Volumetric and Multidimensional Modeling using HyperFun

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www.hyperfun.org

GraphiCon'2000

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Moscow, Russia, http://www.graphicon.ru/

Content

- HyperFun team
- F-rep: surfaces, solids, volumes, ND
- Project motivation
- HyperFun language and interpreter
- HyperFun tools
- Applications

HyperFun Team

- **Japan**
  - *Hosei University*: Pasko, Savchenko
  - *Aizu University*: Goto, Hibi, Vilbrandt
  - *Credit Swiss*: Fausett
- **Russia**
  - *MEPI*: Adzhiev, Ossipov, Kartasheva
  - *MIPT*: Kazakov
- **France**
  - *LABRI*: Schmitt
- **UK**
  - *University of Warwick*: Cartwright

Implicit Surfaces ≠ Blobs

A set of points with

$$i+\{/|/\},\#@\#3$$

is an implicit surface or more precisely

iso-valued surface (*isosurface*) of a function of three variables.

3D Solids

A 3D solid is defined as

$$i+\{\#|\#\},\# \geq 3$$

with the implicit surface as its boundary.

Sphere: $U^5 0\{^5 0|^5 0\}^5 @\#3$

Solid ball: $U^5 0\{^5 0|^5 0\}^5 \geq 3$

Volumes

Volume is a 3D point set with a scalar field

- Voxel model: 3D discrete grid + node value
- Functional model:

$i_4 + \{ \# | \# \}, \# \geq 3 \#$ point set

$i_5 + \{ \# | \# \}, \# \geq 3 \#$ scalar field

F-rep: multidimensional model

$$I = f(x_1, x_2, \ldots, x_q), \quad q \geq 3$$

- Function evaluation procedure processing a general tree structure
- Leaves: primitives (algebraic, skeleton-based, voxel, parametric, procedural)
- Nodes: operations (set-theoretic, blending, metamorphosis, sweeping, Cartesian product, Minkowski sum, etc.) + relations (collision, inclusion, etc.)

Closure of operations on F-rep

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Twist

Blend

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HyperFun project motivation

- Segmentation of implicit modeling
- Lack of exchange protocol
- Multidimensionality
- Cross-platform and Internet-based modeling
- Extendibility and openness
- Building applications
- Education

HyperFun language

- HyperFun is a minimalist language
- Supports all notions of F-rep
- Multiple coordinate variables support multidimensional modeling
- Functional expressions
- Built-in operators for set-theoretic operations: |, &, \, ~, @
- F-rep library of primitives and operations

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HyperFun Project

Language and Software Tools for F-rep Geometric Modeling

HyperFun is a simple geometric modeling language. It is intended for modeling geometric objects described in the form:

$$F(x1, x2, x3, ..., xn) >= 0,$$

This language is applicable to modeling algebraic and skeleton-based "implicit" surfaces, convolution surfaces, distance-based models, voxel objects, and more general F-rep objects.
The model in HyperFun is interpreted by the modeling and visualization software tools.

HyperFun language

Overview (PS+zip, PDF)

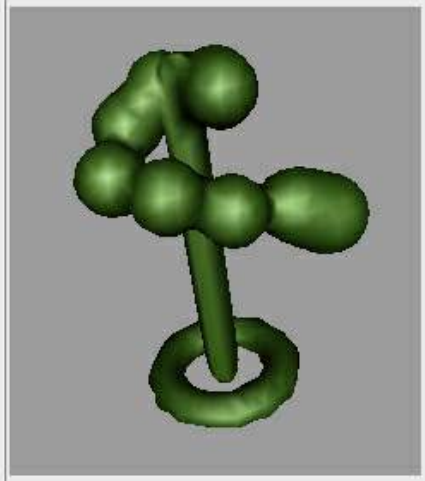
Tools

Examples

Mailing list

See F-rep Home Page

```
--This HyperFun program consists of one object:
--union of superellipsoid, torus and soft object

my_model(x[3], a[1])
{
array x0[9], y0[9], z0[9], d[9], center[3];
x1=x[1];
x2=x[2];
x3=x[3];

-- superellipsoid by formula
superEll = 1-(x1/0.8)^4-(x2/10)^4-(x3/0.8)^4;

-- torus by library function
center = [0, -9, 0];
torus = hfTorusY(x,center,3.5,1);

-- soft object
x0 = [2.,1.4, -1.4, -3, -3, 0, 2.5, 5., 6.5];
y0 = [8, 8, 8, 6.5, 5, 4.5, 3, 2, 1];
z0 = [0, -1.4,-1.4, 0, 3, 4, 2.5, 0, -1];
d = [2.5, 2.5, 2.5, 2.5, 2.5, 2.5, 2.5, 2.7, 3];
sum = 0.;
i = 1;
while (i<10) loop
        xt = x[1] - x0[i];
        yt = x[2] - y0[i];
        zt = x[3] - z0[i];
        r = sqrt(xt*xt+yt*yt+zt*zt);
        if (r <= d[i]) then
                r2 = r*r; r4 = r2*r2; r6 = r4*r2;
                d2 = d[i]^2; d4 = d2*d2; d6 = d4*d2;
                sum = sum + (1 - 22*r2/(9*d2) +
                17*r4/(9*d4) - 4*r6/(9*d6));
        endif;
        i = i+1;
endloop;
soft = sum - 0.2;

-- final model as set-theoretic union
my_model = superEll | torus | soft;
}
```



HyperFun interpreter

API is a suite of functions in ANSI C:

Parse function:

- syntax analysis
- generates internal tree structure (*byte-code*)
- outputs a list of error messages
- is invoked just once for a model.

Calc function performs function evaluation at the given point.

HyperFun Tools and Applications

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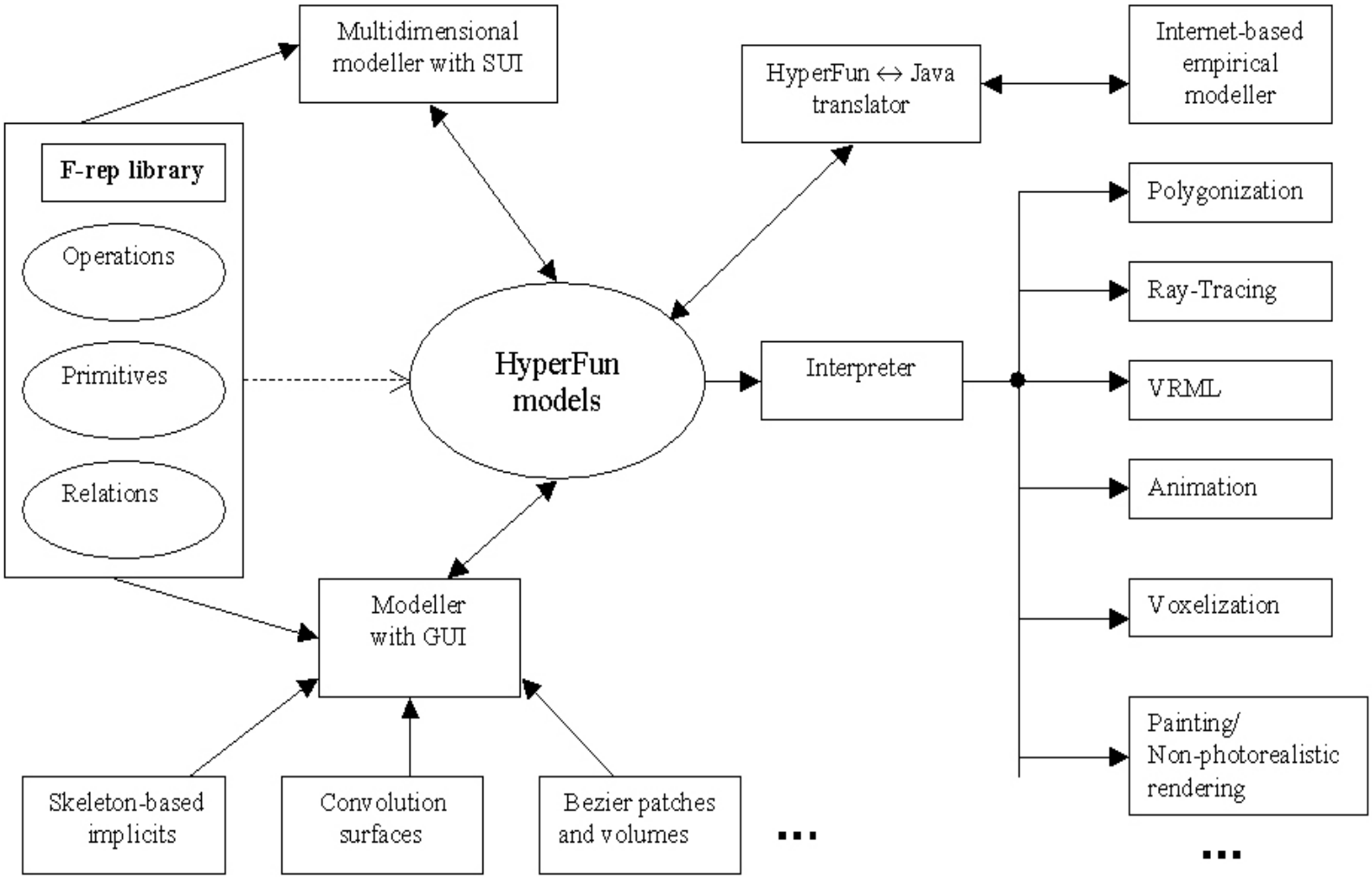
System architecture

