THE INTELLIGENT PENCIL

A framework for CAAD in education

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PROLEGOMENA TO CAAD IN EDUCATION

Computer Aided Architectural Design in Education (CAADE) can only be meaningful if it brings meaningful answers to meaningful questions about architecture and architectural education.
In the discourse about CAAD and CAADE these questions are completely absent; this can be concluded from:

1. an absolute lack of architectural-theoretical and historical reflection, without which no architecture can exist;
2. a frequent confusion between designing and drawing : the latter being a non neutral tool for the former;
3. the absence of a clear understanding of the way in which architecture comes about: what are the concepts and entities an architect is working with and how does he manipulate them?
4. no clear insights about the way architectural "design by hand" should be taught and a fortiori about the way a computer could help.

Those questions are too fundamental to ignore.
Therefore we start with some preliminary remarks about the major concepts appearing in the acronym "CAAD".

1. CAAD *and* ARCHITECTURE.

In fact architecture is completely absent in the discourse about CAAD. The objects of concern seem to exist in a kind of vacuum in time as well as in space: they have no neighbours, they ignore history, they have nothing to do with style.
Architecture does not matter! There are no questions about the way in which an architect creates authenticity - the fundamental characteristic of poetry.
The discourse is about functions, relationships, m^2, heat loss, quantities; only the perspective drawings with their specific "computer graphics" look bring some relief (10).
We see exercises in combinatorial thinking, attempts to optimalisation: the problem solving paradigm.
We see caricatures of what design should be, worse than what the decay of post world war 2 modernism has left behind.

We miss the imagination, the poetry without which no architecture can exist.
We do not discover insight in the historical determination of architecture, we miss the culture of architecture.

Some people will argue that these questions belong to philosophy: that is true. But we must realize that no approach is value-neutral, and neither is CAAD.
The crux is that CAAD can not be developed meaningfully without knowing what architecture is all about, without positioning oneself, without bearing witness to one's point of view. That does not mean that everybody should write about it, but everybody should be full of it.
This kind of reflection is almost completely absent in the debate about CAAD, the exceptions confirming the rule of course (9, 11).
That inhibits the breakthrough of CAAD.

2. CAAD *and* DESIGN.

CAAD is easy to say, is easy to sell: it is "bon ton" to talk about CAAD and to sell all kinds of programs under the guise of CAAD.
The broad definition that was given in Portsmouth (1) to the design process - the sequence of activities ending up in a design- has something to do with that. It somehow legitimizes that a very broad range of application programs (computation and drawing programs, even the computer treatment of specification texts) are called CAAD.
A more precise definition could reserve CAAD for that procedure, for those programs, which form an integral part of the design process, which are part of one and the same reasoning, which in other words do not necessitate a separate model description again and again.
Sometimes there is a confusion between computer aided drafting and computer aided design: those are related, but different concepts.
The designer thinks and works with images (4): the drawing is a tool to exteriorise those images, it is the mirror of his thinking, the drawing is the interlocutor in the non-verbal dialogue the designer has with himself (2).
This dialogue produces the design: with graphicacy playing an essential role. A designer has to master this graphicacy.

When he uses computer aids to design, the first requisite is that this designerly way of thinking is not disturbed or inhibited. That means in oter words that he must have at his disposal drawing routines which permit this way of working.

As well as pantographs, graphic packages have possibilities and limitations: they are not neutral with respect to the design.

Graphic packages which originated in other disciplines, as for example in mechanical engineering, are not suited for architecture. Indeed, mechanical engineering works with a limited number of elements, rather small in dimension, but with very high precision; its components are elementary volumes, often solids of revolution, which can be described (easily) with mathematical formalisms.

Architectural designs however are built up with other concepts:

- types, generally a composition of one or more elementary volumes,
- walls, floors and roof-elements which are in general parallelepipeds,
- openings which are or are not filled up with doors, windows or motives,
- beams and columns.

On a more concrete level the designer is manipulating building materials and building elements, which often have a compound structure (e.g. an insulated cavity wall).

