Haptics 3D – API
Basic Force Models

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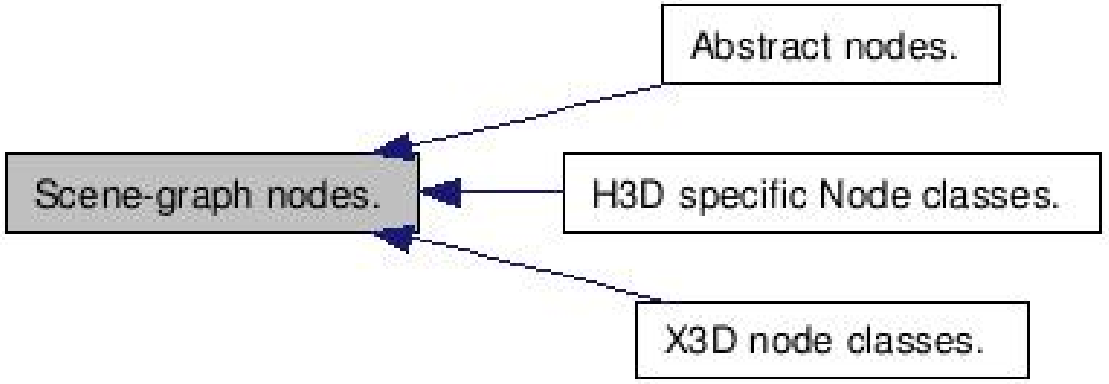
Outline

- What is H3D ?
- Python Programing Language
- Deformable Shapes in H3D
- Elastic vs Plastic Deformation
  - H3D Clay Model
- Force models:
  - H3D Spring Model

H3D

- Haptics3D API – **is OPEN source – developed by SenseGraphics**
  - is an implementation of X3D that also has an extension for haptics capabilities
  - haptics properties can be defined in the scene by adding nodes and fields to the scene graph
  - it takes care of interface to the haptics renderer and device controls
  - implements Python scripting capabilities to manipulate objects in the scene graph
  - implements the combination of graphics, audio and haptics in one unified scene graph, written in C++
  - uses OpenGL for graphics rendering and HAPI for haptics rendering



Python Programing Language (a “crash” course)

- Python:
  - an easy to learn, powerful programming language
  - efficient high-level data structures
  - simple but effective approach to object-oriented programming

- Python interpreter is easily extended with new functions and data types implemented in C or C++
- Current version V3.5

Python (1)

- An example: multiple assignments and a while loop:

```
# Fibonacci series: the sum of two elements defines the next
a, b = 0, 1
while b < 10:
    print(b)
    a, b = b, a+b
```

- An example: For loops

```
# Measure some strings:
words = ['cat', 'window', 'defenestrate']
for w in words:
    print(w, len(w))
...
cat 3
window 6
defenestrate 12
```

Python (2)

- An example: Defining functions

```
def fib2(n):      # return Fibonacci series up to n
"""Return a list containing the Fibonacci series up to n."""
    result = []
    a, b = 0, 1
    while a < n:
        result.append(a)    # see below
        a, b = b, a+b
    return result
...
f100 = fib2(100)    # call it
```

Python (3)

Example:

- using lists as Stacks (LIFO)

```
stack = [3, 4, 5]
stack.append(6)
stack.append(7)
stack
[3, 4, 5, 6, 7]
stack.pop()
7
stack
[3, 4, 5, 6]
stack.pop()
6
stack.pop()
5
stack
[3, 4]
```

Python (4)

- Modules:
  - A module is a file containing Python definitions and statements
  - The file name is the module name with the suffix .py appended
  - Within a module, the module's name (as a string) is available as the value of the global variable __name__

```
# Fibonacci numbers module (fibo.py)

def fib(n):    # write Fibonacci series up to n
    a, b = 0, 1
    while b < n:
        print(b, end=' ')
        a, b = b, a+b
    print()

def fib2(n): # return Fibonacci series up to n
    result = []
    a, b = 0, 1
    while b < n:
        result.append(b)
        a, b = b, a+b
    return result
```

```
>>> import fibo
```

```
>>> fibo.fib(1000)
1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987
```

Python (5)

