Universität Bielefeld

Realtime 3D Computer Graphics
Virtual Reality

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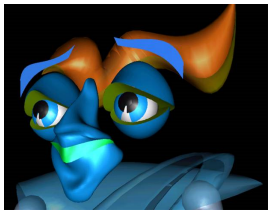


VRML and X3D

Virtual Reality Modeling Language
Extensible 3D

VRML – X3D

- X3D is a considerably more mature refined standard than VRML (taken from www.web3d.org)
- VRML compatible
  - "Classic VRML" encoding which can play most non-scripted VRML 2 worlds with only minor changes.
  - None of the technology has been lost; instead, it has evolved into X3D.
  - X3D has made a very large effort to maintain as much compatibility with VRML as possible while still solving incompatibility problems that directly lead to non-interoperability of environments between players.
- XML encoding to integrate smoothly with other applications
  - XML is fast becoming a prerequisite for including information in corporate and government data bases.
  - Having an XML encoding simply makes it easier to manage, control, validate, and exchange information. The XML encoding of X3D plays nicely in this world.
- X3D scenes and environments operate predictably between different players
  - A major problem with VRML is that it is difficult to develop VRML environments that play on all conformant browsers/players. This is due to lack of adequate specification of VRML behavior in the VRML standard. A concerted effort has been made to provide adequate specification of X3D behavior in such a way that scenes and environments can interoperate between browsers.
- X3D is componentized
  - X3D is componentized which allows for the specification of profiles tailored to a particular large market segment (e.g., CAD, Medical, Visualization). It also allows cleaner introduction of new technology as the industry develops.
- X3D authoring for any player is consistent and simpler
  - X3D Scene Authoring Interface provides consistent functionality for all scripting languages both internal and external (not true of VRML where Java and ECMAScript have widely different programming models).
  - X3D SAI solves all of this by specifying a unified set of abstract services that can then be mapped to any programming/scripting language (environments play consistently regardless of programming language).
  - Language bindings have been provided for Java and ECMAScript. This makes authoring X3D much simpler.

VRML – X3D

- X3D is more feature rich
  - A large number of features requested for VRML have been provided in X3D in a manner that is completely integrated into the architecture (as well as being standardized).
  - Thus, many ad hoc solutions that are vendor-specific have been avoided. You can think of X3D as "VRML3".
- X3D is continually being enhanced and updated
  - X3D is growing in functionality. Proposed Draft Amendment 1 specification adds such things as 3D textures and shading languages is available.
  - This also corrects some identified anomalies in the original X3D specification.
  - Structure of X3D makes it much easier to update on a regular basis. It is also easier to add new features that adapt to the changing graphics and commercial markets.
- X3D applications can be certified as reliable and predictable
  - An X3D conformance program is being developed by the Web3D Consortium to provide service marks for conformant X3D software. This means authoring and playback applications (browsers/players) will be reliable and predictable.
- An X3D open source conformant application is available as a developer resource
  - An open source implementation of nearly all of X3D (Xj3D) is available and proprietary conformant browsers such as Flux are also being developed.
  - Unlike with VRML scenes, X3D scenes will play consistently in each conformance certified player.
- X3D binary format offers encryption (i.e. security) and compression (i.e. speed)
  - A Compressed Binary encoding is under development that allows encryption for model security and very high compression (signficantly more compressed than VRML's gzip) of X3D environments.
  - Scene parsing and loading speedups of 300-500% are commonplace.
  - Note that it is easy for all browsers to support all encodings since the only real difference in an implementation between them is that a different parser is required. Thus, the encodings can be intermixed in a world provided that the browser supports all of the used encodings. Current X3D browser developers plan to support all of the encodings.

1. VRML information

- **The VRML repository**: http://www.web3d.org/vrml/vrml.htm
- **Browsers and plug-ins**: z.B. cosmo player http://www.cai.com/cosmo/home.htm
- **Books** (example):
  VRML 2.0 Source Book, Andrea L. Ames, David R. Nadeau and John L. Moreland, 2nd Edition, Wiley & Sons, 1996. ISBN 0-471-16507-7

VRML-models in the www

- http://www.web3d.org/vrml/oblib.htm
- http://www.rdservice.de/german/produkte/VRCreator/library/vrlibrary.htm
- http://home.t-online.de/home/kiwano6/models.htm
- http://www.rccad.com/Gallery.htm

VRML Files

ASCII Files: `<my_world>.wrl`

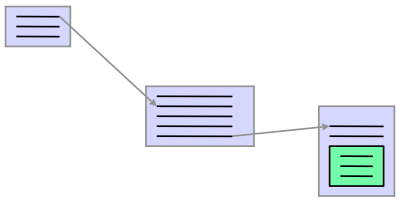
- **VRML header**: `#VRML V2.0 utf8`
- Comments: `#`
- **Prototypes**
- **Nodes**: Shapes, transformations, timers, interpolators, sensors, scripts, ...
- **Routes**

utf8 is an international character set standard. It stands for: UCS (Universal Character Set) Transformation Format, 8-bit. Encodes 24,000+ characters for many languages, ASCII is a subset