Graphical routines should allow easy handling of these concepts and permit all the operations a designer needs: designerly definition, combination, repetition and transformation by translation, rotation, mirroring, extrusion,.......

Isn't architecture the delimitation of space with materials for use by men? How far removed are we still from manipulating light and space, the basic concepts in architecture,within CAAD?

3. CAAD *and* COMPUTERS.

The computer is without doubt a powerful tool for the elaboration of production documents. It has many advantages:

- all documents are 100% mutually consistent,
- modifications are easy and can automatically be carried through the whole dossier,
- production documents can be produced more rapidly.

The resulting time gain in this phase of the design process allows

the designer to spend more time on the conception of his design or to shorten his response time.
A shorter response time and a better technical quality of his dossier consolidate the designer's position in the market and increase his chances for commissions.
An important resource for this kind of applications is a data bank of the building industry with product and manufacturer data, such as the one which is in development in our country and which is structured according to the CI/SfB classification system. In the long run this data bank can be extended with permanently updated information on costs and, why not, with data on damage cases. This would be a step towards an expert system.

Concerning the contribution of the computer during the genesis of a design however, something different has to be said: we do not know of any building, playing a significant role in the architectural debate or showing a special quality because of CAAD. Neither did N.Cross find objectively better buildings in his search for the impact of CAAD (3).
The attempts to generate optimum layouts on the sole basis of transportation costs have fortunately been abandoned: it became clear that only an interactive way of working has any chance of success.
The use of computers in the early stages of the design process is still in its experimental phase.
Without exaggeration we can state that up to now this approach shows more limitations than possibilities. Some examples of this computer inhibited design are: restriction to orthogonality, laborious input and manipulation of form, 2D or pseudo 3D-thinking, a highly analytic procedure, very fragmentary software packages as black-boxes, substitution of metaphorical thinking by combinatorial thinking: the former being the key to authenticity (12), the latter being able at best to produce variations on the same theme.
Only when these limitations will have disappeared, will the computer be a real aid to design.

4. CAAD *and* EDUCATION.

It is not clear how architectural design should be taught. Some claim it is not teachable at all, others maintain that every student with average intelligence can learn how to make a design which is not wrong (i.e. without functional shortcomings).
In many schools of architecture both opinions coexist, but it would bring us too far to enter this debate.
Considering the state of the art in CAAD, it is clear to us that students should first of all learn to design by hand and only afterwards be brought in contact with CAAD, preferably in the context of a thesis, in which the experimental aspects prevail.
We have serious doubts about the pedagogical benefits of the impressive and brilliant push button shows we saw at software package demo's.
Whether we are talking about design by hand or about CAAD, we should not forget to impart to our students a good insight in architectural theory and history.

THE INTELLIGENT PENCIL.

In what has been said until now, serious reserve has been made with regard to CAAD as it is in the early stage of design by now. Doing this we aimed firstly to point out where the shortcomings are, and secondly to define a platform from where CAAD can be (re)oriented.
Indeed CAAD will only become successful, if it provides the designer with designerly tools.
In the search for such tools, our interest focusses on the sketch design phase for many reasons:

- in this phase the decisions are taken with the most important cost consequences,
- when a design is built up with a computer right from the beginning, one avoids the unproductive and labour intensive input of a handmade design into the computer, for further processing.
- the attempt to support the designer with a computer, will produce new knowledge about design as a mental activity.

With this in mind a project has been set up, aiming at the development of "an intelligent pencil".
An intelligent pencil is a metaphor for a set of interactive computer programs for the designerly creation of an archirectural design, to which are added a series of drawing- and calculation programs, to test and evaluate the design.
Doing so the designer in fact is still designing by hand, but now he can make decisions with full knowledge of their implications instead of intuitively.
This presupposes a flexible graphical manipulation and immediacy of response. All the tests must be integrated: i.e. they have to be based on one and the same data structure representing the architectural objects. This data structure has to be created in a user-friendly and designerly way, as has already been said. We have learned from experience that without this the whole framework becomes obsolete as a design tool. It is also very important to adapt the precision of the methods used in the tests to the precision and to the provisional character of the design.
The tests which we consider to be relevant at the sketch design phase, are:

T1. floor surface
T2. outer wall surface
T3. building volume
T4. compactness
T5. heat loss and heat gain
T6. cost evaluation
T7. 2D and 3D visualization, simultaneous views
T8. daylight illumination
T9. shade and shadowing

Other tests which are specific for the masterplanning of complex buildings such as hospitals, warehouses, schools, offices, etc. can be included. We are thinking of the efficiency of the circulation (-pattern), expansibility, gross-net ratio, elementary checks of stability, routing of the piping, prediction of room-acoustical characteristics,.......
All these checks make use of the same information structure, in which the geometry and the topology of the objects is represented.

Per test new data which are specific for each test are added to this basic description (quantities and qualities, properties, material characteristics).

The relevance of the above mentioned tests can be described as follows:

T1. The floor surface has to stay within certain bounds in order to be considered for state grants: this is the case for social housing, and is also true for hospitals, schools,.....

The designer can work more efficiently when he has permanent control over the floor surface he is realising.

Floor surface as well as building volume (Test 3) can also be used for rough cost estimates.

T4. The compactness of a building i.e. the volume (Test 3) to the outer wall surface (Test 2) ratio, in combination with the mean value of the heat transfer coefficient, gives a good idea of the level of global-thermal insulation of the building. Control of compactness results in better decision making in design.

T5. Calculations of heat loss and heat gain, allow good estimates of temperatures to be expected inside (for example in greenhouses). They also give an idea of yearly energy demands. On the basis of these figures the designer can decide to alter his design.

T6. In the sketch design phase all important options are taken: figures concerning the cost of the alternatives can direct the design process. Here again, as well as in the previous test, the precision of the costing method (per m^2 or per m^3) has to be tuned to the provisional character of the design.

As soon as the configuration becomes more definitive, alternative constructive solutions can be costed with "the element-method". Such computations can be done with spreadsheet software.

T7. Visualization, as has been said, plays an essential role in the architectural design process:

- several kinds of views (orthogonal and axonometric projections for example) can be generated and displayed simultaneously: the designer draws in one projection and gets at the same time two or more different views. Further development of this feature will allow for real 3D design.

- visual simulations can be performed with a series of perspective drawings (wireframes or hidden line perspectives).
  They give a good idea of how the design will look in reality, as well from the inside as from the outside.
  Perspective programs are very good examples of software that becomes completely useless as design tool, when it needs a labour-intensive input.

T8. Computation and visualization of isolux-lines can interactively govern correct daylight design by window adjustments.
It is better to represent the daylight distribution by means of grey-tones because this is more meaningful to the designer than numerical values.

T9. Shade and shadowing can be decisive for the location of a building on a site; it is important for window design and for the design of shading devices.

From 1983 until now, parts of this project have already been realised in students' theses and a Ph.D.
The programs were written for micro-computers, because the average architecture office in Belgium can best afford this kind of device.
In conclusion we give some examples of what has been developed so far:
- user friendly input on grids, transformations of grids, (7); ill.1.
- scale dependent symbolic representation in plan, (7); ill.2.
- simultaneous views during the interactive design of trusses, (13); ill. 3.
- visualization of daylighting, (8); ill.4.
- cost estimation during the design phase with the element method, (5); ill. 5.
- perspective drawings with elimination of hidden lines; a very fast algorithm for PC, (6); ill. 6.

The specificity of these programs and/or approach is highlighted in the short explanatory notice accompanying each illustration.
So far we are working on the separate tests, the basic information structure common to all these tests is still missing.
The intelligent pencil, as it is by now, exists merely as a concept, as a framework, governing all our efforts.

