There are more things in heaven and earth, Horatio, than are dreamt of in your philosophy.
William Shakespeare, Hamlet Act I Scene V
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Concepts
Prototype motivation: extensibility

The X in X3D stands for Extensible: we have engineered the X3D standard for future growth

- Supporting innovation by individual authors, rather than waiting for future versions of the specification

Other extensibility mechanisms available:

- Inline node allows one scene to pull in other scenes, but without modification or customization
- Script node allows creation of arbitrary functionality that receives (and responds to) routed events

Prototypes create new full-fledged X3D nodes

- With field definitions, render capability, etc.
Comparison with Inline node

Inline is easier to create and use

• Simply loads and inserts another X3D scene

Inline nodes are less flexible

• Cannot be customized when imported since there is no override mechanism for internal field values
• Events can be passed into, out of Inline scene at run time by using predefined IMPORT, EXPORT statements, for exposed internal nodes inside Inline

Prototypes are preferred if initialization values are needed, routing also works unambiguously
Prototype functional summary

A Prototype creates a new full-fledged X3D node
- With field definitions, render capability, etc.

X3D prototypes provide a way for X3D authors to create new node definitions
- ProtoInstance allows repeated reuse of a new node
- Fields can be exposed an parameterized, allowing customization (unlike Inline which is fixed content)

Prototypes can be used within the scene where they are defined, or used externally
- ExternProtoDeclare gives reference to declaration
Declaration versus instances

Prototype declarations can be thought of as defining a cookie-cutter for a new node

• ProtoDeclare constructs the definition
• Definition does not yet create an actual new node

Prototype instances are the actual copies of the new node which gets displayed

• Just as cookie cutter is used to create new cookies

ProtoDeclare is a template
ProtoInstance copies actually exist and render
<table>
<thead>
<tr>
<th>ProtoDeclare</th>
<th>Defines prototype</th>
</tr>
</thead>
<tbody>
<tr>
<td>• ProtoInterface</td>
<td>• Hold field definitions</td>
</tr>
<tr>
<td>• field</td>
<td>• Defines each field interface</td>
</tr>
<tr>
<td>• ProtoBody</td>
<td>• Hold nodes, scene subgraph</td>
</tr>
<tr>
<td>• Initial node</td>
<td>• First node defines type, use</td>
</tr>
<tr>
<td>• Additional nodes</td>
<td>• Initial siblings not rendered</td>
</tr>
<tr>
<td>• IS/connect links</td>
<td>• Link interfaces to internal fields</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ExternProtoDeclare</th>
<th>Retrieve external declaration</th>
</tr>
</thead>
<tbody>
<tr>
<td>• field</td>
<td>• List of fields without values</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ProtoInstance</th>
<th>Actual copy of prototype node</th>
</tr>
</thead>
<tbody>
<tr>
<td>• fieldValue</td>
<td>• Override default interface values</td>
</tr>
</tbody>
</table>
Potential power

Prototypes are a powerful technique for extending the capabilities of X3D.

Few computing languages provide authors with the capability to extend the core vocabulary of the language itself.

In one sense, an scene author defining a prototype for a new node in a scene can be thought to have similar power as the X3D specification team which defines new nodes for everyone to use in X3D.
Strong typing of nodes

Each prototype declaration must contain at least one node in the prototype body

• First node is primary, defining type for prototype
• ProtoInstances can only appear where that primary node might be allowed to appear
• If primary node contains children, together they must define a valid scene subgraph

Subsequent sibling nodes can follow first node

• But are not rendered, nor do they affect node type

Thus prototype instances remain strongly typed

• Any errors are discoverable before run time
Syntax alert: contrast .x3d .x3dv

Syntax for prototype definition and usage is significantly different when comparing the XML (.x3d) and ClassicVRML (.x3dv) encodings.

Functional correspondence remains identical:
• Declaration, field definitions, instance creation, etc.

Book compares both forms of syntax in detail.
Functional Descriptions and Examples
A prototype declaration includes two constructs: prototype interface and prototype body

```xml
<ProtoDeclare name='MyNewBlueMaterial'>
  <ProtoInterface>
    <field name='concentration' accessType='inputOutput' type='SFInt32' Value='0.75' appinfo='how blue is my new Material, range 0..1'/>
  </ProtoInterface>
  <ProtoBody>
    <!-- First node in body determines node type of prototype--> 
    <Material/>
    <!-- Subsequent nodes do not render, but must be valid X3D subgraph -->
    <Script DEF='CalculateNewBlueValueFromConcentration'/>
  </ProtoBody>
</ProtoDeclare>
```
Naming considerations 1

Good naming is important for prototypes, fields
  • Helps authors understand their intent and then utilize them correctly
  • Naming-convention guidelines found in X3D Scene Authoring Hints

Only one declaration is allowed for each individual prototype node
  • Cannot have conflicting same-name definitions from ProtoDeclare and/or ExternProtoDeclare
  • Name collisions (i.e. “overloading”) not allowed
Naming considerations

Good test of a prototype name (or field name) is to use it in a sentence, to see if it makes sense

- “a MaterialModulator node mimics a Material node and modulate fields as an animation effect”
- Awkward names are revealed by awkward sentences
- Descriptions are helpful when added as `appinfo`

Good names provide clarity when thinking about, modifying, and debugging a scene

Best name is when no one asks what it means!

- Alternatively, questions imply need to improve
Naming conventions, excerpted

CamelCaseNaming: capitalize each word, never use abbreviations, strive for clarity, be brief but complete

startsWithLowerCaseLetter when defining field names (i.e. attributes) for Prototypes, Scripts

Ensure consistent capitalization throughout

Use the underscore character ("_") to indicate subscripts on mathematical variables. Otherwise avoid use of underscores since they look like whitespace when part of a URL address

Avoid use of hyphens ("-") since these are erroneously turned into subtraction operators when converted into class or variable names
ProtoInterface and field declarations

<ProtoInterface> is section of <ProtoDeclare> that holds <field> definitions

• Which are the interface for the prototype
• Zero or more <field> definitions allowed
• <ProtoInterface> omitted if no <field> definitions

Same as <field> definitions for Script node

• Defines name, type, accessType, and initial value
• SFNode, MFNode initializations are contained elements
• initializeOnly, inputOutput fields must have initial value
• inputOnly, outputOnly fields have no initial value
<table>
<thead>
<tr>
<th>Field-Type Names</th>
<th>Description</th>
<th>Default Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>SFBool</td>
<td>Single-Field boolean value</td>
<td>false (XML syntax) or FALSE (ClassicVRML syntax)</td>
</tr>
<tr>
<td>MFBool</td>
<td>Multiple-Field boolean array</td>
<td>Empty list</td>
</tr>
<tr>
<td>SFCColor</td>
<td>Single-Field color value, RGB</td>
<td>0 0 0</td>
</tr>
<tr>
<td>MFCColor</td>
<td>Multiple-Field color array, RGB</td>
<td>Empty list</td>
</tr>
<tr>
<td>SFColorRGBA</td>
<td>Single-Field color value, red-green-blue alpha (opacity)</td>
<td>0 0 0 0</td>
</tr>
<tr>
<td>MFColorRGBA</td>
<td>Multiple-Field color array, red-green-blue alpha (opacity)</td>
<td>Empty list</td>
</tr>
<tr>
<td>SFInt32</td>
<td>Single-Field 32-bit integer value</td>
<td>0</td>
</tr>
<tr>
<td>MFIInt32</td>
<td>Multiple-Field 32-bit integer array</td>
<td>Empty list</td>
</tr>
<tr>
<td>SFFloat</td>
<td>Single-Field single-precision floating-point value</td>
<td>0.0</td>
</tr>
<tr>
<td>MFFloat</td>
<td>Multiple-Field single-precision floating-point array</td>
<td>Empty list</td>
</tr>
<tr>
<td>SFDouble</td>
<td>Single-Field double-precision floating-point value</td>
<td>0.0</td>
</tr>
<tr>
<td>MFDDouble</td>
<td>Multiple-Field double-precision array</td>
<td>Empty list</td>
</tr>
</tbody>
</table>
| SFImage          | Single-Field image value | 0 0 0 
Contains special pixel-encoding values, see Chapter 5 for details |
<table>
<thead>
<tr>
<th>Field Type</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MFImage</td>
<td>Multiple-Field image value</td>
<td>Empty list</td>
</tr>
<tr>
<td>SFNode</td>
<td>Single-Field node</td>
<td>Empty node, NULL</td>
</tr>
<tr>
<td>MFNode</td>
<td>Multiple-Field node array of peers</td>
<td>Empty list</td>
</tr>
<tr>
<td>SFRotation</td>
<td>Single-Field rotation value using 3-tuple axis, radian-angle form</td>
<td>0 0 1 0</td>
</tr>
<tr>
<td>MFRotation</td>
<td>Multiple-Field rotation array</td>
<td>Empty list</td>
</tr>
<tr>
<td>SFString</td>
<td>Single-Field string value</td>
<td>Empty string, representable as two adjacent quotation marks</td>
</tr>
<tr>
<td>MFString</td>
<td>Multiple-Field string array</td>
<td>Empty list</td>
</tr>
<tr>
<td>SFTime</td>
<td>Single-Field time value</td>
<td>-1, sentinel indicating no time value.</td>
</tr>
<tr>
<td>MFTime</td>
<td>Multiple-Field time array</td>
<td>Empty list</td>
</tr>
<tr>
<td>SFVec2f/SFVec2d</td>
<td>Single-Field 2-float/2-double vector value</td>
<td>0 0</td>
</tr>
<tr>
<td>MFVec2f/MFVec2d</td>
<td>Multiple-Field 2-float/2-double vector array</td>
<td>Empty list</td>
</tr>
<tr>
<td>SFVec3f/SFVec3d</td>
<td>Single-Field vector value of 3-float/3-double values</td>
<td>0 0 0</td>
</tr>
<tr>
<td>MFVec3f/MFVec3d</td>
<td>Multiple-Field vector array of 3-float/3-double values</td>
<td>Empty list</td>
</tr>
</tbody>
</table>
ProtoBody

First node in ProtoBody is required and critical, defining the node type

• This node is how a ProtoInstance will appear to scene graph

Additional nodes are allowed, but not rendered

• This is how prototypes provide extensibility while maintaining strong node typing
• X3D-Edit will provide warning about this, unless author inserts a comment beforehand

No object-oriented “inheritance” but...