Object description in VRML

Nodes (in an acyclic graph) with

- **Fields** and **Field Values** of predifined **Field Value Types**
  - **Inputs** and **Outputs**
  - **Bounding Boxes**



Examples:

- Shape nodes
  `Shape {appearance SFNode, geometry SFNode}`
- Geometry nodes
  `Cylinder {height SFFloat, radius SFFloat}`
- Appearance nodes
  `Appearance {material SSFNode, texture ...}`

Minimal VRML-worlds

```
#VRML V2.0 utf8

# generic cylinder
Shape {
    geometry Cylinder {
    } # Cylinder
} # Shape
```

```
#VRML V2.0 utf8

# cylinder of variable
  size
Shape {
    geometry Cylinder {
        height 4.0
        radius 2.0
    } # geometry Cylinder
} # Shape
```


Minimal VRML-worlds

```
#VRML V2.0 utf8

# colored cylinder of variable size
# with missing pieces

Shape {
    appearance Appearance {
        material Material {
            diffuseColor 0.5 0.5 0.0
        } # material Material
    } # appearance Appearance
    geometry Cylinder {
        height    4.0
        radius    1.5
        side      TRUE
        top       FALSE
        bottom    TRUE
    } # geometry Cylinder
} # Shape
```

More geometry nodes

- Box {size ...}
- Cone {bottomRadius ..., height ..., ...}
- Sphere {radius ...}
- Text {string [“...”, “...”, ...], fontStyle ..., ...}

3. combination of objects

- Inlining of files

```
Inline {url [..., ...], ...}
```

- geometric Transformationen

```
Transform {
    children [...]
    translation ... ... ...
    Rotation ... ... ... ...
    Scale ... ... ...
}
```

Example: sphere and cylinder

```
#VRML V2.0 utf8

# 1. Object
Inline {url "sphere.wrl"} # Inline sphere

# 2. Object
Transform {
    translation 0.0 2.0 0.0
    rotation 0.0 0.0 1.0 -0.524   # radians; 30
  degrees
    children [ Inline {url "cylinder-c.wrl”} ]
} # Transform
```


Example: wooden parts (Baufix)

```
#VRML V2.0 utf8
Transform {
    translation -6.0 0.5 0.0
    children [ Inline {url "yellow-box1.wrl"} ]
} # Transform
Transform {
    translation -4.5 1.0 0.0
    children [ Inline {url "blue-box2.wrl”} ]
} # Transform
...
```

4. Reuse of models

multiple use of objects

- Inlining
- DEF und USE

```
DEF Green-Box3
    Inline {url "../blocks-
       world/green-box3.wrl"
    } # Inline cylinder
...
USE Green-Box3
```

multiple use of object groups

- Groups

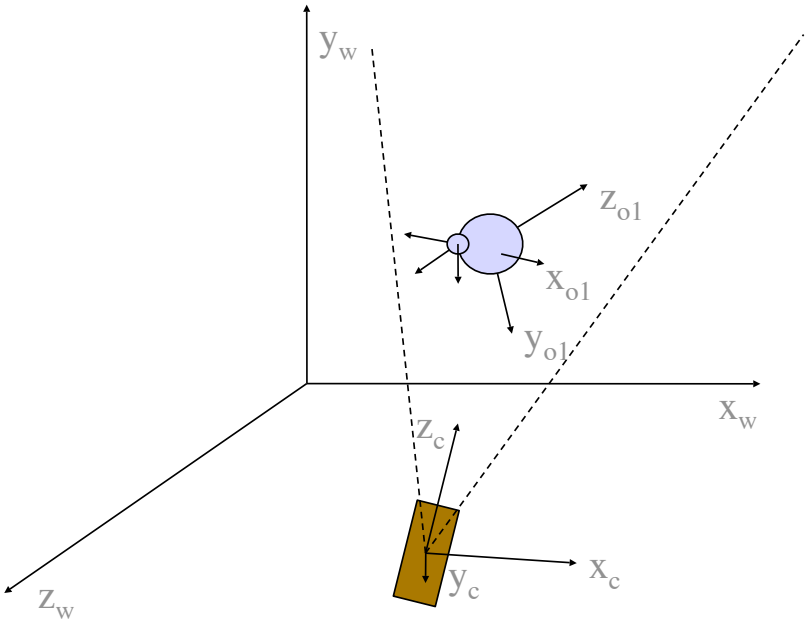
```
Group {
    children [
        ...
    ]
    ...
}
```


Example: replicated model

```
DEF Rep-Structure Group {
    children [
        DEF Baufix-Structure Inline {url "structure-group.wrl"} # 1.
   structure
        Transform
   {                                                          #
   replicated structure
            translation 0.0 0.0 -2.0
            children [USE Baufix-Structure]
        } # Transform 2. Structure
        # ... Further structures ...
    ] # children
} # group
Transform {
    translation 5.0 0.0 0.0
    children [USE Rep-Structure]
   # replicated group
}
```

CS in virtual worlds

- world CS
- object(s)
- camera(s)