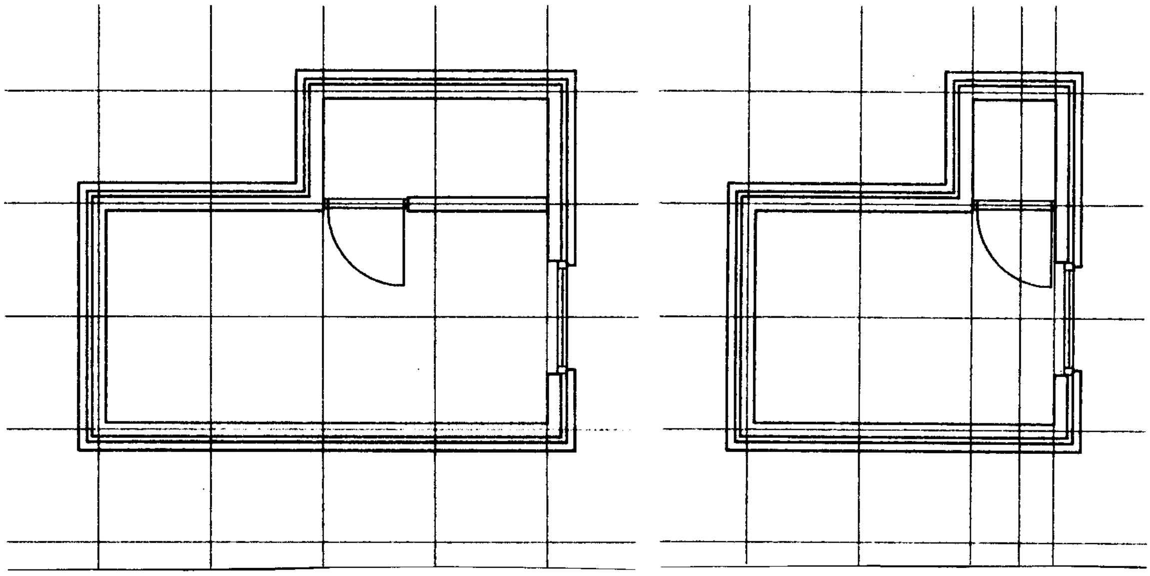


ILLUSTRATION 1

Walls are positioned relative to the nodes of the grid; doors and windows relative to the origin of the wall. A contraction of the grid results in a shortening of the whole design.
The wall attributes are: type (single or cavity wall), height, thickness, displacement of the axis versus the gridline.

