

XISL – A Development Tool for Construction of Implicit Surfaces



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Overview

- Problem outline
- XISL introduction
 - Implicit surfaces (implicits) in XISL
 - XISL language
 - Representation of implicits
- Conclusions and future work



Introduction

- Implicit surface – a set of points satisfying equation $f(\mathbf{x})=0$
- Basic modeling approaches
 - GUI modelers, programming languages and declarative text files
- Representation of complex implicit models is still a challenge



Goals

- Assist in construction of arbitrary implicit models
- Propose a declarative modeling language
 - Textual model representation
 - Clear and easily understandable
- Build a simple and intuitive API
- Provide conversion tools to various representations



Related Work

Modeling systems for implicit:

- BlobTree [Wyvill99]
 - CSG system, skeletal based surfaces, Python based scripting
- Hyperfun [Adzhiev99]
 - F-rep objects, high-level programming tool
- VTK toolkit, POV-Ray, ...



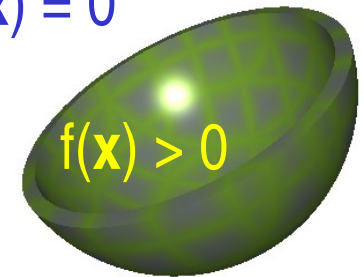
XISL Overview

- XISL - **XML** based scripting of **Implicit Surfaces**
- Components:
 - XISL language
 - Supporting software package
 - Construction of complex implicit models
 - Rendering, conversion to other representations

XISL Building Blocks

- Implicit objects: $f(\mathbf{x}) \geq 0$
 - Bounded by implicit surface
 - Analytic, geometric, convolution,...
- Operations on objects
 - Transformations, deformations, CSG, interpolations,...

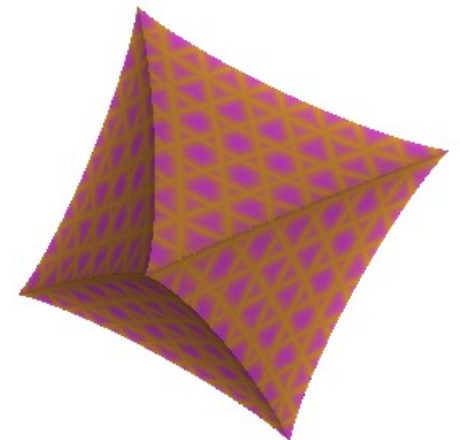
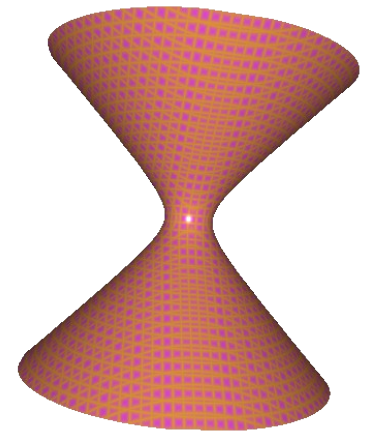
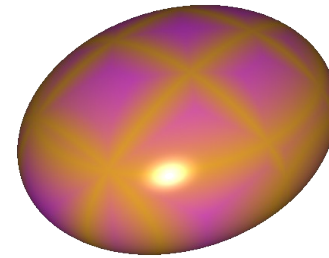
$$f(\mathbf{x}) = 0$$





Analytic Objects

- Algebraic functions
 - First and second order polynomials
 - Plane, quadrics
- Non-algebraic functions
 - Exponentiations of quadrics
 - Supershapes [Gielis03]





Geometric Objects

- Defined as a signed distance function
 - Offset surfaces
 - Distance from a skeleton
- Quadrics as distance based functions
 - Representation proposed by [Hart96]



Convolution Objects

- Convolution of a kernel function $h(r)$ and a skeleton primitive $S(p)$



$$f(\mathbf{p}) = \int_{R^3} S(\mathbf{p}) h(\|\mathbf{s} - \mathbf{p}\|) d\mathbf{s}$$

$$h(r) = \frac{1}{(1 + s^2 r^2)^2}$$

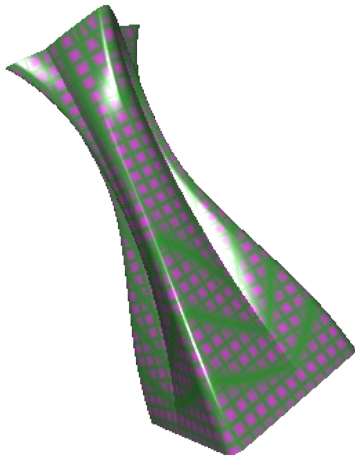
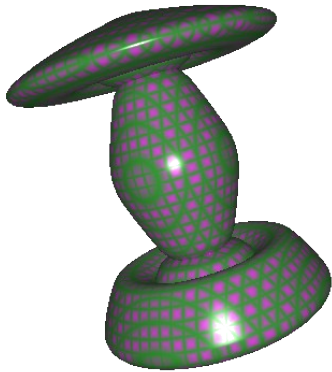
Cauchy kernel
(infinite domain)

$$h(r) = \begin{cases} \left(1 - \frac{r^2}{R^2}\right)^2 & r \leq R \\ 0 & r > R \end{cases}$$