• first node in body can be a nested ProtoInstance
Simple example: UniversalMedia excerpt 1

The Universal Media Materials archive provides a number of example materials

- Available as prototypes, or cut + paste
- Built in, selectable within X3D-Edit Material editor
- No ProtoInterface/fields needed, just ProtoBody

```xml
<ProtoDeclare name='ArtDeco00'>
    <ProtoBody>
        <Material ambientIntensity='0.25'
            diffuseColor='0.282435 0.085159 0.134462'
            emissiveColor='0.0 0.0 0.0' shininess='0.127273'
            specularColor='0.276305 0.11431 0.139857' transparency='0.0'/>
    </ProtoBody>
</ProtoDeclare>
```
Simple example: UniversalMedia excerpt 2

Alternatively, ExternProto retrieval:

```xml
<ExternProtoDeclare name='ArtDeco00'
    url="ArtDecoPrototypesExcerpt.x3d#ArtDeco00"
    "http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter14-
    Prototypes/ArtDecoPrototypesExcerpt.x3d#ArtDeco00"
    "http://www.web3d.org/x3d/content/examples/Basic/UniversalMediaMaterials/ArtDecoPrototypes.x3d#ArtDeco00"
/>```

Invocation is identical in either case:

```xml
<Shape>
    <Appearance>
        <ProtoInstance containerField='material' name='ArtDeco00'/>
    </Appearance>
    <Sphere DEF='Ball' radius='0.5'/>
</Shape>
```

containerField tells parent node the node type of the contained Proto Instance.
<xml version="1.0" encoding="UTF-8">
<DOCTYPE X3D PUBLIC "ISO//Web3D//DTD X3D 3.0//EN" "http://www.web3d.org/specifications/x3d-3.0.dtd">
<X3D profile='immersive' version='3.0' xmlns:x3d="http://www.w3.org/2001/XLink" xmlns:meta="http://www.w3.org/1999/xhtml">
<head>
<meta content='ArtDecoPrototypesExcerpt.x3d' name='title'/>
<meta content='Prototype declarations defining values for X3D/VRML materials, originally converted from SGI\apos;s Open Inventor material examples.' name='description'/>
<meta content='David Roussel' name='creator'/>
<meta content='7 April 2002' name='created'/>
<meta content='18 November 2008' name='modified'/>
<meta content='http://vmlstuff.free.fr/materials' name='reference'/>
<meta content='http://www.x3d.org/x3d-2.0/javadoc/UniversalMediaMaterialLibrary.html' name='subject'/>
<meta content='http://www.x3d.org/x3d-2.0/examples/Basic/UniversalMediaMaterials/ArtDecoPrototypes.x3d' name='identifier'/>
<meta content='http://x3dGraphics.com/examples/X3dForWebAuthors/Chapter14-Prototypes/ArtDecoPrototypesExcerpt.x3d' name='identifier'/>
<meta content='Vrml97ToX3dNist, http://ovrt.nist.gov/v2_x3d.html' name='generator'/>
<meta content='.' name='license'/>
</head>

<Scene>
  <ProtoDeclare name='ArtDeco00'>
    <ProtoBody>
      <Material ambientIntensity='0.25' diffuseColor='0.282435 0.085159 0.134462' emissiveColor='0.0 0.0 0.0' shininess='0.127723' specularColor='0.666667 0.666667 0.666667'/>
    </ProtoBody>
  </ProtoDeclare>
  <ProtoDeclare name='ArtDeco01'>
    <ProtoBody>
      <Material ambientIntensity='0.254777' diffuseColor='0.686208 0.134679 0.382385' emissiveColor='0.0 0.0 0.0' shininess='0.071429' specularColor='0.666667 0.666667 0.666667'/>
    </ProtoBody>
  </ProtoDeclare>
  <ProtoDeclare name='ArtDeco02'>
    <ProtoBody>
      <Material ambientIntensity='1.0' diffuseColor='0.536861 0.0529 0.245479' emissiveColor='0.0 0.0 0.0' shininess='0.832432' specularColor='0.666667 0.666667 0.666667'/>
    </ProtoBody>
  </ProtoDeclare>
  <Anchor description='ArtDecoPrototypeExample' parameter='target=_blank' url='ArtDecoExamplesExcerpt.x3d' http='http://x3dGraphics.com/examples/X3dF' />
  <Shape Appearance>
    <!-- replace Material node with a corresponding Prototype -->
    <ProtoInstance containerField='material' name='ArtDeco00'/>
  </Appearance>
  <Text>This is a Materials Prototype declaration file. For an example scene using these nodes, "click" for X3D width='100' height='100'/>
  </Shape>
</Scene>
</X3D>
</xml>
ProtoDeclare editor X3D-Edit

Selecting ProtoDeclare, ProtoInterface or ProtoBody launches the ProtoDeclare interface:
### ProtoBody
ProtoBody collects ProtoDeclare body nodes.

**Warning**: only the first top-level node and its children are rendered, subsequent nodes (such as Scripts and ROUTEs) will be active but will not be drawn.

### ProtoDeclare
ProtoDeclare is a Prototype declaration, defining a new node made up of other node(s).

**Hint**: define field interfaces using the `<field>` tag, then scene nodes.

**Hint**: initial scene node in a ProtoDeclare body determines this prototype's node type.

<table>
<thead>
<tr>
<th>Name</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>[name of the PROTO node being declared NMTOKEN #REQUIRED]</td>
</tr>
<tr>
<td>appinfo</td>
<td>[appinfo type SFFloat CDATA #IMPLIED]</td>
</tr>
</tbody>
</table>

Application information to provide simple description usable as a tooltip, similar to XML Schema appinfo tag.

<table>
<thead>
<tr>
<th>Documentation</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>documentation</td>
<td>[documentation type SFFloat CDATA #IMPLIED]</td>
</tr>
</tbody>
</table>

Documentation url for further information, similar to XML Schema documentation tag.

### ProtoInstance
ProtoInstance creates a copy of a locally or externally defined PROTOtype node.

**Warning**: override default initializations of field values using `<fieldValue>` tags.

**Warning**: match PROTO node type to local context.

<table>
<thead>
<tr>
<th>Name</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>[name of the PROTO node being instanced NMTOKEN #REQUIRED]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DEF</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>[DEF ID #IMPLIED]</td>
<td>DEF defines a unique ID name for this node, referenceable by other nodes.</td>
</tr>
</tbody>
</table>

**Hint**: descriptive DEF names improve clarity and help document a model.

<table>
<thead>
<tr>
<th>USE</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>[USE IDREF #IMPLIED]</td>
<td>USE means reuse an already DEF-ed node ID, ignoring <em>all</em> other attributes and children.</td>
</tr>
</tbody>
</table>

**Hint**: USEing other geometry (instead of duplicating nodes) can improve performance.

**Warning**: do NOT include DEF (or any other attribute values) when using a USE attribute!

<table>
<thead>
<tr>
<th>containerField</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>[containerField: NMTOKEN &quot;children&quot;]</td>
<td>containerField is the field-label prefix indicating relationship to parent node. Examples: geometry Box, children Group, proxy Shape. containerField attribute is only supported in XML encoding of X3D scenes.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>[class CDATA #IMPLIED]</td>
<td>class is a space-separated list of classes, reserved for use by XML stylesheets. class attribute is only supported in XML encoding of X3D scenes.</td>
</tr>
</tbody>
</table>

### ProtoInterface
ProtoInterface collects ProtoDeclare field definitions.
| **field** | A field element defines an interface attribute or node.  
**Hint:** first add Script, ProtoDeclare or ExternProtoDeclare before adding a field.  
**Hint:** put initializing SFNode/MFNode into contained content. |
| --- | --- |
| **name** | [name: NM TOKEN #REQUIRED]  
Name of this field variable. |
| **accessType** | [accessType: (inputOnly|outputOnly|initializeOnly|inputOutput) #REQUIRED]  
Event-model semantics for field set/get capabilities. Hint for VRML 97: inputOnly=eventIn, outputOnly=eventOut, initializeOnly=field, inputOutput=exposedField.  
**Warning:** inputOutput=exposedField not allowed in VRML 97 Script nodes, use initializeOnly=field for backwards compatibility. |
| **type** | [type: (select from types list) #REQUIRED]  
Base type of this field variable. |
| **value** | [value: outputOnly CDATA #IMPLIED]  
Provide default initialization value for this field variable (may be later re-initialized by ProtoInstance fieldValue).  
**Hint:** SFNode/MFNode are initialized using contained content, instead of this value attribute.  
**Hint:** required for Script and ProtoDeclare.  
**Warning:** not allowed for ExternProtoDeclare.  
**Warning:** not allowed by inputOnly or outputOnly variables. |
| **appinfo** | [appinfo type SFString CDATA #IMPLIED]  
Application information to provide simple description usable as a tooltip, similar to XML Schema appinfo tag. |
| **documentation** | [documentation type SFString CDATA #IMPLIED]  
Documentation url for further information, similar to XML Schema documentation tag. |
<IS> and <connect>

<IS><connect> definitions link field interfaces to internal nodes within the prototype body. These as direct links between outward-facing prototype interface fields and internal fields:

- Any initialization or routed input value for the ProtoInterface field definition goes directly into matching internal IS/connect fields.
- Any change to a connected internal field is routed out of the prototype, if `accessType='outputOnly'` or `accessType='inputOutput'`.

Multiple connections are allowed for each node and for field, both for inputs and for outputs.
**<connect>**

IS / connect constructs link field interfaces to internal nodes within the prototype declaration

- Each named field IS connected to a prototype field
- Only legal to use within ProtoBody declarations

Each `<connect>` definition provides connection between a given field within local parent node and a corresponding `<field>` definition in the ProtoInterface

- Each name must match field, interface exactly
- Identical (eponymous) names often best for clarity
- Must also match `type` and `accessType` exactly
Prototype interface fields linked to internal fields

<ProtoDeclare appinfo='mimic a Material node and modulate fields as an animation effect'
    name='MaterialModulator'>
    <ProtoInterface>
        <field accessType='inputOutput' name='enabled' type='SFBool' value='true'/>
        <field accessType='inputOutput' name='diffuseColor' type='SFColor' value='0.8 0.8 0.8'/>
        <field accessType='inputOutput' name='emissiveColor' type='SFColor' value='0 0 0'/>
        <field accessType='inputOutput' name='specularColor' type='SFColor' value='0 0 0'/>
        <field accessType='inputOutput' name='transparency' type='SFFloat' value='0.0'/>
        <field accessType='inputOutput' name='shininess' type='SFFloat' value='0.2'/>
        <field accessType='inputOutput' name='ambientIntensity' type='SFFloat' value='0.2'/>
    </ProtoInterface>
    <ProtoBody>
        <Material DEF='MaterialNode'>
            <IS>
                <connect nodeField='diffuseColor' protoField='diffuseColor'/>
                <connect nodeField='emissiveColor' protoField='emissiveColor'/>
                <connect nodeField='specularColor' protoField='specularColor'/>
                <connect nodeField='transparency' protoField='transparency'/>
                <connect nodeField='shininess' protoField='shininess'/>
                <connect nodeField='ambientIntensity' protoField='ambientIntensity'/>
            </IS>
            <!-- etc. -->
        </Material>
    </ProtoBody>
</ProtoDeclare>
IS / connect in X3D-Edit

<IS> editor is simple

<connect> editor prompts author to connect proper type and accessType between parent-node and prototype fields
### IS

IS connects Prototype interface fields to node fields inside ProtoDeclare definitions. Add one or more connect tags to define each pair of Prototype field connections.

**Warning:** IS tag only allowed within ProtoDeclare body definitions.

**Hint:** IS tag precedes any Metadata tag, which precedes any other children tags.

<table>
<thead>
<tr>
<th>connect</th>
<th>connect tags define each Prototype field connection within ProtoDeclare definitions.</th>
<th>Warning: IS/connect tags are only allowed within ProtoDeclare body definitions.</th>
</tr>
</thead>
<tbody>
<tr>
<td>nodeField</td>
<td>[nodeField: NMTOKEN #REQUIRED] Name of field in this node connecting to parent ProtoDeclare field definition.</td>
<td>Hint: use multiple connect tags for multiple fan-in/fan-out.</td>
</tr>
<tr>
<td>protoField</td>
<td>[protoField: NMTOKEN #REQUIRED] Name of parent ProtoDeclare field definition connecting to field in this node.</td>
<td>Hint: use multiple connect tags for multiple fan-in/fan-out.</td>
</tr>
</tbody>
</table>
Connecting an embedded Script 1

A common design goal: create a Prototype that is modified version of specific node

Example:

• Prototype name='NewMaterial'
• ProtoInterface holds definitions for all original fields plus possibly some additional fields
• ProtoBody initial node is essential: e.g. Material, fully linked by IS/connect definitions for each field
• Next (nonrendered) node is modifying Script, also holding IS/connect field definitions plus connection to Material (via ROUTE or DEF/USE in a field)
Connecting an embedded Script 2

X3D-Edit can insert Script if fields are defined

- May eventually add support for full design pattern