5. Viewpoints

- Position of virtual camera with respect to the embedding CS

```
Viewpoint {
    description "initial camera position"
    position  0.0  0.0  25.0
    orientation  0.0  0.0  1.0    0.0
    fieldOfView  0.785   # 45 degrees
}
```

avatar navigation model

- movement types
  - Walk
  - Fly
  - Examine
  - NONE
- Speed
- Size
- Headlight
- Frustum

```
NavigationInfo {
    type "EXAMINE"
    headlight  TRUE
    visibilityLimit
0.0
    avatarSize [0.25
1.6  0.75]
}
```


6. Animation in dynamic worlds

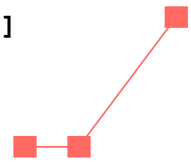
- Sensors: "Sources" of events
  - TimeSensor
  - Interactive sensors
  - Collision detection

```
TimeSensor {
    enabled    TRUE
    startTime    0.0
    stopTime    0.0
    cycleInterval
1.0
    loop   TRUE
    fraction_changed
    time
}
```

Movement Interpolationen (keyframe animation)

- VRML: linear interpolation between n **key frames**

```
PositionInterpolator {
    key [0.0  0.3  0.55]
    keyValue [
        0.0  0.0  0.0
        1.0  0.0  0.0
        3.5  3.5  0.0
    ]
    set_fraction
    value_changed
}
```



```
OrientationInterpolator {
    key [0.55  0.6  1.0]
    keyValue [
        0.0  0.0  1.0  0.0
        0.0  0.0  1.0  1.571
        0.0  0.0  1.0  6.284
    ]
    set_fraction
    value_changed
}
```


7. Routing between fields

- Route: connection between object node fields to propagate events

```
DEF T TimeSensor {
    enabled
    fraction_changed
}
```

```
DEF P
PositionInterpolator {
    key [...]
    keyValue […]
    set_fraction
    value_changed
}
```

```
DEF O Transform {
    translation ...
    rotation …
    children [
        shape {

geometry ...
} ]   }
```

```
ROUTE T.fraction_changed TO P.set_fraction
ROUTE P.value_changed    TO O.set_translation
```

8. Anchor points

- Connection between two virtual worlds are established by anchor points
- (e.g., dungeon worlds, game levels)

```
Anchor {
    url ["…", ...]
    children […Box{}...]
    description "…"
    ...
}
```


Anchors in AR-applications

- "hot-spots"
  - in 3D Menus (e.g., beside the object "at the wall") for a dynamic, time-dependent help
  - in virtual models to augment specific areas with information
  - in virtual models to switch between alternative object views
  - in reality to visit alternative camera positions

9. Sensors

- Sensors for different interaction types:
  - Pointer position (TOUCH): **isOver, isActive**
    ```
    DEF Touch-Green TouchSensor{}
    ROUTE Touch-Green.touchTime TO Clock.set_startTime
    ```
  - Pointer motion (MOTION)
    - CylinderSensor
    - PlaneSensor
    - SphereSensor
      ```
      DEF Spin-Cylinder SphereSensor{}
      ROUTE Spin-Cylinder.rotation_changed TO Red-Cylinder2-
      b.set_rotation
      ```
  - If sensors are embedded, the most inner wins
  - Different incrementation modes (offsets)

10. Scripts

- Connection VRML -> Java to enable more complex simulations
- Movement paths of objects (e.g., to realize physical object behaviors)
  - Intelligent object responses
  - Communication in distributed systems (e.g., games with multiple players)

Scripts

- Example: Movement interpolator

VRML:

```
DEF Mover Script {
    url "move1.js"
    eventIn     SFFloat    set_fraction
    eventOut   SFVec3f   value_changed
}
...
ROUTE Clock.fraction_changed TO Mover.set_fraction
ROUTE Mover.value_changed TO  Red-Cylinder2-b.set_translation
```

Java file (move1.js):

```
// move a shape in a sinusoidal path
function set_fraction (fraction,eventTime) {
    value_changed[0] = 6.0 + Math.sin (fraction * 6.28); // x component
    value_changed[1] = -2.0; // y component
    value_changed[2] = -2 +fraction*4; // z component
}
```


VRML

Interactive demonstration

Examples

Sensor nodes

- ... sense *changes*
- ... watch attributes
- ... react to changes
- ... trigger an control animations

Types of sensor nodes (using VRML)

