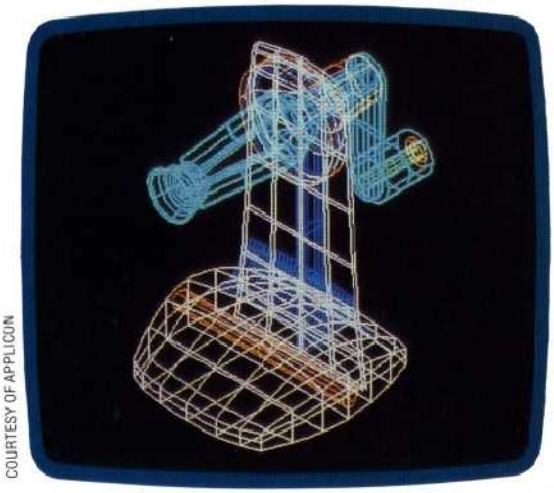
the use of computers to assist with the designing of future generations of computers.

Printed circuit board design, for example, is quite complex, involving optimising techniques in order to arrange components and their interconnection paths in the most economical way possible (bearing in mind that connection paths can never cross). The designer is often forced to fall back on trial and error — and it is here that CAD packages are particularly useful. All the individual components are stored as pre-defined images, and are called up as and when required. It is a simple matter to try out a particular design on the visual display unit to see if it meets all the criteria before committing it to paper as part of a working drawing. By this method it is possible to assemble a design, and even test out the efficiency of a variety of different solutions, in the time it would otherwise take to complete a single draft.

Integrated circuits are designed in almost exactly the same way, but due to the density of components and connecting pathways, a further software feature is necessary: the ability to magnify a part of the drawing, work on it at the enlarged scale and then place it in position again within the overall design. This effect is now an important part of the CAD repertoire, and has added considerably to the efficiency of the system. By its use, the specification of a complete object can be held in just one drawing, and the scale can be adjusted to meet the viewer's requirements.

And it's not only the scale that can be varied in this way. If we take the case of a more complex object — a car, for example — we are presented with a variety of sub-systems that go together to



COURTESY OF APPLICON

make up the whole: the electrical system, the hydraulic system, the exhaust, the suspension, and so on. While the aesthetic designer will be concerned with the overall package, individual engineers are more likely to be interested in just one sub-system. It is a simple matter to keep each sub-system in a different colour, and then extract the objects of just that one colour from the whole drawing. That is not to say that the drawing must always be a coloured mixture — the coding can be suppressed at will when not required.

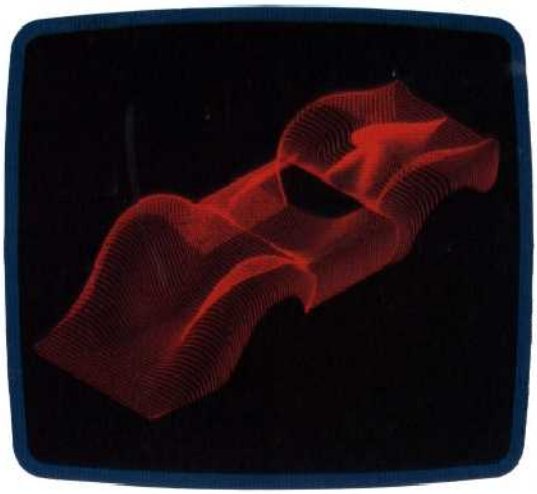
It is the ability to retain the *complete* specification of an object (not just its form and

COURTESY OF SIGGRAPH

Just Imagine...
The background to this shot from the Lucasfilms production 'Road To Point Reyes' was largely composed by fractals, a new and ingenious CAD technique. Fractals are phenomena that increase in complexity the more closely they are viewed. The hills and mountains in the background started life as simple polygons, described within the memory of a computer. Each polygon was then made successively more complex by the addition of its own shape to each of its sides, and the process repeated with a degree of randomisation. The development in shape of the snowflake, shown below, from a simple triangle, illustrates this principle

appearance, but also information on the material of which it is constructed, its weight, cost, etc.) that is the real breakthrough. Retrieving information about the shape and size of the object is only one function of the system, which can be regarded as a visually orientated database. By asking different questions of that database it is possible to: place orders to suppliers; schedule sub-assembly and component manufacture; integrate production lines to ensure that components arrive exactly where and when they are required; analyse costs; monitor manufacturing efficiency: and much more as well. It is tempting to speculate that the next step will be a regular system of direct computer control of manufacture, and with the burgeoning use of robots in the industrial process, that next step is not such a large one.

Most of the applications we have discussed here require mainframe computers or else very powerful minicomputers, but that is not to say that even small microcomputers cannot play a useful part in the design process. There is a wide variety of CAD software available for machines running under CP/M, for example, and most manufacturers offer at least one package, even for computers as relatively unsophisticated as the Sinclair ZX81. As we noted, the size and speed of the computer dictates the quality of the stored image, but the home user's requirements are unlikely to be as stringent as those of the professional designer, so it is quite feasible to achieve exciting results for a modest outlay.



COURTESY OF INTERGRAPH

Wired Up
The first stage in creating an image or design in three dimensions is known as 'wire framing'. The image is defined as a series of point co-ordinates, appropriately joined by straight lines. These lines can be manipulated using the curve smoothing algorithm, hidden lines removed, and then the planes filled in with colour and shaded as necessary to increase the illusion of depth