- Classes:
  - Python's class mechanism adds classes with a minimum of new syntax and semantics
  - provide all the standard features of Object Oriented Programming:
    - the class inheritance mechanism allows multiple base classes,
    - a derived class can override any methods of its base class or classes,
    - a method can call the method of a base class with the same name

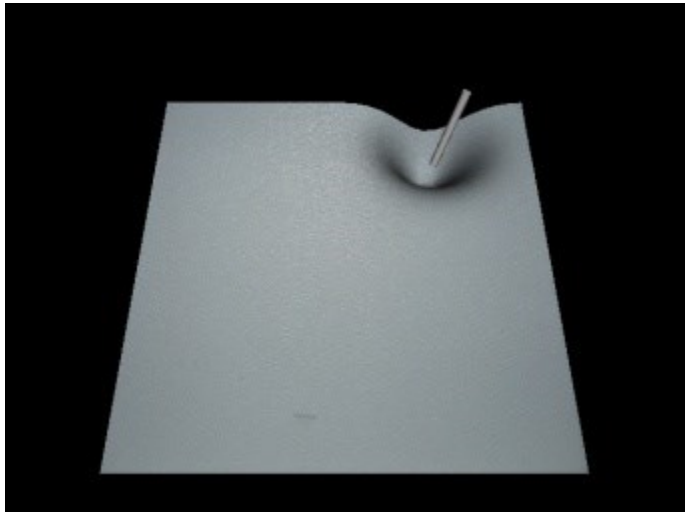
```
class Dog:

    kind = 'canine'         # class variable shared by all

    def __init__(self, name):
        self.name = name  # instance variable

>>> d = Dog('Fido')
>>> e = Dog('Buddy')
>>> d.kind                  # shared by all dogs
'canine'
>>> e.kind                  # shared by all dogs
'canine'
>>> d.name                  # unique to d
'Fido'
>>> e.name                  # unique to e
'Buddy'
```