Quartic kernel
(finite domain)



Non-categorized Objects

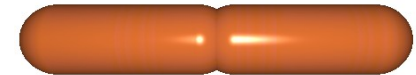
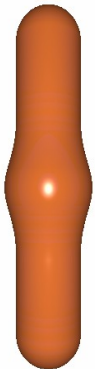


- Surface approximation and reconstruction
 - RBF approach reconstruction [Savchenko95] and [Turk and O'Brien 99]
- Implicit curved polygons [Pasko96]
 - Function takes zero value at polygon edges
 - Surface of revolution
 - Interpolation between implicit polygons



Operations on Objects

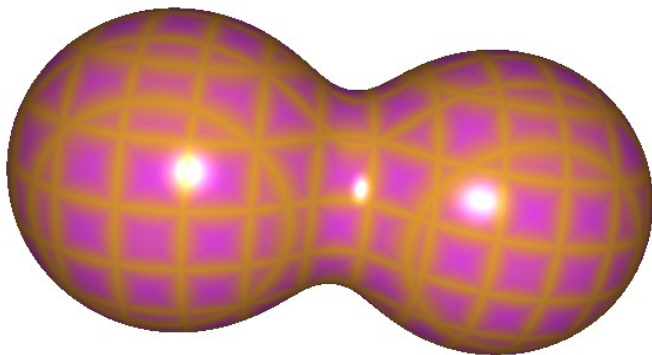
- Unary operations
 - Affine transformations, offsetting, twist,...
- Binary (n-ary) operations
 - Blending, interpolation
 - CSG operations
 - Min / Max operators: $\text{union}(f,g)=\max(f,g)$
 - R-functions: $\text{union}(f,g)=f+g+\sqrt{f^2+g^2}$
 - Blend extension of CSG operations [Pasko95,Dekkers94]



The XISL Language

Tags (1)

- Tag: a basic element
- Object tags
- Operation tags (with sub-tags)
- Special tags (object variables)

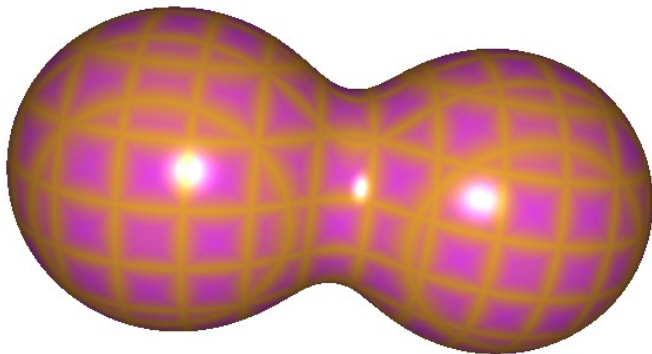


```
<defObject name="two_spheres_union">  
  <blendedUnionRf a0="0.3" a1="0.2" a2="0.2">  
    <gSphere>  
      <vec4 x1="0" x2="0" x3="0" x4="1"/>  
    </gSphere>  
    <gSphere>  
      <vec4 x1="0" x2="2" x3="0" x4="1"/>  
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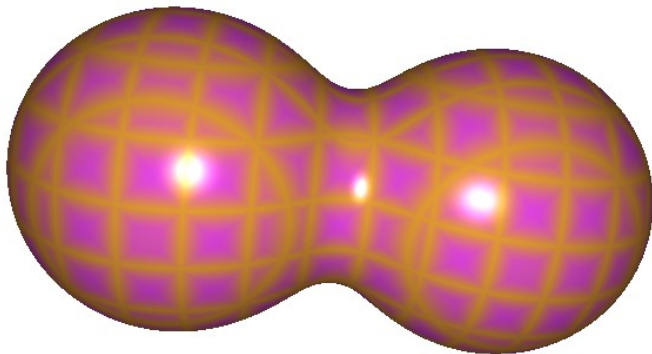


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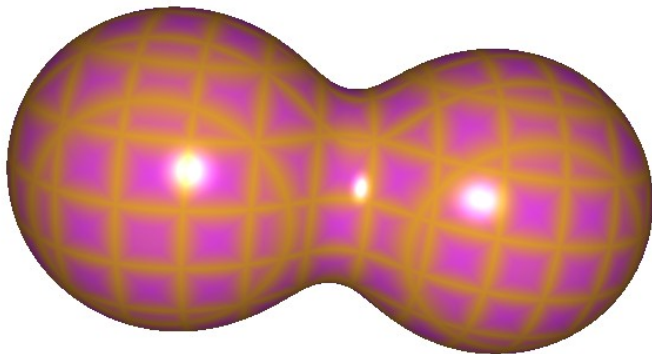


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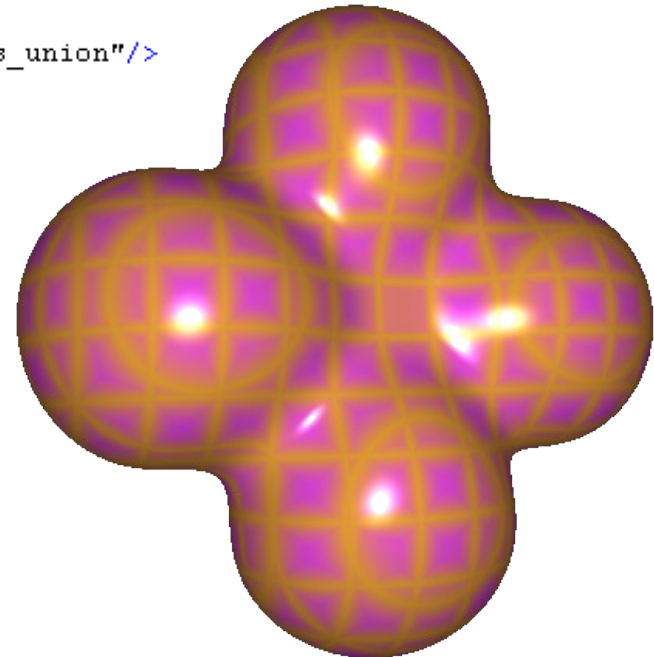


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<defObject name="two_spheres_union">  
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    </gSphere>  
  </blendedUnionRf>  
</defObject>
```


