7 On the Development of 3-D Schematic Design System

Utilities for Planning Sketches and 3-D modeling

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Though it is the basic tasks of designers in a schematic design stage both to program design requirements and, then, to develop spatial images of a building following those programs, most CAD systems have lacked convenient utilities to interpret a program for some forms of spatial designs, or to assess developed designs referring to the prepared programs. This paper, in the first part, reviews design procedures of designers and the internal limits of the existing CAD system, and in the second part, discusses a schematic design system that the authors have developed. Presenting the case study with the system, the authors show that the system provides a convenient environment of schematic design.

1.0 OBJECTIVES OF THE STUDY

With all the recent trends in using CAD systems as common tools of drafting and visual presentations, their use, especially three dimensional modeling systems, in schematic design stages still remains limited. First, most designers have little experience in developing building images with the system, and second, few systems have sufficient utilities or user interfaces that could well fit the process of a designer's thought. Though it is the basic tasks of designers in a schematic design stage both to program design requirements and, then, to develop spatial images of a building following those programs, most CAD systems have lacked convenient utilities to interpret a program for some forms of spatial designs, or to assess developed designs referring to the prepared programs. Complicated procedures required to edit a graphic object also prevent their use in a schematic design stage in which designers must repeat a long chain of trial-and-error processes to develop formal images.

Progress in CAD education will improve the first limitation in the near future. The authors have mainly worked to solve the second problem: to develop a schematic design system that allows programming studies and spatial design studies in one seamless environment.

In this paper, there are five major topics:

1) a model of activities in a schematic design process, which the authors have defined, reviewing the interviews of designers and their works,

2) internal limits of existing CAD system, such as a CAFM system that has space planning utilities, and a 3D modeling system that can introduce a knowledge base of buildings,

3) functional features of the proposed system that are based on the model of a schematic design process,

4) and a case study of the system,

5) evaluation of the system and notes on future tasks.

2.0 A MODEL OF A SCHEMATIC DESIGN PROCESS AND CHARACTERISTICS OF THE WORKS

To identify the process of schematic design, as well as to find features expected for a schematic design system, the authors interviewed six Japanese design offices of different sizes and different design characteristics and, five US design offices that assumed active use of CAD systems. The authors also reviewed a series of sketches, drawings, and photographs of study models, produced by Japanese designers. Their purpose is to analyze how designers use different media for their design development.

Though there are cases in which designers start designs with the formal images and adjust their designs to functional requirements later, it became evident that most offices have regarded schematic design as a process to set up a building program and to develop 3-D building designs following the program.

The common procedure can be described as the following:

Step-1: Set up a building program: site conditions, functional requirements, cost and schedule requirements, etc.

Step-2: Sketch site plans, floor plans, and 3-D building envelopes: designers generally use hand drawn schematic program diagram drawings. They draw lines repeatedly gradually adjusting their locations first, and then define approximate locations, shapes, and sizes of "space units" (functional units or rooms) in the form of a group of polygons. A mix of two different procedures tends to be used in these studies: assembling polygons, and subdividing polygons.

Step-3: Develop floor plans: considering space requirements, structural arrangements, or images of the building envelope, designers gradually fix the locations, sizes, and shapes of "space units" that the polygons represent. They usually start describing the location of building elements, such as columns, walls, stairs, and windows. Their point of focus seems to shift from "space units" to "building structures" in this step.

Step-4: Develop a schematic spatial image of the interior and exterior: they manipulate 3-D building elements in a 3-D modeling system, a physical scale model, sketches, or section drawings. In the beginning, they use models of simple geometry (fundamental object) to represent building elements, however, they gradually replace them with specifically designed models (custom objects) as the design advances.

Step-5: Check developed designs: drawing plans, sections, and elevations, designers check developed designs reviewing programming and engineering factors.

Step-6: Produce documents of the project.

3.0 INTERNAL LIMITS OF THE EXISTING CAD SYSTEMS

The design firms the authors visited used 2-D CAD systems for each step after Step-3, and the 3-D modeling system in Step-4. They pointed out certain difficulties in their work. First, the CAD system does not have enough of an ability for editing graphics to support the laborious trial-and-error processes in Step-2 and Step-3. Revising a part of a drawings, such as changing the size or the shape of a room, generally requires an extra process of line editing to fit the change into its surroundings.

Second, because the 2-D and the 3-D system do not have utilities to report the area of stud plans, designers often face hardships in revising developed plans in the last stage of the project. They have expected a utility that can report such information timely.

In spite of the general notion of CAD as a formal design tool, designers have expected utilities that support the programming aspect of the schematic design process.

