VOLUME : A COMPUTER PROGRAM FOR BUILDING MODELISATION AND MANIPULATION

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ABSTRACT

We describe a computer program VOLUME for inter-
active 3D modelling of building which can be used in
many problems (heat losses calculations, architectural
evaluation, ...) where a geometric representation is
required. The program is more than a tool to input a
geometry : it is also a tool for design; manipulations
are very easy and many design solutions can be tried.
We then discuss about developments for improving the
quality of that tool in the design process.

Keywords : computer aided design, 3D modelling,
            computer-user interface, evaluations.

Data input and preparation is a bottleneck of
many computer programs. This is especially true for
programs needing data representing geometry of buil-
ding (e.g. : for heat loss calculation prgorams ...).
Moreover, in architecture (in fact in all disciplines
dealing with design) data manipulations is very impor-
tant : poor data manipulation   slows or even
inhibits the design process loop (analysis ———> design
———> evaluation ———> analysis ...).

VOLUME tries to be a response to this problem.
It has been designed to easily and interactively build
a 3D model of a building : the building is seen as a
collection of polyhedrons (prism, pyramid, cylinder...).
The elaboration of the building as a collection of
simple volumes is one way of thinking which, we believe,
is very understandable to the architects working at the
early stage of the design.

These polyhedrons define the global 3D structure
of the building : defining a building at the detail
level would be impossible or very complicated if the
computer (and the user) does not have a good idea of
that structure; this model must be considered as a first
step which, along the design process, should evolve
towards a more detailed one.

The user interface has been carefully designed :

- computer-user communication is by a simple com-
    mand language :

```
>?
list of commands :
CREATE      DELETE      DESTROY     DISPLAY    ESPFIL
EVAL        FILBIB      GEOM        HPROJ      LIST
LOAD        LOCATION    NAME        ORIGINE
ORTHO       PERSP       POINT       RENAME
SAVE        SET         SHOW        STATUS
TWIND       VPROJ       ZOOM        END
WINDOW
To input an expression type  :  as first character ;
For help while typing a command, type ? ;
For help on the graphic syntax read the file Syntax.doc
>

>SET ?
  sets values of system parameters :
    SET <param> [ = <num>]
    <param>:= ALPHA / BETA / DASHED / EFACTOR / EFS / FOCAL /GRID /
              GRIDSIZE / HIDDEN / LOCALPLOT / NOGRID / NOHIDDEN/
              FILPLOT/ NOFILPLOT/ WINDOW/ NOWINDOW/  Z
>

>PERSP ?
  perspective :
PERSP <3point>   <3point> [<expr>]
      eyepoint   focuspoint
PERSP will draw the perspective of the
volumes defined by <expr>; if <expr> is not input, it
wil' draw the volumes of the last <expr> input in a PERSP command
>
```
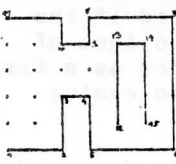
- a "graphic syntax" has been designed to input
    graphic items (points, lines, vectors, planes...)
    in a simple and flexible way;

- polyhedrons are created very simply by primitive
    commands creating different type of volumes with
   the minimum of information.

```
CREATE X  . . . . . . . . . . . . . . . . . . . .
GEOM X=PRBAN . . . . . . . . . . . . . . . . . . .
synt. err. in <secprim> . . . . . . . . . . . . .

GEOM X=PRISM . . . . . . . . . . . . . . . . . . .
basepoints : . . . . . . . . . . . . . . . . . . .

holes points ! . . . . . . . . . . . . . . . . . .

. . . . . . . . . . . . . . . . . . . . . . . . .

holes points ! . . . . . . . . . . . . . . . . . .
plane :
Z 10  . . . . . . . . . . . . . . . . . . . . . .

. . . . . . . . . . . . . . . . . . . . . . . . .

. . . . . . . . . . . . . . . . . . . . . . . . .
```