```xml
<ProtoBody>
...
<Script DEF='MaterialModulatorScript'>
<field accessType='inputOutput' name='enabled' type='SFBool'/>
<field accessType='inputOutput' name='diffuseColor' type='SFColor'/>
<field accessType='inputOutput' name='emissiveColor' type='SFColor'/>
<field accessType='inputOutput' name='specularColor' type='SFColor'/>
<field accessType='inputOutput' name='transparency' type='SFFloat'/>
<field accessType='inputOutput' name='shininess' type='SFFloat'/>
<field accessType='inputOutput' name='ambientIntensity' type='SFFloat'/>
<IS>
<connect nodeField='enabled' protoField='enabled'/>
<connect nodeField='diffuseColor' protoField='diffuseColor'/>
<connect nodeField='emissiveColor' protoField='emissiveColor'/>
<connect nodeField='specularColor' protoField='specularColor'/>
<connect nodeField='transparency' protoField='transparency'/>
<connect nodeField='shininess' protoField='shininess'/>
<connect nodeField='ambientIntensity' protoField='ambientIntensity'/>
</IS>
</Script>
</ProtoBody>
```
ExternProtoDeclare

ExternProtoDeclare references an individual ProtoDeclare definition in an external scene

- Allows single “master” definition of a prototype, avoids versionitis from cut/paste redistributions
- Multiple prototype nodes require multiple ExternProtoDeclare statements

Includes <field> definitions matching interface signature of the original prototype

- Minus initial values, so that conflicts are avoided
- Allows X3D browser to “understand” new nodes and create proper scene graph when loading
ExternProtoDeclare editor X3D-Edit

ExternProtoDeclare editor for multiple url values

- Note #ProtoName appended to each filename
- Can edit, locally load, or launch each address
- Can sort url list (relative, .x3d before online, .wrl)
**appinfo, documentation attributes**

The *appinfo* and *documentation* attributes accompany ProtoDeclare, ExternProtoDeclare and field definitions

- *appinfo* holds a simple summary or tooltip
- *documentation* holds a url to further information

These match identical constructs in XML Schema

- Allowing tools to further support authoring, editing
- Allowing authors to properly document new nodes

These are important to use, and help long-term extensibility of your work and X3D itself
ProtoInstance

Finally you can make copies of your new node:
create Prototype instances using ProtoInstance

- Must be preceded by either ProtoDeclare or ExternProtoDeclare with same name
- Otherwise a run-time error results for end user

Nevertheless simple to invoke and instantiate:
<ProtoInstance name='ArtDeco00'/>

Can override default initialization values for fields

- This is how a prototype is customized upon creation
- <fieldValue name='someField' value='someValue'/>
- Can also initialize child nodes, if any
**containerField considerations**

*containerField* is how the field name for a node is provided, relative to the node's parent

- Usually not needed since default matches most common case: *containerField* = 'children'
- ClassicVRML syntax is different, more verbose
- As ever, functionality is identical

```xml
<!-- Rendered geometry follows prototype declaration -->
<Shape>
  <Sphere/>
  <Appearance>
    <ProtoInstance containerField='material' name='MaterialModulator'>
      <fieldValue name='enabled' value='true'/>
      <fieldValue name='diffuseColor' value='0.5 0.1 0.1'/>
    </ProtoInstance>
  </Appearance>
</Shape>
```

```c
// Rendered geometry follows prototype declaration
Shape {
  geometry Sphere {
  }
  appearance Appearance {
    material MaterialModulator {
      enabled TRUE
      diffuseColor 0.5 0.1 0.1
    }
  }
}
```
fieldValue initializations

fieldValue name must match; initialization values must match the type specified in declaration

• Otherwise a run-time error results for end user
• Take special care to check correctness, avoid errors

To initialize simple types: use value parameter

```xml
<ProtoInstance name='MaterialModulator' containerField='material'>
  <fieldValue name='enabled' value='true'/>
  <fieldValue name='diffuseColor' value='0.5 0.1 0.1'/>
</ProtoInstance>
```
fieldValue initializations 2

To initialize SFNode or MFNode types, use contained nodes within the fieldValue element:

```xml
<ProtoInstance name='SomethingNew'>
  <fieldValue name='newSFNodeField'>
    <!-- initialization node goes here -->
  </fieldValue>
</ProtoInstance>
```

As might be expected, fieldValue initializations are only allowed for fields with accessType of initializeOnly or inputOutput.
<protoDeclare appinfo='mimic a Material node and modulate fields as an animation effect' name='MaterialModulator'>

<protoInterface>

<field accessType='inputOutput' name='enabled' type='SFBool' value='true'/>
<field accessType='inputOutput' name='diffuseColor' type='SFColor' value='0.6 0.6 0.6'/>
<field accessType='inputOutput' name='emissiveColor' type='SFColor' value='0 0 0'/>
<field accessType='inputOutput' name='specularColor' type='SFColor' value='0 0 0'/>
<field accessType='inputOutput' name='transparency' type='SFFloat' value='0.0'/>
<field accessType='inputOutput' name='shininess' type='SFFloat' value='0.2'/>
<field accessType='inputOutput' name='ambientIntensity' type='SFFloat' value='0.2'/>

</protoInterface>

<protoBody>

<Material DEF='MaterialNode'>

<IS>

<connect nodeField='diffuseColor' protoField='diffuseColor'/>
<connect nodeField='emissiveColor' protoField='emissiveColor'/>
<connect nodeField='specularColor' protoField='specularColor'/>
<connect nodeField='transparency' protoField='transparency'/>
<connect nodeField='shininess' protoField='shininess'/>
<connect nodeField='ambientIntensity' protoField='ambientIntensity'/>

</IS>

</Material>

<Script DEF='MaterialModulatorScript' directOutput='true'>

<field accessType='inputOutput' name='enabled' type='SFBool' value='true'/>
<field accessType='inputOutput' name='diffuseColor' type='SFColor' value='0.6 0.6 0.6'/>
<field accessType='inputOutputOnly' name='newColor' type='SFColor' value='0 0 0'/>
<field accessType='inputOnly' name='clockTrigger' type='SFTime'/>

<IS>

<connect nodeField='enabled' protoField='enabled'/>
<connect nodeField='diffuseColor' protoField='diffuseColor'/>

</IS>

</Script>

</protoBody>

</protoDeclare>
ProtoInstance, fieldValue X3D-Edit

MaterialModulator.x3d part 2

```xml
<Material>
  <Script DEF="MaterialModulatorScript" directOutput='true'>
    <field accessType="inputOutput" name="enabled" type="SFBool"/>
    <field accessType="inputOutput" name="newColor" type="SFColor"/>
    <field accessType="outputOnly" name="newColor" type="SFColor" value='0 0 0'/>
    <field accessType="inputOnly" name="clockTrigger" type="SFTime"/>
  </IS>
  <connect nodeField='enabled' protoField='enabled'/>
  <connect nodeField='diffuseColor' protoField='diffuseColor'/>
</Material>

<ecmascript>

  function initialize () {
    newColor = diffuseColor; // start with correct color
  }

  function clockTrigger (timeValue)
  {
    if (!enabled) return;
    red = newColor.r;
    green = newColor.g;
    blue = newColor.b;

    // note different modulation rates for each color component, % is modulus operator
    newColor = new SFColor ((red + 0.02) % 1, (green + 0.03) % 1, (blue + 0.04) % 1);
    Browser.print ('diffuseColor=' + newColor.r + ' ' + newColor.g + ' ' + newColor.b + ');
  }