XISL language

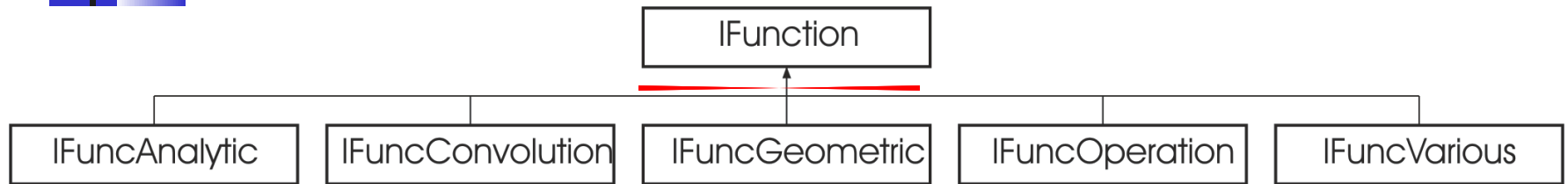
Tags (2)

```
<defObject name="complex_spheres">
  <blendedUnionRf a0="-0.5" a1="0.2" a2="0.2">
    <rotation x="90" y="0" z="0">
      <getObject name="two_spheres_union"/>
    </rotation>
    <translation x="0" y="-1" z="1">
      <rotation x="0" y="90" z="0">
        <getObject name="two_spheres_union"/>
      </rotation>
    </translation>
  </blendedUnionRf>
</defObject>
```