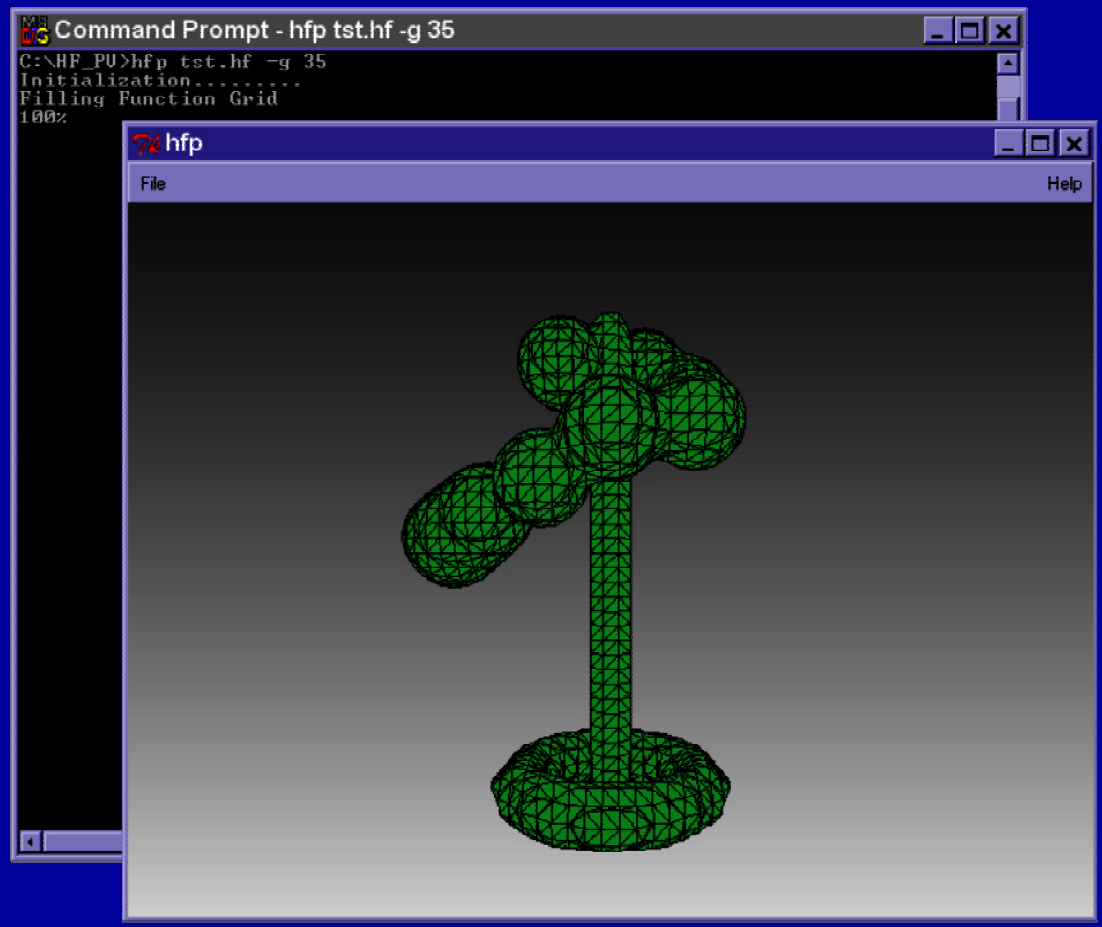


HyperFun Tools

- Available on-line:
  - HyperFun Polygonizer
  - HyperFun for POV-Ray
- Graphical User Interface:
  - Skeleton modeling (convolution surfaces)
  - Construction Tree
  - Special Interfaces (volume splines)
- HyperFun-to-Java compiler and Empirical Worlds
- GNU++ license

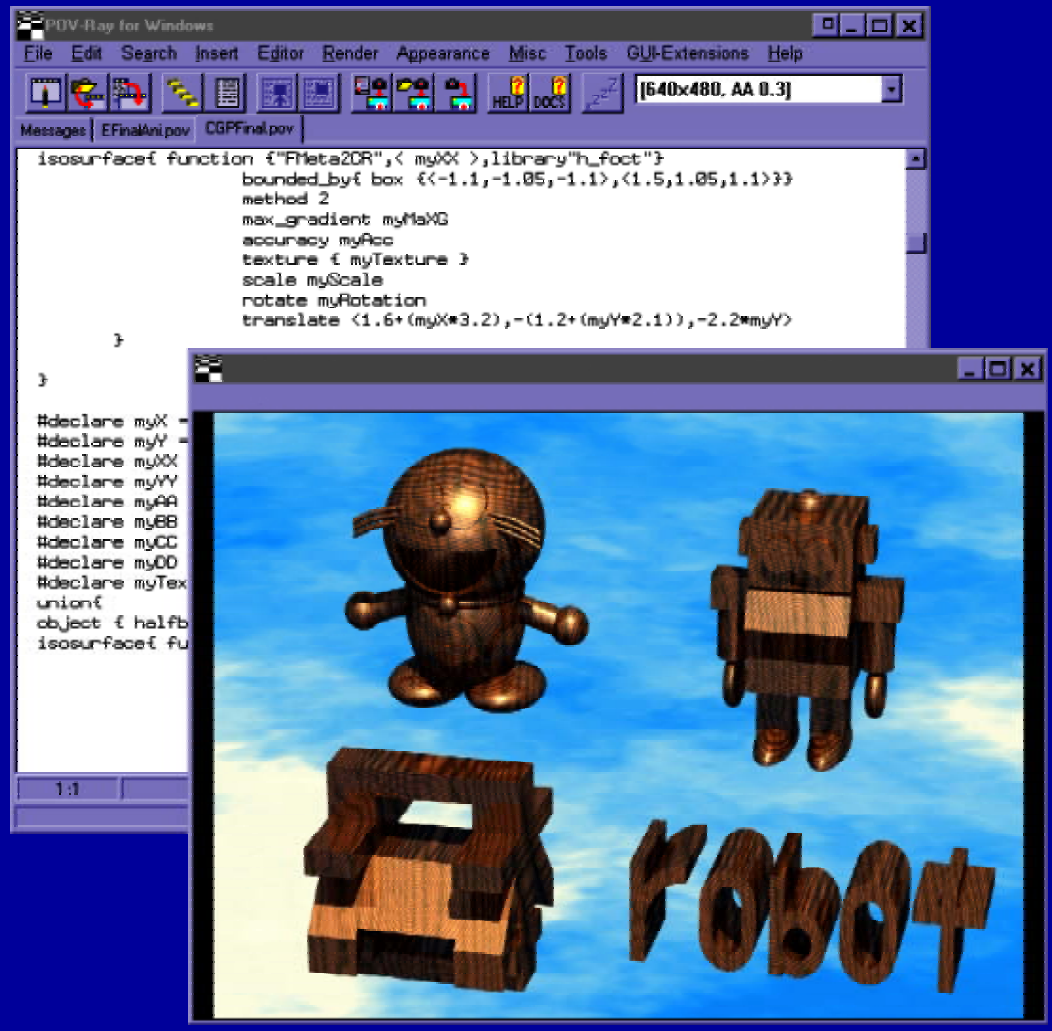
HyperFun Polygonizer

- Polygonization algorithm [Pasko et al. 1988] using hyperbolic arcs
- Command line interface
- VRML export
- MAM/VRS + Tcl/Tk
- Multi-Platform:
  - Windows
  - Unix
  - Linux