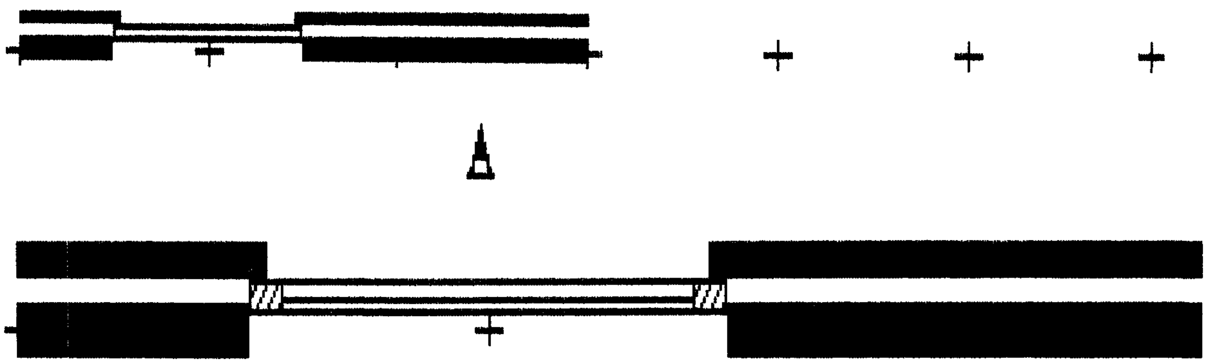
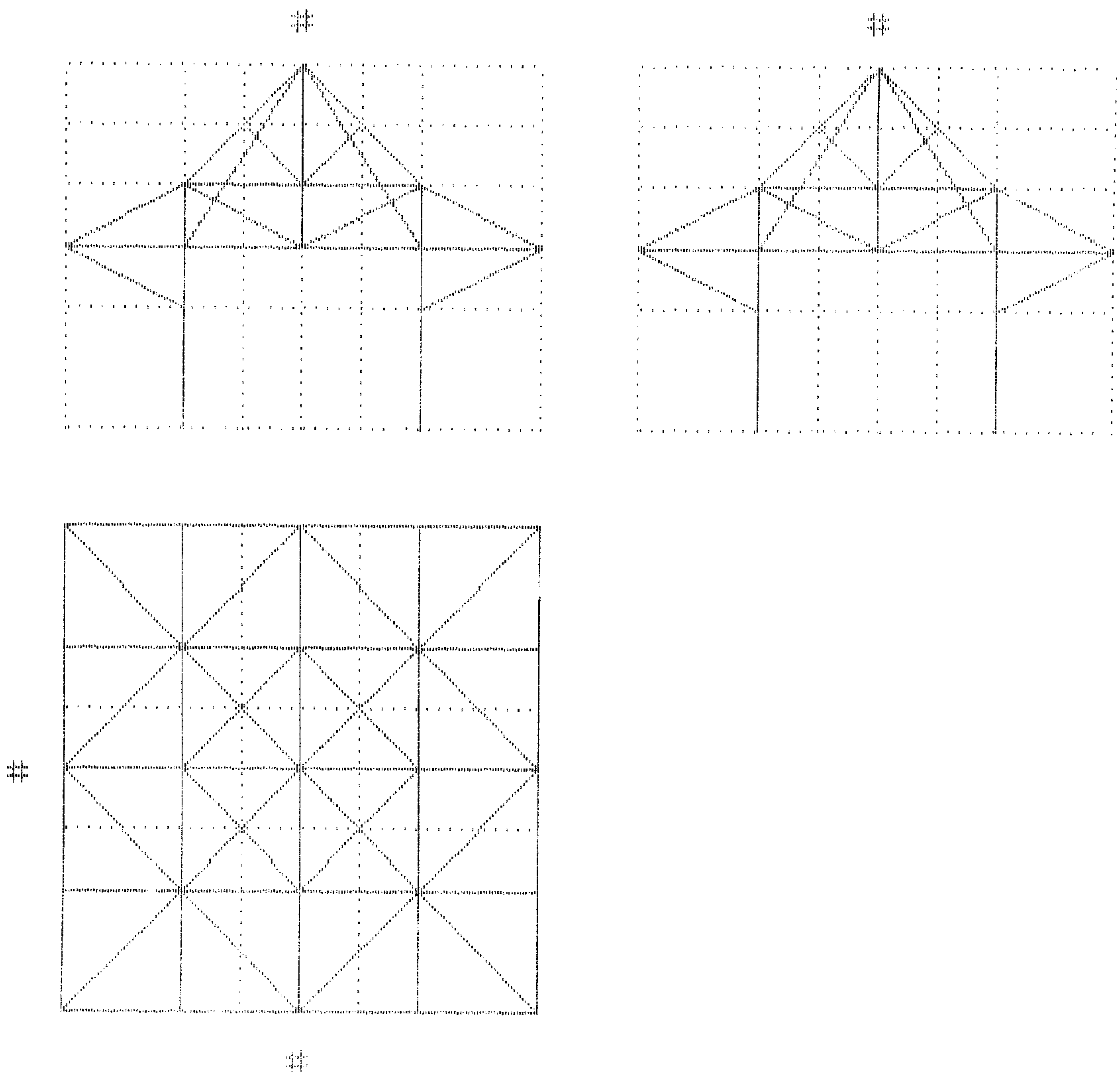


ILLUSTRATION 2

Scale dependent graphical representation of windows, here at scales 1/20 and 1/50. An architectural drawing made on a small scale cannot just be blown up to a larger scale by zooming: the larger scale has to show more and other information.

ILLUSTRATION 3

Simultaneous views seem to be a very handsome extension of the designers capabilities. In this symmetrical structure, built up with trusses and frames, the input is done on a threedimensional grid in orthogonal projection or in axonometric view upon choice.
Moments (for the frames) and bar forces are calculated by means of the 3D-displacement method on PC.