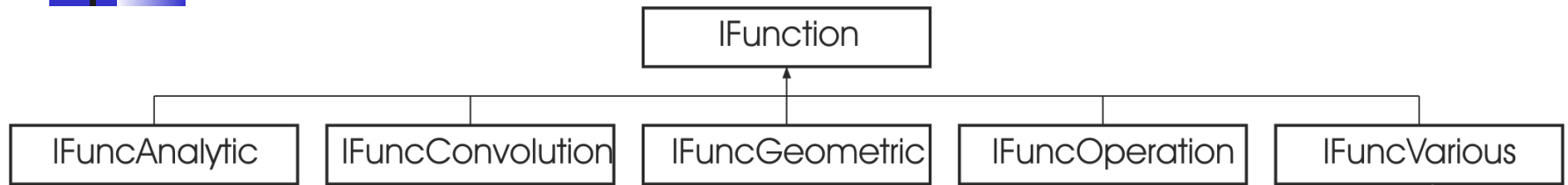
C++ Implementation



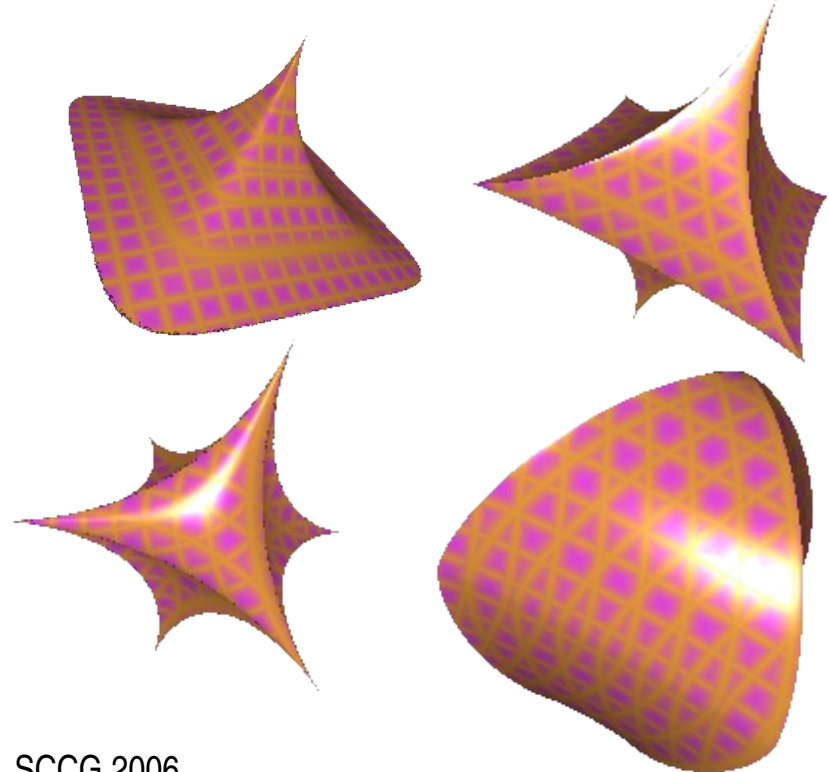
- **Class IFunction**

- Basic abstract class
- Implements common functionality
- Other implicit functions are derived from IFunction

C++ Implementation

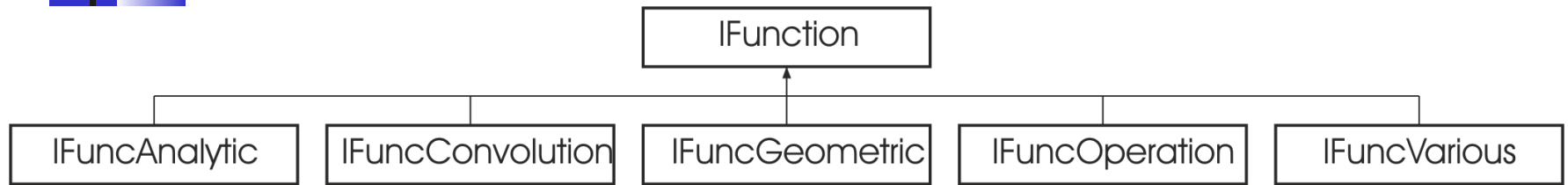


- IFuncACone,
IFuncACylinder,
IFuncAParaboloid,...
- IFuncSuperEllipsoid,
IFuncSuperToroid,...

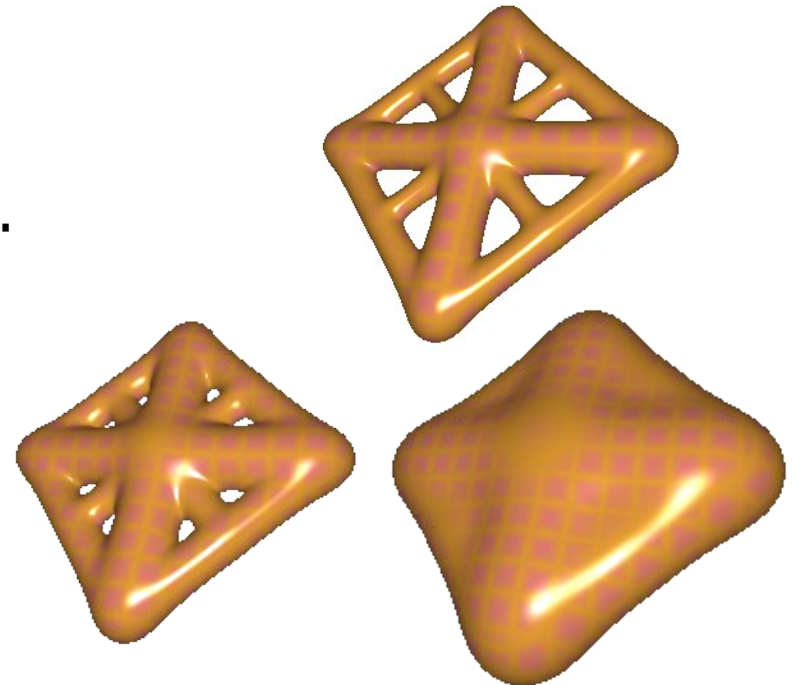




C++ Implementation

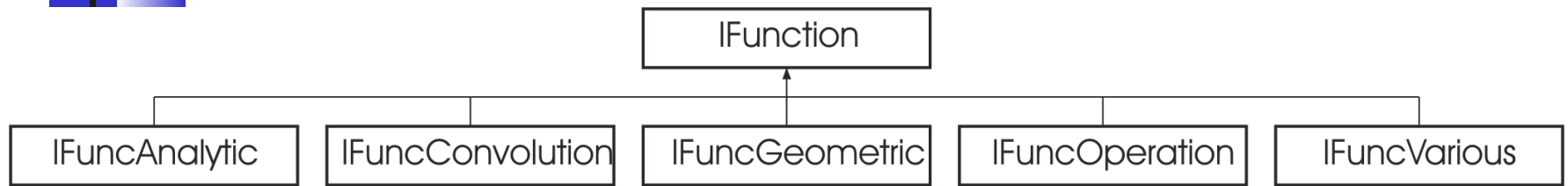


- IFuncCauchyLine,
IFuncCauchyLineWeighted,...
- IFuncQuarticPoint,
IFuncQuarticLine,...

