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Computer Graphics for Modelling

by D.J. Vanier

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ABSTRACT

A three-dimensional computer graphic of the new Canadian Museum of Man, presently under construction, is used to explain current techniques for entering the building data and manipulating the geometric model. The final image consists of 200 sculptured surfaces used to represent the exterior envelope, windows and roof systems. Landscape architecture features are electronically stippled on to the geometric model to produce trees, bushes and building ivy.

RÉSUMÉ

Un dessin réalisé par infographie en trois dimensions du nouveau Musée national de l'Homme, actuellement en construction, sert d'exemple dans cette communication pour expliquer les plus récentes techniques d'entrée des données relatives aux bâtiments et de manipulation des modèles géométriques. L'image finale est composée de 200 surfaces en relief qui représentent l'enveloppe extérieure du bâtiment, les fenêtres et le toit. Les caractéristiques du paysage, telles que les arbres, les arbustes et le lierre, sont pointillées électroniquement sur le modèle géométrique.

COMPUTER GRAPHICS FOR MODELLING

Computers: D.J. Vanier

A well-defined series of steps is required to produce a computer model of a building (the term "computer model" implies a graphic representation of the shape and form of a building and does not mean a complete computer data base of all the building components). Unfortunately, it is not as simple as demonstrated at computer shows: "Push this button and a three-dimensional, fully shaded, colour image of your building will appear in 15 nano seconds!" Normally many hours, if not days, of work are behind every still picture or every second of computer graphics film.

The modelling of the new Museum of Man by architect Douglas Cardinal, under construction in Hull, illustrates the process in practice. The computer model was constructed using the architect's plans and physical model. This produces a computer replica which faithfully duplicates the building for presentation purposes. The eventual use of these techniques will use the software as a design tool, where the building model becomes malleable in the designer's hands.

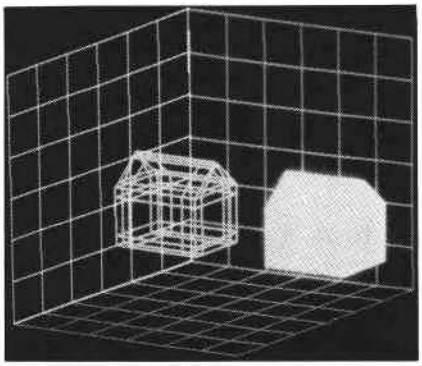
Building entry

In this example the building information was obtained by extracting the data from the concept plans on a digitizer. The software used allows the representation of the curvilinear form on the screen with a minimum number of control points. That is, the perimeter does not have to be traced millimetre by millimetre; only significant curve changes have to be located.

A three-dimensional image is obtained by creating a similar (or dissimilar) outline at a different height. These two curves, when connected, form a module that can be manipulated graphically by the designer. In this case the module is a complete storey of the building. A number of modules would comprise the computer model. These can all be translated, rotated, or scaled individually or collectively.

Module manipulation

Rotation and translation are used to



orient or to position modules or groups of modules, while scaling permits a change in dimensions in the X, Y or Z directions of modules or groups of modules. Transformation implies a combination of any or all of the above.

A module can be rotated around the X, Y or Z axis. This type of rotation is required to place modules with respect to a background or other modules. In some computer graphics systems the rotation of the wire frame module occurs in real time; that is, the network of lines and nodes can be moved interactively on the screen by the user. This must not be confused with a method for viewing the modules. In this case, the object does not move but the user changes his eye point by changing position and distance from the object. The computer software will then calculate the new location and display the resulting image. This position change may help the designer find a better vantage point for module placement.

A translation or move can be carried out along the X, Y, or Z axis. The same is true for scaling an object. The first feature allows the designer to locate a module or group of modules on a site or in relation to each other. Scaling offers the ability to quickly alter the aspect ratio of a module.

The three-dimensional module can then be transformed, that is, translated, scaled or rotated to the desired angle and location by the user. An extremely useful transformation is the ability to move from orthographic to perspective with ease. Although this is a lengthy manual procedure, computer processing speeds enable users to view one-, two- or three-point perspectives in a matter of seconds, depending on the complexity of the wire frame image.

Module placement

The user can select a portion of the total image, the "active module(s)," to rotate, scale and translate, leaving the remaining "passive modules" in their relative locations. The entire set of modules can also be manipulated together. The use of different coloured meshes allows the designer to distinguish different modules on the complicated image.