DAYLIGHTFACTOR (%) AT TABLE HEIGHT

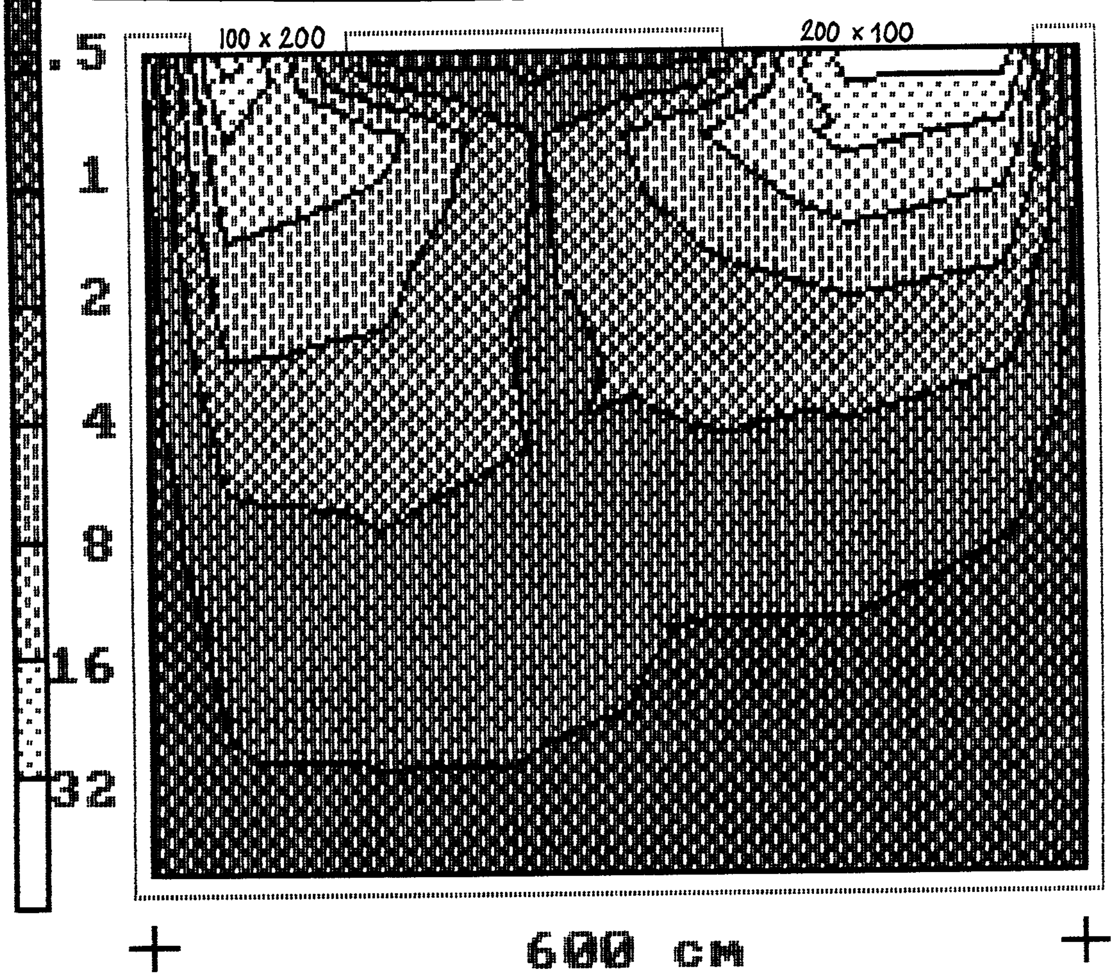


ILLUSTRATION 4

Computation and visualization of daylighting on PC.
Several simplifications had to be introduced to keep the computing time into realistic limits (± 2 minutes). Firstly, the skydome is considered to be built up of discrete (point) light sources. Secondly, only the first reflection of the incident light is taken into account and this reflection is considered to be constant over the room as a whole.
The limitations however of the PASCAL TURBO GRAPHICS made the infill of greytones very tedious and timeconsuming (also ± 2 minutes).