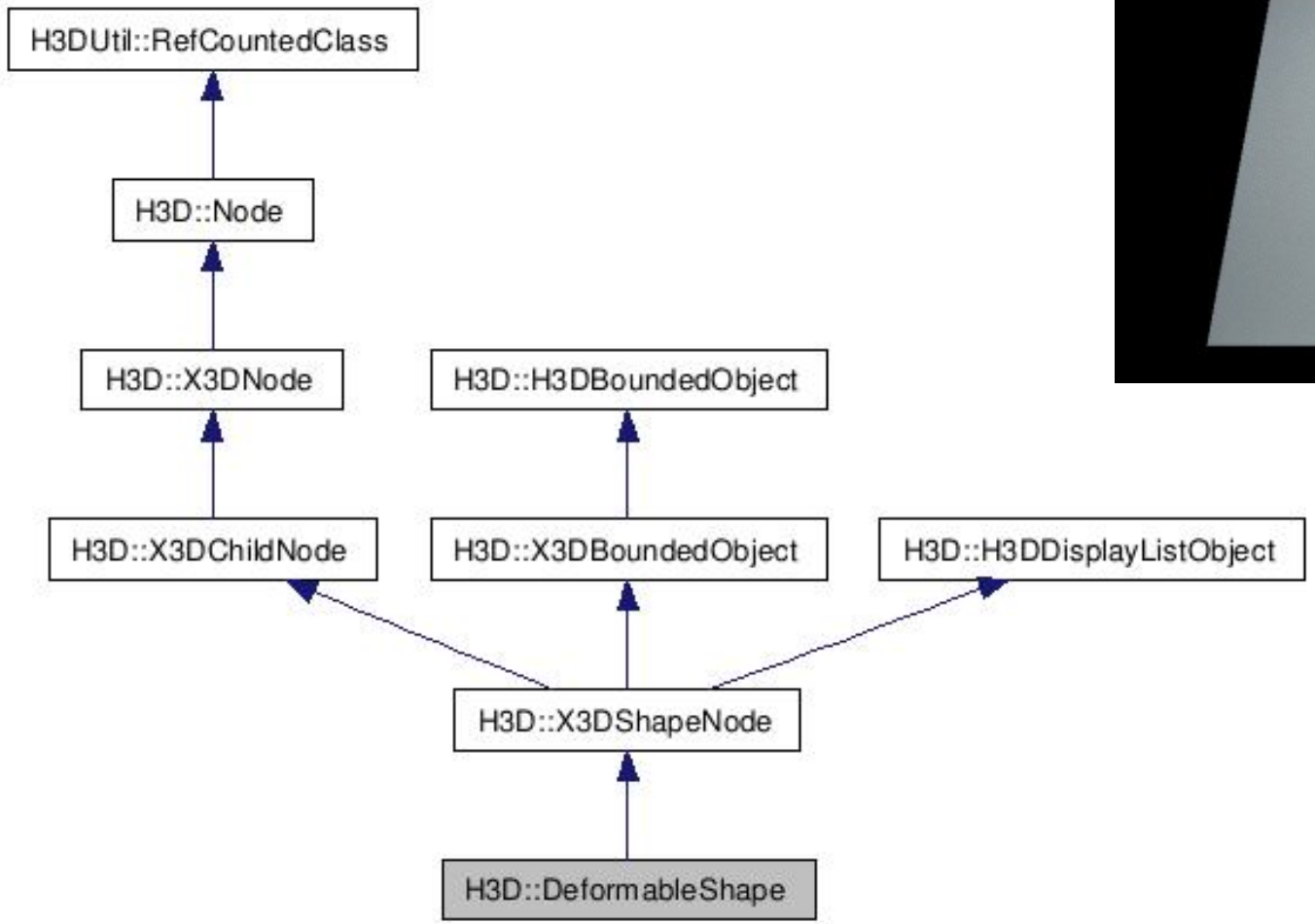
Deformable Shapes

- 3D Deformable shapes:
  - Consist of deformable polygonal meshes
  - Vertices in the mesh can change position
  - The rendering complexity of such model is significantly increased
  - Vertices motion is given by appropriate function => goal is to mimic real deformable object visual behavior

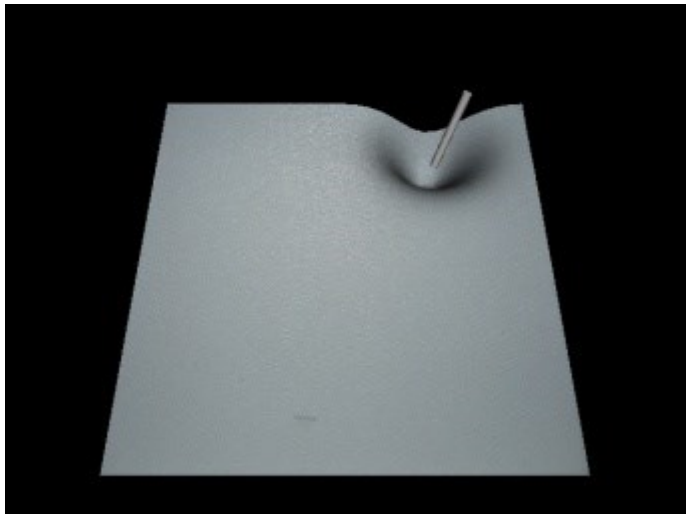
- 3D Haptic component:
  - Interaction between the haptic pointer (we assume 1 point of interaction) and the object must be monitored
  - Collision with the object's surface
  - Surface penetration distance

H3D: Deformable Shape (1)





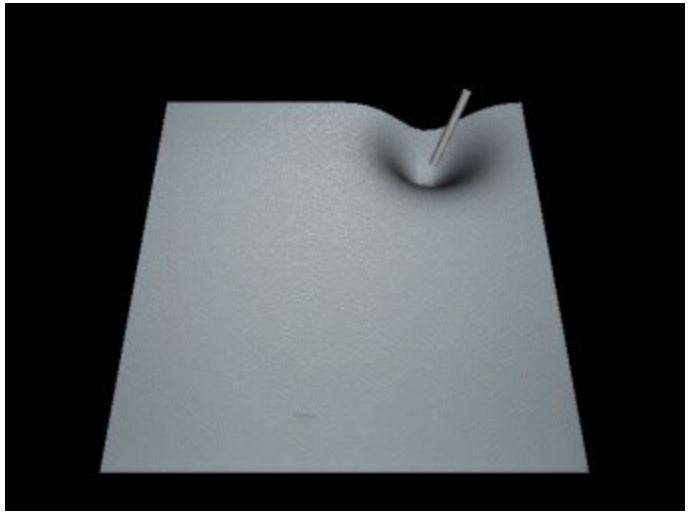
H3D: Deformable Shape (2)



```
<Group>
 <Collision enabled="false">
  <Transform rotation="1 0 0 -0.5">
   <DeformableShape DEF="DEFORM_SHAPE" >
    <CoordinateDeformer>
     <GaussianFunction width="0.05" containerField="distanceToDepth"/>
    </CoordinateDeformer>
    <Appearance DEF="LOCAL_APP" >
        <ImageTexture url="plastic_2.jpg" />
        <Material/>
        <SmoothSurface stiffness="0.1" />
    </Appearance>
    <Rectangle2D size="0.4 0.4" DEF="HAPTIC_GEOM" solid="FALSE“ containerField="hapticGeometry" />
   </DeformableShape>
  </Transform>
 </Collision>

 <PythonScript DEF="PS" url="deform.py" >
     <DeformableShape USE="DEFORM_SHAPE" containerField="references" />
 </PythonScript>
</Group>
```