  </ecmascript>

<script>
  <ROUTE fromField='newColor' fromNode='MaterialModulatorScript' toField='diffuseColor'/>
  <TimeSensor DEF='ModulationClock' cycleInterval='0.05' loop='true'/>
  <ROUTE fromField='cycleTime' fromNode='ModulationClock' toField='clockTrigger'/>
</script>
</Material>

<ProtoDeclare name='MaterialModulator'>
  <ProtoBody>
    <!-- Rendered geometry follows prototype declaration -->
    <Shape>
      <Sphere/>
      <Appearance>
        <ProtoInstance containerField='material' name='MaterialModulator'>
          <fieldValue name='enabled' value='true'/>
          <fieldValue name='diffuseColor' value='0.5 0.1 0.1'/>
        </ProtoInstance>
      </Appearance>
    </Shape>
  </ProtoBody>
</ProtoDeclare>
```

Edit fieldValue

ProtoDeclare name: MaterialModulator
ProtoInstance fieldValue:
name enabled type SFBool inputOutput value true
ProtoInstance creates a copy of a locally or externally defined PROTOtype node.

**Hint:** override default initializations of field values using `<fieldValue>` tags.

**Warning:** match PROTO node type to local context.

<table>
<thead>
<tr>
<th>name</th>
<th>[name of the PROTO node being instanced NMTOKEN #REQUIRED]</th>
</tr>
</thead>
</table>

**DEF**

<table>
<thead>
<tr>
<th>[DEF ID #IMPLIED]</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEF defines a unique ID name for this node, referencable by other nodes.</td>
</tr>
<tr>
<td><strong>Hint:</strong> descriptive DEF names improve clarity and help document a model.</td>
</tr>
</tbody>
</table>

**USE**

<table>
<thead>
<tr>
<th>[USE IDREF #IMPLIED]</th>
</tr>
</thead>
<tbody>
<tr>
<td>USE means reuse an already DEF-ed node ID, ignoring <em>all</em> other attributes and children.</td>
</tr>
<tr>
<td><strong>Hint:</strong> USEing other geometry (instead of duplicating nodes) can improve performance.</td>
</tr>
<tr>
<td><strong>Warning:</strong> do NOT include DEF (or any other attribute values) when using a USE attribute!</td>
</tr>
</tbody>
</table>

**containerField**

<table>
<thead>
<tr>
<th>[containerField: NMTOKEN &quot;children&quot;]</th>
</tr>
</thead>
<tbody>
<tr>
<td>containerField is the field-label prefix indicating relationship to parent node. Examples: geometry Box, children Group, proxy Shape. containerField attribute is only supported in XML encoding of X3D scenes.</td>
</tr>
</tbody>
</table>

**class**

<table>
<thead>
<tr>
<th>[class CDATA #IMPLIED]</th>
</tr>
</thead>
<tbody>
<tr>
<td>class is a space-separated list of classes, reserved for use by XML stylesheets. class attribute is only supported in XML encoding of X3D scenes.</td>
</tr>
</tbody>
</table>

**fieldValue**

| A fieldValue element is used to re-initialize default field values in ProtoInstances. Field names must be already defined in ProtoDeclare or ExternProtoDeclare. |
| **Hint:** put initializing SFNode/MFNode into fieldValue’s contained content. |

<table>
<thead>
<tr>
<th>name</th>
<th>[name: NMTOKEN #REQUIRED]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name of this field (already defined in ProtoDeclare or ExternProtoDeclare).</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>value</th>
<th>[value: outputOnly CDATA #IMPLIED]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial value for this field (overrides default initialization value in ProtoDeclare or ExternProtoDeclare).</td>
<td></td>
</tr>
<tr>
<td><strong>Hint:</strong> initialize SFNode/MFNode using contained content instead.</td>
<td></td>
</tr>
</tbody>
</table>
Advanced Examples
ViewFrustum is a helpful visualization prototype

- Prototypes simplify creation of new X3D nodes
- Shows near and far clipping planes that truncate the viewable area
- Depends on Viewpoint and NavigationInfo parameters

Detailed example: ViewFrustum

\[
\text{Near clipping plane distance} = \text{avatarSize[0]}
\]
\[
\text{Far clipping plane distance} = \text{visibilityLimit}
\]

\[
\text{nearHalfWidth} = \tan\left(\frac{\text{fieldOfView}}{2}\right) \times \text{avatarSize[0]};
\]
\[
\text{farHalfWidth} = \tan\left(\frac{\text{fieldOfView}}{2}\right) \times \text{visibilityLimit};
\]
ViewFrustum prototype, example

Good practice: make two separate files to simplify ExternProtoDeclare reuse
Prototype features of interest

Highlighted ProtoDeclare, ExternProtoDeclare, ProtoInstance and Script show:

• Using initialize() method to setup geometry nodes
• Usage of IS/connect for direct node inspection
• Usage of event-passing via ROUTE when changing Extrusion, which doesn't support direct modification
• Matching type and accessType, toString() function
• External script code, accessing node fields
• Duplicate url addresses, local and remote
• Browser.println statements, silencable by trace field
• Internal var declarations, Javascript Math library
field definitions

Coordinate points for outline, need initialization

Extrusion for frustum polygons, need initialization

Small Sphere shows Viewpoint position
ViewFrustrumProtoDeclare

IS/connect links match field definitions

Output fields for ROUTE links

Match ProtoInterface field definitions

User selects Text message to launch example scene

ROUTE links
function initialize () {
    var scriptName = 'ViewFrustrumScript';
    if ((ViewpointNode == null) || (NavigationInfoNode == null)) {
        Browser.println ('[' + scriptName + '] ' + Viewpoint and/or NavigationInfo undefined, no ViewFrustrum drawn');
        return;
    }
    if (trace) Browser.println ('[' + scriptName + '] ' + 'input ' + '<Viewpoint position=''' + ViewpointNode.position.toString() + ''' + ' orientation=''' + ViewpointNode.orientation.toString() + ''' + ' fieldOfView=''' + ViewpointNode.fieldOfView.toString() + ''' + ' />
    position_changed = ViewpointNode.position;
    orientation_changed = ViewpointNode.orientation_changed;
    if (trace) Browser.println ('[' + scriptName + '] ' + 'input ' + '<NavigationInfo averateSize=''' + NavigationInfoNode.averateSize.toString() + ''' + ' visiblityLimit=''' + NavigationInfoNode.visibilityLimit.toString() + ''' + ' />
    var nearClipPlaneDistance = NavigationInfoNode.averateSize[0];
    var farClipPlaneDistance = NavigationInfoNode.visibilityLimit;
    if (farClipPlaneDistance == 0) farClipPlaneDistance = 10000.0;
    var nearHalfWidth = Math.tan((ViewpointNode.fieldOfView / 2.0) * nearClipPlaneDistance);
    var farHalfWidth = Math.tan((ViewpointNode.fieldOfView / 2.0) * farClipPlaneDistance);
    spine_changed = new MFVec3f (new MFVec3f (0.0, 0.0, nearClipPlaneDistance),
        new MFVec3f (0.0, 0.0, farClipPlaneDistance));
    scale_changed = new MFVec2f (new MFVec2f (nearHalfWidth, aspectRatio * nearHalfWidth),
        new MFVec2f (farHalfWidth, aspectRatio * farHalfWidth));
    if (trace) Browser.println ('[' + scriptName + '] ' + 'output ' + '<Extrusion DEF="ViewFrustrumExtrusion" + ' spine=''' + spine_changed.toString() + ''' + ' scale=''' + scale_changed.toString() + ''' ; // default crossSection used
    point_changed = new MFVec3f (new MFVec3f (nearHalfWidth, aspectRatio * nearHalfWidth, nearClipPlaneDistance),
        new MFVec3f (nearHalfWidth, aspectRatio * nearHalfWidth, nearClipPlaneDistance),
        new MFVec3f (-nearHalfWidth, aspectRatio * nearHalfWidth, nearClipPlaneDistance),
        new MFVec3f (-nearHalfWidth, aspectRatio * nearHalfWidth, nearClipPlaneDistance),
        new MFVec3f (farHalfWidth, aspectRatio * farHalfWidth, farClipPlaneDistance),
        new MFVec3f (farHalfWidth, aspectRatio * farHalfWidth, farClipPlaneDistance),
        new MFVec3f (-farHalfWidth, aspectRatio * farHalfWidth, farClipPlaneDistance),
        new MFVec3f (-farHalfWidth, aspectRatio * farHalfWidth, farClipPlaneDistance));
    if (trace) Browser.println ('[' + scriptName + '] ' + 'output ' + '<Coordinate DEF="ViewFrustrumCoordinate" + ' point=''' + point_changed.toString() + ''' ;
}
<ExternProtoDeclare name="ViewFrustum">
  <field definitions="ViewFrustumPrototype.x3d" url="http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter14-Prototypes/ViewFrustumExample.x3d"/>
  <field accessType="initializeOnly" name="ViewportNode" type="SFNode"/>  
  <field accessType="initializeOnly" name="NavigationInfoNode" type="SFNode"/>  
  <field accessType="inputOutput" name="lineColor" type="SFCOLOR"/>  
  <field accessType="inputOutput" name="frustumColor" type="SFCOLOR"/>  
  <field accessType="inputOutput" name="transparency" type="SFFLOAT"/>  
  <field accessType="inputOutput" name="asymmetric" type="SFBOOL"/>  
</ExternProtoDeclare>

<ProtoInstance name="ViewFrustum">
  <fieldValue name="ViewportNode">
    <Viewport DEF="TestViewport" fieldOfView='0.78'/>
  </fieldValue>
  <fieldValue name="NavigationInfoNode">
    <NavigationInfo DEF="TestNavigationInfo" avatarSize='1 1 0.75' visibilityLimit='15'/>
  </fieldValue>
  <fieldValue name="lineColor" value='0.9 0.9 0.9'/>
  <fieldValue name="frustumColor" value='0.8 0.8 0.8'/>
  <fieldValue name="transparency" value='0.75'/>
</ProtoInstance>

<Viewpoint description="Above view" orientation='1 0 0 -1.57' position='0 40 0'/>
<Viewpoint description="Frustum viewpoint"/>  
<Viewpoint description="Behind frustum viewpoint" position='0 0 15'/>

<NavigationInfo type="EXAMINE" FLIGHT="ANY"/>

<Inline DEF="GridXZ_28x10F1x6d.x3d" url="http://savage.nps.edu/Savage/Tools/Authoring/GridXZ_28x10F1x6d.x3d"/>
<Transform scale='1 1 1'/>

Additional Prototype Examples

Numerous prototypes and examples are available in the Savage archive, especially

• https://savage.nps.edu/Savage/Tools/Animation