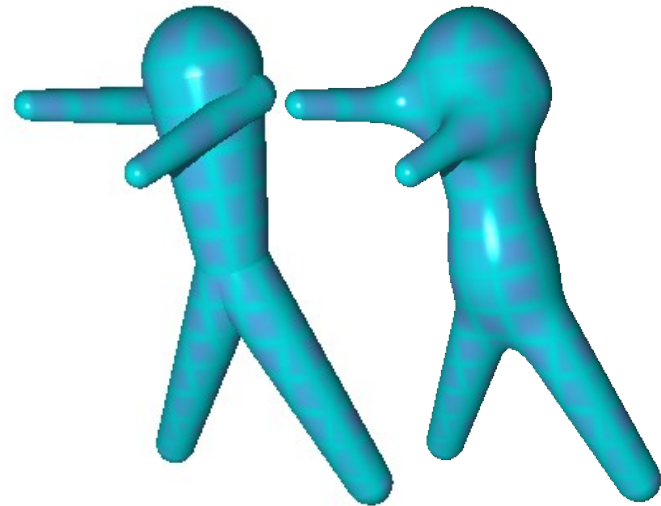




C++ Implementation

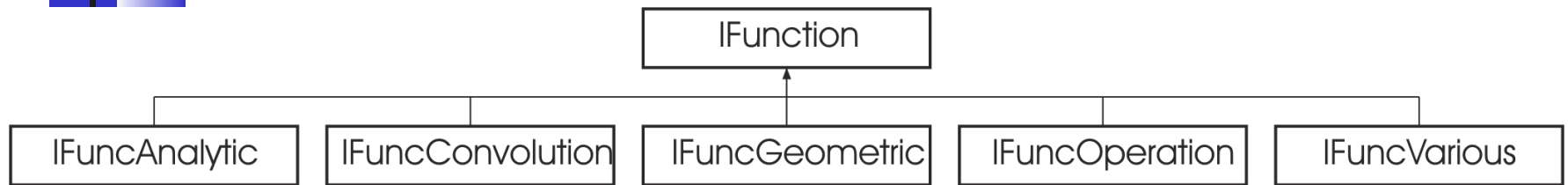


- IFuncGTube,
IFuncGSphere,...
- IFuncGCone,
IFuncGCylinder,...

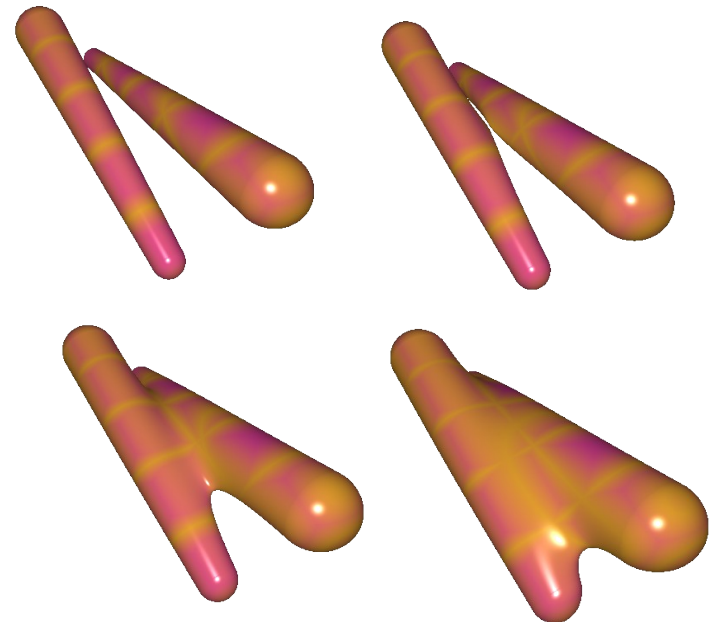




C++ Implementation

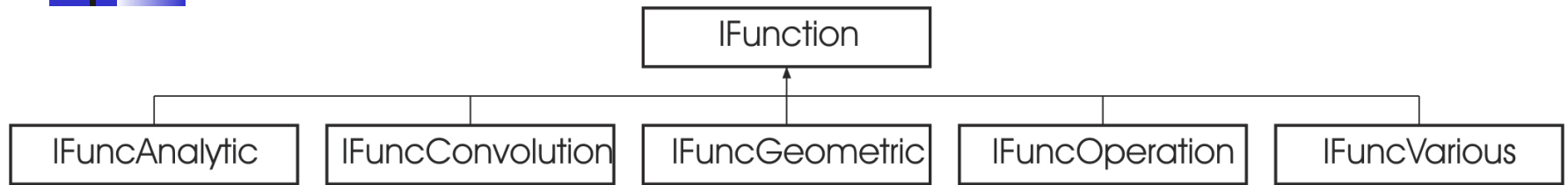


- IFuncBlendMax,...
- IFuncRfBlendUnion,...
- IFuncOffset,..
- IFuncNaryQuadraticInt,...

