A future interface for computer-aided styling

Kay Dekker, School of Art and Design, Coventry Polytechnic, Gosford Street, Coventry CV1 5RZ, UK

Why do stylists frequently complain that CAD systems are hard to use? In many cases the problem is that the CAD human-machine interface fails to preserve the metaphors and idioms of the traditional studio. Historically, human utility has been seen as a less-important resource than computing power, and users' needs have been sacrificed to make computer use even possible. Now, computer power is cheap, and looks to become ever cheaper: perhaps now we can afford to make computer systems versatile for their users, and not make the users ingenious for their computers. This paper examines how vastly cheaper computing power might be used to make stylists' lives more pleasant.

Coventry Polytechnic's research project 'Computer aided vehicle styling' is concerned with the issues which CAD systems present to automotive stylists, and with devising systems and procedures to facilitate their design activities. • Automotive stylists are specialized designers who are responsible for the initial concept design and the complete appearance design of the vehicle. However, although automotive stylists represent a particular, and highly-specialized, aspect of the general design field, their activities are mostly typical of general product design. If CAD systems can be specified that meet the needs of automotive stylists, they would have wide applicability in other areas of design. • One of the critical factors thrown up by the research project is that of the design of the user interfaces of CAD systems. This paper discusses some of the problems of traditional CAD system interfaces, both in terms of presentation and interaction, and proposes ways of using new technology to make CAD systems more designerly.

Keywords: Virtual reality, computer aided design, car styling

1 The interface problem

'Talking about music is like dancing about architecture' Steve Martin

0142–694X/92/01042–12

From the outside, the average CAD system looks much like any other computer system: a processor cabinet, a display, a keyboard, and a mouse. Some CAD systems may differ slightly: a light-pen may replace the mouse, for example, or there might be a dial-box or a touchpad; however, a CAD system looks like a computer, and the means provided for interacting with it are those typically associated with computers. Also, its physical placement is worth noting. The average CAD system sits on a desk, at just the right height so that the user can sit and look comfortably at the display while using the keyboard and the other input devices. • One of the most vaunted features of CAD packages is their ability to produce 'almost-photographic' renderings of a solid model: ask any CAD company rep what their product can do, and they are certain to show you pretty pictures of coffee pots, chess pieces, or cars. And very nice these images are, too, with smooth shading, naturalistic colour, sparkly highlights and reflections in metallic surfaces. Yes, surface renderings can be a great help in evaluating surface characteristics – but what if you need to compare and contrast a few renderings of similar products? • In the traditional studio, it is the work of a minute or two to take the sketches or photographs and pin them to a display wall, where they can all be seen at once. A CAD system, however, is pretty much limited to displaying one image at a time on its single screen. Image-processing techniques can resize an image, it is true, and in this way it is possible to fit a very few images on the screen simultaneously; however, the fixed resolution of the screen, which may just be sufficient to display one image with reasonable clarity, then has to be divided among several images with a corresponding loss in detail. Of course, multiple screens could be attached to a single CAD system, but since a good quality colour monitor costs several thousand pounds and occupies several cubic feet, this is an expensive and bulky semi-solution. • Therefore, even if the traditional CAD interface is capable of displaying one reasonable quality rendered image, it fails to fulfill the usual design need of being able to evaluate multiple images in parallel. • So much for the physical (or hardware) interface. The conceptual (or software) interface has rather more variability: while the ergonomics of physical interfaces seems relatively well understood, software interface design is rather a black art. However, there are enough common principles for an example to be worthwhile. • Suppose that an object is to be produced whose surface is composed of curved panels. First, the curves which bound the surfaces have to be produced. Rather than drawing the curves free-form, as one might do on paper, the user must give a command to tell the CAD system that she wishes to make a curve. This is generally done by using the keyboard to type the command, or by causing a menu of commands to appear on the screen, so that the correct command can be indicated with the mouse or other pointing device. Having indicated to the