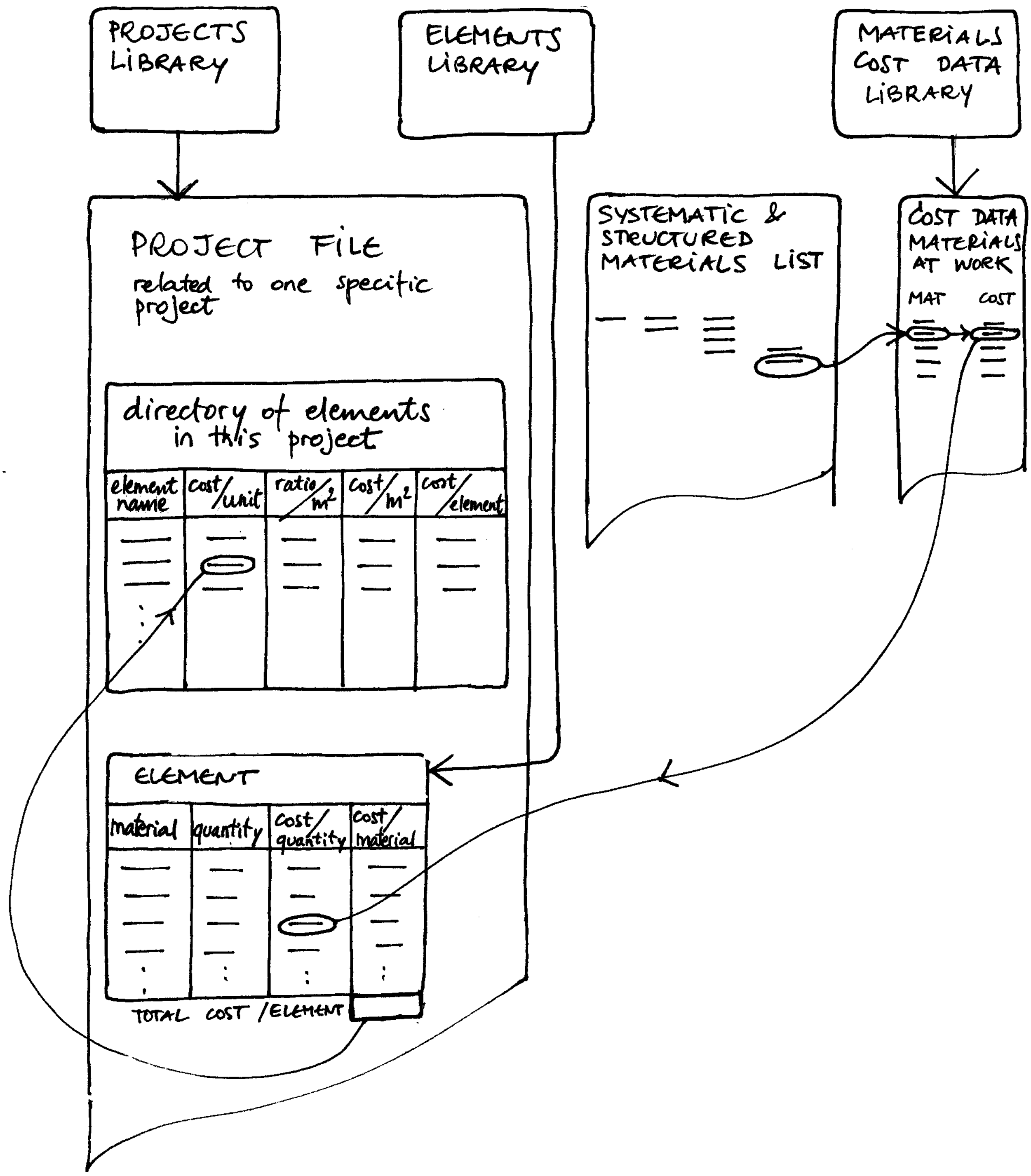


ILLUSTRATION 5

This scheme, developed by DE TROYER F. shows the links between material and cost files with elements and projects files as required for cost estimation by means of 'the elements method'.