• https://savage.nps.edu/Savage/Tools/Authoring
  Animated Viewpoint Recorder, Single Type Conversion, View Position Orientation
Chapter Summary
Chapter Summary

Concepts
  • Motivation and Functional Summary

Functional Descriptions and Examples
  • ProtoDeclare, ProtoInterface, ProtoBody and field declarations
  • IS / connect linking of field interfaces to internals
  • ExternProtoDeclare and field signatures
  • ProtoInstance, containerField, fieldValue initializations
  • Advanced examples: design and re-use
Suggested exercises

Add a given external prototype declaration and instance to improve an already-existing scene

Write three prototypes of increasing complexity:
- No ProtoInterface, no field definitions
- One or more field definitions, no Script
- Multiple field definitions, multiple IS/connect, Script

Design a multiple fan-in fan-out prototype by emulating an existing X3D node while adding new functionality
- Example: MaterialModulate
References
References 1

**X3D: Extensible 3D Graphics for Web Authors**
by Don Brutzman and Leonard Daly, Morgan Kaufmann Publishers, April 2007, 468 pages.

- Chapter 14, Creating Prototype Nodes
- [http://x3dGraphics.com](http://x3dGraphics.com)
- [http://x3dgraphics.com/examples/X3dForWebAuthors](http://x3dgraphics.com/examples/X3dForWebAuthors)

**X3D Resources**

- [http://www.web3d.org/x3d/content/examples/X3dResources.html](http://www.web3d.org/x3d/content/examples/X3dResources.html)
References 2

X3D-Edit Authoring Tool
  • https://savage.nps.edu/X3D-Edit

X3D Scene Authoring Hints
  • http://x3dgraphics.com/examples/X3dSceneAuthoringHints.html
    (especially those for Inline and Prototypes)

X3D Graphics Specification
  • http://www.web3d.org/x3d/specifications
  • Also available as help pages within X3D-Edit
References 3


• http://www.wiley.com/legacy/compbooks/vrml2sbk/cover/cover.htm
• http://www.web3d.org/x3d/content/examples/Vrml2.0Sourcebook
• Chapter 31 - Prototypes
The Computer Graphics Educational Materials Source (CGEMS) site is designed for educators

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- as a service to the Computer Graphics community
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- http://cgems.inesc.pt

**X3D for Web Authors** recognized by CGEMS! 😊

- Book materials: X3D-Edit tool, examples, slidesets
- Received jury award for Best Submission 2008

CGEMS supported by SIGGRAPH, Eurographics
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Chapter 14 - Creating Prototype Nodes

There are more things in heaven and earth, Horatio, than are dreamt of in your philosophy.
William Shakespeare, Hamlet Act I Scene V

Here is the story of my high-school senior English project about building a concordance of Shakespeare's Hamlet. Building a concordance was a relatively new concept in 1974: first creating a full index of words in a document, then counting the occurrence of each word, and afterwards using that information to analyze the writing style of the author. At that time, this technique was being applied to try to determine whether the same author had written all of the plays attributed to Shakespeare.

In this case, my program was written in Fortran and run on an IBM 1130. It took several weeks to type in the entire play onto punch cards (with help from a pretty classmate). Typing mistakes usually meant retyping the entire card; this was before time sharing and personal accounts with disk space. Because the dataset was considered quite large, we were only able to test the concordance-creation program in small batches. Columbia High School's data processing department provided an empty hard disk (which was about as big as a garbage-can lid) to store the sorting data, then let us use the computer over the weekend... We started the job late Friday afternoon, reading in several thousand cards (i.e. lines of prose, one line per 80-character card) to disk and then starting the counting, sorting and cross-referencing routines. Output went to the line printer.

The job ran all weekend... At 7 am Monday morning I arrived early, excited and full of anticipation. Sure enough the lab was hot and the computer console was running steadily, with all of the memory-bit lights flashing on and off. There on the chain-drive line printer was page after page of concordance entries, word by word, listing word frequency and line references. That was the good news. However, checking the pages revealed that the program output had only produced words starting with letter “A” up to words somewhere in the middle of letter “C”... Gee whiz, there sure was a lot of alphabet left! We shut down the program and reopened the lab. Later that day in Shakespeare class, the teacher clapped and laughed, as did we all. This was an interesting lesson in the limits of brute-force programming, memory and computation.
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Concepts
Prototype motivation: extensibility

The X in X3D stands for Extensible: we have engineered the X3D standard for future growth

• Supporting innovation by individual authors, rather than waiting for future versions of the specification

Other extensibility mechanisms available:

• Inline node allows one scene to pull in other scenes, but without modification or customization
• Script node allows creation of arbitrary functionality that receives (and responds to) routed events

Prototypes create new full-fledged X3D nodes

• With field definitions, render capability, etc.

Editorial note. Regarding capitalization of the word “Extensible,” the Web3D Consortium follows the example of the Extensible Markup Language (XML) rather than some less-grammatical capitalization like eXtensible.
Comparison with Inline node

In line is easier to create and use
- Simply loads and inserts another X3D scene

In line nodes are less flexible
- Cannot be customized when imported since there is no override mechanism for internal field values
- Events can be passed into, out of Inline scene at run time by using predefined IMPORT, EXPORT statements, for exposed internal nodes inside Inline

Prototypes are preferred if initialization values are needed, routing also works unambiguously

Inline nodes are easier to use, prototypes are a little harder to create but more powerful. Your mileage may vary (YMMV).

Often a good development technique is to test out an approach by simply creating, copying and pasting a scene subgraph a few times until the desired structure and field definitions are clear. Then encapsulating the functionality in a single ProtoDeclare can be simpler. Upon creating the prototype declaration, the example subgraphs are replaced by ProtoDeclare nodes with appropriate fieldValue override values..
Prototype functional summary

A Prototype creates a new full-fledged X3D node
  • With field definitions, render capability, etc.
X3D prototypes provide a way for X3D authors to create new node definitions
  • ProtoInstance allows repeated reuse of a new node
  • Fields can be exposed an parameterized, allowing customization (unlike Inline which is fixed content)
Prototypes can be used within the scene where they are defined, or used externally
  • ExternProtoDeclare gives reference to declaration
Declaration versus instances

Prototype declarations can be thought of as defining a cookie-cutter for a new node

• ProtoDeclare constructs the definition
• Definition does not yet create an actual new node

Prototype instances are the actual copies of the new node which gets displayed

• Just as cookie cutter is used to create new cookies

ProtoDeclare is a template
ProtoInstance copies actually exist and render

In object-oriented parlance:

• ProtoDeclare corresponds to a class definition
• Protolnstance corresponds to an object instance

From Wikipedia, the free encyclopedia:
“A cookie cutter is a tool to cut out cookie dough in a particular shape. They are often used for seasonal occasions when well-known decorative shapes are desired, or for large batches of cookies where simplicity and uniformity are required.”

Image: Jigsaw Cookie Cutter, Cox and Cox

“Little ones will love helping out in the kitchen with this metal jigsaw piece cutter. Especially as they're allowed to play with their food! It provides endless fun for kids and is popular with adults, too. Imagine the effect of pieces running down the centre of a party table, or individual jigsaw piece biscuits being decorated with different children's names.”
http://www.coxandcox.co.uk/index.php?main_page=product_info&cPath=9&products_id=51
# Summary of XML element structure

<table>
<thead>
<tr>
<th>ProtoDeclare</th>
<th>Defines prototype</th>
</tr>
</thead>
<tbody>
<tr>
<td>- ProtoInterface</td>
<td>- Hold field definitions</td>
</tr>
<tr>
<td>- field</td>
<td>- Defines each field interface</td>
</tr>
<tr>
<td>- ProtoBody</td>
<td>- Hold nodes, scene subgraph</td>
</tr>
<tr>
<td>- Initial node</td>
<td>- First node defines type, use</td>
</tr>
<tr>
<td>- Additional nodes</td>
<td>- Initial siblings not rendered</td>
</tr>
<tr>
<td>- IS/connect links</td>
<td>- Link interfaces to internal fields</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ExternProtoDeclare</th>
<th>Retrieve external declaration</th>
</tr>
</thead>
<tbody>
<tr>
<td>- field</td>
<td>- List of fields without values</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ProtoInstance</th>
<th>Actual copy of prototype node</th>
</tr>
</thead>
<tbody>
<tr>
<td>- fieldValue</td>
<td>- Override default interface values</td>