CAD system that she wishes to make a new curve, the user must, in general, produce it by specifying sets of points in three-dimensional space which the curve either passes through or snakes past in some mathematically suitable way. • Mathematically? yes: even though the CAD system user may not have to understand the mathematical representation of curves in her CAD system, she still must understand that a curve is not *per se* a curve, but an abstract object controlled by the positions of certain points that may not even lie on it . . . • The more complex the curve, the more points that must be specified. This might not be too arduous if the curves were restricted to being planar: the screen might be treated as a sheet of paper lying in the plane, and the third dimension thus neglected. Life is rarely, however, so simple. So the screen must be divided into areas, each of which gives one of the orthogonal projections of the design space. • And how are the points placed into the design space? By manipulating the mouse, or light-pen, or dials, until a little pointer (called the cursor) on the screen is in the correct position, and then clicking a button on the mouse, or pressing the light-pen against the screen, or typing a key on the keyboard. Or, alternatively, some systems allow the user to specify the coordinates of a point by typing them in on the keyboard. This has to be done for every control point on every curve that bounds every panel on the surface of the object . . . • After the curves have been made, a panel can then be constructed by issuing another command. Each of the boundary curves of the panel must in turn be selected, either by pointing-and-clicking, or by typing its name into the computer. • Eventually, enough panels have been constructed, the object is finished, and a solid form can be milled with a CNC machine. But how different the process has been from traditional practice! • Traditional model-making is a tactile process, whereby a form is gradually evolved from an amorphous mass of a deformable or carvable material. When modelling in clay, at least, if too much material is removed from a surface the problem can be remedied by building up the surface again with a little more clay. If a surface is a little too tightly curved, clay can be pared away from it, the material to be removed being determined by holding a template up against the defective surface. Blending of two adjacent surfaces can be done by filling the gap with more clay and smoothing it to the correct blend radius. All these operations are, at best, difficult with CAD systems, and, if they can be performed at all, are not performed in the traditional manner. • It is hardly surprising, then, that people who have been trained in traditional design and modelling practice, and are experienced and skilled in the idioms and metaphors, have difficulties when faced with a CAD system. I often explain the problem to people in this way: 'Styling with CAD is like sculpting through a small plate-glass window with one eye shut and your hands tied behind your back and typing instructions in a foreign language to an engineer'. • That may sound humorous, but the problems that it encapsulates are significant: CAD systems fail stylists in that

a) The screen is too small to see enough in enough detail
b) There is no direct binocular perception of objects as solids
c) There is no tactile interaction with the objects
d) The methods of interaction are alien to stylists
e) The metaphors and idioms of use are also alien

2 *A possible solution*

Can anything be done to preserve the well known utility of CAD systems (the modifiability of data models, the ability to summon previous work for restyling, the speed with which data models can be rendered with different surface characteristics under differing lighting conditions, incorporation into management information systems (MIS), and so forth) while making the mode of use as familiar and flexible as traditional design techniques? • I believe that some new developments in computing known collectively as *virtual reality*,[1-3] while not completely solving the problem, show promise, especially when augmented by speech-understanding and speech-generating modules, and connected into a company's MIS. • In its simplest form, the hardware of a virtual reality (VR) interface consists of a headset and a glove. The headset contains two display screens, one for each eye. These screens display the left- and right-eye perspective views of data held in a computer. It also contains a position sensor, so that changes in head location and angle can be detected by the computer. The glove contains a similar position sensor and flexion sensors in the joints, giving data on changes in the flexion of the digits. • Let us imagine (for such a system has not yet been developed) how Mary, our designer, might set about her task with a VR-interfaced CAD system. We'll feel free to let imagination have its head; it's better to think about what we would actually like from a system, rather than be continually considering what is currently practical. After our daydream we can emerge into the real world and see how nearly current VR systems can approximate our desires. Where a particular point of interest occurs, it will be flagged by a bold number in square brackets: for example **[1]**. Such points will be discussed in some detail in Section 3 of this paper. • Mary walks into the large room that used to be the clay modelling shop before her company switched to a VR-CAD-MIS methodology. The room is empty, a pure blank space, but the walls and floors are covered with soft foam padding: even skilled VR users can occasionally over-reach themselves and take a tumble. Under her arm, she carries her interface kit: a polycarbonate helm, rather like a

