Function Representation and HyperFun Project

A. Pasko

Department of Digital Media, Hosei University, Japan
E-mail: pasko@k.hosei.ac.jp

Extended Abstract of Tutorial

Advantages of using implicit surfaces in computer graphics have been well known for a long time (e.g., ease of point classification and ray-tracing, natural blending) [B97]. However, the application was limited by organically looking blobby shapes (metaballs, soft objects). The *function representation* or FRrep [PASS95] is a generalization of traditional implicit surfaces and constructive solid geometry (CSG). In FRep, an object is represented by a tree structure, where leaves are arbitrary "black box" primitives and nodes are arbitrary operations. Function evaluation procedures traverse the tree and evaluate the function value in any given point. This model makes it possible to represent by a single continuous function such different objects as traditional skeleton-based implicit surfaces, convolution surfaces, constructive solids (using so-called R-functions in the nodes of the tree), swept objects, and volumetric objects. Many operations are closed on the representation, i.e., generate an object (defined by a continuous function), which again can be a subject for further transformations. In this sense, in F-rep there is no difference between soft objects, CSG solids, and volumetric (voxel) objects, which are processed in the same manner. This allowed us to solve such long standing problems as metamorphosis between objects of different topology, sweeping by a moving solid, controlled blending for all types of set-theoretic operations, collision detection and hypertexturing for arbitrary solids, direct modeling of space-time and multidimensional objects, etc.

The R&D group has been working for more than 15 years and includes researchers and students from several countries. The results are presented in more than 50 academic publications and at the dedicated Web site [FrepW].

HyperFun language [HF99, HFW] was introduced for teaching and practical use of FRep modeling. It is a minimalist programming language supporting all notions of FRep. Application software deals with HyperFun models through the built-in language interpreter or using HyperFun-to-C/C++/Java compiler and utilities of the HyperFun API. Software tools are being developed in an open source project manner by the international team of developers. Some of them are currently available for free download at the Web site [HFW]: HyperFun Polygonizer for the surface mesh generation with VRML output and HyperFun plug-in to POVRay, which makes it possible to generate high quality photorealistic images on an ordinary PC. Other experimental tools include: interactive modelers of convolution surfaces [GP] and 4D volume splines [SPS], graphical user interface for FRep constructive tree [HP], and interactive fly through and carving of volumetric objects [KAP]. Further development includes creation of virtual reality and haptic interfaces, special hardware design for visualization of hybrid F-rep/voxel models, research on genetic, physics based and finite-element methods for advanced CAD applications.

F-rep naturally supports 4D (space-time) and multidimensional modeling using functions of several variables. We investigate approaches and tools for further utilizing of multidimensional models. The main idea is to provide a mapping of such object to a multimedia space with such coordinates as 2D/3D world space coordinates, time, color, textures and other photometric coordinates, sounds, and others. Using this approach we have produced an animation "Homotopic Fun in 5D Space" [FPA] generated using HyperFun tools and ray-tracing. More

deep connections between multimedia space, geometric multidimensional spaces, and virtual reality should be investigated in the context of computer animation and computer art applications [PSS01].

HyperFun was designed to serve as a lightweight protocol for exchanging FRep models between people, software systems, and networked computers. Average size of HyperFun files is 3-5K. This allows for efficient implementation of a client-server modeling system where a client can run a simple interface tasks and generate a HyperFun protocol to be sent to the server. The server site can be a powerful parallel computer or a computer cluster to perform time-consuming tasks such as ray-tracing, polygonization, voxelization and others. Empirical Worlds modeler described in [HF99] is the first step towards Interned-based FRep modeling.

Open source of HyperFun tools will be distributed under the GGPL license [GGPL]. The distribution under this agreement requires that this powerful technology is not used to create weapons of mass destruction, violate human rights or continue the degradation of the environment of the Earth.

References

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