Creation of a prism X with one hole in its base. First,
the external contor is input with the points 1, 2, 3,...,
,11 and is finished with the terminator T. Then the contor of
the hole is input with the points 12,...,15 and finished
with the terminator. The program then asks if the user
wants to define an other hole. As the answer is no, the user
types T. The upper plane Z=10 is then defined.
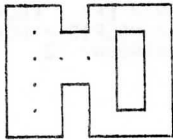
After the user has defined the upper plane, the
program generates the volume and draws it on the
current horizontal plane.
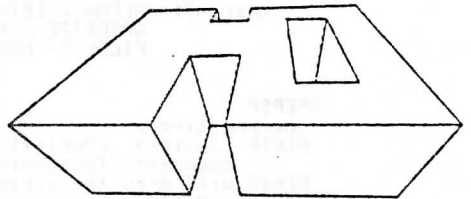
- geometric transformations (translation, scaling,
  symmetry, rotation) can be applied on sets of
  volumes : the user writes expressions (like alge-
  braic expressions) built with graphic and set
  operators (union, intersection, difference) ap-
  plied to set of volumes. The result of an expres-
  sion is always a set of volumes and so the defi-
  nition is recursive. This resulting set can be
 stored in a "variable".

exemple :

- the expression SA=V+W+U defines a variable of
  name SA which is a set or collection of 3 volu-
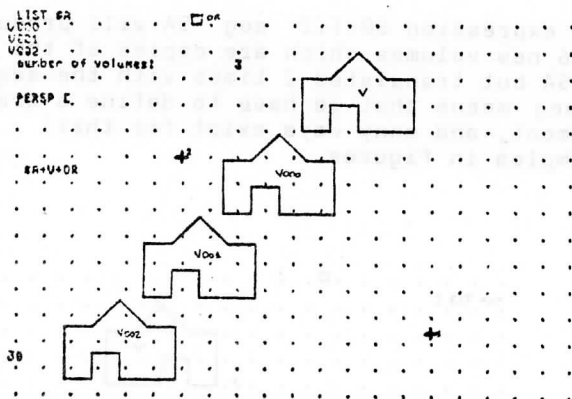 mes : the volumes V, W and U.

- the expression SB=T:2 seg SA will produce a set
  of 6 new volumes which are copies of the volumes
  in SA but translated 2 times with the segment seg
  (seg means that we have to define a graphic
  segment, and many ways exist for that)
- exemples in figures.
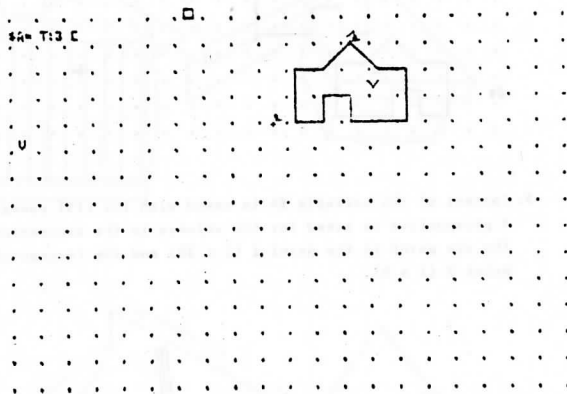
Translation with repeater.
The volume V will give 3 new volumes which are copies of V but
translated successively by the segment 1 → 2.
The expression T: 3 ⟨seg⟩ V gives a set of 3 new volumes and this
result is put into the variable SA.
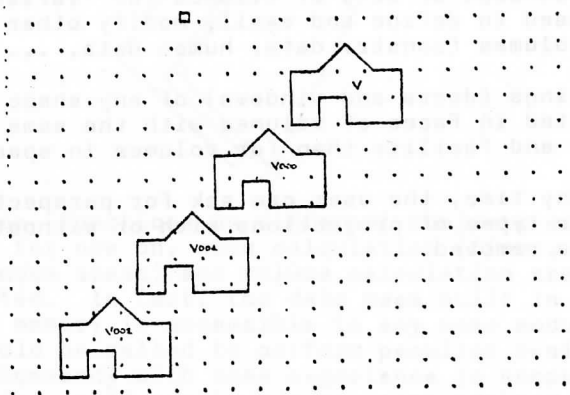
Result. The program gives names to the 3 new volumes : V000, V001,
V002.

```
LIST $A        . . .  □ OR  . . . . . . . . . . . .
V£00
V£C1
V£02
number of volumes:        3
PERSP C.

$A+V+OR                +↓

                              Vono

                        Voo↓

    30          Vco2          ↓
```