H3D: Deformable Shape – Python Scripting (3)

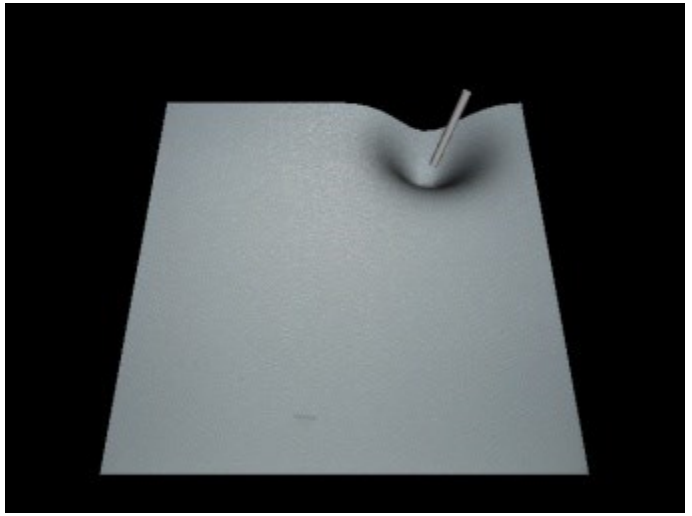
```
#deform.py
from H3DInterface import *
di = getActiveDeviceInfo()
if( di ):
        devices = di.device.getValue()
for d in devices:
        d.proxyWeighting.setValue( 0 )

columns = 31
rows = 31
size = Vec2f( 0.4, 0.4 )
coords = []
tex_coords = []
index = []

step_c = size.x / (columns-1)
step_r = size.y / (rows-1)
tc_step_c = 1.0/ (columns-1)
tc_step_r = 1.0/ (rows-1)
```



H3D: Deformable Shape – Python Scripting (4)

#deform.py

```
for c in range( columns ):
  for r in range( rows ):
    coords.append( Vec3f( step_c * c - size.x / 2, step_r * r - size.y/2, 0 ) )
    tex_coords.append( Vec2f( tc_step_c * c, tc_step_r * r ) )

for c in range( columns - 1 ):
  for r in range( rows - 1 ):
    v0 = r * columns + c
    v1 = r * columns + c+1
    v2 = (r+1) * columns + c+1
    v3 = (r+1) * columns + c
    index = index + [v0, v1, v2, v0, v2, v3 ]
```



H3D: Deformable Shape – Python Scripting (5)

```
#deform.py
deform_node, = references.getValue()

its =  createX3DNodeFromString( "<IndexedTriangleSet  solid=\"FALSE\" />" )[0]
coord = createX3DNodeFromString( "<Coordinate />" )[0]
coord.point.setValue( coords )
tex_coord = createX3DNodeFromString( "<TextureCoordinate />" )[0]
tex_coord.point.setValue( tex_coords )

its.index.setValue( index )
its.coord.setValue( coord )
its.texCoord.setValue( tex_coord )
deform_node.geometry.setValue( its )
```