There are CAFM systems that have blocking and stacking, and space planning utilities.

It seems quite helpful to use a bubble diagram and rubber-band expressions of adjacency evaluation. Because they were originally designed to study space lay-out of a building in fixed floor conditions, they do not have the utility to interpret the results of analysis to a new plan. Designers have to draw plans at each separate step of the work.

Three-dimensional modeling systems that introduce a knowledge base of building models have a powerful utility to evaluate designs in many aspects, such as area, cost, energy consumption, etc. Their ability to adjust 3-D shapes of geometric models after some design changes appears to be attractive to designers. In spite of all these advantages, they still have internal limits. Because they generally require designers to build designs using standardized building elements, they would not be attractive to designers who want an original design. It is another decisive disadvantage that they need high speed mainframe computers.

4.0 FEATURE OF THE DEVELOPED SYSTEM

4.1. Hardware and Software environment for the system

Reviewing design procedures of designers and the internal limits of the existing CAD system, the authors have developed a schematic design system customizing AutoCAD R13J for Windows. It is planned to support the studies listed in Step-2 to Step-5 in the former section.

No special software, like the RDB management system was used. All the utilities of AutoCAD R13J and the utilities developed by the authors can be used together.

As the system works quite smoothly on a DOS/V machine that has pentium 120mHz CPU, it is possible to use the system in a normal working environment of designers.

4.2. Procedure of the system use

The basic procedure of studying floor plans will be like this (Figure 1):

1) The designer can define working planes(layers) at any level in the 3-D world, so that they can study different floors or zones of the building at the same time. He/she can freely select viewing conditions and viewport configurations using the original utilities of the CAD.

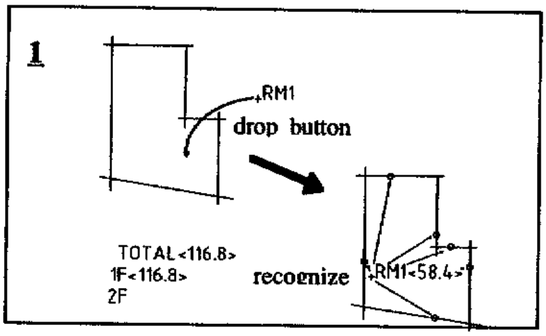
2) The system uses the following procedure to define "space units," such as rooms or functional units: first, the designer freely draws lines following their image. Once he/she composes a closed section with some lines to represent a space, and drops a "button" in it, the system recognizes this section as a "space unit." The system indicates the size of the area next to the space name he/she has typed in.

3) Designers can develop plans following both procedures: jointing spaces and subdividing spaces.

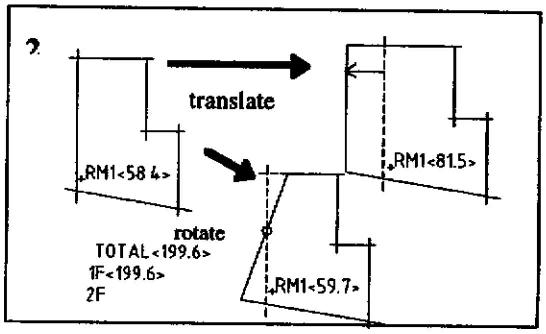
4) The system provides two groups of editing utilities: editing spaces, and editing boundary lines: that is transforming the shape of the spaces. When designers want to edit spaces, it is possible to select objects to be edited by just hitting the buttons of the corresponding spaces.

5) To make the editing operation simple, the system automatically adjusts the locations, the length, and the slopes of related boundary lines to keep the former topological relationships among the spaces.

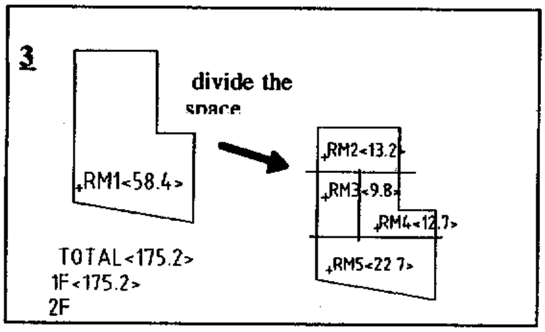
6) It is possible to get the information on the size of areas for each space, each level, and the total spaces at any time of the work.