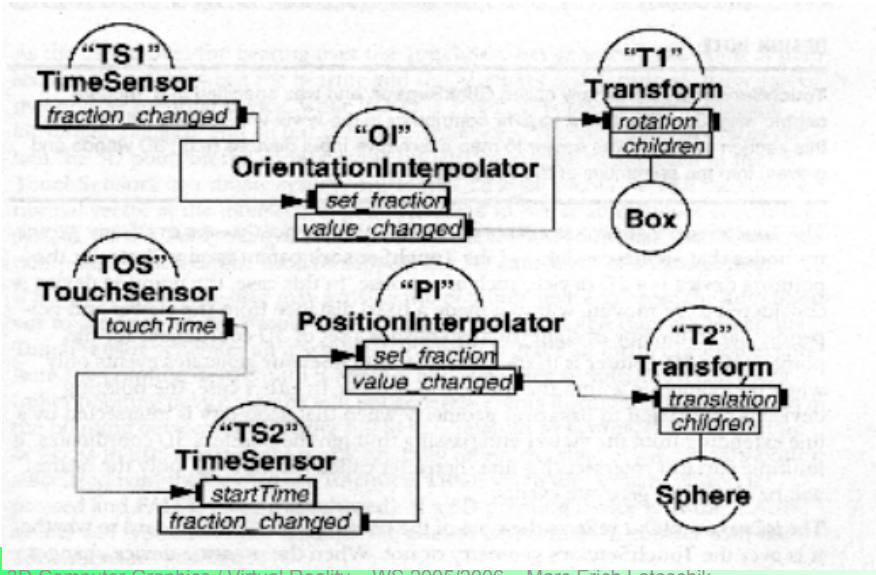
environment sensors

- Proximity Sensor
- Time Sensor
- Visibility Sensor
- *Collision*

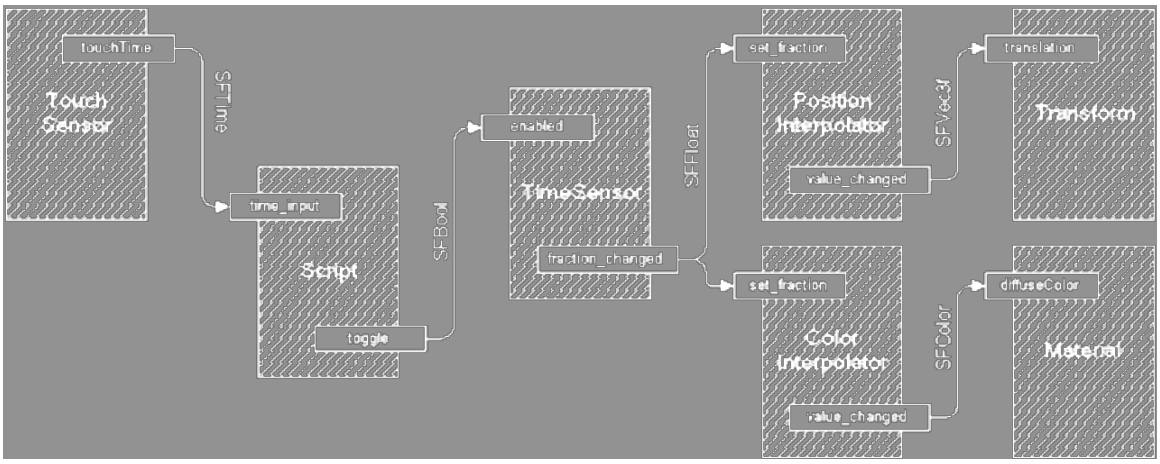
input sensors

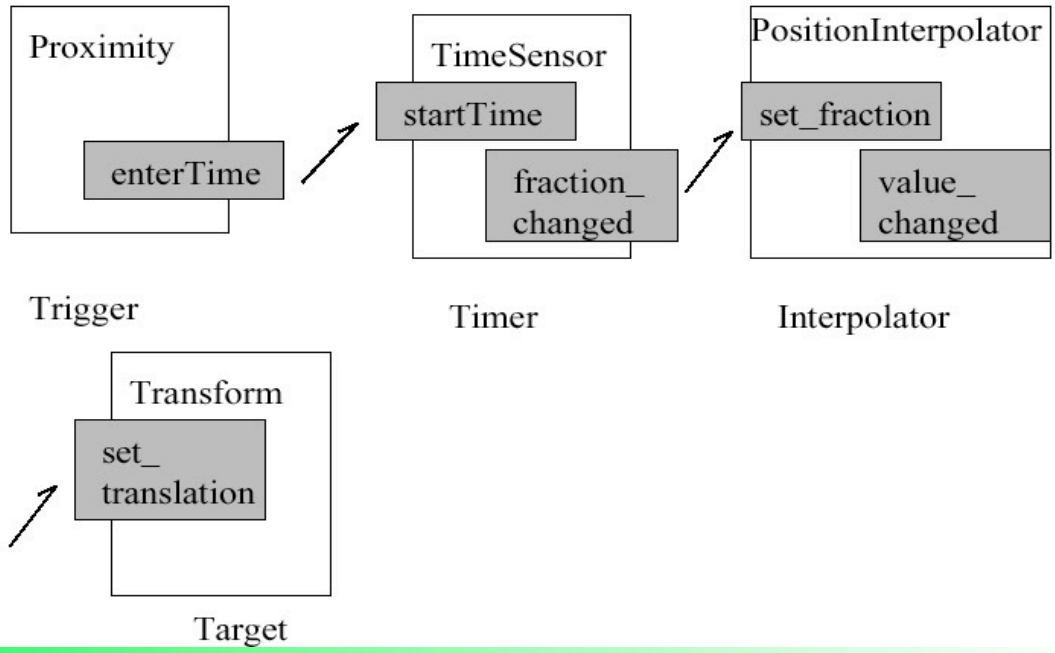
- Anchor
- Cylinder sensor
- Sphere sensor
- Touch sensor
- Plane sensor