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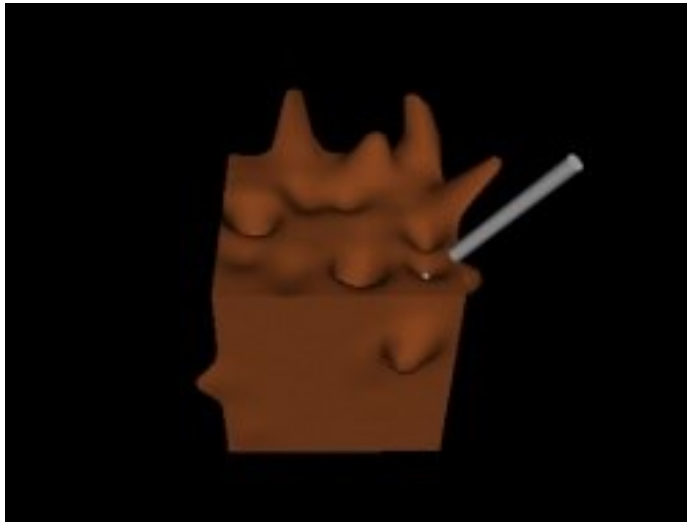
- Force models:
  - H3D Spring Model

Elastic vs Plastic Deformation

- Elastic Deformation:
  - Visual component returns to the resting position (rest state –not deformed)
  - Tactile component receives a force of opposite direction and proportional with the deformation until the object returns to the rest state.
    - Ex: Spring Model => $F=k*\Delta x$
- Plastic Deformation:
  - Visual component keeps last position (of maximum deformation)
  - Tactile component received a resistance force until maximum deformation is reached then the force is 0
    - Ex: Clay Model => $F = h*f(\Delta x)$, until max deformation is reached, then F = 0

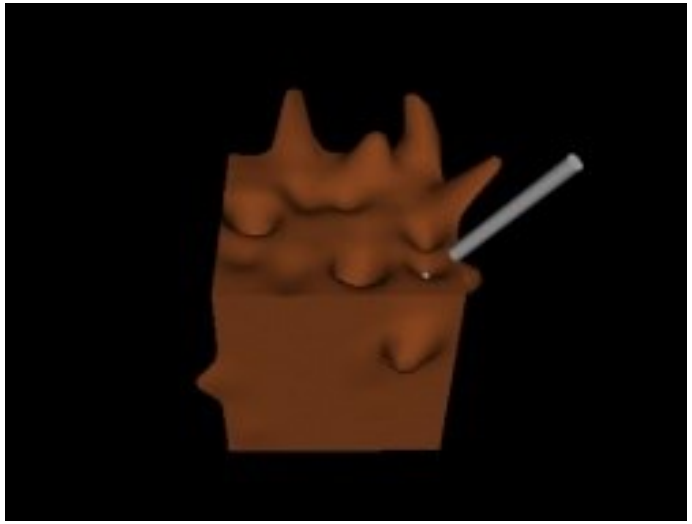
H3D: Plastic Deformation - Clay Effect (1)

- DeformableShape has three fields which describe plasticity:
  - **origCoord** which contains the coordinates of the geometry before deformation, specified by the coordinates of DeformableShape's geometry,
  - **restingCoord** which contains the final coordinates of the geometry after deformation,
  - **deformedCoord** which are the coordinates of the geometry as the deformation occurs.



H3D: Plastic Deformation - Clay Effect (2)

- A non-plastic deformation would ensure that the values of *restingCoord* are always the same as that of *origCoord*, while in a full plastic deformation, *restingCoord* is always the same as *deformedCoord*.