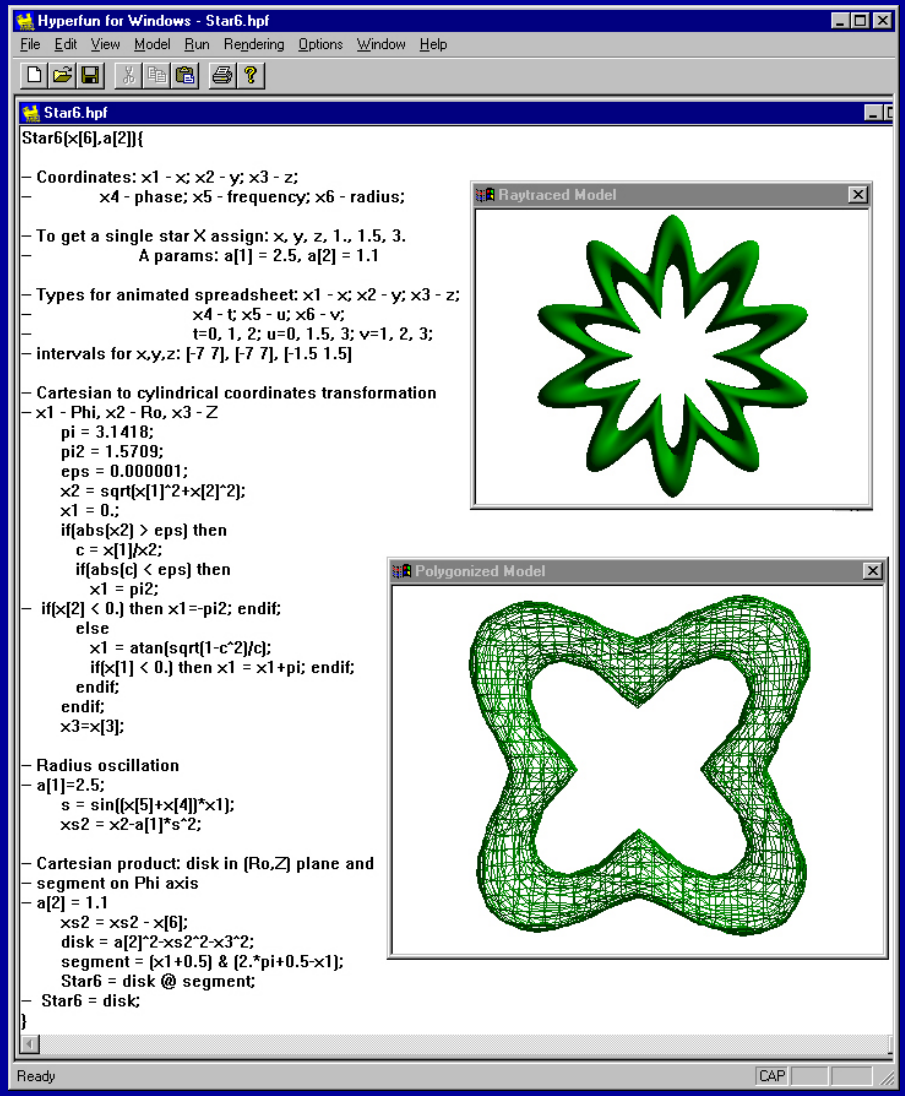
HyperFun for POVRay

- Uses Suzuki's Isosurface Patch
- HyperFun Objects manipulated as POVRay Objects
- Object Parameters and Coordinate Mappings
- Animation Capabilities
- Multi-Platform:
  - Windows
  - Unix
  - Linux



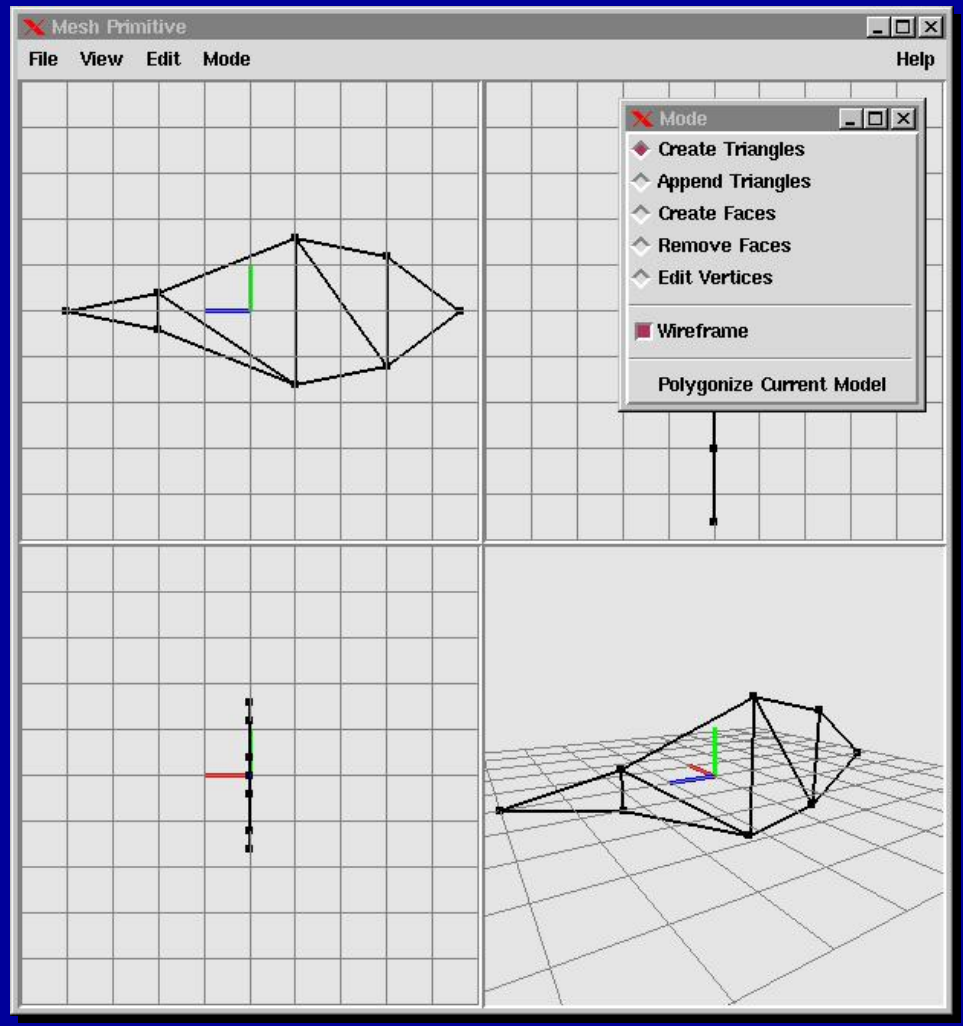
Symbolic Windows Interface

- Input-Edit-Output HyperFun models
- Scene composing
- Coordinate mapping
- Modeling and viewing parameters control
- Polygonization and ray-tracing