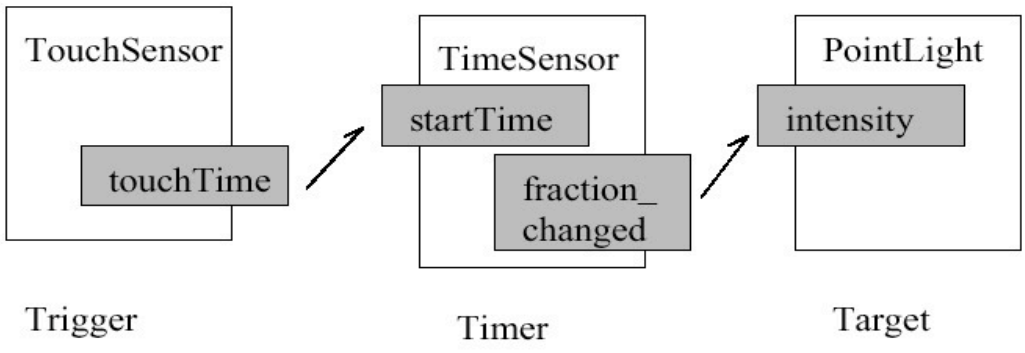
sensor-event-routing



sensor-event-routing




Proximity
enterTime
TimeSensor
startTime
fraction_
changed
PositionInterpolator
set_fraction
value_
changed
Trigger
Timer
Interpolator
Transform
set_
translation
Target


TouchSensor
touchTime
TimeSensor
startTime
fraction_
changed
PointLight
intensity
Trigger
Timer
Target

time sensor

- abstract *wall clock*
- no position in the virtual scene
- generation of repeating (or unique) events
- e.g., to drive an interpolation

➪ This concept is the basis for animations!

time sensor (VRML)

```
TimeSensor {
   exposedField   SFTime      cycleInterval      1
   exposedField   SFBool      enabled            TRUE
   exposedField   SFBool      loop               FALSE
   exposedField   SFTime      startTime          0
   exposedField   SFTime      stopTime           0
   eventOut       SFTime      cycleTime
   eventOut       SFFloat     fraction_changed
   eventOut       SFBool      isActive
   eventOut       SFTime      time
}
```

visibility sensor

- activates if it comes into view (almost like an interaction sensor)
- can activate certain simulation parts to avoid unnecessary calculations

visibility sensor (VRML)

```
VisibilitySensor {
   exposedField   SFVec3f     center          0 0 0
   exposedField   SFBool      enabled         TRUE
   exposedField   SFVec3f     size            0 0 0
   eventOut       SFTime      enterTime
   eventOut       SFTime      exitTime
   eventOut       SFBool      isActive
}
```

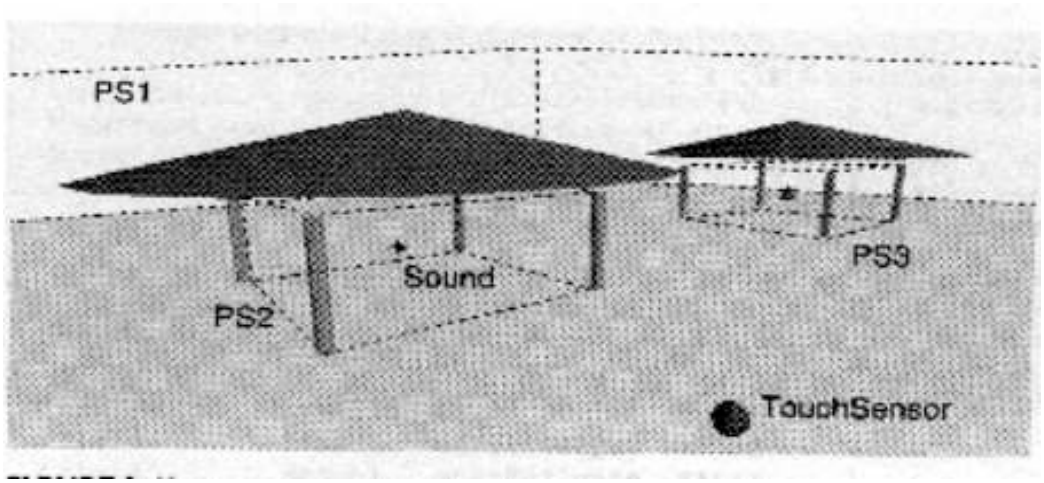
proximity sensor

- activates if the user (e.g., the view platform) reaches the sensors proximity
- is activated during the whole time something is in its proximity
- Can test for different proximity shapes (e.g., a box in VRML)

proximity sensor (VRML)

```
ProximitySensor {
   exposedField   SFVec3f     center              0 0 0
   exposedField   SFVec3f     size                0 0 0
   exposedField   SFBool      enabled             TRUE
   eventOut       SFBool      isActive
   eventOut       SFVec3f     position_changed
   eventOut       SFRotation  orientation_changed
   eventOut       SFTime      enterTime
   eventOut       SFTime      exitTime
}
```

proximity sensor (Box, VRML)