1 Foley, J D, 'Interfaces for advanced computing, *Scientific American*, October 1987

2 MONDO 2000, Summer 1990 issue, Fun City MegaMedia (publication)

3 SIGGRAPH 1989 Proceedings: *Virtual Environments and Interactivity* bike helmet but lighter and with an opaque wrap-round visor [**1**], a pair of thin flexible gauntlets [**2**], and a waist belt. She unclips thin flexible cables from the gauntlets and the helm, and plugs them into sockets on the belt, which she straps on. • Tethered to the walls, and leading up into the ceiling, are several ports, data connections to the MIS [**3**]. She detaches a small transceiver from her belt and plugs it into one of the ports: all the data flow (vision, sound, movement, and so forth) between Mary and the MIS are sent by radio between this transceiver and a similar one on Mary's belt. Mary puts on her gauntlets, and dons her helm. • It is momentarily dark, then a soft light comes on, and she can see that she is standing inside the virtual version of the former model room. It looks very much like the room that she could see before she put her helm on, except that the door she came in by isn't there you don't need doors in the virtual world. As she turns her head, different areas of the room come into view; raising her hands, she can see their virtual projections moving in synchrony. She flexes them to make sure that all the flexion sensors are responding: all is well. Time to work . . . • 'MIS?' she asks, quietly [**4**]. A calm voice answers, which apparently comes from a point a few feet in front of her, where the persona [**5**] of MIS has appeared. MIS is the management information system, the software that ties together and manages all the myriad pieces of information that Mary's company uses. Everybody here uses MIS: the secretaries, the designers, the engineers, the managers. • For Mary, MIS handles her interaction with the VR interface to her CAD system, translating Mary's verbal and gestural commands into commands to the CAD system; handles messages for her; allows her to communicate with other people in the company; stores and retrieves Mary's designs, computer models, engineering test data, images . . . in short, helps Mary to manage her job effectively. Sometimes Mary wonders how people coped before they had MIS. Even though MIS is a suite of computer programs, Mary relates to it more easily when it appears as a persona.

'Hello, Mary,' the voice says. 'Sign in, please.'

Mary raises her hand and her fingertips trace glowing lines in the air as she makes a flowing gesture. This is her authentication to talk to MIS, who so far has only been able to detect whose interface kit is being used. It would be as hard to forge her gesture as it would be to forge the signature she uses on her cheques [**6**]. Now that MIS knows that it is indeed Mary who is using her kit, she can get on with her work.

'OK, Mary, you're in. Do you want to carry on from where you were?'

MIS remembers exactly where Mary was in her work when she finished working yesterday [**7**].

'Yes, please'.

'OK, Mary, I'll be back soon.'

The glowing face of MIS disappears, and suddenly the room takes on a new appearance. One wall is now covered with pictures: the sketches and roughs that Mary is working from; photographic images of some competing products; line drawings of the ergonomic considerations that Mary's product will have to conform to. The wall is too far away from Mary for her to see the small details clearly, but that does not worry her, because she would rather have the overall view at this stage of the process. She can always walk over to the wall if she needs to see a picture more clearly – or ask MIS to bring one over to her. • Towards the centre of the room there are now several toolracks, containing curve profiles, scrapers, markers, reels of resist tape and spray cans. At the centre stands a workbench, with Mary's half finished project and a few tools on top [**8**]. As Mary moves over to her workbench to start work, MIS's voice sounds in her headset.

'Excuse me, Mary, but Laura's just contacted me. She's left voice-mail [**9**] for you: would you like to hear it, or shall I put it in a popup [**10**] for you?'

'Both, please.'