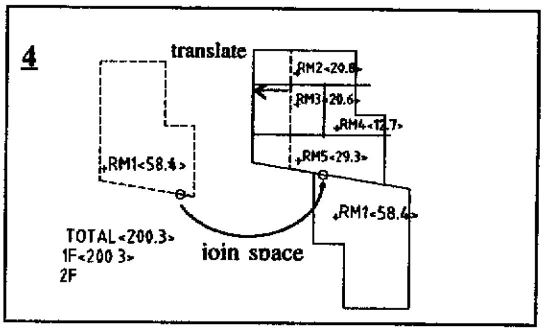
Locating a button and typing the space name(RM1), the system recognizes a space unit. It records the list of boundaries, and indicate the size of the area..



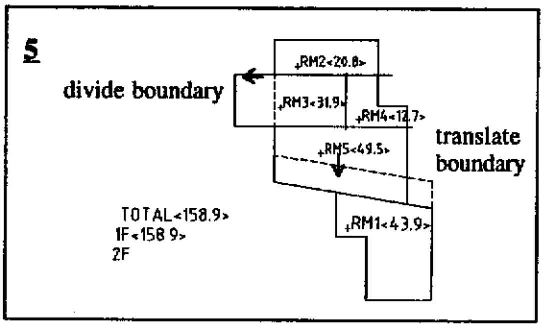
Translating or rotating one of the boundaries, the system adjusts the length of related edges. There are similar commands that keep the length of translated boundary fixed.



Locating buttons after subdividing a space, each button recognizes respective space and indicates the size of the area.

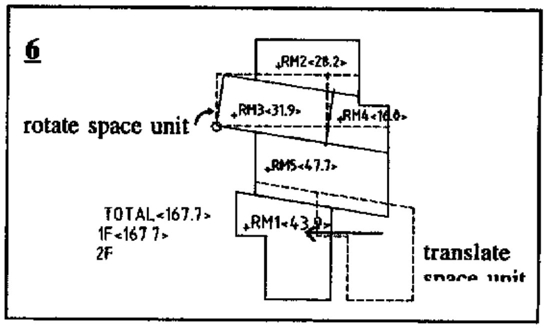


Selecting spaces with button-hit, and hitting two boundary lines, the system joins selected spaces attaching designated boundaries.

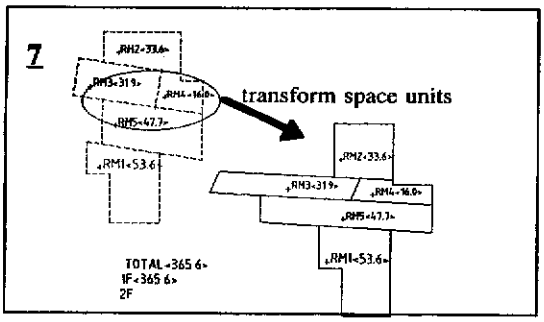


Attached boundary lines works as a single line in a editing operation.

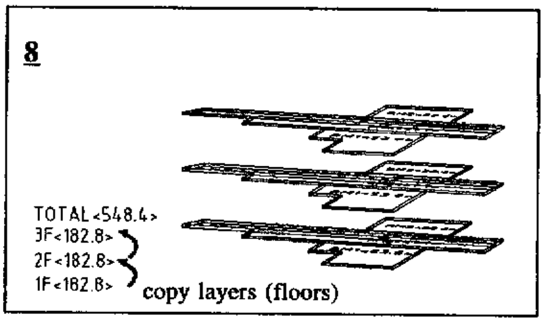
Dividing-line command allows translation or



When space units are rotated hitting buttons(RM3), the system rotates their boundaries and adjusts the length of boundaries connected to them to keep the