Colour shading

When all modules are in place, the three-dimensional mesh image can be enhanced by hidden line suppression, final shading and lighting manipulation. Hidden line suppression is carried out by specialty software packages; depending on the complexity of the wire frame and speed of the computer, this may take from one minute to one hour. Hidden line suppression is normally not required for colour representation, as the colour infill will eliminate the hidden back lines. Textbooks on computer graphics explain several methods for this procedure.

The three-dimensional shading of the mesh model is the most computer-intensive portion of the work. The mesh is divided into triangles automatically by the software package for the calculation of the colour. The colour of every triangulation patch of the grid is calculated by the computer depending on the location of the viewer with respect to the location of the light sources. The software must take into account viewer location, location of the light source, the red, green and blue components of the colour, and the opacity of the object itself, to calculate the colour of each patch of the grid. The individual modules are then shaded on the screen one at a time. This software package uses a Z-buffer technique for recording the Z-depth (depth into the screen) of each triangulation patch of every module. This allows the superimposing of modules, regardless of their depth in the final model.

Colour shading should not be confused with shadowing. A portion of the module facing away from the light source will appear darker than one facing the source. Most graphics modelling systems offer this shading capability. To cast shadows, however, extra calculations are required by the computer to determine which modules will block the light source, thus putting other modules in their shadow. These techniques use ray tracing methods which are not available on most commercial systems.

Final image

At times it becomes too costly to represent specific objects in three-dimensional space. Various landscaping and landscape architectural effects can be superimposed on the completed image after the entire computer graphic object is represented. A "Paint" program allows the designer to electronically stipple trees and bushes. Trees are created individually by applying colours from a "paint palette." These trees or other objects can then be stored for recall and duplicated wherever desired on the shaded model.

The final view of the building is a complete three-dimensional model. One view location of this image can take from five minutes to five hours for the computer to calculate. This of course is entirely dependent on the size and speed of the computer and software.

Dynamic images

A number of techniques can be used for the real-time manipulation of lighting effects or colour. "Look-up Tables" record the colour of each pixel or picture element in a special fast access portion of computer memory. Changing the colour reference will modify all occurrences of that colour on the screen in micro seconds, thus facilitating colour scheme changes. Current hardware will rotate noncomplex shaded objects in real time, but in most cases these are specially designed, dedicated systems. The type of equipment currently available is not powerful enough to take a complex three-dimensional shaded object such as the Museum of Man and rotate it on the screen in front of the designer. This will be available in the future with the advent of faster equipment and special graphics processors for handling large data bases of graphics information.

Film and video clips have presented dynamic walk throughs or fly throughs of computer graphics models of buildings. These are currently produced by manually or semiautomatically splicing large numbers of computer generated still images.

Computer graphics can display design information to the architect and present a realistic representation of a building. It will be some time before designers abandon conventional modelling techniques and before these computer graphics tools will be cost effective. The hardware cost for high resolution computer modelling is around $400,000 but these costs should soon be reduced to one-half or one-third. The current process is laborious, time intensive, costly and repetitive. The warning, caveat emptor, is critical when considering a computer graphic system for modelling buildings. It may be impressive, but man-weeks of work and hundreds of thousands of dollars lie behind every image presented to the client at a computer equipment demonstration.

Notes

Building data entered by Dana Vanier of the Division of Building Research and Jamie Worling, an architecture student employed at the Division of Building Research. BSP3D software developed by Ken Evans of the Computer Graphics Section, Division of Electrical Engineering, National Research Council. Commercially available hardware employed with a prototype colour graphics processor. This article is a contribution of NRC's Division of Building Research and is published with the approval of the division director.

1
Architect's model of the Museum of Man, currently under construction in Hull.

2
The operator has placed the building plan on a digitizer and has entered a number of points graphically on the screen. The curve on the screen is only one half of the building perimeter.

3
The example is shown as a 3D orthographic wire frame. It is quick to display and a module can be rotated easily in seconds.

4
House rotated around the Y axis.

5
The user changes his viewing position to the right (shown by the white angle on the horizontal plane) and alters vertical position as depicted by the blue angle. The distance from the object can also be defined (cyan circle).

