inevitably customizing tools. Sturt (1993, p. 134) records the mix of tool purchase and adaptation that were common in the blacksmith's trade. Skills were associated with a repetitive task rather than demanding fresh insights and techniques. The master craftsman possessed a high degree of control over his tools – their selection, origins, and final form; engendering a parallel mindset in the computer-based design field would be desirable to develop skills in applying, specifying, and customizing IT.

Representation technologies continue to move forward, providing increasing performance, while more design tasks are paralleled within emerging technologies and associated specialist peripherals. Future designers require the ability to discern the underlying principles of technological progress, focusing this ability on their own personal and strategic development. Thus there is a recurring requirement for design practitioners to take charge, to possess a working contextual knowledge of their representational systems and an understanding of the development cycles of technologies within a professional context, not merely to exploit developments once they are established. Without this facility, no matter how skilled, creative or able the designer, there will be an increasing risk of technological redundancy. Clearly, this risk also applies to many other professional groups and their equipment requirements, but the understanding and control, customizing development/adaptation of the technologies and tools is particularly significant for the designer.

Computer-aided representation in transition

As previously argued, a coherent reskilling philosophy requires transferable knowledge of, and attitudes to, skill; the acquisition of such a philosophy might be encouraged on the basis of life-long learning for design practitioners. McCullough (1996, p. 22) observes that the emergence of computation as a medium, rather than a set of tools, suggests a growing correspondence between digital work and traditional craft. He points to the rapid improvements in the physical relationship between users, computers, and the external actions they perform, particularly new forms of direct physical control and haptic feedback. This relationship implies an increasingly sensitive relationship between man and machine: where there are barriers/linkages between direct thought, vision, and intention, the transmission of thought into action is indivisible. Manifestations of this relationship lie in free-form areas of dance and singing, where body and mind are united in expressive and emotionally charged variants. McCullough makes a strong case for a similar level of technological and human integration; the requisite skills become those of hand (or body) and eye, mirroring the traditional crafts. The field of studio ceramics is a useful example in this context; soft clay malleability parallels the instant malleability of virtual digital "materials." Eye, hand, brain become an integrated production mechanism in which "skill" is denoted by the potter's ability to envisage and create simultaneously, with little conscious awareness of the formal, physical interventions required. The example of ceramics is further echoed in the way that humans are able to physically merge with sophisticated haptic controls.

Figure 8.6 illustrates how traditional representational practices have evolved in the post-information era through the changing relationships between *organization* (the management, processing or organization of

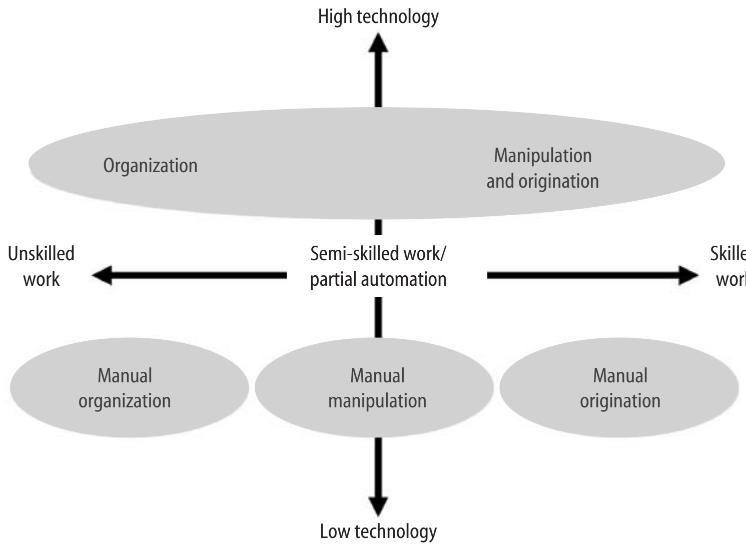

Figure 8.6 The positioning of skill in relation to representational technologies.

completed representations), *manipulation* (representation through the manipulation of pre-existing entities, and *origination* (the creation of representations without deploying pre-existing entities). Technology has integrated all three and, in particular, has closely engaged origination with manipulation. Although this process of integration has, to a degree, deskilled origination, it can be argued that new skills have evolved in relation to the manipulation of entities and that both are now better supported by integrated, highly automated organizational capabilities.

How successfully this harmonization has resulted in improved decision-making or representation is open to question, for, as Tenner (1996) has stated, "The problem is that there is growing evidence that software doesn't necessarily improve decision-making" (ibid., p. 204). In terms of "augmented reality" tools (i.e., tools that require the application of "real-world" skills within virtual design environments), this suggests that more effort is required for the selection and design of HCI hardware to ensure a closer fit between skill potential and machine options.

The intelligent marker or sharp pencil

There is no means of future proofing design representation, given the vagaries of technological development and the uncertainties of market demand. Rather than displacing skills, evolution requires the recombination of human, social, and professional requirements. Ideally, future strategies should be based on near-certainties: the technological context, increasing power of information technology and production cost reduction, will require increasingly sophisticated skills; to stop the new race of robots from ruling the world (Warwick 1997, p. 32).