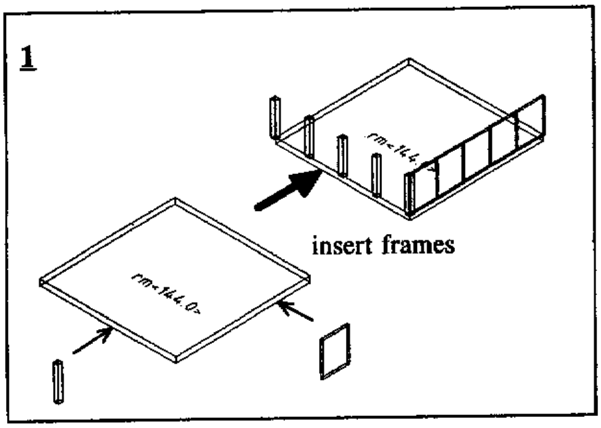


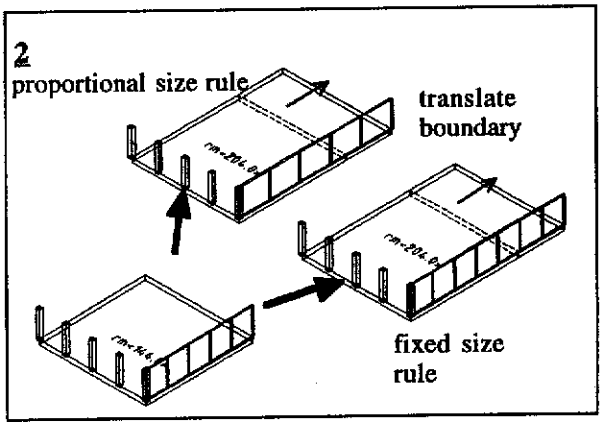
With the equivalent area transformation command, the system continuously generates figures of different X-Y proportion as the mouse



After hitting floor level Button, space copy command copies objects in the designated level to the designate levels.

Figure 1 The Basic Procedure of Studying Floor Plans

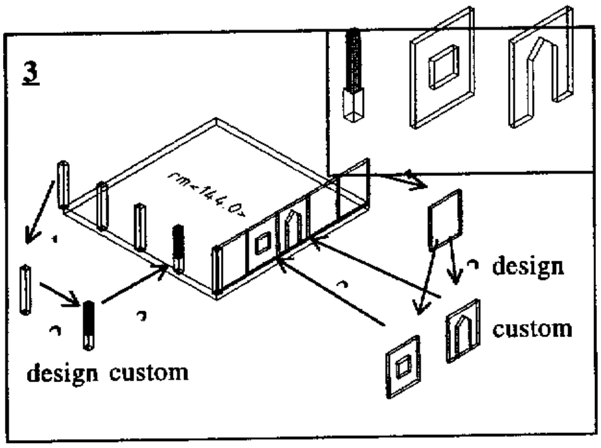


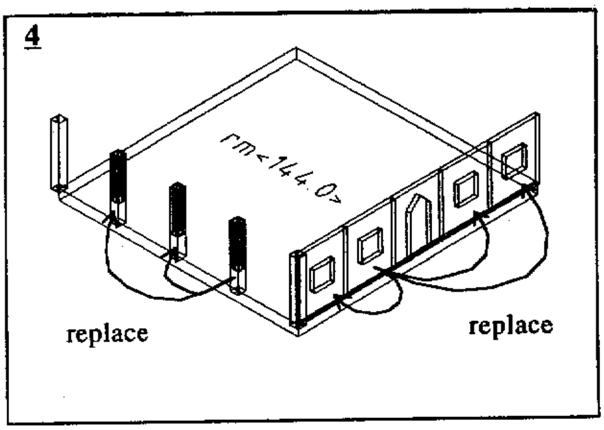


Frame insert commands insert frames along the designated boundary line. COLS locate frames at some interval, while PANELS locate frames attaching each other.

When the space-unit is translated the number or the size of the frames(or intervals) will be adjusted according to the rule defined for the boundary line.

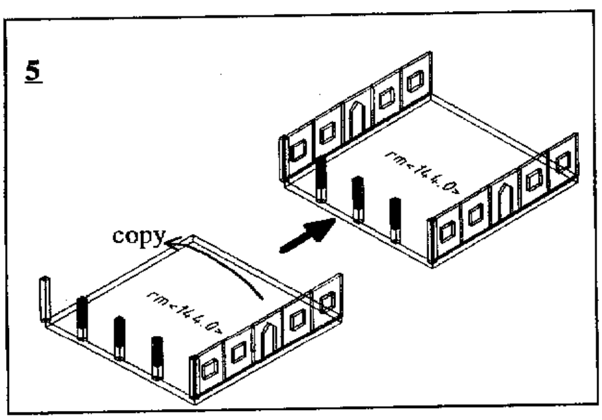
Figure 2 The Basic Procedure of Studying Spatial Images

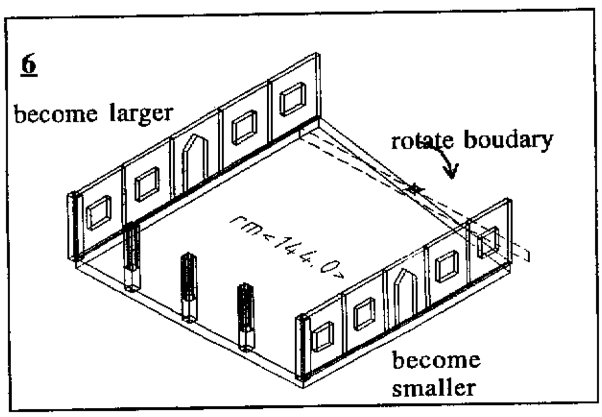




The next procedure inserts a custom object in the model: copy a frame, locate a designed model in the frame, define it as the part of the frame, and replace frames with the model.

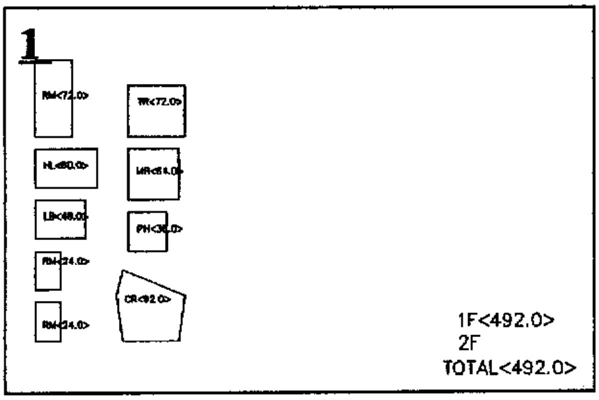
It is possible to replace frames of different custom model among frames. Even if the size of frame differs, the system automatically adjust their proportion.

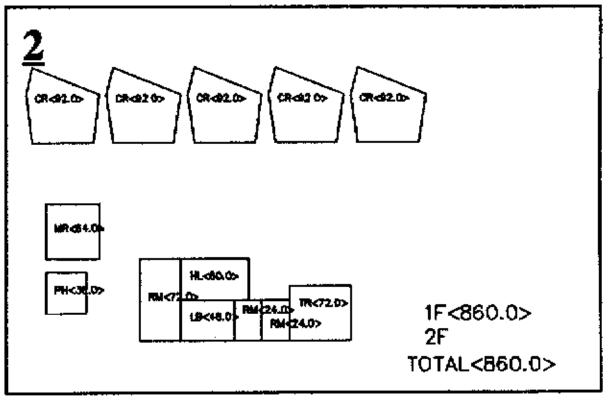




There is a command to copy information attached to a boundary line to others. Frames, custom objects, and location rule will be transmitted.

Referring location rules, the system adjusts the size of custom object, when designer rotates boundary line of the space unit.

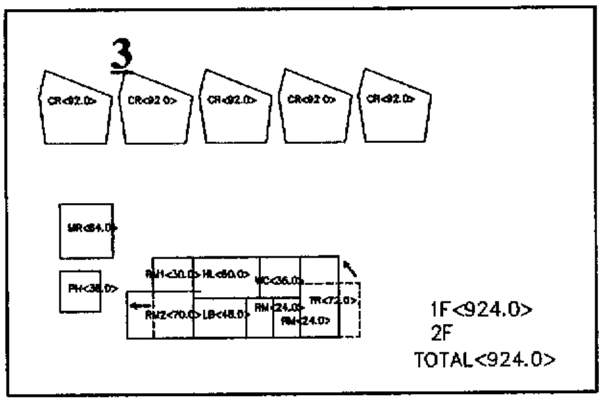


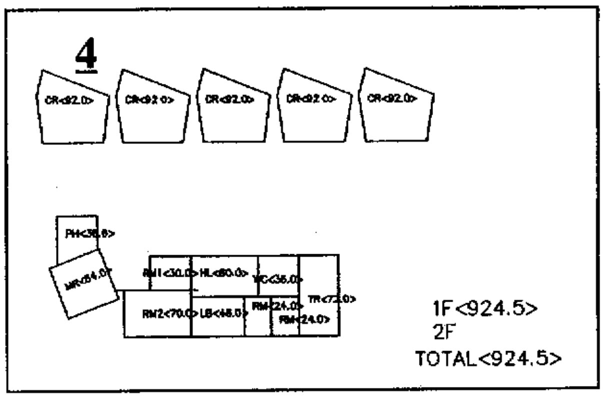


Rooms planned in the initial stage are aligned on the left part of the display. Total area of the rooms is 492.0 sq.mt.

Designer copied requested number of class rooms. Total area became 860.0 sq.mt.