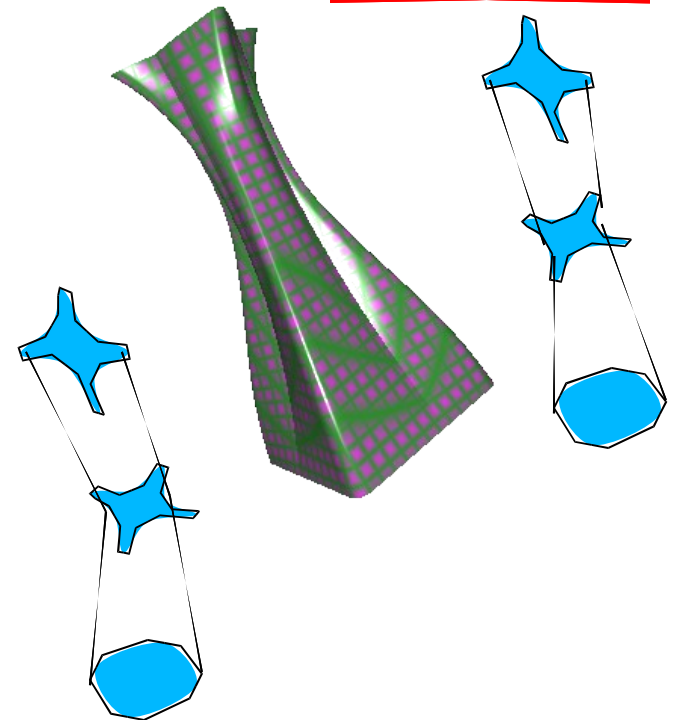
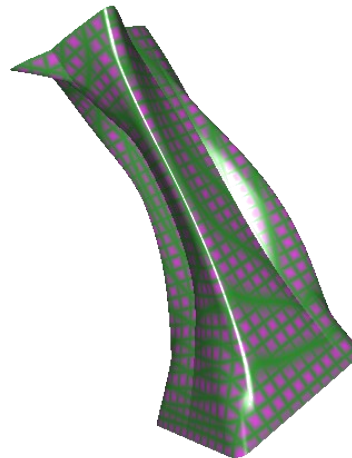




C++ Implementation

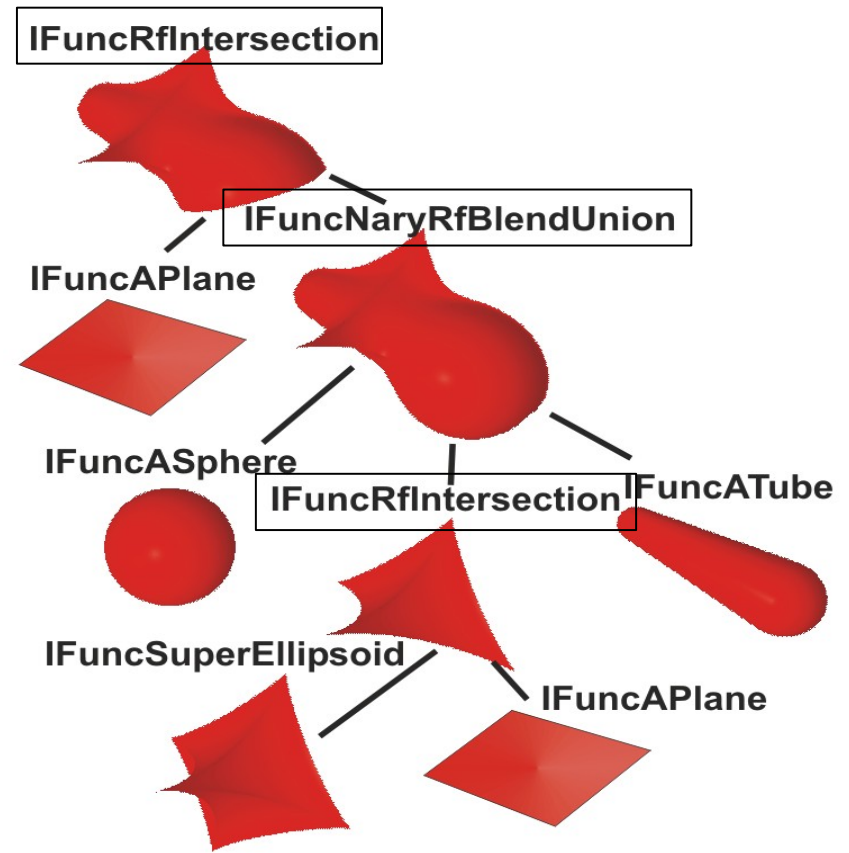


- **IFuncImplicitPolygon**,
IFuncSORImplicitPolygon,...
- IFuncVis2D,
IFuncVis3D,...