A new voice sounds in Mary's ears: it's Laura, the senior designer. She would like to have a quick word with Mary about the progress of the project, when Mary's free for a moment. Simultaneously a glowing rectangle containing Laura's words appears in mid-air in front of Mary. As Mary hasn't started yet, she decides to contact Laura immediately, so she will not need the popup to remind her later. She reaches out, grasps the popup, makes a two-handed ripping gesture, and the popup vanishes silently.

'MIS!'
'Yes, Mary?'
'Put me through to Laura, please?'
'Hang on, I'll see if she's free.'
A brief pause . . .
'OK, Mary, I'm putting you through now.'

Laura's persona appears, a comfortable conversational distance away from Mary.
'Hi, Mary. Hope I'm not disturbing things too much?'
'No, I was just starting up. What's the problem?'
'We've just got a rush job in, and it's worth quite a bit if we can pull it off. I know you're busy, but I've just asked MIS **[11]** about the progress chart, and she **[12]** reckons you could spare a day knocking up a prototype without throwing the project out too much. MIS **[11]**, show Mary the progress chart, will you?'

A popup appears, larger this time, showing a chart with which Mary is only too familiar. Her timeline is brighter than the others.

'This is the current progress. If you work today on the prototype, it'll look like this . . . '

The chart changes **[13]**. Yes, Mary thinks, it could be done – but Laura had better make it worth her while.
'OK, Laura, I'll give it a go. Now, about that payrise . . . '

But Laura's face and the popup have already gone. Some things never change.
'Mary?' MIS's voice again. 'Laura's rescheduled your current project. Shall I display the specifications for your new task?'
'Yes, and hold non-urgent calls for me, please'
'OK, Mary.'

The display wall clears, and fills up with new drawings. Mary walks over to the wall and studies its contents: a few quick sketches by Laura, a list of dimensions and materials, and a short note reading 'OK, we'll talk about the payrise . . . tomorrow!'. Smiling, Mary considers the sketches. The proposal looks rather like a Type Seven unit, but there are a few little extras.

'MIS, clear my bench, please.'
'OK, Mary. Shall I leave your tools out?'
'Yes, please. Get me a Type Seven archetype from the library, and when did we last do a custom Type Seven?'
'Two months ago, for XYZ Corp. Do you want that project folder? **[14]**'
'Please.'

The Type Seven archetype appears on Mary's bench, accompanied by a folder. Mary makes a right-to-left wave over the folder, and it opens to the first page. As she repeats the gesture, she sees successive pages. A left-to-right gesture, and she sees the previous page. Hmmm . . . it would be useful to see all these pages on a display board at once, thinks Mary.

'MIS?'
'Yes, Mary?'
'Spread this on that wall, please.'
She points successively to the folder and to the wall in front of her [**15**]. The folder vanishes, and its pages appear neatly arranged on the wall. Mary wanders over, and spends a few minutes studying the customization report. Yes, there are a few things to bear in mind. Mostly they are physical constraints, and strictly Engineering's problem, but she has enough experience to know that a little forethought may save an expensive finite element analysis later. • First, the new unit needs to be on a slightly larger scale than the standard one.
'MIS, scale this [**15**] by seventy-nine divided by seventy-one, please.' Mary waves round the model.
'That's by one point one one two six seven, Mary. Shall I scale all the dimensions?'
'Yes, except for the material thickness, please.'

The model immediately grows slightly. Now a new tube has to be made, bent, and joined into the main unit.

'MIS, one metre of steel tube, one centimetre diameter, three millimetre thickness, please.'

The tube appears on Mary's bench, next to the model. • Picking it up, she examines it. Yes, that will do. She reaches for a spraycan from the rack behind her, and sprays the tubing at the points where it needs to be bent. Where the spray touches the tubing, the metal loses its dull grey appearance and turns pink. It is only in these pink areas that the tube will bend. Mary holds the tube against the model with her left hand, bending it so that it takes up its final position.