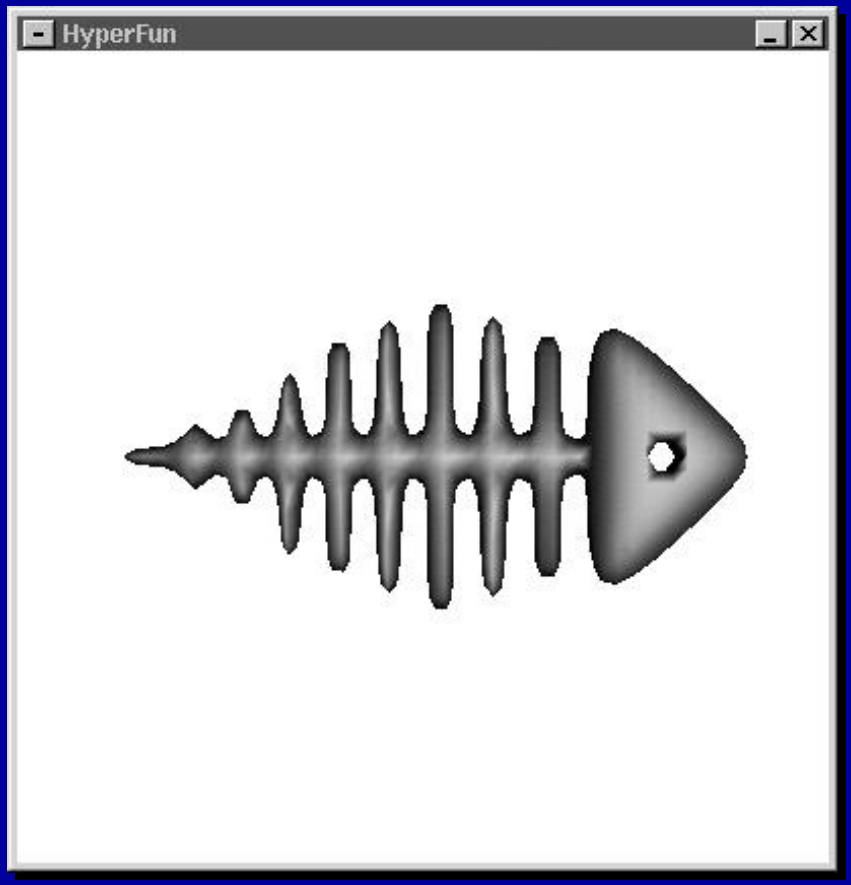


Interactive Skeleton Modeling

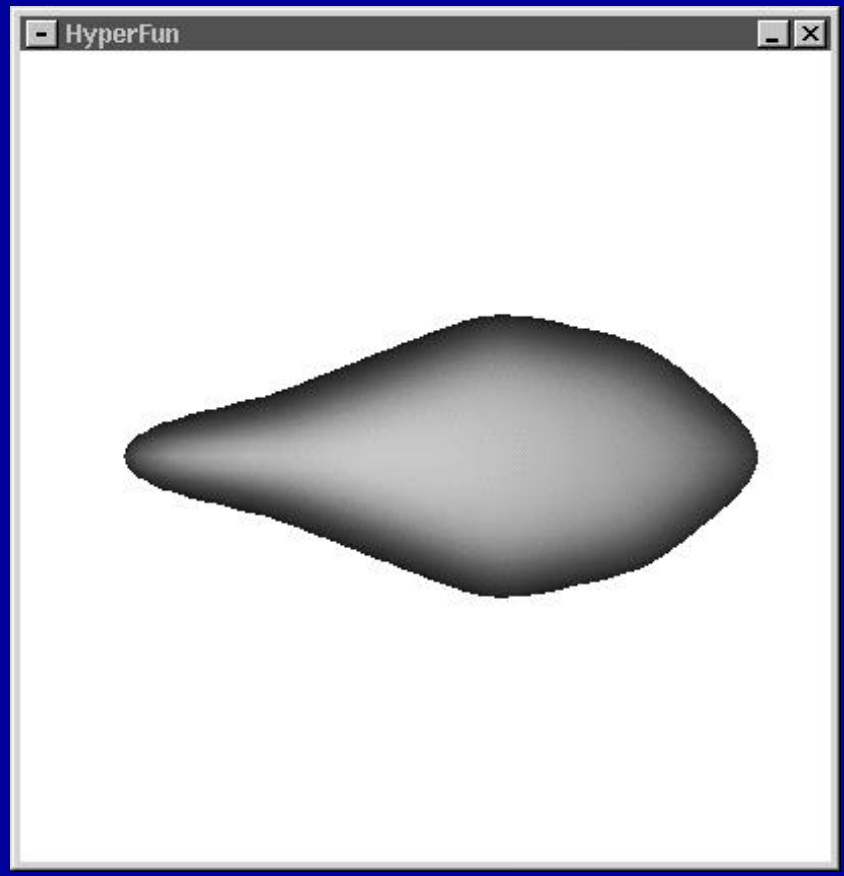
- Interactive modeling of skeletons for convolution surfaces:
  - Points
  - Lines
  - Arcs
  - Triangles
- Export to HyperFun
- Extendable GUI
- To appear in EG'2000 (short papers)