</tr>
</tbody>
</table>
Potential power

Prototypes are a powerful technique for extending the capabilities of X3D.

Few computing languages provide authors with the capability to extend the core vocabulary of the language itself.

In one sense, an scene author defining a prototype for a new node in a scene can be thought to have similar power as the X3D specification team which defines new nodes for everyone to use in X3D.
Strong typing of nodes

Each prototype declaration must contain at least one node in the prototype body

- First node is primary, defining type for prototype
- ProtoInstances can only appear where that primary node might be allowed to appear
- If primary node contains children, together they must define a valid scene subgraph

Subsequent sibling nodes can follow first node

- But are not rendered, nor do they affect node type

Thus prototype instances remain strongly typed

- Any errors are discoverable before run time

This strong typing is important because it ensures that any addition of prototypes into a valid X3D scene remains a valid X3D scene.

This also prevents contradictory errors, such as a Prototype representing a modified Material node appearing someplace other than within a Shape node.
Syntax alert: contrast .x3d .x3dv

Syntax for prototype definition and usage is significantly different when comparing the XML (.x3d) and ClassicVRML (.x3dv) encodings.

Functional correspondence remains identical
- Declaration, field definitions, instance creation, etc.

Book compares both forms of syntax in detail

Because the X3D syntax is more explicit and detailed, it is usually easier to follow.

ClassicVRML and VRML97 syntax are identical for prototypes.
Functional Descriptions and Examples
A prototype declaration includes two constructs: prototype interface and prototype body

<ProtoDeclare name="MyNewBlueMaterial">
  <ProtoInterface>
    <field name="concentration" accessType='inputOutput' type='SFInt32'
      Value='0.75' appinfo="how blue is my new Material, range 0..1'/>
  </ProtoInterface>
  <ProtoBody>
    <!-- First node in body determines node type of prototype-->
    <Material/>
    <!-- Subsequent nodes do not render, but must be valid X3D subgraph -->
    <Script DEF='CalculateNewBlueValueFromConcentration'/>
  </ProtoBody>
</ProtoDeclare>

Corresponding ClassicVRML construct: PROTO, followed by name, as shown in Table 14.2, pp. 386-387.
Naming considerations

Good naming is important for prototypes, fields

- Helps authors understand their intent and then utilize them correctly
- Naming-convention guidelines found in X3D Scene Authoring Hints

Only one declaration is allowed for each individual prototype node

- Cannot have conflicting same-name definitions from ProtoDeclare and/or ExternProtoDeclare
- Name collisions (i.e. “overloading”) not allowed

Scene Authoring Hints are provided in X3D-Edit Help system and are online at http://www.web3d.org/x3d/content/examples/X3dSceneAuthoringHints.html#NamingConventions
Naming considerations

Good test of a prototype name (or field name) is to use it in a sentence, to see if it makes sense
- “a MaterialModulator node mimics a Material node and modulate fields as an animation effect”
- Awkward names are revealed by awkward sentences
- Descriptions are helpful when added as `appinfo`

Good names provide clarity when thinking about, modifying, and debugging a scene

Best name is when no one asks what it means!
- Alternatively, questions imply need to improve

Scene Authoring Hints are provided in X3D-Edit Help system and are online at http://www.web3d.org/x3d/content/examples/X3dSceneAuthoringHints.html#NamingConventions

`appinfo` is a descriptive attribute that authors can define for field and prototype declarations. It is defined similarly to XML Schema `appinfo`.

Acknowledgement: Jeff Weekley came up with our (ironic) metric about how to tell if a name works. Thanks Jeff!
Naming conventions, excerpted

CamelCaseNaming: capitalize each word, never use abbreviations, strive for clarity, be brief but complete

startsWithLowerCaseLetter when defining field names (i.e. attributes) for Prototypes, Scripts

Ensure consistent capitalization throughout

Use the underscore character ("_") to indicate subscripts on mathematical variables. Otherwise avoid use of underscores since they look like whitespace when part of a URL address

Avoid use of hyphens ("-") since these are erroneously turned into subtraction operators when converted into class or variable names

Scene Authoring Hints are provided in X3D-Edit Help system and are online at http://www.web3d.org/x3d/content/examples/X3dSceneAuthoringHints.html#NamingConventions
ProtoInterface and field declarations

<ProtoInterface> is section of <ProtoDeclare> that holds <field> definitions
• Which are the interface for the prototype
• Zero or more <field> definitions allowed
• <ProtoInterface> omitted if no <field> definitions

Same as <field> definitions for Script node
• Defines name, type, accessType, and initial value
• SFNode, MFNode initializations are contained elements
• initializeOnly, inputOutput fields must have initial value
• inputOnly, outputOnly fields have no initial value

Corresponding ClassicVRML construct: [ square brackets around field definitions ] as shown in Table 14.2, pp. 386-387.
<table>
<thead>
<tr>
<th>Field-Type Names</th>
<th>Description</th>
<th>Default Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>SFBool</td>
<td>Single-Field boolean value</td>
<td>false (XML syntax) or FALSE (Classic VRML syntax)</td>
</tr>
<tr>
<td>MBOOL</td>
<td>Multiple-Field boolean array</td>
<td>Empty list</td>
</tr>
<tr>
<td>SFCOLOR</td>
<td>Single-Field color value, RGB</td>
<td>0 0 0</td>
</tr>
<tr>
<td>MFColor</td>
<td>Multiple-Field color array, RGB</td>
<td>Empty list</td>
</tr>
<tr>
<td>SFCOLORRGBA</td>
<td>Single-Field color value, red-green-blue alpha (opacity)</td>
<td>0 0 0 0</td>
</tr>
<tr>
<td>MFColorRGBA</td>
<td>Multiple-Field color array, red-green-blue alpha (opacity)</td>
<td>Empty list</td>
</tr>
<tr>
<td>SFINT32</td>
<td>Single-Field 32-bit integer value</td>
<td>0</td>
</tr>
<tr>
<td>MFINT32</td>
<td>Multiple-Field 32-bit integer array</td>
<td>Empty list</td>
</tr>
<tr>
<td>SFFloat</td>
<td>Single-Field single-precision floating-point value</td>
<td>0.0</td>
</tr>
<tr>
<td>MFFloat</td>
<td>Multiple-Field single-precision floating-point array</td>
<td>Empty list</td>
</tr>
<tr>
<td>SFDouble</td>
<td>Single-Field double-precision floating-point value</td>
<td>0.0</td>
</tr>
<tr>
<td>MDOUBLE</td>
<td>Multiple-Field double-precision array</td>
<td>Empty list</td>
</tr>
<tr>
<td>SFImage</td>
<td>Single-Field image value</td>
<td>0 0 0</td>
</tr>
</tbody>
</table>

Contains special pixel-encoding values, see Chapter 5 for details

Table 14.3, page 388, *X3D Field Types and Default Values*
<table>
<thead>
<tr>
<th>Field Type</th>
<th>Description</th>
<th>Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MFImage</td>
<td>Multiple-Field image value</td>
<td>Empty list</td>
</tr>
<tr>
<td>SFNode</td>
<td>Single-Field node</td>
<td>Empty node, NULL</td>
</tr>
<tr>
<td>MFNode</td>
<td>Multiple-Field node array of peers</td>
<td>Empty list</td>
</tr>
<tr>
<td>SFRotation</td>
<td>Single-Field rotation value using 3-tuple axis, radian-angle form</td>
<td>0 0 1 0</td>
</tr>
<tr>
<td>MFRotation</td>
<td>Multiple-Field rotation array</td>
<td>Empty list</td>
</tr>
<tr>
<td>SFString</td>
<td>Single-Field string value</td>
<td>Empty string, representable as two adjacent quotation marks</td>
</tr>
<tr>
<td>MFString</td>
<td>Multiple-Field string array</td>
<td>Empty list</td>
</tr>
<tr>
<td>SFTime</td>
<td>Single-Field time value</td>
<td>-1, sentinel indicating no time value.</td>
</tr>
<tr>
<td>MFTime</td>
<td>Multiple-Field time array</td>
<td>Empty list</td>
</tr>
<tr>
<td>SFVec2f/SFVec2d</td>
<td>Single-Field 2-float/2-double vector value</td>
<td>0 0</td>
</tr>
<tr>
<td>MFVec2f/MFVec2d</td>
<td>Multiple-Field 2-float/2-double vector array</td>
<td>Empty list</td>
</tr>
<tr>
<td>SFVec3f/SFVec3d</td>
<td>Single-Field vector value of 3-float/3-double values</td>
<td>0 0 0</td>
</tr>
<tr>
<td>MFVec3f/MFVec3d</td>
<td>Multiple-Field vector array of 3-float/3-double values</td>
<td>Empty list</td>
</tr>
</tbody>
</table>

Table 14.3, page 388, *X3D Field Types and Default Values*
ProtoBody

First node in ProtoBody is required and critical, defining the node type
• This node is how a ProtoInstance will appear to scene graph

Additional nodes are allowed, but not rendered
• This is how prototypes provide extensibility while maintaining strong node typing
• X3D-Edit will provide warning about this, unless author inserts a comment beforehand

No object-oriented “inheritance” but...
• first node in body can be a nested ProtoInstance

Corresponding ClassicVRML construct: { squiggly brackets around node declarations } as shown in Table 14.2, pp. 386-387.

Nested prototypes are interesting but a little bit risky... they are well defined and unambiguous according to the specification, but in practice, X3D players have had trouble implementing them correctly and consistently. So caveat emptor, “your mileage may vary” if you use this construct.
Simple example: UniversalMedia excerpt 1

The Universal Media Materials archive provides a number of example materials

- Available as prototypes, or cut + paste
- Built in, selectable within X3D-Edit Material editor
- No ProtoInterface/fields needed, just ProtoBody