6
House translated along the X axis.

7
House translated in the X direction and scaled by a factor of two in all directions.

8
House transformed in perspective view.

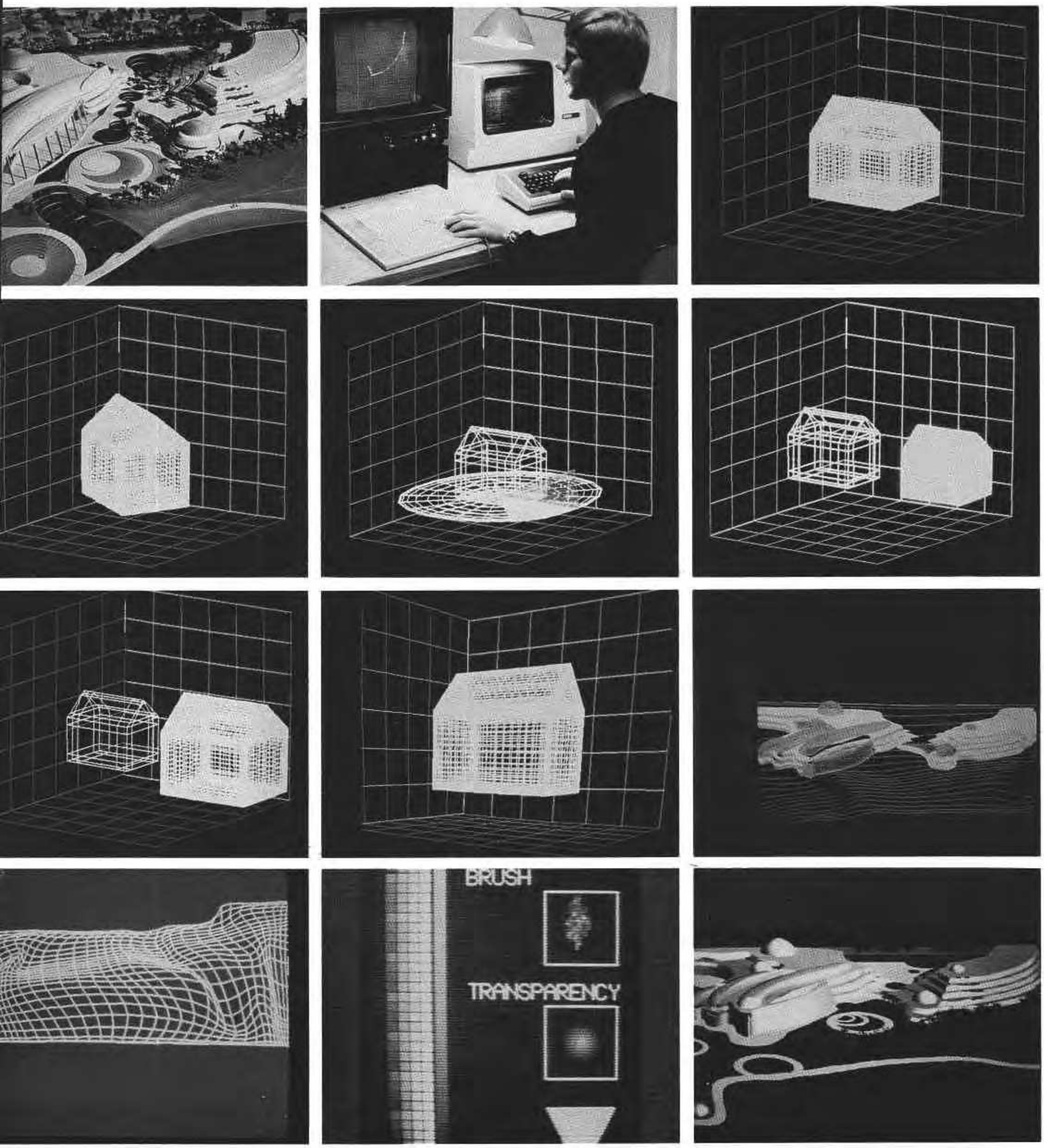
9
The building is placed on the landscape (another module) and the various components are oriented for visualization. This is only the wire frame, not the fully shaded object; it appears solid because the mesh grid lines are so close.

10
Approximately half of the land has been shaded. Location and direction of the light source are selected by the designer, as is the colour of both sides of the module.

11
The tree was created by pointing at desired colours on the palette and positioning these colour dots in the brush area. The finished tree becomes the brush, which is then applied onto the shaded model.

12
Complete 3D computer image. The landscape is also 3D and shaded, as are the sidewalks and ponds.

1	2	3
4	5	6
7	8	9
10	11	12



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