5. Content of the variable $A is asked with the LIST command.
A perspective is asked for the volumes in the expression $A+V+OR.
The eye point is the point 1 (Z = 30) and the focuspoint is
point 2 (Z = 0).
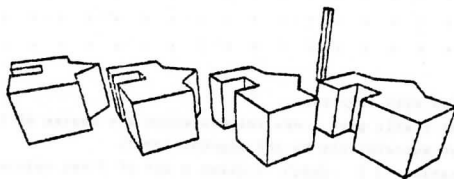
- the concept of sets of volumes (or "variables") will
  be used to define and easily modify other attributes
  of volumes (constr. data, human data, ...);

- operings (doors and windows) of any shape can be
  created in faces of volumes with the same flexibi-
  lity and facility than for volumes in space;

- at any time, the user can ask for perspectives or
  other types of projections with or without hidden
  lines removed.
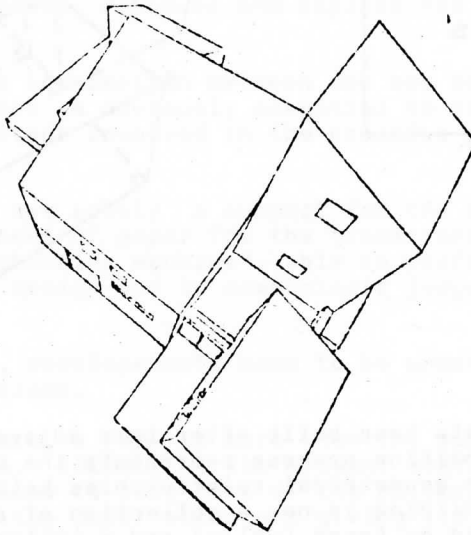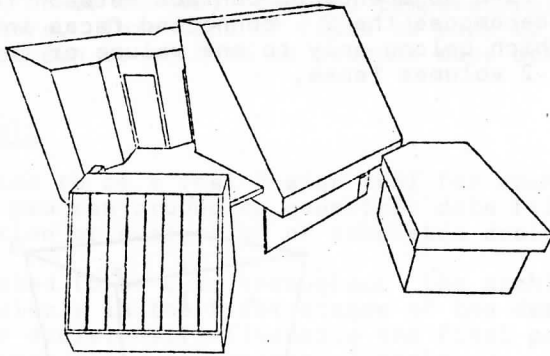
evaluation functions on different subjects will be
written; for now on, area calculation (floor, wall,
roof, window areas) and volume calculation are
implemented. In fact, the data base built in the
computer memory is accessible to any user module
which could be called to perform peculiar evalua-
tions. Somebody with some experience in computer
programming could easily add new commands and func-
tions;

-    files describing the volumes can be produced (e.g.
for the ESP program).