'MIS, fit this to that, please,'

Mary says tapping first the tube and the model with her other hand. The tube nestles against the model, carefully keeping a constant cross-section, and when Mary takes away her hands, it stays put. She picks up another spray can, and sprays all the pink areas, which return to their normal, nonpliable, grey. Now the lower end has to be joined with the lower chamber of the unit. She'll have to make a hole in the chamber wall for the tube to fit into. Taking a small marker, she draws a roughly-circular mark on the chamber wall.

'MIS, make a circular hole there, please.'

A glowing circle appears on the chamber wall, and the material within it disappears [**16**]. Through the hole, Mary can see the chamber wall and the interior of the chamber. Now to join the tube end to the chamber . . .

'MIS, join this to that, please.'

Keeping a firm grip on the loose end of the tube, holding it just away from the hole on the chamber, she strokes the cut surfaces with the pointer. A pink mist appears around the junction, and solidifies. The tube is now joined to the chamber by a flared pink join; while it's pink, Mary can reposition or shape it until it is exactly right. When she is satisfied that the join is correct, she sprays it with the fixing spray, and it becomes the same dull grey colour as the rest of the unit. That's the first modification done . . . • After an hour or so, Mary has finished her first attempt at the prototype. She carries it over to the display wall, and checks it visually against the rough sketches and the technical details. It's a good attempt, she thinks, but it'll have to go over to Engineering so they can simulate its performance.

'MIS?'
'Yes, Mary?'
'Store this for me, and sign it over for a FE run, please.'
'OK. There's one message waiting for you, marked nonurgent.'
'Read it to me, please, MIS.'
'From Simon Jones, Secretary's Office, to Mary Evans, Design: How about a coffee when you've finished? End of message. Any reply, Mary?'
. . .
'Yes, please. The reply is: "I'll be up in five minutes." End of reply.'
'Thank you, Mary, I'll deliver it to Simon now.'
'MIS, save my state, please'.
'OK, Mary . . . state saved. Quit now?'
'Yes please, MIS'
''bye for now, Mary . . . '

Mary's work area vanishes, and again she sees the empty virtual room. Slipping off her helm and gauntlets, she unplugs her transceiver from the port, and heads off to the secretaries' office to pick Simon up for a coffee while the engineers run the FE analysis . . .

3 *How far in the future?*

The scenario described in the previous section may sound far-fetched, particularly to current CAD users. Surprisingly enough, all of the technologies exist as of the time of writing (December 1990), though some of them are not as fully developed as in our scenario. • [1] The flat LCD (Liquid Crystal Display) screens used in the VR helm are currently available, and are being used in experimental and commercial VR interfaces. These displays are capable of displaying colour images of television quality, which is unfortunately only about a quarter of the resolution of a good-quality CAD monitor, but with high-density television (HDTV) on the brink of wide-scale availability, LCD panels of corresponding higher densities are under development. • Available graphics processors can render about 3000 smooth-shaded polygons per frame at video rates: this is at least an order of magnitude too few to display complex scenes, such as the interior of a studio, but again the technology is being intensively developed and should be available within a few years. • Current helm designs are somewhat heavy and clumsy; they are not yet suitable for long-period use, but increasing technological advance should gradually remedy the problem. Design considerations for an entertainments-oriented helm may be found in Holmes.[4] • [2] The gauntlets are similarly commercially available (the DataGlove and its cut-down game-controller version, the PowerGlove, which is already being sold for US$ 85 to work with Nintendo games), but they are primarily sensing devices, and though fine-grained (tactile) and coarse-grained (movement restriction) feedback systems are under development, no technology has yet established preeminence. • Mary's ability to feel surface imperfections in the data model with her fingertips, and to grasp her spraycans without her fingers passing through them is therefore some little time away. The fibre-optic flexion sensors and the position-orientation sensors for the gauntlets and helm are, however, well-developed. • Even though current VR systems seem to use one gauntlet only, very few stylists are one-handed; Mary's system, therefore, uses two gauntlets. • [3] Current VR interfaces communicate with their computers via cabling: the radio link is, however, not impossible. I feel that a VR system that allows free body movement and gesture cannot have clumsy umbilical connections which would obstruct and hamper the user. • [4] The speech/sound interface exists in rudimentary form. In the scenario, Mary communicates with the MIS very naturally. One of the few restrictions I've imagined is that commands to MIS would 'get its attention' by being prefixed by a 'start' sound – in this case 'MIS' – that the speech-recognizer can 'listen' for, and are terminated by 'please'. Politeness costs very little in terms of the overall sophistication of the