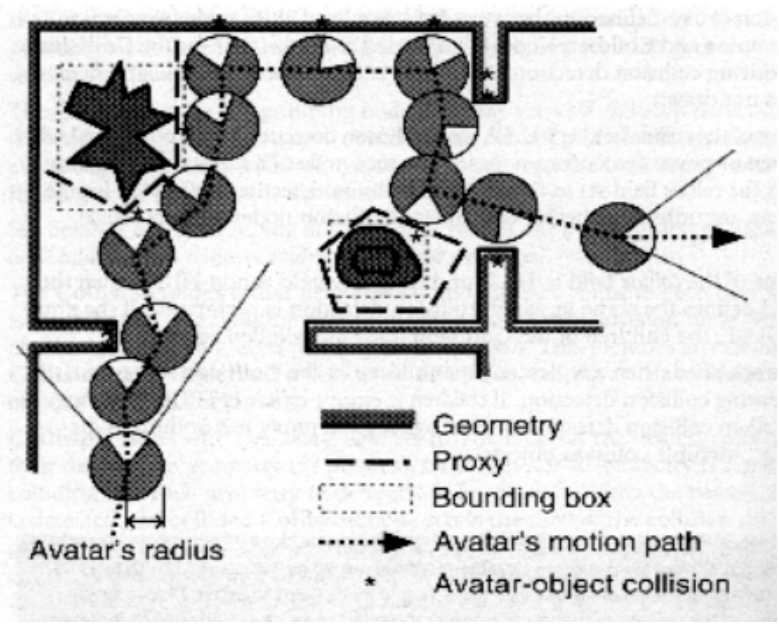


collision (VRML)

- tests for collision with the user (the view platform)
- is implemented as a group node
- has additional alternative test geometry (e.g., to speed up calculation)

➪How would you implement an arbitrary collision engine?

collision (VRML)



collision (VRML)

```
Collision {
   eventIn        MFNode     addChildren
   eventIn        MFNode     removeChildren
   exposedField   MFNode     children       []
   exposedField   SFBool     collide        TRUE
   field          SFVec3f    bboxCenter     0 0 0
   field          SFVec3f    bboxSize       -1 -1 -1
   field          SFNode     proxy          NULL
   eventOut       SFTime     collideTime
}
```

interaction sensors

- map data from input devices to scene changes
- input devices: mouse, trackball, stylus, gloves or gesture events
- detects **`isOver`** and **`isActive`** as events

Touch Sensor (VRML)

- Detektiert Mausinteraktion mit *benachbarter* Geometrie
- Liefert Touchtime (Zeit zwischen button down und button up)
- Liefert Normale, Punkt und Texturkoordinate am Auftreffpunkt (während **`isOver`**)

Touch Sensor (VRML)

```
TouchSensor {
   exposedField   SFBool      enabled            TRUE
   eventOut       SFVec3f     hitNormal_changed
   eventOut       SFVec3f     hitPoint_changed
   eventOut       SFVec2f     hitTexCoord_changed
   eventOut       SFBool      isActive
   eventOut       SFBool      isOver
   eventOut       SFTime      touchTime
}
```

➪Frage: Wie ist das Touch Sensor Konzept auf immersive VR Anwendungen zu erweitern?

Drag Sensoren

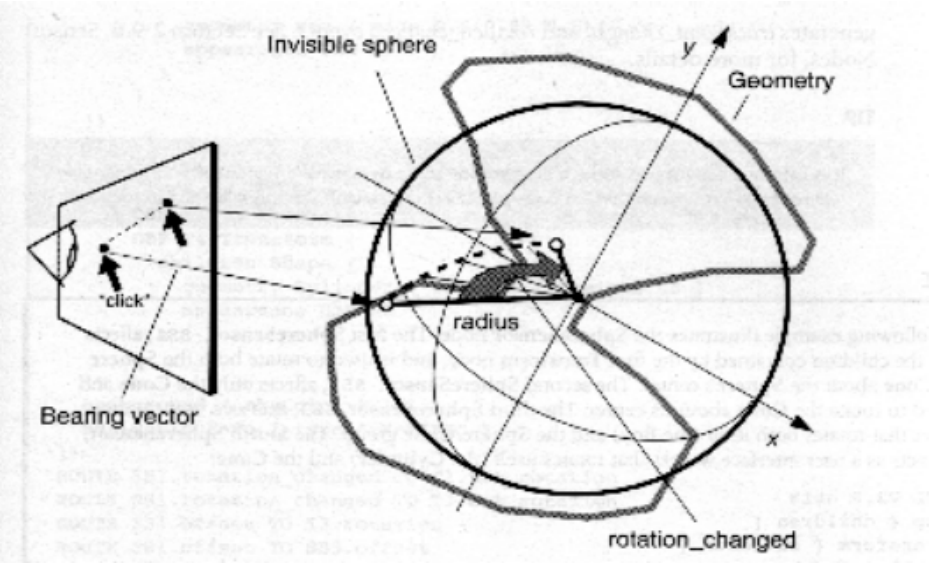
- Spezielle Interaktionssensoren
- *Mappen* Pointing-Device Bewegungsinformationen auf Objektänderungen
- Siehe dazu z.B. auch die OpenInventor Klassenbibliothek