Once the user is satisfied with a design, with one
collection of volumes representing the building, the pro-
gram is able to find adjacency or contact between faces of
volumes and to decompose the 2   connected faces in simple
faces : faces which belong only to one volume or to the
intersection of 2 volumes faces.
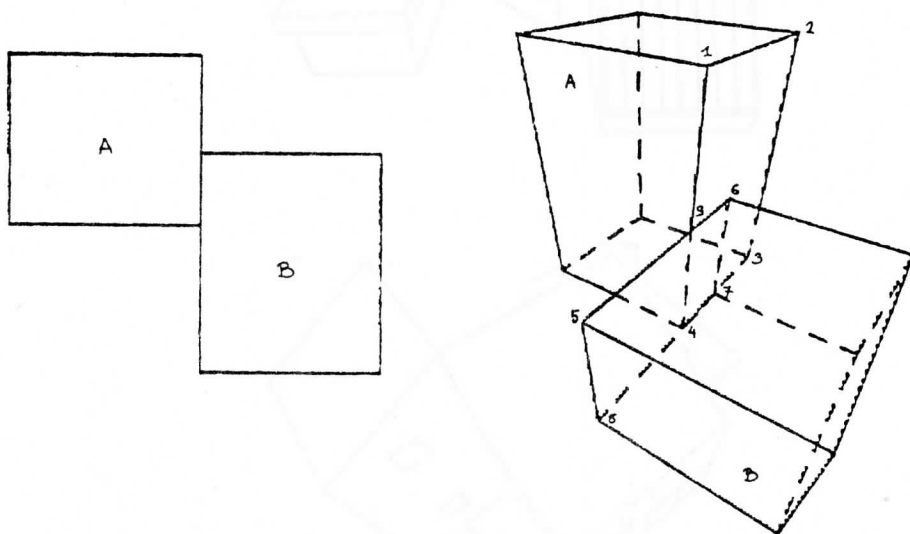
So the data base built after this adjacency analysis
and face decomposition process represents the building
geometry and the geometrical relationships between the
volumes : the building is now a collection of spaces
(volumes) limited by faces (walls) and a collection of
faces, each face being the separation between 2 volumes
or one volume and the external space. This information
allows more elaborate evaluations (area calculation, cir-
culation, ...) which can help the user in judging his
design.

This data base is a first step for the elaboration
of a more complex geometric model : routines will be added
to manipulate (add, delete, move) the faces or walls. So
as the design goes on, the model will become more precise
and detailed.

From this data base, files can be produced for
various types of evaluation programs. Fors instance, many

heat losses calculation programs require a set of walls
(each wall being described by some geometric parameters
and thermal data and by the adjacent spaces) and a set of
spaces with their thermal (desired temperature, occupancy,
...)parameters. This kind of files is easy to produce
and routines can be written to produce many other types of
files.

DEVELOPEMENTS

VOLUME claims to be a real design tool for architects :
not only a program producing geometric data files for peculiar
representation or evaluation of completed designs.

It is intended to be used throughout the architect's work
and particularly in the first stages of the design process
where major decisions, influencing the final performances,
are taken very often on irrational basis.

Using VOLUME would be a process of gradual enrichment for the
design through which the architect would organize his ideas,
clarify his concepts, discover and explore his own way of
thinking.

Therefore a real interaction between man and machine working
at very high speed is obviously essential to bring efficient
aid to the architect involved in the creative process of
designing.

The computer is not solely a support for the architect's
ideas (like a sheet of paper for the traditional architect)
but is also a "thinking machine", able to perform analysis
on the proposed design and to communicate judgements to the
user.

For the purpose, developements have to be undertaken in the
following directions.

1. In architecture, a form is more than the sum of its
elementary parts. VOLUME, at its present state of develop-
ment, doesn't allow to take care of the polyhedrons'
organization,of the super structure giving its architectural
signification to the whole.

Therefore VOLUME has to be expanded in two ways

   - New attributes must be attached to elementary poly-
     hedrons. These attributes (axis, center, plane of
     symmetry,roof height and slope, global floor area...)
     are closer to architectural thinking. They add
     constraints to the each polyhedrons and particularize
     them.
     Attention must be paid to alteration effects induced
     from working operators, either they are recognized
     and accepted or refused.
     New operators dealing with this attributes have
   also to be added.