4 **Holmes, R**, 'Health and safety issues concerning virtuality systems' in *Proc. Computer Graphics 90 Conf.*

speech recognizer), but helps the end of commands to be spotted rather more easily. • Mary's speech in the example is continuous; the words are not spoken separately and distinctly. While this is much more natural for a human speaker, it is very much harder for a speech-recognition system to recognize word boundaries in the sound stream. Current continuous-speech-recognition systems can handle vocabularies of a few hundred words, with analysis time of a few seconds; our system may not need many more words (many of the words in human speech are nonfunctional, and can be skipped as 'noise'), but an analysis time of a tenth of a second or so would be more natural. • The speech recognition systems available can be trained to recognize a voice in less than a work-day, and are relatively insensitive to changes caused by colds or sore throats.[5] • Speech synthesis (MIS's 'voice') is quite generally available, and will require little further development. • [5] A persona is the virtual presence of a person (or, in the case of MIS, a pseudo-person) in a VR environment. It may, but need not, resemble the person who it represents. • [6] Why not use voice-printing as an authentication? Simply that voices may be forged rather more easily. In less security conscious environments, voice prints, or even whispered passwords might suffice. • [7] During a work session, MIS silently records the state of Mary's virtual world, so that in the event of a systems failure, not too much work would be lost. As an effect of this, MIS has perfect records of Mary's command sequences, which are helpful when a command sequence has to be aborted or work backtracked from. • [8] Hopefully this sort of environment should look familiar to a designer. Part of my current research is investigating the particular tool uses of designers so that the tools' virtual counterparts will behave correctly. Of course, this doesn't mean that a VR-CAD system should be bound by a slavish adherence to tradition. • [9] Voice mail: a type of electronic message where the speech of the sender is recorded for playback by the recipient(s). • [10] Popup: a virtual display object that can contain text, pictures, or sounds. They are a sort of three-dimensional analogue of the 'alert windows' often found in graphical interfaces, except that popups are semi-permanent: they persist until 'ripped up'. • [11] MIS stays out of the conversation until an utterance commences with 'MIS'. • [12] Laura, too, personalizes MIS. • [13] Presumably Laura has just modified the version of the chart which exists in her personal space, and the modification has caused an update to the projection in Mary's. • [14] Here MIS has made a reasonable inference: that inquiries about past projects are often followed by a request for the project folder. This knowledge could either be programmed in by a knowledge engineer, or acquired heuristically by MIS from observing Mary's work patterns. • [15] A gestural interface makes it much easier to use deictic references ('this', 'there'). • [16] MIS knows that holes have to be made in something, so it

5 Zbyslaw A , Centre for Speech Technology Research, University of Edinburgh (personal communication)

gets made through the chamber wall. MIS has also inferred that the roughly-circular mark serves as a reasonable description of the boundary of a circular hole, so the 'best-fit' hole gets produced.

4 *Summary*

The equipment that would provide our hypothetical system is either available now, or will be available in the near future – at a price. A top-end VR system, which, admittedly, can do less than we want, currently costs around US$ 300 000. It is not unreasonable to expect that hardware costs will continue to fall steeply, with that system costing less than US$ 100 000 in under five years. Top-end CAD systems can cost more than that now. In a personal communication, a systems designer at a major VR company confirmed that in his belief the system I have proposed, or something very much like it, will be industry-standard before the turn of the century. • The major difficulties in developing the hypothetical system will be in integrating the existing technologies into a multimodal interface, and in ensuring that the interface actually provides the appropriate and powerful metaphors and idioms that it promises.