He/she starts assembling rooms for teacher sections

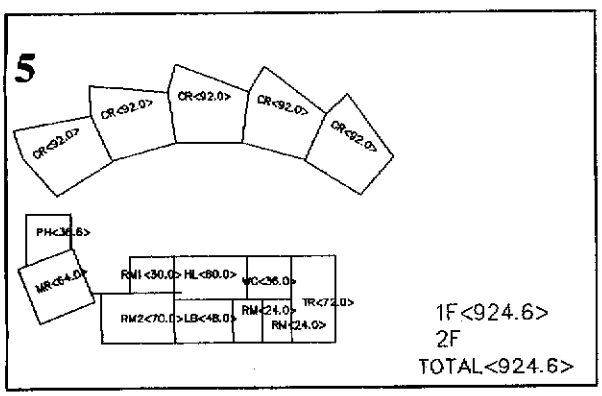


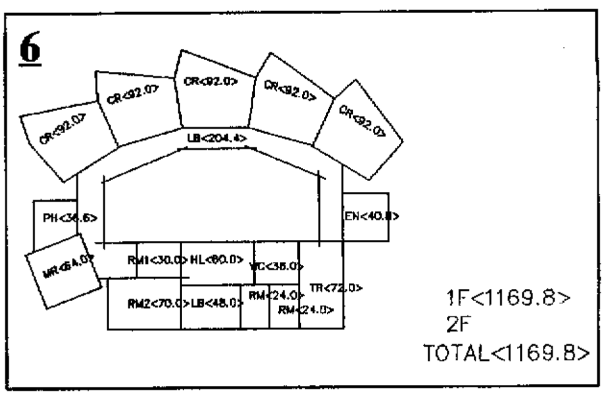


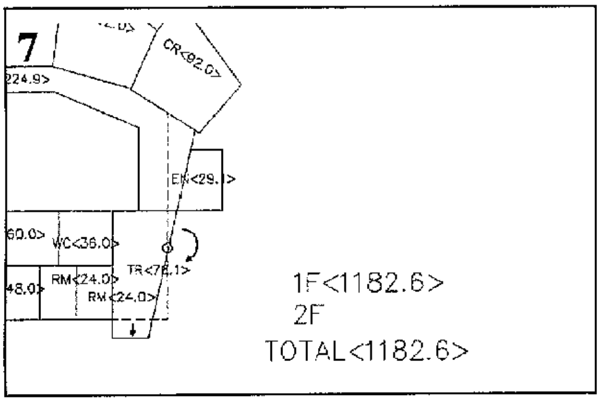
Using equivalent-area-transformation command, he/she adjusts the proportion of TR room. The upper boundary line was aligned to others. Dividing the line, RM2 is transformed.

After joining MR and PH, designer slightly rotated the MR to soften the image of total shape.

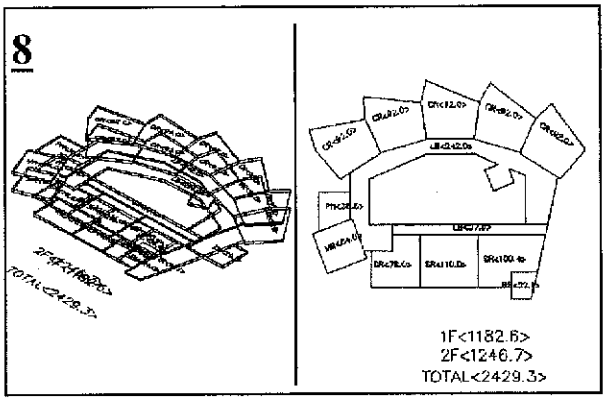
WC was located between HL and TR extending upper boundary of TR in the prior state.





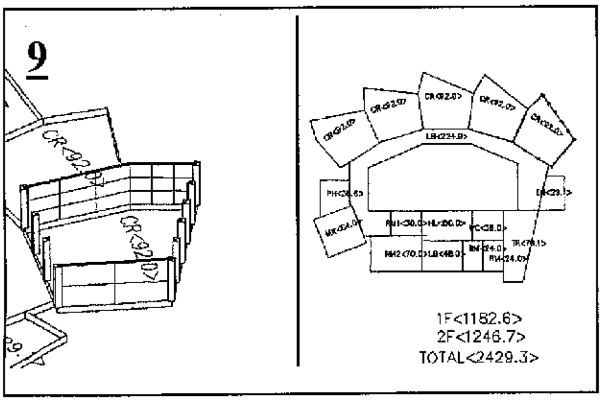


Designer rotates boundary line of the TR and EH to give a different design rules to entrance side of the building. He/she adjusted size of TR translating lower edge.