Sphere Sensor (VRML)

- Rotiert benachbarte Geometrie um den Nullpunkt des Sensors

```
SphereSensor {
   exposedField   SFBool       autoOffset          TRUE
   exposedField   SFBool       enabled             TRUE
   exposedField   SFRotation   offset              0 1 0 0
   eventOut       SFBool       isActive
   eventOut       SFRotation   rotation_changed
   eventOut       SFVec3f      trackPoint_changed
}
```


Sphere Sensor (VRML)

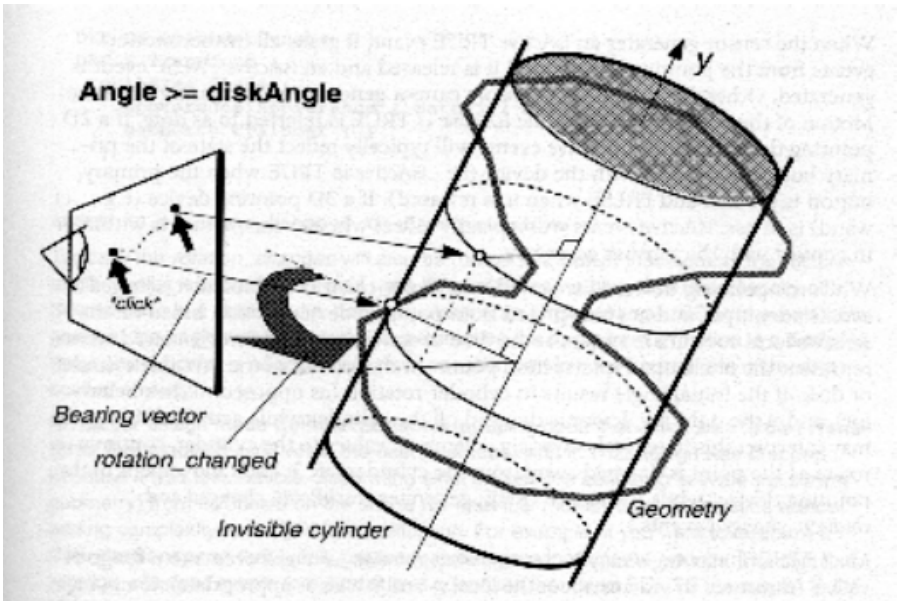


Cylinder Sensor (VRML)

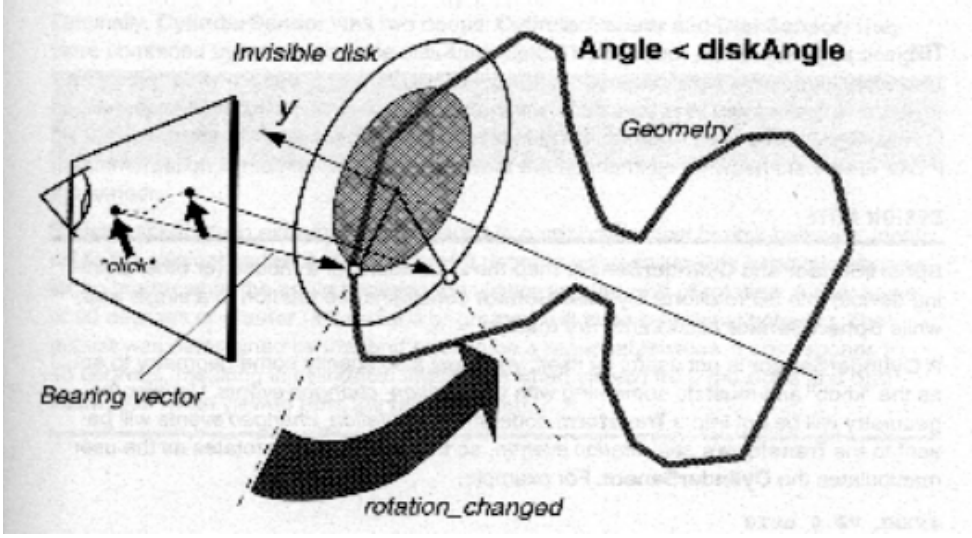
- Rotiert benachbarte Geometrie in zwei Arten um die y-Achse des Sensors

```
CylinderSensor {
   exposedField   SFBool      autoOffset          TRUE
   exposedField   SFFloat     diskAngle           0.262
   exposedField   SFBool      enabled             TRUE
   exposedField   SFFloat     maxAngle            -1
   exposedField   SFFloat     minAngle            0
   exposedField   SFFloat     offset              0
   eventOut       SFBool      isActive
   eventOut       SFRotation  rotation_changed
   eventOut       SFVec3f     trackPoint_changed
}
```


Cylinder Sensor (VRML)



Cylinder Sensor (VRML)