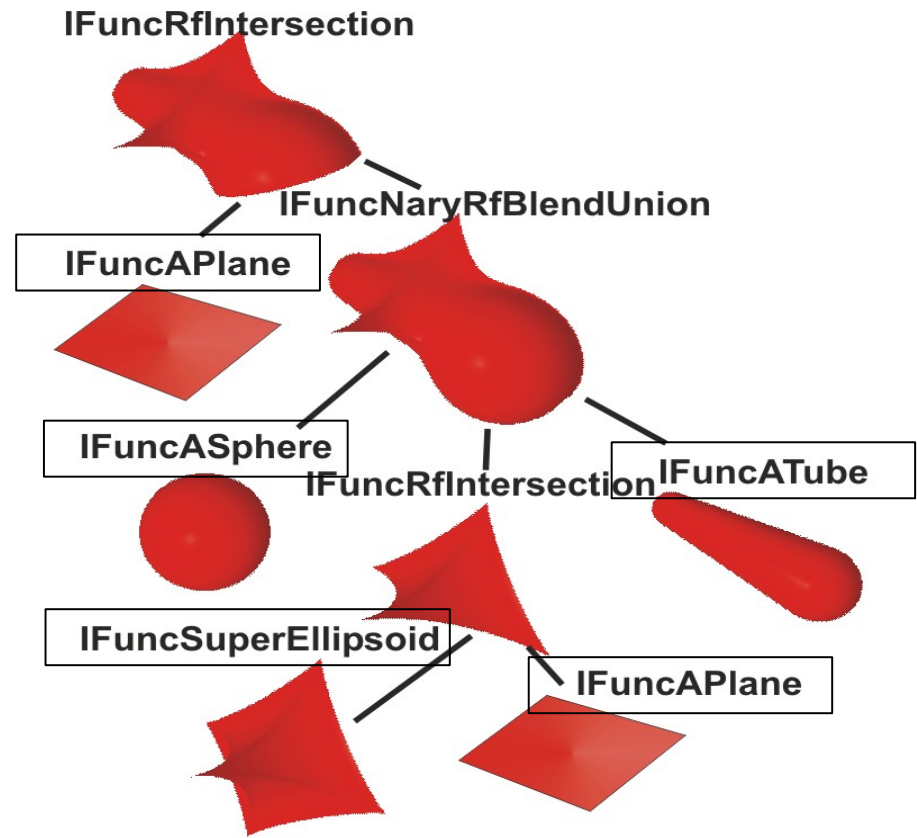
CSG Hierarchies

- Inner nodes:
operations
- Leaves:
objects



CSG Hierarchies

- Inner nodes:
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- Leaves:
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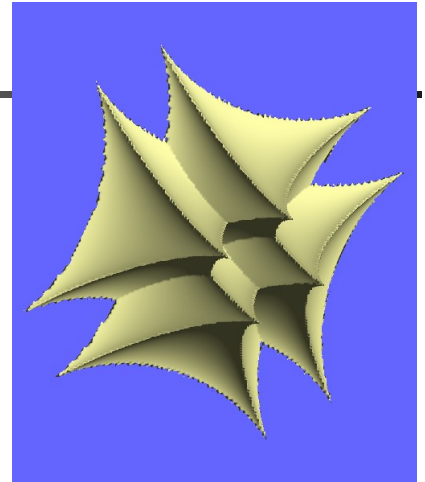


XISL Tools

- Simple C++ API
 - XISL file loading and parsing
 - Object manipulation
 - Conversion to other representations
 - Object voxelization
 - Object polygonization

Object Voxelization

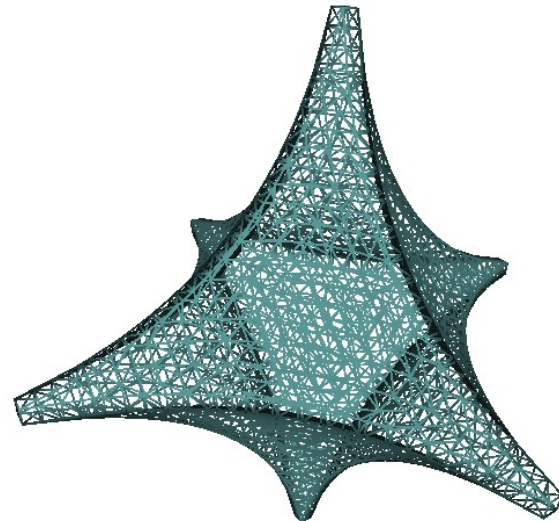
- Discrete 3D grid representation
- Voxelization methods
 - Direct voxelization
 - Representation by distance fields
 - Sharp details correction (SDC) [Novotny05]