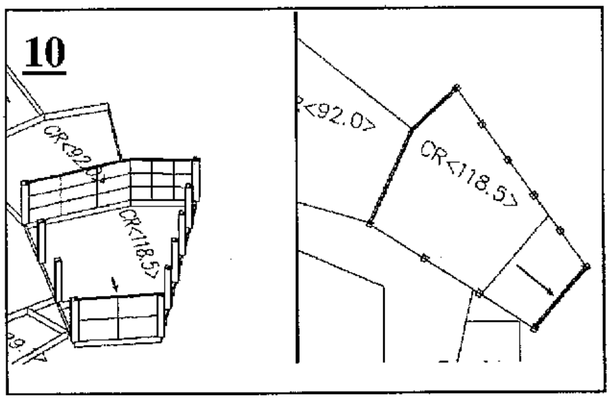


Copying first floor plan to the second floor, designer studies second floor plan.

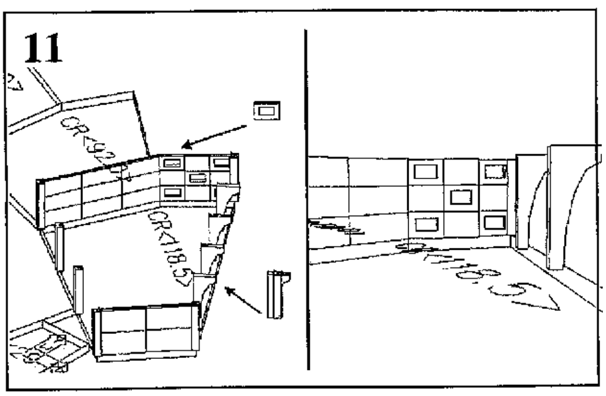
The area of the 2F become 1246.7 and total area 2429.3 sq.mt.



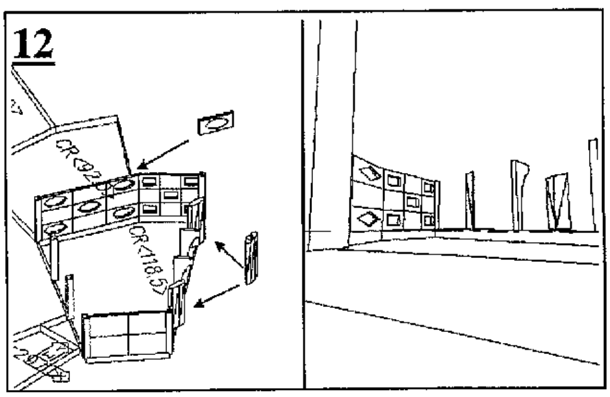
After changing viewing conditions, designer inserts frames that represent wall elements and rows of columns. He/she also subdivides wall elements to allow varying expression in one wall.



When designer translates one of the edges of the CR to respond to the request to this room, the system automatically adjusts the size and interval of frames inserted to the boundaries.



Designer starts to play with the formal image of the building elements. He studies in a perspective view images.



Object replacement commands allow speedy test of design images.

Figure 3-2 The Process of Designing a Small School(continued)