This method takes into account the ratio pro m^2 floor surface of a building element. The information is processed on Olivetti M24 by means of the speadsheet techniques available in OPEN ACCESS.

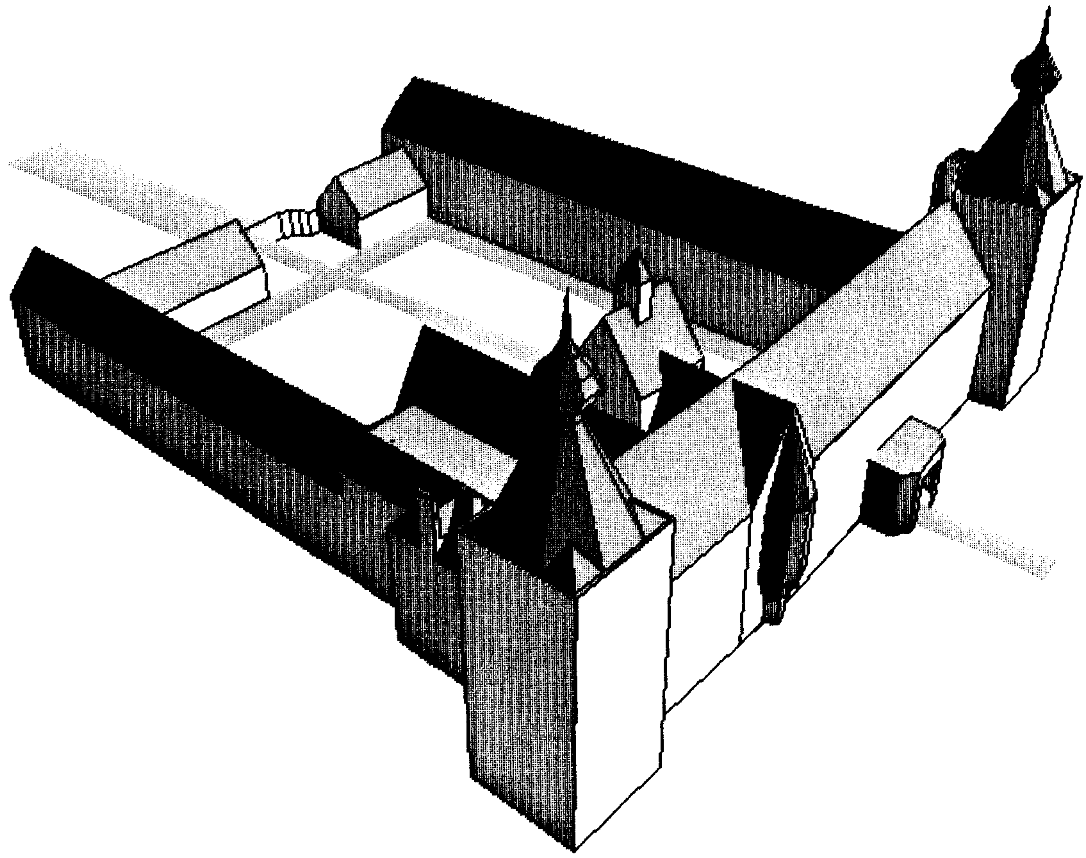


ILLUSTRATION 6

Aereal view of the castle of Arenberg - Leuven (Belgium).

This perspective drawing has been produced with a new recursive algorithm for hidden-line and hidden-surface elimination developed by P. Houthuys.

This algorithm, also working on PC, is based upon an improvement of the Liang-Barski line clipping algorithm, an adapted Sutherland-Hodgman polygon clipping and a multidimensional binary tree sort for the detection of overlappings between polygons.

(This illustration has been made with a graphical printer Tektronix 4695, connected to a graphical colorscreen Tektronix 4109 and VAX 11/750; total execution time without printing ± 20 sec.)

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