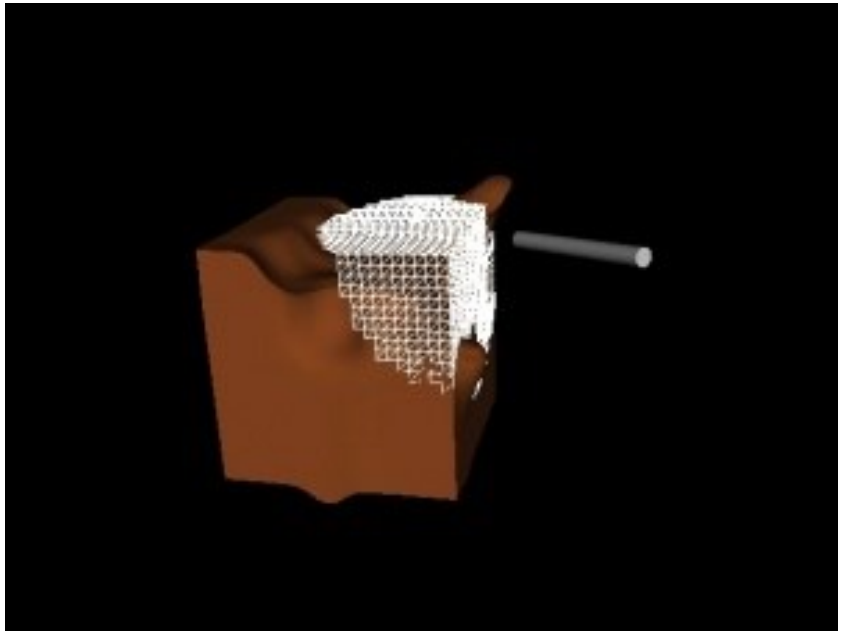
- The extent to which the *restingCoord* falls back to the *origCoord* is adjusted with *plasticity* value between 0 and 1.

H3D: Plastic Deformation - Clay Effect (3)

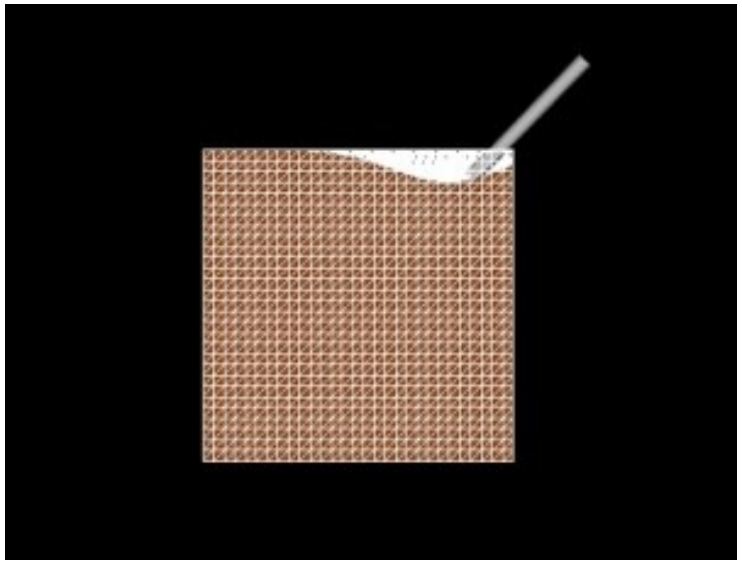
```
<Scene>
    <GlobalSettings>
            <HapticsOptions maxDistance="0.1" useBoundTree="false" />
    </GlobalSettings>
    <Collision enabled="false">
       <DeformableShape DEF="D">
            <CoordinateDeformer plasticity="0.3">
                    <GaussianFunction containerField="distanceToDepth" center="0" amplitude="1" width="0.012"/>
            </CoordinateDeformer>
            <Appearance>
                    <Material diffuseColor="0.543 0.273 0.121"/>
                    <FrictionalSurface stiffness="0.5" staticFriction="0.7" dynamicFriction="0.5" />
             </Appearance>
         </DeformableShape>
     </Collision>
     <PythonScript moduleName="CUBE" url="ITSCube.py" />
     <PythonScript url="script.py">
            <DeformableShape USE="D" containerField="references" />
      </PythonScript>
</Scene>
```