Object Polygonization

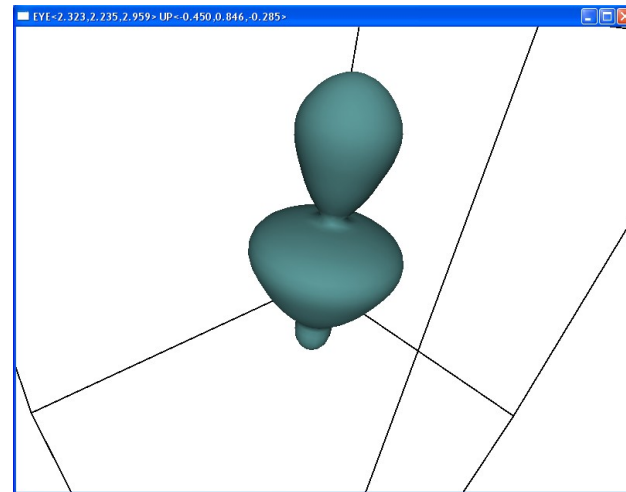
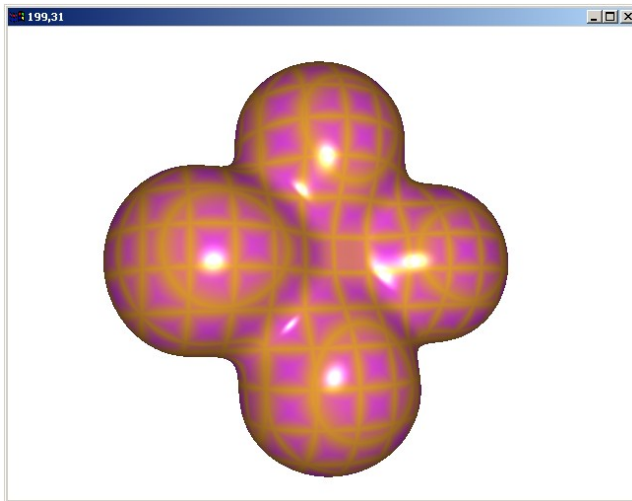
- Adaptive polygonization [Bloomenthal88]
- Marching cube based algorithm [Lorensen87]





XISL tools

- POV-Ray format (xisl plugin for version 3.1g) export
- OpenGL based viewer





Availability

- Open source software
 - Zlib licence
 - Download (Windows/Linux versions)
www.sccg.sk/~parulek/xisl
- Supported IDEs
 - CodeBlocks, MSVC, make



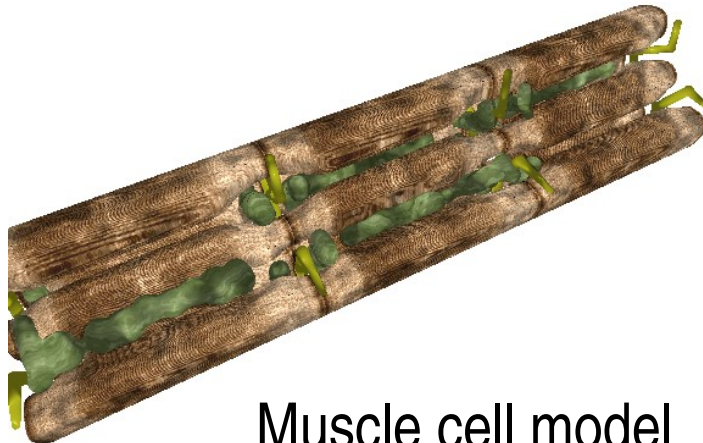
Conclusions

- XISL – a development tool for implicits
 - Language for complex implicits
 - A way to script/store objects
 - Support for most popular implicits
 - Well defined API
 - External tools

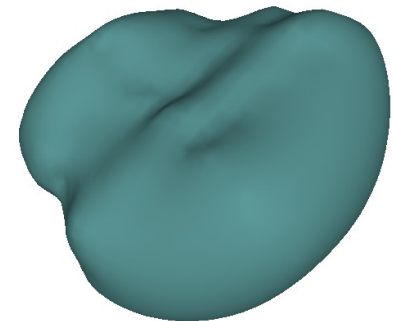


Future work

- Interactive modeler / GUI front-end
- Application to current research
 - Development of high-level XISL tags for biological models



Muscle cell model



Heart model



Thank you



```
<defObject name="pe3">
  <intersectionRf>
    <unionRf>
      <blendedUnionRf a0="0.2" a1="0.3" a2="0.3">
        <aEllipsoid>
          <vec3 x1="0" x2="0" x3="0"/>
          <vec3 x1="0.5" x2="0.2" x3="0.5"/>
        </aEllipsoid>
        <blendedDifferenceRf a0="-0.1" a1="0.3" a2="0.2">
          <aTube>
            <vec4 x1="0" x2="0" x3="0" x4="0.25"/>
            <vec4 x1="0" x2="1.3" x3="0" x4="0.20"/>
          </aTube>
          <aEllipsoid>
            <vec3 x1="0" x2="1.4" x3="0"/>
            <vec3 x1="0.3" x2="0.4" x3="0.3"/>
          </aEllipsoid>
        </blendedDifferenceRf>
      </blendedUnionRf>
      <translation x="0" y="1.25" z="0">
        <getObject name="head"/>
      </translation>
    </unionRf>
    <aPlane>
      <vec3 x1="0" x2="0" x3="0"/>
      <vec3 x1="0" x2="1" x3="0"/>
    </aPlane>
  </intersectionRf>
</defObject>
```

- www.sccg.sk/~parulek/xisl
- parulek@sccg.sk