- Ways should be found to express the relationships defined between volumes and the specific structure of their layout (alinement, axis, grid ...)

These two ways expanding VOLUME should allow to define some specifications on elementary volumes avoiding the complete definition of its final shape or geometry. By this way, the design project would be defined at a very high level (and at a very early stage of the design)without being hampered by a precise geometry. The user is allowed to express his first idea of what the volumes and their organization have to be even when they are poorly defined and if the project is judged interesting then he can go on in the geometry definition process.

2. The program now deals mainly with geometric data. Routines have to be written to easily input and structure non geometric data (cost data, occupancy data, light data, confort data...) so that the user can roughly describe the building, its general frame. Default or suggested parameter values should always be proposed according to the type of building, (houses, offices,...); this frame and its parameters can in fact represent a part of the current architectural knowledge.

3. More evaluation functions should be implemented (thermal costs, privacy, circulation, check agains regulations rules... and the presentations of results (drawings, colors) sould suggest ways to solutions (e.g. showing walls with important heat losses). These functions results should be checked against the default or input values describing the general frame defined previously. (e.g. : suppose that in the general frame specifications we said an office building with 200 employees ;we then define the geometry. If the computer finds a floor area of 200 sq.m2 for that geometry, it has to warn the user). These evaluations functions constitute the tools with which the user can make a judgement on his project.

4. A site description module should be added. Then the program could deal with urban problems (site analysis, solar mask analysis, circulation and view analysis,...). In fact, with VOLUME it is very easy to define urban groupings.
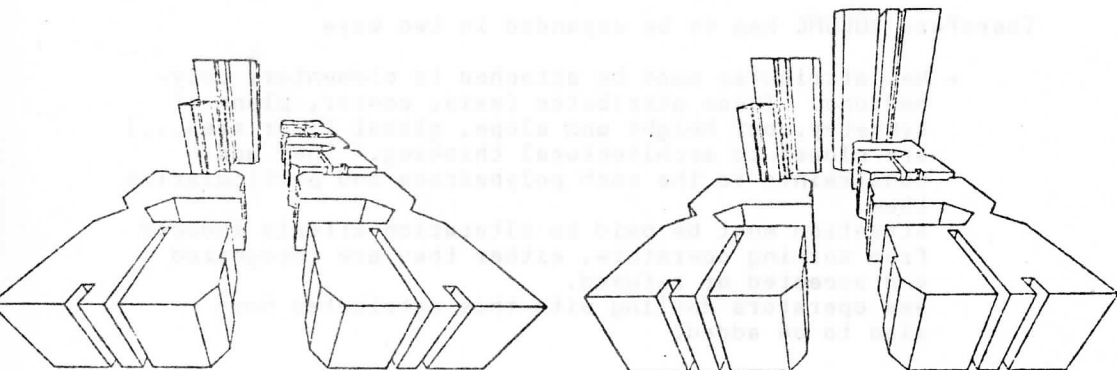
IMPLEMENTATION

The program is written in PASCAL and FORTRAN. The FORTRAN
part is due to historical reason : the hidden line removal
routine is a modified version of the BIBLE program from
ABACUS group and is written in FORTRAN (the number of source
lines is about 4000 lines in each language).

The hidden line removal routine should be replaced with
an hidden surface elimination algorithm allowing color
rendering of perspectives. Routines will be added to deal
with color terminals (AED 512 and 767). The FORTRAN part,
if we have time, should be slowly coded into PASCAL.

For now, the polygon routines (polygon intersections and
differences) needed in the adjacent faces decomposition
problem have been written and are inserted in the program.

The program runs on a VAX 11/780 with tektronix series
4010 terminal or visual 500 (raster-scan) terminal. It can
handle complex scenes of one or more hundreds of volumes
and perspectives with hidden lines elimination are computed
in time of the order of a few minutes cpu.

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PROCEEDINGS

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