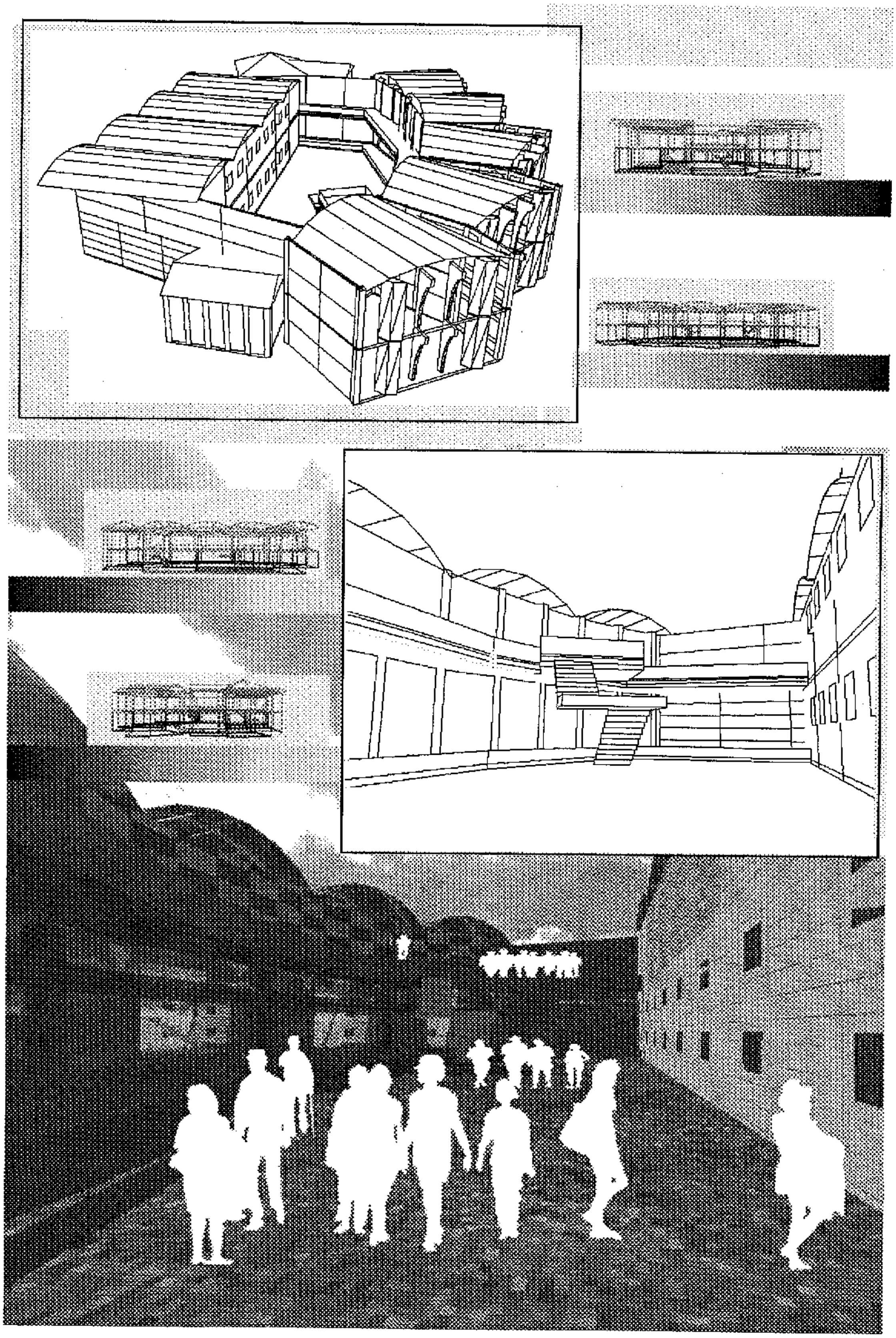


Figure 4 Final Output of the Case Study

The Basic procedure of studying schematic spatial images will be(Figure 2):

7) The system has utilities to insert 3-D models that represent building elements into "space unit" models used for floor planning: slabs, walls, columns, stairs, etc.

8) It is also possible to insert a row of walls or columns for each boundary line. The designer can apply location rules to these operations. For example, it is possible to locate some fixed number of elements of the proportional size to the total length, or to locate some number of elements of the fixed size, inserting irregular sized elements to adjust to the total length.

9) The system inserts square frame/frames (fundamental model) along the designated boundary lines, first. Once the designer gains some formal images of the building element, he/she can replace them with the designed object (custom object) with a simple replacing procedure. The system asks designer to define the custom objects being adding to a frame object, because the system uses the frame to adjust the size and the shape of custom object. There is a mode in which the system hides frames that have custom objects. This does not necessarily mean that the designer must design custom objects inside the frame.

10)When the designer edits a space model, the system automatically adjusts the size or the interval of the building elements.

5.0 EXAMPLE OF THE SYSTEM USE

The following figures in Figure 3-1 and 3-2 represent a process of designing a small school. In the final stage, shown in Figure 4, the designer added some of the 3-D objects, such as roofs, using normal commands.

6. EVALUATION OF THE SYSTEM AND FUTURE TASKS

1) It can be concluded that the system achieved a sufficient ability of operation as a tool of sketching floor plans, because the system has provided designers with a handy operation for a complicated process of editing the shapes, location, and sizes of space units. When the authors gave a demonstration in several design firms, they stated that this would support practical projects very well. The authors intend to revise and add some more commands, analyzing the workability of the system through case studies. Some have requested the development of utilities to exchange area data to other software for a report production.

2) Though the authors added only short programs, the system has provided a flexible and convenient environment for schematic spatial design studies. It can not only deal with plans of various shapes but allows users to test user defined building elements with easy operations. The next goal is to provide utilities that can automatically rearrange the shapes of intersections of building elements. The system has only two rules that regulate the lay out of building elements at this moment, though, the authors intend to add more rules in the near future.

3) The system used the area of buildings as the indices to evaluate design. Though there are the most important and basic indices, because they can be used to estimate building costs, there are many design firms that wanted to add other

indices, such as to evaluate costs referring to vertical elements, or to analyze engineering factors. It would not be so easy to develop utilities to provide interfaces with those analytical models, but the authors have a strong interest in working on this subject.

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