursor, the study is considered as one of the first examples in which the description of ways in which the parties interact during the design process is precisely defined[17].
An example of this is provided by the two appendices to the book *Notes on the Syntesis of Form*. The first is dedicated to an example of the farming village of 600 people to be reorganized[18] (Fig. 8) and the second to the theme of the mathematical treatment of decomposition, which has a series of equations relating to the cyclic decomposition of a system into subsystems[19].
Among the major studies that have addressed the issue of the design process control we have to mention also that of Skidmore, Owings & Merrill (SOM), which from the late Sixties started a computerization process in which the themes of building information design are present. Among the actors of this operation we find G. Neil Harper, associate at SOM who developed the algorithm BOP (Building Optimization Program) for the control of construction costs directly and automatically in the planning stage. The optimization allowed to define the estimate value in relation to the area of intervention[20]. A more extensive discussion on the relationship between the electronic processing of information and ~~the~~ architecture is described in a book published by Harper, entitled *Computer Applications in Architectu-*

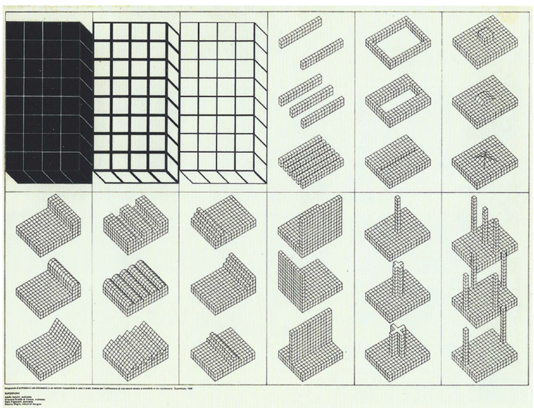

Fig. 7. Superstudio, catalogue of Histograms of Architecture, 1969; from Angelidakis, Andreas, Pizzigoni, Vittorio, Scelsi, Valter (2015), p. 273.

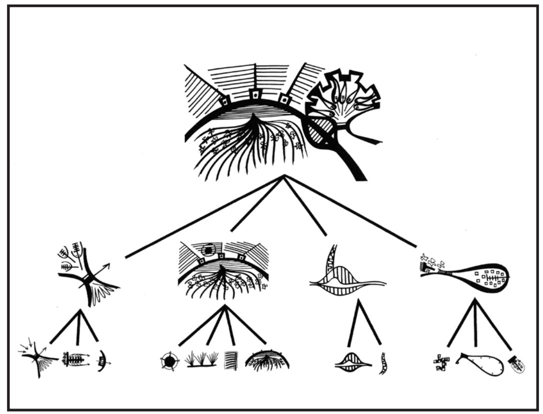

Fig. 8. C. Alexander, logical-compositive scheme for agricultural village; from Alexander, Christopher (1964) p. 153.

re and Engineering[21], which records the academic and professional research in the field. Almost all the essays in this book address the issue of the new technologies applied to architecture but a particular attention should be paid to the one by Lavette C. Teague Jr., of the Massachusetts Institute of Technology, which presents the BUILD system, a prototype of information system for building design, drawing examples applied to the sphere of functionalization of work spaces[22].
The most complete classification of the issues related to computer-aided design for architecture of those years is perhaps due to William Mitchell's Computer-Aided Architectural Design[23] (1977), a book which is rich of examples and with an exhaustive bibliography. Every chapter contains some useful information as all readers can confirm. But part 2, in particular, dedicated to databases, can be of great interest to understand the state of art on this subject. The reduction in quality and quantity standards, in fact – i.e. chapters 6 and 7, dedicated to the topological and geometric description of the buildings (Figs. 9, 10) and the definition of standard elements and detail[24] – will prove to be of paramount importance, introducing the more complex issue of the logical analysis of architecture in its computational forms[25].

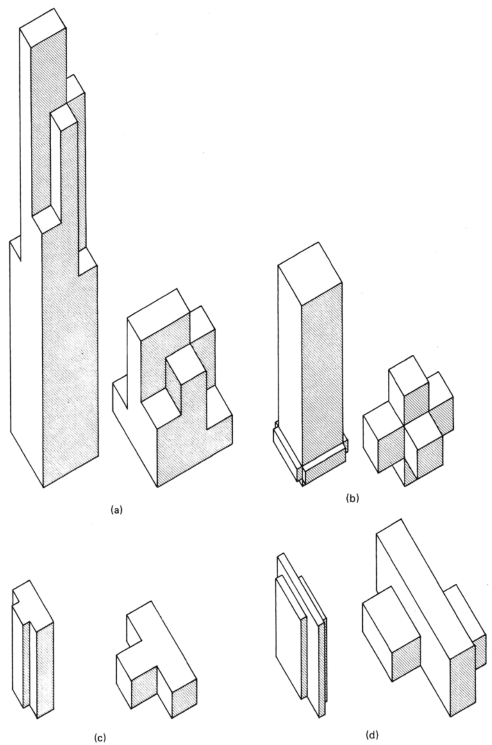

Fig. 9. Examples of volumetric reduction of architectures: a. Sears Tower, Chicago (SOM); b. Place Victoria, Montreal, (Moretti e Nervi); c. One Charles Center, Baltimore, (Mies van der Rohe); d. Thyssen-Rohrenwerke office, Dusseldorf, (Hentrich e Perschnigg); from Mitchell, William J. (1977), p. 181.