Polygonization: fish bones and body

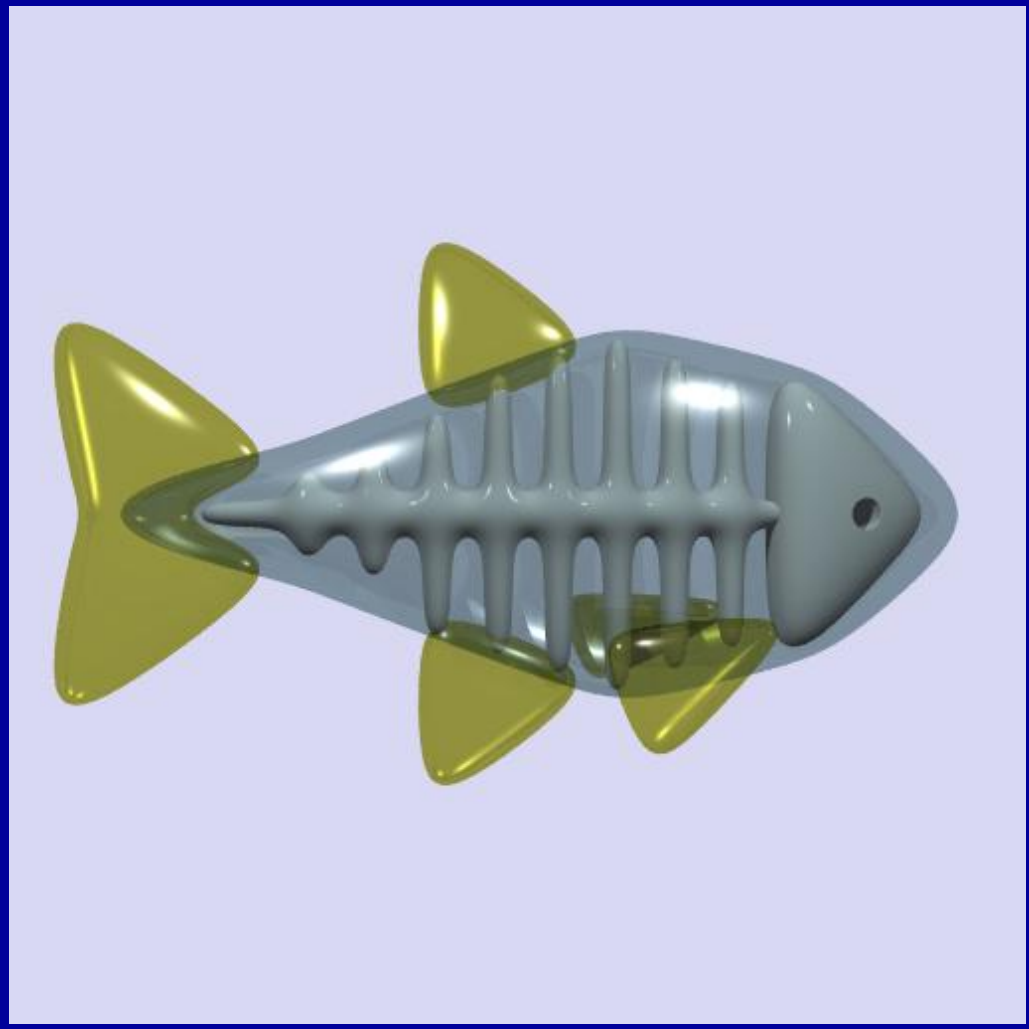


Skeleton lines



Skeleton triangles

Ray-traced convolution fish



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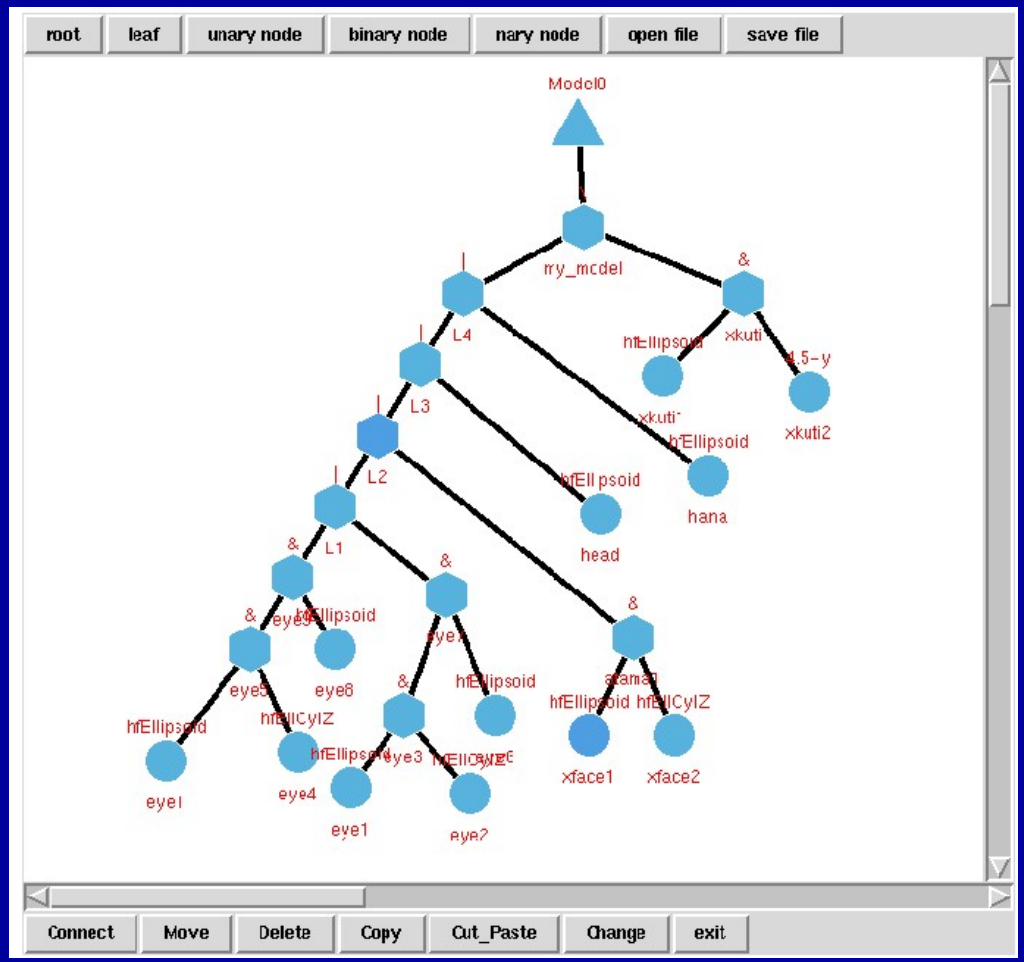
Construction Tree

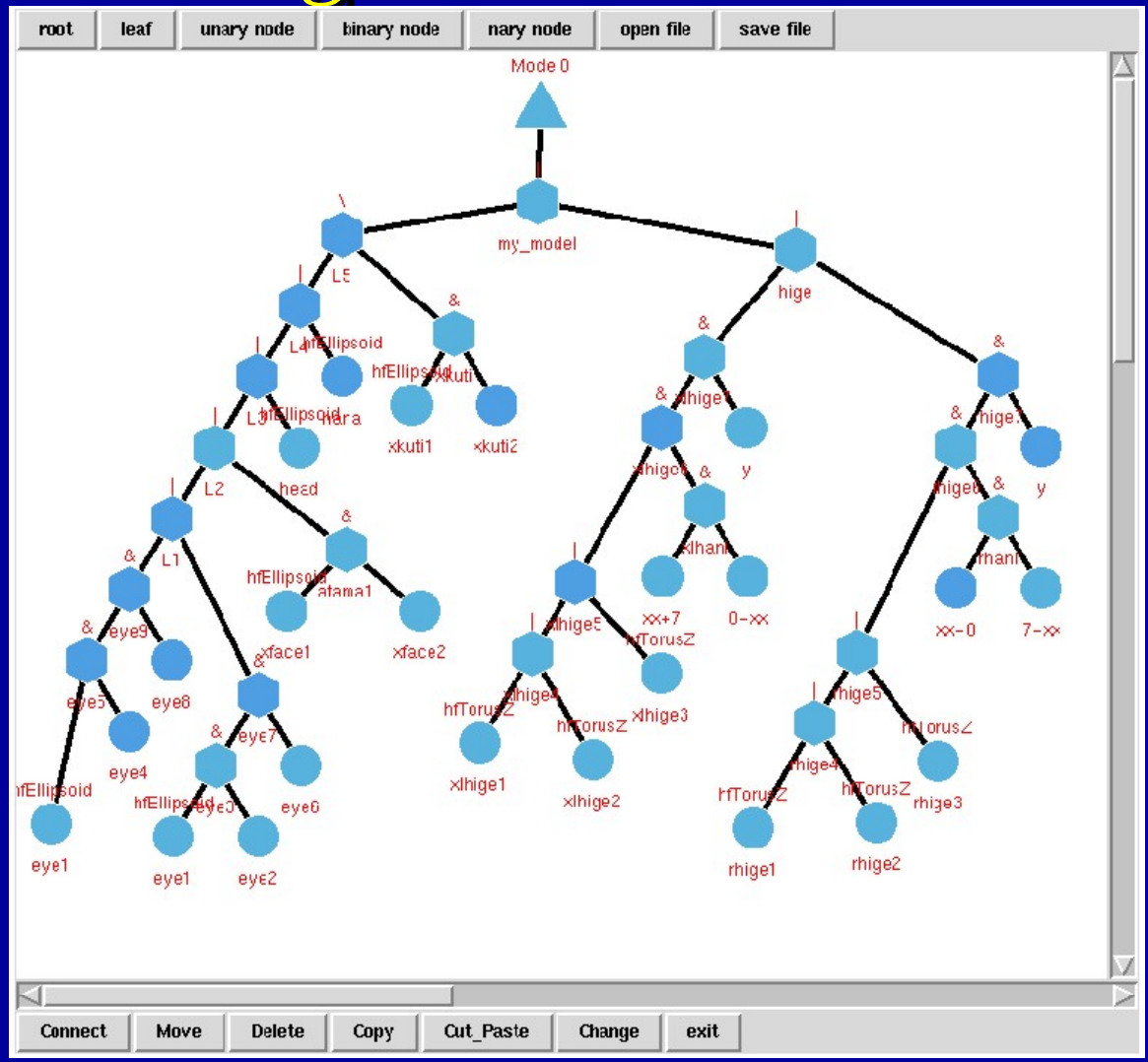
- Graphical display of the F-rep construction tree:
  - root
  - leaves (primitives)
  - nodes (unary, binary, n-ary operations)
- Direct manipulation on the tree:
  - Create/Delete nodes
  - Connect nodes
  - Edit parameters of nodes
- Import and export to HyperFun

Construction Tree Import




```
-- head final
L1 = eye9 | eye7;

L2 = L1 | atama1;

L3 = L2 | head;

L4 = L3 | hana;

my_model = L4 \ xkuti;

}
```