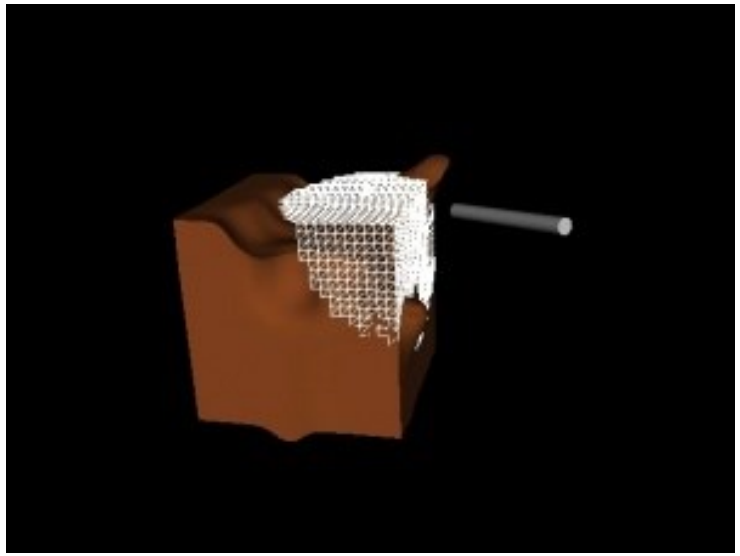
H3D: Plastic Deformation - Clay Effect (4)

```
# script.py
from H3DInterface import *
import CUBE

if getActiveDeviceInfo():
  for h in getActiveDeviceInfo().device.getValue():
    h.proxyWeighting.setValue( 0 )

d, = references.getValue()
size = Vec3f(0.15, 0.15, 0.15)

d.geometry.setValue( CUBE.createConstantITSCube(size, 25, 25) )
h = CUBE.createConstantITSCube(size, 25, 25)
d.hapticGeometry.setValue( h )
d.restingCoord.route( h.coord )
```



H3D: Plastic Deformation - Clay Effect (5)

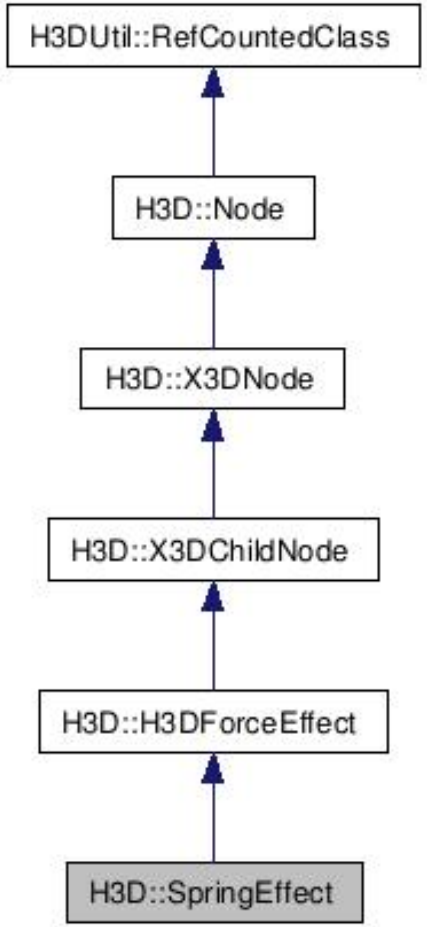




See **ITSCube.py**

H3D: Elastic Deformation - Spring Effect (1)

The spring effect models force by spring and is added to a scene with the SpringEffect node.



H3D: Elastic Deformation - Spring Effect (2)

The_Spring.x3d

```
<Group>
  <Shape>
    <Appearance>
      <Material diffuseColor="1 0 0" transparency="0.5"/>
    </Appearance>
    <Sphere DEF="SPHERE" radius = "0.01" />
  </Shape>
  <SpringEffect DEF="SPRING" escapeDistance="0.03"/>

  <PythonScript DEF="PS" url="springs.py" />
  <ROUTE fromNode="SPRING" fromField="active" toNode="PS" toField="sphereRadius"/>
  <ROUTE fromNode="SPRING" fromField="startDistance" toNode="PS" toField="sphereRadius"/>
  <ROUTE fromNode="SPRING" fromField="escapeDistance" toNode="PS" toField="sphereRadius"/>
  <ROUTE fromNode="PS" fromField="sphereRadius" toNode="SPHERE" toField="radius"/>
</Group>
```

H3D: Elastic Deformation - Spring Effect (3)

#springs.py

```
from H3DInterface import *

class SphereRadius( TypedField( SFFloat, ( SFBool, SFFloat, SFFloat )  ) ):
  def update( self, event ):
    routes_in = self.getRoutesIn()
    active = routes_in[0].getValue()
    start_dist = routes_in[1].getValue()
    escape_dist = routes_in[2].getValue()
    if( active ):
      return escape_dist
    else:
      return start_dist

sphereRadius = SphereRadius()
```

Acknowledgments

- Tommy Forsell and Daniel Evestedt

http://sensegraphics.com