remembered visual images. This and related work provide reminders that, although we may think of a drawing as an external optical representation, it is only available for interpretation by our brains as a preprocessed internal representation. However, in order for such descriptive processes to act on images from memory, the images need support and replacement as they fade in working memory (Kosslyn 1994). The evidence that covert mental scanning actually accesses spatially depictive images in our brains and is used to derive novel descriptive information is complex but fascinating and persuasive. It is well reviewed in Denis and Kosslyn (1999).

I have proposed a model (Fish 1996) in which the contour fragments of sparse or untidy sketches act as skeletal support structures for superimposed mental imagery. As the image is assembled, the image parts are mentally positioned, scaled, and rotated in an alignment match with parts of the sketch. If the match is successful, the image parts are then superimposed on the sketch percept as a hybrid image in which optical and image components are confused. Thus the image is sufficiently stabilized to allow mental inspection and analysis but fluid enough to support a constant stream of mental alternatives.

Hayes (1973) has provided elegant support for the use of such hybrid mental images when paper is used to support mental arithmetic. In one study he compared the abilities of European- and US-educated subjects to perform mental long division when looking at the dividend and divisor written on paper. He noticed that European-trained subjects found that such a problem was more difficult if the two-figure divisor was written to the left of the three-figure dividend (as is usual in the US and the UK, e.g., 15|673). They had been trained to place the divisor on the right (e.g., 673|15). The opposite was the case for subjects trained in the US or UK. Hayes considered two models of the solution process. In the first, the subject generates an image in the familiar format and then solves the problem using the generated (but not a hybrid) image by the usual manipulation. In the second model, the subject might solve the problem with a hybrid image, correcting the unfamiliar to the familiar format digit by digit. Thus the effects of the unfamiliar versus the familiar format would, if the first model is correct, be expected to be limited to the first stage of the solution process, while the second model predicts that the effects would be distributed digit by digit throughout the solution process. He tested this prediction with a group of 2 European and 9 American subjects each with 12 familiar and 12 unfamiliar 2-digit into 3-digit division problems. The differences in the means of subjects' times to compute successive digits of the answers for the familiar and the unfamiliar formats were distributed throughout the solution process, confirming the hybrid model.

Similarly, Chase and Simon (1973) have suggested that hybrid imagery is important in chess where the visible squares of the board support superimposed imagined movements of the pieces and, incidentally, where the existing visible pieces may interfere with their imagined new positions. However, I know of no attempts to apply hybrid image theory directly to design representation.

Convergent evidence shows that visual percepts and mental images can support each other if they are spatially compatible, but that they interfere with each other if they are incompatible (reviewed Farah 1985). I speculate that there is a selective gate between images and percepts that acts rather like the gate that controls retinal rivalry between the two eyes, ensuring that either

only the most salient image is perceived or that a meaningful hybrid image is constructed. Because of the danger of image suppression by salient but incompatible visual stimuli, sketches need empty spaces for image components and must contain no distracting detail if they are to support imagery effectively. Ambiguity and incompletion in the sketch allow a flexible train of alternative images to be inspected or manipulated.

Figure 7.6 shows a sketch acting as a mental translation catalyst. Mentally represented propositions temporarily combine with written notes or symbols and partly descriptive elements of the sketch. Skilfully used, these sketch components decrease the mental effort needed to retrieve stored descriptive hierarchies and object descriptions that are in turn used to generate new depictive images. Incomplete contour fragments and other spatial components of the sketch then act as temporary holding structures for percept-image hybrids. Such hybrids provide a more stable platform for the image scanning and

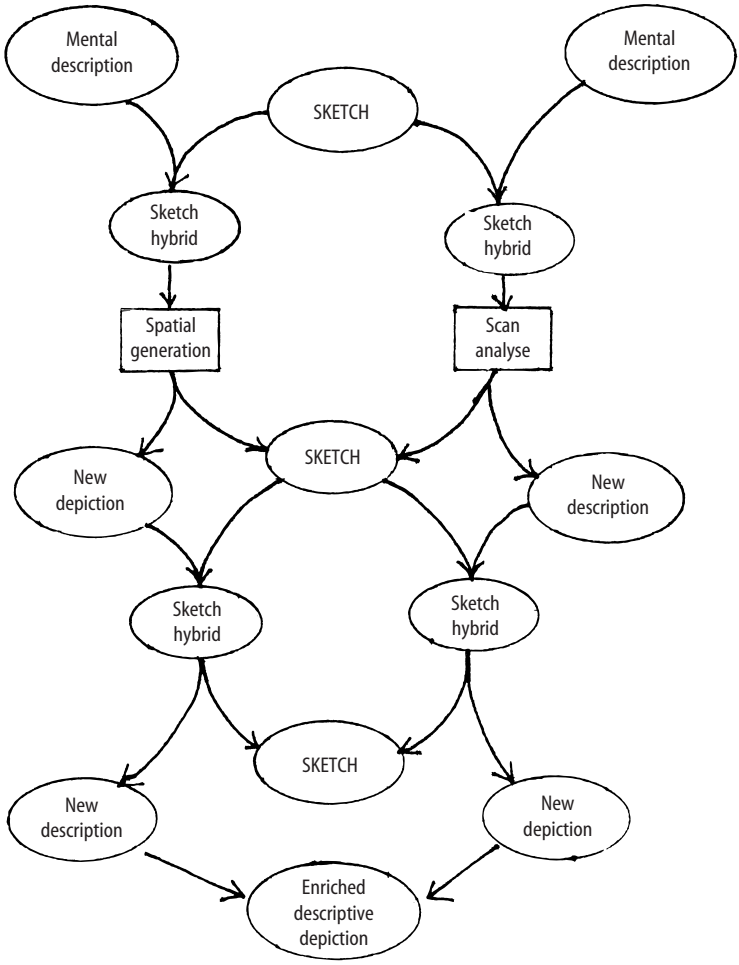

Figure 7.6 The sketch as a cognitive translation catalyst.