Editing Construction Tree



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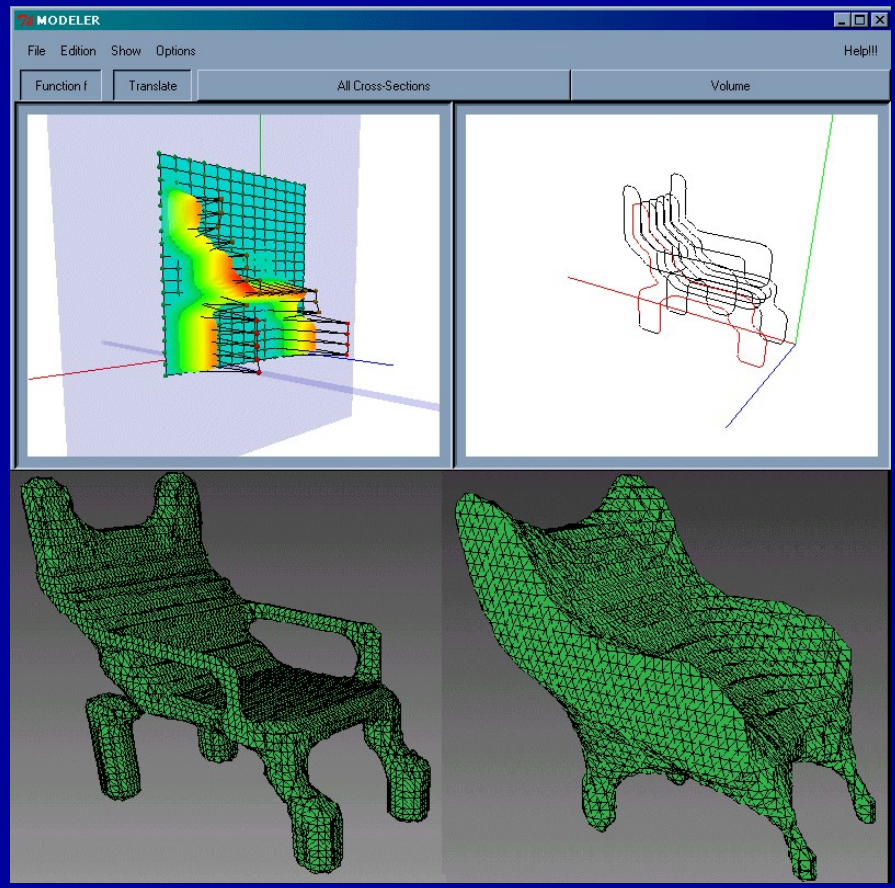
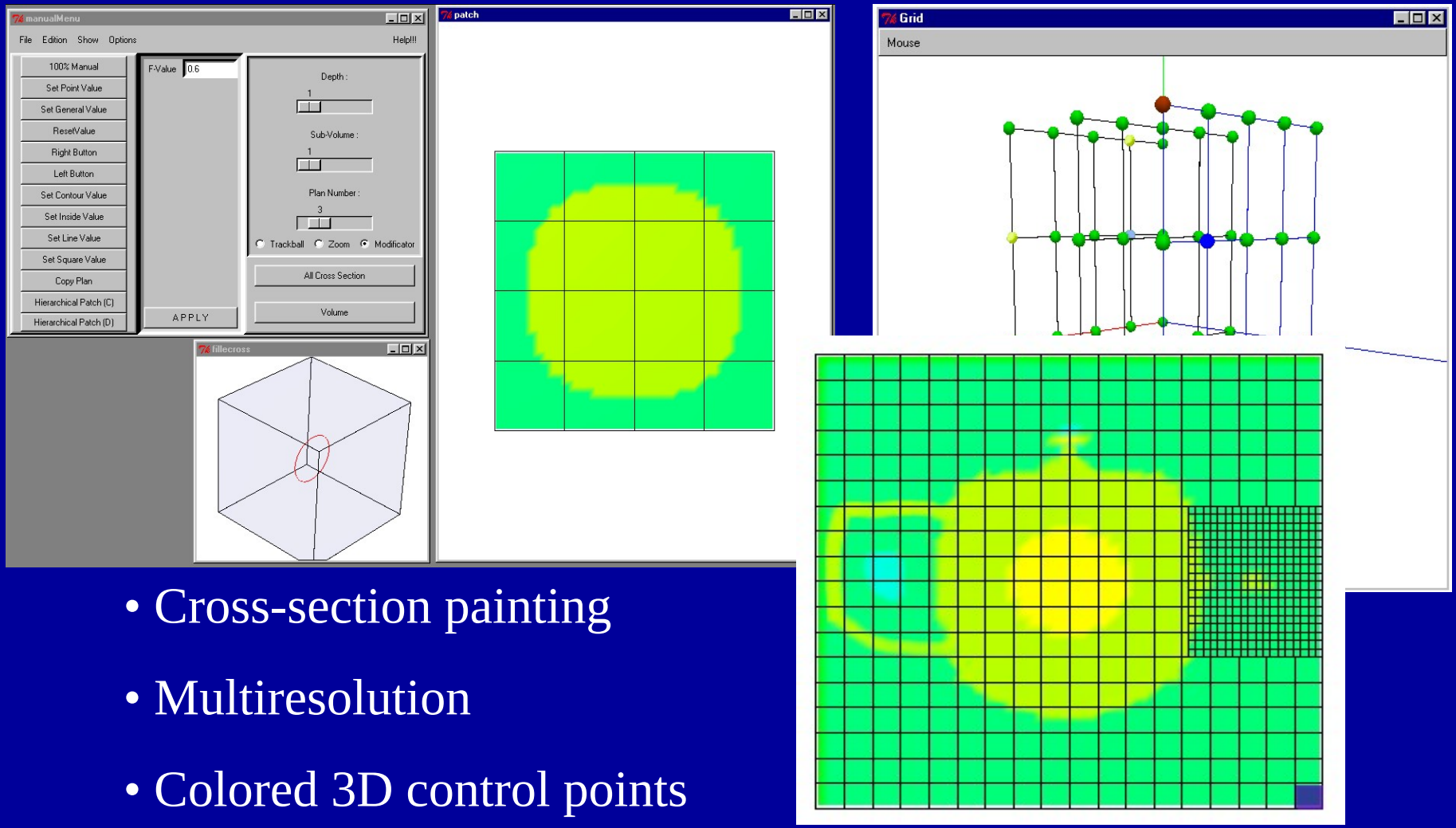
Sculpting Using 4D Volume Splines

- Interactive control of 4D Bezier or B-splines
- Multiresolution
- Export to HyperFun
- B. Schmitt (U. Bordeaux), *Implicit Surfaces '99*



Volume Spline Control Techniques



- Cross-section painting
- Multiresolution
- Colored 3D control points

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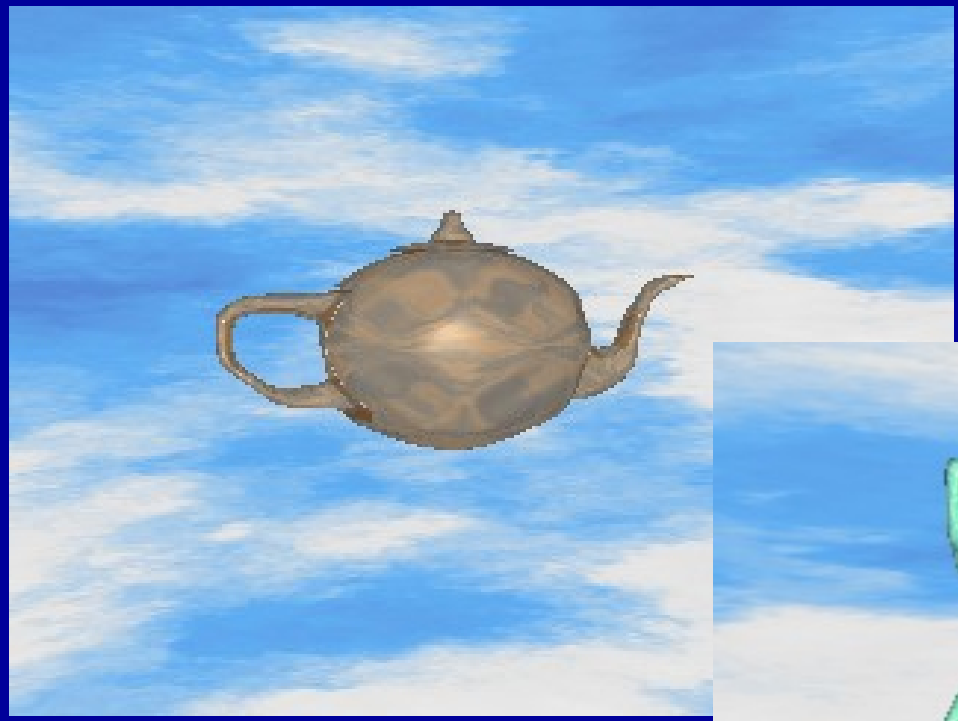
Volume spline primitives