```
<ProtoDeclare name='ArtDeco00'>
  <ProtoBody>
    <Material ambientIntensity='0.25'
      diffuseColor='0.282435 0.085159 0.134462'
      emissiveColor='0.0 0.0 0.0' shininess='0.127273'
      specularColor='0.276305 0.11431 0.139857' transparency='0.0'/>
  </ProtoBody>
</ProtoDeclare>
```
Simple example: UniversalMedia excerpt 2

Alternatively, ExternProto retrieval:

```xml
<ExternProtoDeclare name='ArtDeco00'
   url='"ArtDecoPrototypesExcerpt.x3d#ArtDeco00"
   "http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter14-
   Prototypes/ArtDecoPrototypesExcerpt.x3d#ArtDeco00"
   "http://www.web3d.org/x3d/content/examples/Basic/UniversalMediaMaterials/
   ArtDecoPrototypes.x3d#ArtDeco00"/>
```

Invocation is identical in either case:

```xml
<Shape>
  <Appearance>
    <ProtoInstance containerField='material' name='ArtDeco00'/>
  </Appearance>
  <Sphere DEF='Ball' radius='0.5'/>
</Shape>
```

Note that `containerField='material'` is essential here to let the Shape know the node type of ArtDeco00. Otherwise the default `containerField='children'` is used by the browser, which is illegal inside a Shape node and would fail at run time.
Chapter 14 - Creating Prototype Nodes

http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter14-Prototypes/ArtDecoPrototypesExcerpt.x3d
ProtoDeclare editor X3D-Edit

Selecting ProtoDeclare, ProtoInterface or ProtoBody launches the ProtoDeclare interface:

This example is very simple: there is no ProtoInterface and no field definitions.

ProtoInterface and ProtoBody are container elements only, with no attributes or independent functionality. Therefore there are no editor panes for these elements.

The ProtoInterface panel is minimalist, simply describing rules for use.
### Four prototype tooltips

**ProtoBody**
- Protobody collects ProtoDeclare body nodes.
- Warning: only the top level node and its children are rendered, subsequent nodes (such as Scripts and ROUTE) will be active but will not be drawn.

**ProtoDeclare**
- ProtoDeclare is a prototype declaration, defining a new node made up of other node(s).
- Use: defines field interfaces using the `field` tag, then scene nodes.
- Note: initial scene node in a ProtoDeclare body determines this prototype's node type.

**ProtoInstance**
- ProtoInstance creates a copy of a locally or externally defined PROTOTYPE node.
- Use: override default initializations of field values using `fieldValue` tags.
- Warning: match PROTO node type in local context.

**ProtoInterface**
- ProtoInterface collects ProtoDeclare field definitions.

---

**X3D Tooltips for ProtoBody, ProtoDeclare, ProtoInstance, ProtoInterface**

- [http://www.web3d.org/x3d/content/X3dTooltips.html#ProtoBody](http://www.web3d.org/x3d/content/X3dTooltips.html#ProtoBody)
- [http://www.web3d.org/x3d/content/X3dTooltips.html#ProtoDeclare](http://www.web3d.org/x3d/content/X3dTooltips.html#ProtoDeclare)
- [http://www.web3d.org/x3d/content/X3dTooltips.html#ProtoInstance](http://www.web3d.org/x3d/content/X3dTooltips.html#ProtoInstance)
- [http://www.web3d.org/x3d/content/X3dTooltips.html#ProtoInterface](http://www.web3d.org/x3d/content/X3dTooltips.html#ProtoInterface)
## field

A field element defines an interface attribute or node.

**Type**: the `field` element name.

**Field Type**: a field type, such as `inputOutput`, `initOnly`, `outputOnly`, etc.

**Fields**: any special fields, such as a `default` value or a `description`.

**Node**: the `field` element is a `node` that can be referenced in a script.

**Values**: the field value, which can be a string or an XML node.

**Outputs**: any output fields, such as `value` or `description`.

**Inputs**: any input fields, such as `value` or `description`.

**Documentation**: any documentation, such as `description` or `example`.

---

**X3D tooltips for field**

[http://www.web3d.org/x3d/content/X3dTooltips.html#field](http://www.web3d.org/x3d/content/X3dTooltips.html#field)
<IS> and <connect>

<IS><connect> definitions link field interfaces to internal nodes within the prototype body. These direct links between outward-facing prototype interface fields and internal fields:

- Any initialization or routed input value for the ProtoInterface field definition goes directly into matching internal IS/connect fields.
- Any change to a connected internal field is routed out of the prototype, if `accessType='outputOnly'` or `accessType='inputOutput'`.

Multiple connections are allowed for each node and for field, both for inputs and for outputs.

Corresponding ClassicVRML construct: after field definition in prototype body, the keyword IS is appended, followed by name of corresponding field in proto interface, as shown in Table 14.4, pp. 389-391.
<connect>

IS / connect constructs link field interfaces to internal nodes within the prototype declaration

• Each named field IS connected to a prototype field
• Only legal to use within ProtoBody declarations

Each <connect> definition provides connection between a given field within local parent node and a corresponding <field> definition in the ProtoInterface

• Each name must match field, interface exactly
• Identical (eponymous) names often best for clarity
• Must also match type and accessType exactly

Corresponding ClassicVRML construct: after field definition in prototype body, the keyword IS is appended, followed by name of corresponding field in proto interface
<IS> and <connect> example

Prototype interface fields linked to internal fields

```
<ProtoDeclare appinfo='mimic a Material node and modulate fields as an animation effect'
    name='MaterialModulator'>
    <ProtoInterface>
        <field accessType='inputOutput' name='enabled' type='SFBool' value='true'/>
        <field accessType='inputOutput' name='diffuseColor' type='SFColor' value='0.8 0.8 0.8'/>
        <field accessType='inputOutput' name='emissiveColor' type='SFColor' value='0 0 0'/>
        <field accessType='inputOutput' name='specularColor' type='SFColor' value='0 0 0'/>
        <field accessType='inputOutput' name='transparency' type='SFFloat' value='0.0'/>
        <field accessType='inputOutput' name='shininess' type='SFFloat' value='0.2'/>
        <field accessType='inputOutput' name='ambientIntensity' type='SFFloat' value='0.2'/>
    </ProtoInterface>
    <ProtoBody>
        <Material DEF='MaterialNode'>
            <IS>
                <connect nodeField='diffuseColor' protoField='diffuseColor'/>
                <connect nodeField='emissiveColor' protoField='emissiveColor'/>
                <connect nodeField='specularColor' protoField='specularColor'/>
                <connect nodeField='transparency' protoField='transparency'/>
                <connect nodeField='shininess' protoField='shininess'/>
                <connect nodeField='ambientIntensity' protoField='ambientIntensity'/>
            </IS>
        </Material>
    </ProtoBody>
</ProtoDeclare>
```

http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter14-Prototypes/MaterialModulator.x3d

Note that you can <connect> multiple fields in a node to multiple protoFields, all at one time. Now we see why the <IS> element is used: to keep multiple <connect> definitions together.

Question: hey, where is the enabled field hook up? Hmm, can't be hooked up to the Material since that node doesn't an enabled field of it's own. Must be connected somewhere else...
<IS> editor is simple

<connect> editor prompts author to connect proper type and accessType between parent-node and prototype fields
X3D Tooltips for IS, connect

http://www.web3d.org/x3d/content/X3dTooltips.html#IS

http://www.web3d.org/x3d/content/X3dTooltips.html#connect
Connecting an embedded Script

A common design goal: create a Prototype that is a modified version of specific node

Example:

- Prototype name='NewMaterial'
- ProtoInterface holds definitions for all original fields plus possibly some additional fields
- ProtoBody initial node is essential: e.g. Material, fully linked by IS/connect definitions for each field
- Next (nonrendered) node is modifying Script, also holding IS/connect field definitions plus connection to Material (via ROUTE or DEF/USE in a field)

X3D-Edit feature: the ProtoDeclare editor offers an option to create a fully connected internal Script node by appropriately copying the prototype interface fields and then producing a Script containing corresponding field declarations and IS/connect definitions. When no \textit{appinfo} is already provided, default values can be inserted.
Connecting an embedded Script

X3D-Edit can insert Script if fields are defined

- May eventually add support for full design pattern

```xml
<ProtoBody>

<Script DEF="MaterialModulatorScript">
  <field accessType="inputOutput" name="enabled" type="SFBool"/>
  <field accessType="inputOutput" name="diffuseColor" type="SFColor"/>
  <field accessType="inputOutput" name="emissiveColor" type="SFColor"/>
  <field accessType="inputOutput" name="specularColor" type="SFColor"/>
  <field accessType="inputOutput" name="transparency" type="SFFloat"/>
  <field accessType="inputOutput" name="shininess" type="SFFloat"/>
  <field accessType="inputOutput" name="ambientIntensity" type="SFFloat"/>

  <IS>
    <connect nodeField="enabled" protoField="enabled"/>
    <connect nodeField="diffuseColor" protoField="diffuseColor"/>
    <connect nodeField="emissiveColor" protoField="emissiveColor"/>
    <connect nodeField="specularColor" protoField="specularColor"/>
    <connect nodeField="transparency" protoField="transparency"/>
    <connect nodeField="shininess" protoField="shininess"/>
    <connect nodeField="ambientIntensity" protoField="ambientIntensity"/>
  </IS>

</Script>

<ProtoBody>
```
ExternProtoDeclare

ExternProtoDeclare references an individual ProtoDeclare definition in an external scene

- Allows single “master” definition of a prototype, avoids versionitis from cut/paste redistributions
- Multiple prototype nodes require multiple ExternProtoDeclare statements

Includes <field> definitions matching interface signature of the original prototype

- Minus initial values, so that conflicts are avoided
- Allows X3D browser to “understand” new nodes and create proper scene graph when loading

Corresponding ClassicVRML construct: EXTERNPROTO, followed by name, as shown in Table 14.6, pp. 395-396.

Some or all ExternProtoDeclare field definitions can be omitted if they are not initialized and not used by any of the corresponding ProtoInstance nodes.
Chapter 14 - Creating Prototype Nodes

http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter14-Prototypes/ArtDecoExamplesExcerpt.x3d
**ExternProtoDeclare editor X3D-Edit**

**ExternProtoDeclare editor for multiple url values**
- Note #ProtoName appended to each filename
- Can edit, locally load, or launch each address
- Can sort url list (relative, .x3d before online, .wrl)

http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter14-Prototypes/ArtDecoExamplesExcerpt.x3d

Note that the *appinfo* field is typically a short description, suitable as a tool tip.
Note that the *documentation* field is typically a single url value linking to a help page.

A check button lets you confirm whether the ExternProtoDeclare definitions match the parent ProtoDeclare in a separate file. If there is a mismatch, the incorrect data fields are highlighted in read. The second button will then replace and fix any mismatches.

Loading the scene holding the referenced ProtoDeclare is sometimes convenient.

Author-assist editing feature allows you to append a corresponding new ProtoInstance that implements this ExternProtoDeclare.

**TODO:** add … launch button for documentation url
appinfo, documentation attributes

The appinfo and documentation attributes accompany ProtoDeclare, ExternProtoDeclare and field definitions

- appinfo holds a simple summary or tooltip
- documentation holds a url to further information

These match identical constructs in XML Schema

- Allowing tools to further support authoring, editing
- Allowing authors to properly document new nodes

These are important to use, and help long-term extensibility of your work and X3D itself

TODO under consideration: define X3D specification syntax for adding appinfo and documentation definitions to the ClassicVRML encoding.
ProtoInstance

Finally you can make copies of your new node: create Prototype instances using ProtoInstance

- Must be preceded by either ProtoDeclare or ExternProtoDeclare with same name
- Otherwise a run-time error results for end user

Nevertheless simple to invoke and instantiate:

```xml
<ProtoInstance name='ArtDeco00'/>
```

Can override default initialization values for fields

- This is how a prototype is customized upon creation
- `<fieldValue name='someField' value='someValue'/>`
- Can also initialize child nodes, if any

Corresponding ClassicVRML construct: no keyword, simply use of the prototype name when a node is expected, as shown in Table 14.7, page 398.
ProtoInstance X3D-Edit 1

ArtDecoExamplesExcerpt.x3d

http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter14-Prototypes/ArtDecoExamplesExcerpt.x3d

Need ProtoInstance editor snapshot (TODO, bug 1765, fails when no fieldValue given)
**containerField** considerations

*containerField* is how the field name for a node is provided, relative to the node's parent

- Usually not needed since default matches most common case: *containerField* = 'children'
- ClassicVRML syntax is different, more verbose
- As ever, functionality is identical

<!-- Rendered geometry follows prototype declaration -->
```
<Shape>
  <Sphere/>
  <Appearance>
    <ProtoInstance containerField='material' name='MaterialModulator'>
      <fieldValue name='enabled' value='true'/>
      <fieldValue name='diffuseColor' value='0.5 0.1 0.1'/>
    </ProtoInstance>
  </Appearance>
</Shape>
```

There have been a number of proposals to make ProtoInstance elements into “native node” elements, and to replace the containerField attribute with named elements, also called “wrapper tags.” Although these approaches have some interesting characteristics, they also have a significant number of drawbacks when applied to XML syntax.

The primary virtue of the ProtoInstance/containerField approach is that author-defined prototype instances can be validated by XML. By contrast, defining new XML elements that match the prototype names is visually appealing, but this approach quickly leads to nonvalidatable, erroneous content. So X3D doesn't do that.
fieldValue initializations

fieldValue name must match; initialization values must match the type specified in declaration

- Otherwise a run-time error results for end user
- Take special care to check correctness, avoid errors

To initialize simple types: use `value` parameter

```xml
<ProtoInstance name='MaterialModulator'
    containerField='material'>
    <fieldValue name='enabled' value='true'/>
    <fieldValue name='diffuseColor' value='0.5 0.1 0.1'/>
</ProtoInstance>
```

Re-using the same default initialization value is OK. Actually this is a common debugging technique when testing various combinations of field initialization values.
fieldValue initializations

To initialize SFNode or MFNode types, use contained nodes within the fieldValue element:

```xml
<ProtoInstance name='SomethingNew'>
  <fieldValue name='newSFNodeField'>
    <!-- initialization node goes here -->
  </fieldValue>
</ProtoInstance>
```

As might be expected, fieldValue initializations are only allowed for fields with `accessType` of `initializeOnly` or `inputOutput`.

Re-using the same default initialization value is OK. Actually this is a common debugging technique when testing various combinations of field initialization values.
The ProtoDeclare editing panel provides a single interface to enter, view and change ProtoDeclare, ProtoInstance, and ProtoBody.

A separate panel for individual field editing is also provided:
Note that the editing panel shows that only two <fieldValue> initializations are being overridden. The other <fieldValue> defaults are shown as a convenience.

The screen snapshot series in the lower right illustrate how the diffuseColor for the MaterialModulator nodes causes the Sphere appearance to change rapidly.

A separate panel for individual <fieldValue> editing is also provided. Note that it will list all available fields, allowing selection of the field of interest to be overridden. Here is the same <fieldValue> editing panel shown on the slide above, but with the author selecting the pull-down menu to choose the already-defined field of interest.
### X3D Tooltips for ProtoInstance and *fieldValue*

http://www.web3d.org/x3d/content/X3dTooltips.html#ProtoInstance

http://www.web3d.org/x3d/content/X3dTooltips.html#fieldValue
Advanced Examples
Detailed example: ViewFrustum

ViewFrustum is a helpful visualization prototype
- Prototypes simplify creation of new X3D nodes
  Shows near and far clipping planes that truncate the viewable area
- Depends on Viewpoint and NavigationInfo parameters

Viewpoint and NavigationInfo fields are covered in Chapter 4, Viewing and Navigation.

http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter14-Prototypes/ViewFrustumExample.x3d
ViewFrustrum prototype, example

Good practice: make two separate files to simplify ExternProtoDeclare reuse

http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter14-Prototypes/ViewFrustrumPrototype.x3d

http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter14-Prototypes/ViewFrustrumExample.x3d
Prototype features of interest

Highlighted ProtoDeclare, ExternProtoDeclare, ProtoInstance and Script show:
  • Using initialize() method to setup geometry nodes
  • Usage of IS/connect for direct node inspection
  • Usage of event-passing via ROUTE when changing Extrusion, which doesn’t support direct modification
  • Matching type and accessType, toString() function
  • External script code, accessing node fields
  • Duplicate url addresses, local and remote
  • Browser.println statements, silencable by trace field
  • Internal var declarations, Javascript Math library
Chapter 4 - Viewing and Navigation

ViewFrustrum Prototype field definitions

Coordinate points for outline, need initialization

Extrusion for frustum polygons, need initialization

Small Sphere shows Viewpoint position

http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter14-Prototypes/ViewFrustrumPrototype.x3d
Match ProtInterFace field definitions

Output fields for ROUTE links

IS/connect links match field definitions

User selects Text message to launch example scene

http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter14-Prototypes/ViewFrustumPrototype.x3d
Editing the Script as a separate file provides Netbeans javascript syntax checking, code coloration, code completion, etc. This can catch a lot of errors.

Script header:

```javascript
// Description: Perform geometric computations for ViewFrustratum prototype
// Filename:    ViewFrustrumScript.js
// Author:      Don Brutzman
// Identifier:  http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter14-Prototypes/ViewFrustrumScript.js
// Created:     16 August 2008
// Revised:     17 August 2008
// Reference:   ViewFrustrumPrototype.x3d
// Reference:   ViewFrustrumExample.x3d
// Drawing:     ViewFrustrumComputation.png
// License:     ../license.html
```
ExternProtoDeclare, ProtoInstance examples field definitions, no initializations

fieldValue initializations override default values

http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter14-Prototypes/ViewFrustumExample.x3d
Additional Prototype Examples

Numerous prototypes and examples are available in the Savage archive, especially

- https://savage.nps.edu/Savage/Tools/Animation
- https://savage.nps.edu/Savage/Tools/Authoring
  Animated Viewpoint Recorder, Single Type Conversion, View Position Orientation

Each of these prototypes has both __Prototypes.x3d and __Examples.x3d scenes, showing ProtoDeclare definitions and separate ExternProtoDeclare invocations.

Looking at examples is very helpful for designing your own prototypes.

Each of these are maintained under version control and offered under an open-source license.

https://savage.nps.edu/svn/nps/Savage
Chapter Summary
Chapter Summary

Concepts
• Motivation and Functional Summary

Functional Descriptions and Examples
• ProtoDeclare, ProtoInterface, ProtoBody and field declarations
• IS / connect linking of field interfaces to internals
• ExternProtoDeclare and field signatures
• ProtoInstance, containerField, fieldValue initializations
• Advanced examples: design and re-use
Suggested exercises

Add a given external prototype declaration and instance to improve an already-existing scene

Write three prototypes of increasing complexity:

- No ProtoInterface, no field definitions
- One or more field definitions, no Script
- Multiple field definitions, multiple IS/connect, Script

Design a multiple fan-in fan-out prototype by emulating an existing X3D node while adding new functionality

- Example: MaterialModulate
References
References

X3D: Extensible 3D Graphics for Web Authors
by Don Brutzman and Leonard Daly, Morgan Kaufmann Publishers, April 2007, 468 pages.

- Chapter 14, Creating Prototype Nodes
- http://x3dGraphics.com
- http://x3dgraphics.com/examples/X3dForWebAuthors

X3D Resources
- http://www.web3d.org/x3d/content/examples/X3dResources.html
Prototyping Excerpts from Scene Authoring Hints

**Prototype Declarations**
* Follow X3D naming conventions for node and field definitions.
* Provide useful/safe default initialization values for each field, rather than depending on default field values internal to the ProtoBody.
  * Include annotation tooltips for each field.
  * Avoid copying ProtoDeclare definitions into scenes, instead copy ExternProtoDeclare/ProtoInstance definitions.
  * Tooltips for ProtoDeclare, ProtoInterface and ProtoBody
  * X3D specification

**External Prototype Declarations**
* Do not wrap field definitions in a ProtoInterface element since that construct is illegal.
* For important prototypes, make a separate NewNodeExample.x3d scene that provides copyable/reusable ExternProtoDeclare/ProtoInstance definitions corresponding to each NewNodePrototype.x3d scene. This encourages authors to avoid copying ProtoDeclare definitions, so that a master version remains stable and improvable.
  * Do not include initialization values in field definitions. They are illegal since the defaults in the original ProtoDeclare field declarations take precedence.
  * Copy annotation tooltips from corresponding ProtoDeclare tooltips for each ExternProtoDeclare field.
  * ExternProtoDeclare tooltips and X3D specification

**Prototype Instances**
* Explicitly include initialization values, even if they match default values, to ensure proper operation. Sometimes a prototype can have different initialization values than expected, if it is modified elsewhere.
  * Remember to include proper containerField attribute, identifying parent-node field name for this ProtoInstance. Default value: children. Example values: color, coord, geometry, fontStyle, proxy, sound, texture, textureTransform.
  * First debug proper ProtoInstance operation in the scene defining the original ProtoDeclare, rather than using an ExternProtoDeclare. Why - to make sure they work first! Browser debugging can be more cryptic for externally defined prototypes and different versions may occur in various remote url addresses, making it difficult to determine precisely which ExternProtoDeclare is being referenced.
  * ProtoInstance tooltips and X3D specification

References

X3D-Edit Authoring Tool
* https://savage.nps.edu/X3D-Edit

X3D Scene Authoring Hints
* http://x3dgraphics.com/examples/X3dSceneAuthoringHints.html (especially those for Inline and Prototypes)

X3D Graphics Specification
* http://www.web3d.org/x3d/specifications
  * Also available as help pages within X3D-Edit
References 3


- http://www.wiley.com/legacy/compbooks/vrml2sbk/cover/cover.htm
- http://www.web3d.org/x3d/content/examples/Vrml2.0Sourcebook
- Chapter 31 - Prototypes
CGEMS, SIGGRAPH, Eurographics

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*X3D for Web Authors* recognized by CGEMS! 
• Book materials: X3D-Edit tool, examples, slidesets
• Received jury award for Best Submission 2008

CGEMS supported by SIGGRAPH, Eurographics

From the CGEMS home page:
• http://cgems.inesc.pt

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Good references on open source:
