APPLICATIONS OF RP

RP is applicable in any industry engaged in the production of consumer or engineering products, or tooling. Thus, RP and associated processes are used extensively for automotive, aerospace, aeronautics, railway and electronics applications. Several RP and RT processes and process routes and some areas of application have been described in previous chapters.

RP is of strategic importance wherever product innovation or time-to-market are important. An example of such an industry is the automotive industry, so RP/RT plays a key role in maintaining the competitive advantage of every automobile manufacturing company. For instance, as early as the start of 1990, Daimler-Benz AG had started replacing its traditional model-making approaches by RP techniques such as streolithography and laser sintering processes. By 1996, the RP activity in the company had grown to such a level and complexity as to prompt it to form a rapid prototyping consortium aimed at coordinating internal RP activities, monitoring international projects, and exchanging information among members (Widemann and Jantzen 1999). As a result, the company’s RP portfolio expanded to include reverse engineering, LOM (e.g., for mock-ups of exhaust systems and engines), rapid tooling, precision casting from SLS models (e.g., for aluminum engine bearers), and sand sintering (e.g., for water jackets).

This chapter summarizes emerging applications of the various RP processes described in previous chapters in areas beyond rapid fabrication of engineering parts and tooling. In fact, the term ‘part’ can be misleading since it denotes a component satisfying a specified function in an assembly but not necessarily to, say, a biological model of a virus, a human 3D portrait, or a 3D ‘map’ of the surface of the moon. This chapter will also refer to such objects. However, the important area of virtual prototyping through collaborative design via the Internet, etc. will not be covered.
10.1 HETEROGENEOUS OBJECTS

Many objects contain regions with different materials. As early as in 1995, it was anticipated that RP would quickly progress from single material parts to multi-material parts (Chandru et al. 1995). We have already noted that some RP processes such as SDM (see Chapter 8) allow heterogeneous external objects such as sensors to be embedded while the part is being fabricated in a layered manner. Heterogeneous objects are those with clear material domains or with continuous material variations as in functionally graded materials (FGM). The latter are usually composites characterized by a continuously varying property such as composition, morphology, and crystal structure so as to attain a desirable response to mechanical, thermal, electromagnetic, or biochemical loading (Shishkovsky 2001). For instance, for FG filter elements, a structure and a porous connectivity can be defined to set up a preferred direction for fluid flow.

Traditional FGM fabrication processes include thermally sprayed coating, spark plasma sintering, self-propagated high temperature synthesis (SHS), chemical vapor deposition, photo-lithography, galvanoplastics, sol-gel processes, epitaxial growth, and etching. Owing to their analog nature, such processes are not easily automated. In contrast, the digital nature of most layered or voxel-based RP processes makes them highly suited for the production of FGM. Several of the RP processes described in previous chapters have already been applied for the fabrication of FGM, e.g., SLS (Gureev et al. 1999 and Shishkovsky et al. 2001), LENS (Griffith et al. 1996, Griffith et al. 1997 and Hofmeister et al. 1999), DLF (Lewis et al. 1997 and Lewis and Schlienger 2000), DMD (Mazumdar et al. 1999), FDC (Safari 1999 and Haffiangadi and Bandyopadhyay 2000), and SDM (Fessler et al. 1997). Non-powder methods such as LOM, laser-stereolithography and Z-printer can also be used for FGM fabrication. For instance, parts with gradient color tones are very useful in medicine, architecture and art. Amongst the currently available RP processes, 3D Printing has been found to be particularly flexible owing to features such as drop-on-demand.

The majority of current RP systems utilize CSG or B-Rep part representations that assume uniform material distribution. Further, when the CAD model is converted into the .STL format, the file contains only the facet information without providing any clue regarding the nature of part interior. In view of these considerations, considerable effort has been put in recent years to extend current part representations to include FGM requirements. The first noteworthy step in this direction is the modeling of multi-material objects as generalized B-rep models through $r$-sets extended to include composition $r_m$-sets with accompanying Boolean operators (Kumar and Dutta 1997). The $r_m$ object model is a set-based approach to the