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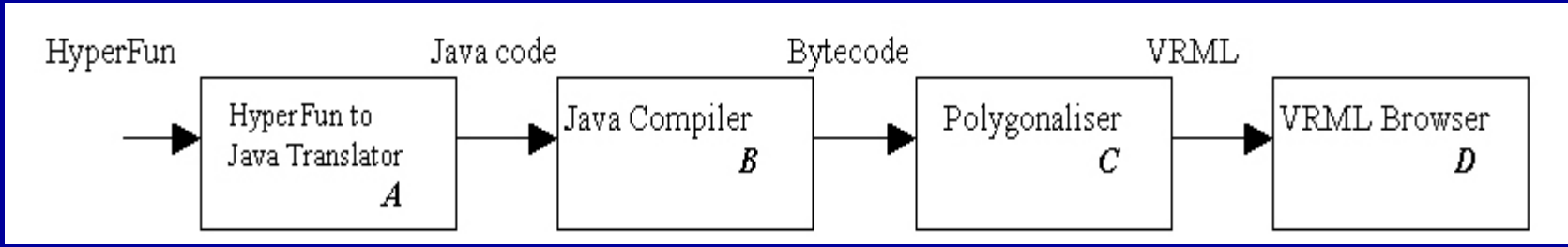
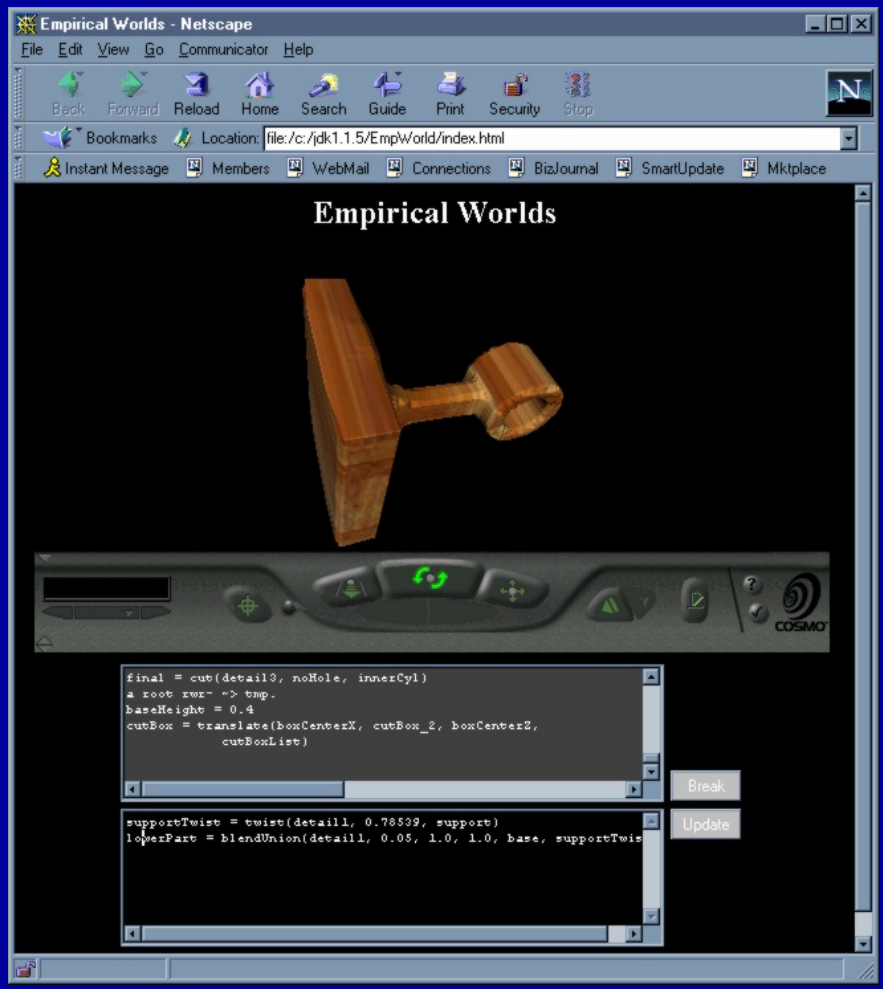
HyperFun-to-Java compiler



- HyperFun → Java code → Bytecode → Application
- Alternative approach to fast processing HyperFun shapes
- Platform independent and easy distribution
- Uses polygonizer in Java
- R. Cartwright (U. of Warwick), *Implicit Surfaces'99*

Empirical Worlds

- Spreadsheet-like environment
- Collaborative and concurrent interaction of agents
- Incremental development of shape models
- R. Cartwright (BBC Research)



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GNU++ License

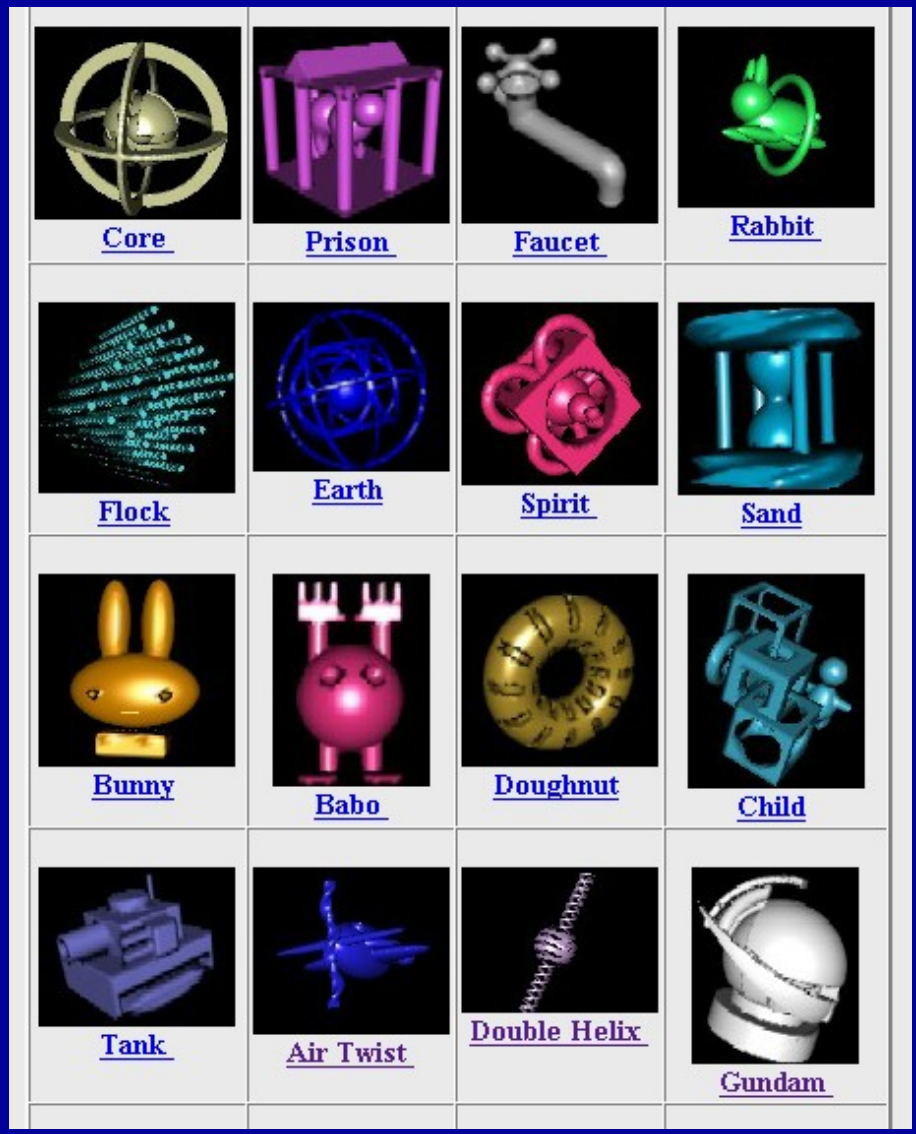
- GNU GPL + Human rights
  + Environmental rights
- Product is not during its making or application to promote the violation of Human Rights
- Product is not to be used to promote or support actions that impoverish the environment

Applications

- Research tool
- Education:

  geometry, CG, modeling, compilers
- Art and culture
- Animation
- CAD → B-rep + CSG + F-rep + Voxels