FUTURE DEVELOPMENTS

We should also reflect on the change that occurred in the work of the architect during the design process, especially considering the 'BIM variable', i.e. the need to codify the initial idea project following the precise information required by the *Building Information Modeling*. It should also be noted that there now are a lot of service companies that provide the transformation in BIM model of a project, so that it can be controlled directly in the production phase. For this purpose, it seems to be particularly interesting the reflection made by Mario Carpo, who has been studying for many years the variation of the paradigm from analog to digital that particularly concerns the field of architecture. In his book *The Alphabet and the Algorithm*, in fact, the author compares allography with authorship, reproduction with copy, especially from specific Albertian references. In facing also the issues of the new BIM technologies he highlights the now stable presence of two key figures in the definition process of the project, namely: the "primary author", who is the subject of the creative act and the "secondary author", who, in the production process, transforms the basic idea in the final solution. According to Carpo, the relationship established between the two figures is similar to the one existing between the player and the game designer: "each gamer invents (or, in a sense, authors) her or his own story, but playing by the rules of the game and within an environment conceived by someone else"[26]. Something similar happens to the design and to the BIM format translation of an idea so that it takes over all the potentialities expressed by the reduction procedures.
The history of CAAD origins is linked inseparably to the idea of being able to systematize the design process in order to generate graphics primitives oriented to architecture; primitives, that is, maintaining, in addition to the formal characteristics, even those semantic annotations that allow the allographic parameterization of every single element in order to be rapidly used while composing architecture. The suspicion that we are increasingly in front of a work with a reduced creative characterization than in past – in which the architect was asked to invent thanks mainly to authorship synthesis of her/his mental processes – is legitimate[27]. This suspicion made Jean Nouvel say, during a well-known conversation with the philosopher Jean Baudrillard: "What could be easier than re-using already defined data, since the computer can adapt them very quickly? You change some parameters, the process takes a few hours and hop! ... Here is a new building. All these buildings, therefore, are not things you think, but they are simply the result of immediate profitability and hasty decisions"[28]. Interestingly, the conversation ends, however, by giving back to the architect that autonomy of decision which constitutes the added value of architecture: "An automatic architecture created by interchangeable architects: it is not a looming inevitability; it is already the essence of reality. It is the exception to prove the rule"[29].

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NOTES

[1] Eastman, Charles M. and others, (1974), p. 5.

[2] Sutherland, Ivan E. (1963).

[3] Cfr. the documentary *Computer Sketchpad* of the National Education Television, MIT 1964, presenting the drawing system Sketchpad III by Timothy Johnson. Cfr. also Sdegno, Alberto (2013). On history of CAD, see: Sdegno, Alberto (2009).

[4] Eastman, Charles M. and others, (1974), p. 21.

[5] Eastman, Charles M. (1972), *General Space Planner: a System of Computer-Aided Architectural Design*, in W.J. Mitchell (ed.) (1972), pp. 23.5.1-12.

[6] Souder, James J., Clark, Welden E., Elkind, Jerome I., Brown, Madison B. (1964).

[7] D. Campion, David (1968).

[8] See above all: Negroponte, Nicholas (1972); Negroponte, Nicholas (1975).

[9] See also the chapter titled *Architect-Machine Symbiosis*, in Negroponte, Nicholas (1972), pp. 8-29.

[10] Licklider, Joseph C.R. (1960).

[11] Chalk, Warren (1965).

[12] Engelbart, Douglas C. (1962); Bardini, Thierry (2000).

[13] Engelbart, Douglas C. (1962).

[14] Coons, Steven A. (1963), p. 300. On the work of Coons see: Sdegno, Alberto (2012).

[15] Coons, Steven A. (1963), p. 300.

[16] Cfr. Cardoso Llach, Daniel (2015), p. 65.

[17] Alexander, Christopher (1964).
[18] Ibidem, Appendix 1. *A Worked example*, pp. 136-173.

[19] Ibidem, Appendix 2. *Mathematical Treatment of Decomposition*, pp. 174-191.

[20] Harper, G. Neil (1968).

[21] Harper, G. Neil (ed.) (1968).

[22] L.C. Teague Jr, *Research in Computer Applications to Architecture*, in Harper, G. Neil (ed.) (1968), pp. 189-214.

[23] Mitchell, William J. (1977).

[24] Ibidem, Chap. 6. *Descriptions of Building Topology and Geometry*, pp. 155-221; e Chap. 7. *Standard Element and Detail Libraries*, pp. 223-247.

[25] Mitchell, William J. (1990).

[26] Carpo, Mario (2011).

[27] On influence of new technologies on allography and authorship for architectural design, see: Sdegno, Alberto (1996); and Sdegno, Alberto (2001).

[28] Baudrillard, Jean, Nouvel, Jean (2003), p. 53.

[29] Ibidem, p. 76.

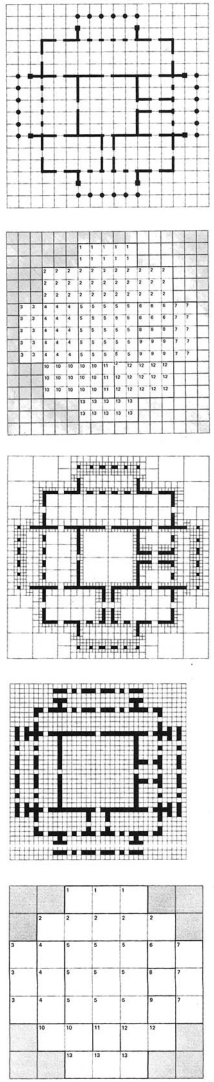

Fig. 10. Comparison of different methods of geometric description, from Mitchell, William J. (1977), pp. 218-219.

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