HyperFun Gallery by Students



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Virtual Lacquer Ware

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HyperFun Project

Space-Time and Higher Dimensional Modeling for Animation

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Multidimensional F-Rep

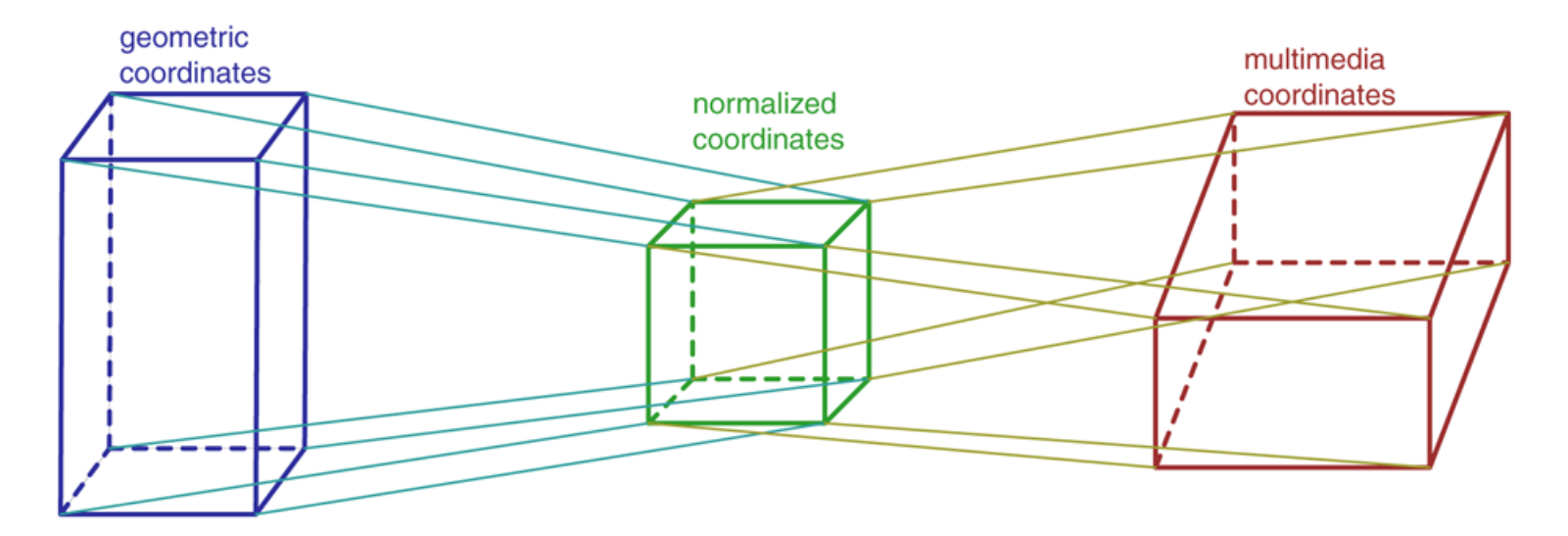
Space-Time Modeling

$F(x, y, z, t) \geq 0$

Higher Dimensional Modeling

$F(x_1, x_2, x_3, x_4, x_5, \ldots..) \geq 0$

Coordinate Mapping



- F-Rep Object is Mapped to Normalized Coordinates
- Normalized Coordinates are then Mapped to Multimedia Coordinates

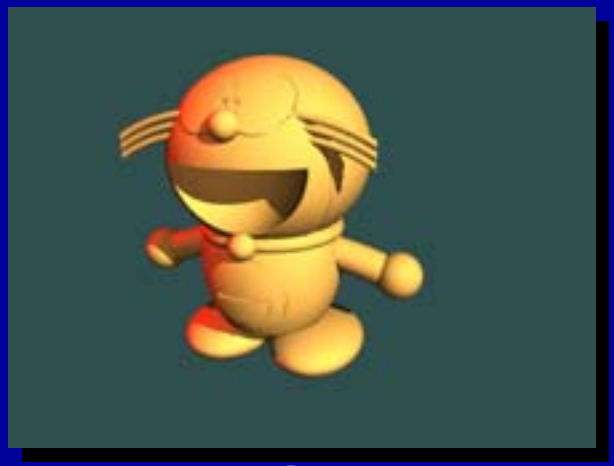
Multimedia Coordinates

- World
  - 2D (x, y) or 3D (x , y , z)
- Dynamic
  - single (t) or multiple (t_1, t_2)
- Spreadsheet
  - (u, v)
- Transformation
- Audio/Video
- Other
  - Haptic

Case: 3D Metamorphosis

- Basic Modeling
- Dimension Increase
- Mapping
- Rendering

Basic 3D Modeling



Cat

NiHon

Robot

Rob_let

Dimension Increase

Bi-linear Interpolation

$$Meta5D(x_1, x_2, x_3, x_4, x_5) =$$
$$\left(\begin{array}{l} Cat(x_1, x_2, x_3) \cdot (1 - x_4) \\ + Robot(x_1, x_2, x_3) \cdot x_4 \end{array} \right) \cdot (1 - x_5) + \left(\begin{array}{l} NiHon(x_1, x_2, x_3) \cdot (1 - x_4) \\ + Rob\_let(x_1, x_2, x_3) \cdot x_4 \end{array} \right) \cdot x_5$$

Coordinate Mapping

$x_1 \rightarrow x$ *(world x)*

$x_2 \rightarrow y$ *(world y)*

$x_3 \rightarrow z$ *(world z)*

$x_4 \rightarrow u$ *(spreadsheet u)*

$x_5 \rightarrow v$ *(spreadsheet v)*

Spreadsheet Rendering

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Coordinate Mapping

$x_1 \rightarrow x$ *(world x)*

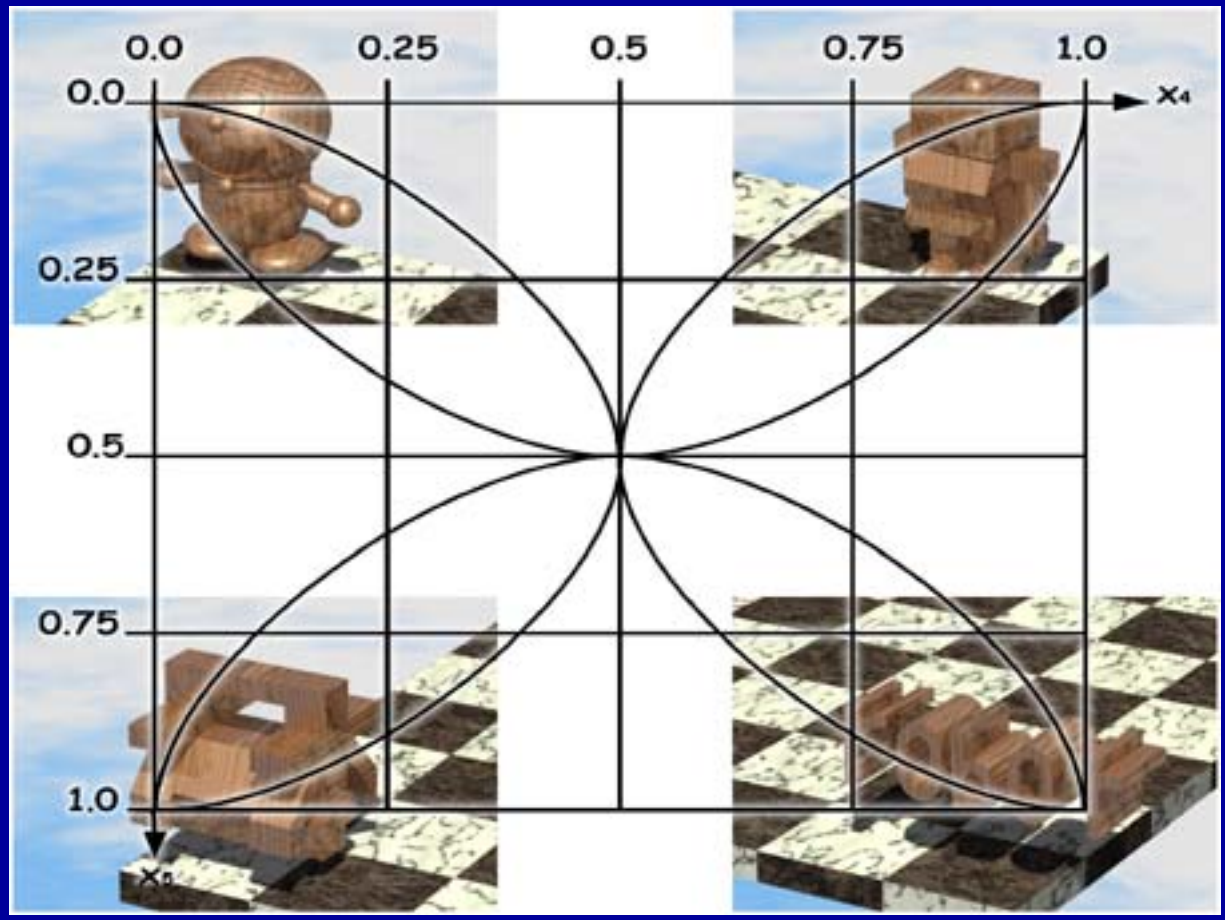
$x_2 \rightarrow y$ *(world y)*

$x_3 \rightarrow z$ *(world z)*

$x_4 \rightarrow t_1$ *(dynamic)*

$x_5 \rightarrow t_2$ *(dynamic)*

Animation Path in $t_1 t_2$ Plane



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Show animation
“Homotopic Fun in 5D Space”

The End

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