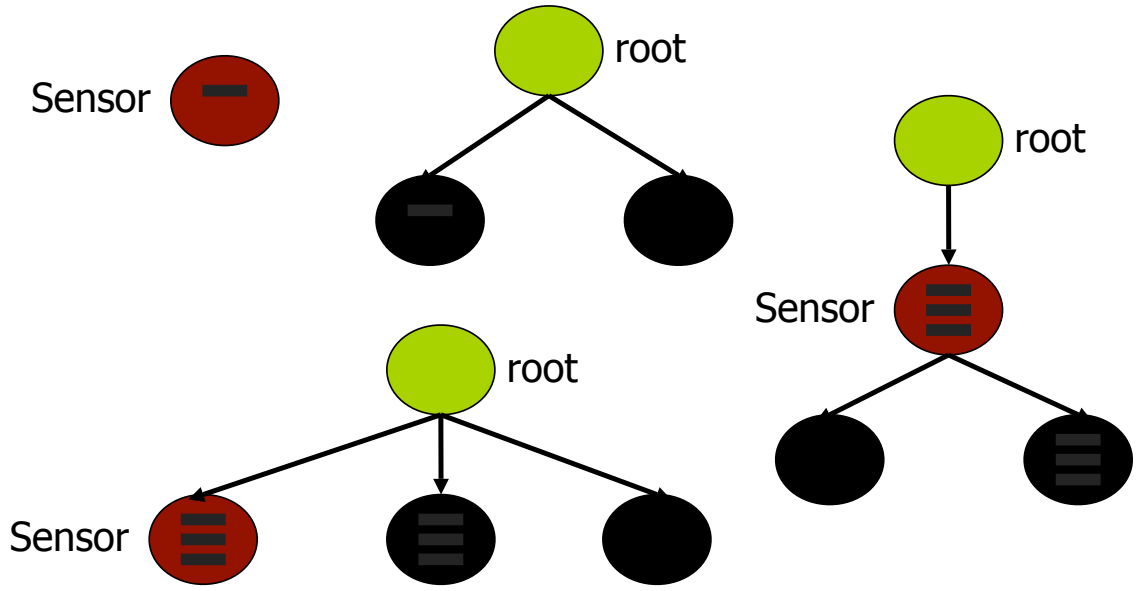


Plane Sensor (VRML)

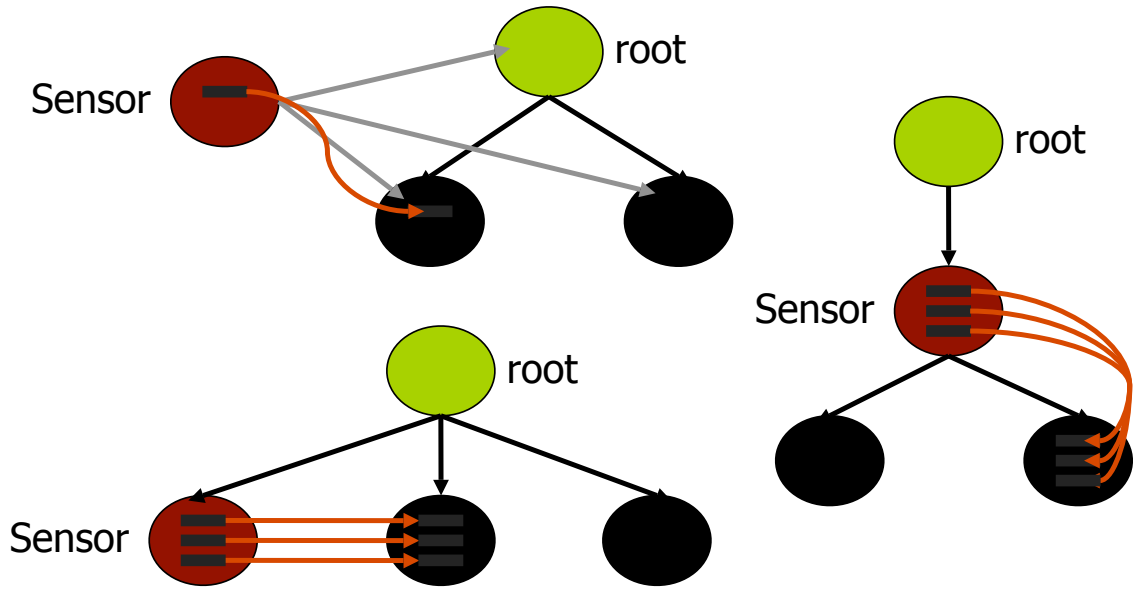
- Translatiert in Sensor-lokaler xy-Ebene

```
PlaneSensor {
   exposedField   SFBool      autoOffset          TRUE
   exposedField   SFBool      enabled             TRUE
   exposedField   SFVec2f     maxPosition         -1 -1
   exposedField   SFVec2f     minPosition         0 0
   exposedField   SFVec3f     offset              0 0 0
   eventOut       SFBool      isActive
   eventOut       SFVec3f     trackPoint_changed
   eventOut       SFVec3f     translation_changed
}
```

Prinzipielle Sensorenlage im Szenengraph



Prinzipielle Sensorenlage im Szenengraph



Designüberlegungen

- Übertragbarkeit auf andere VR-Anwendungen bzw. VR-Designsysteme
- Homogene Einbettung in existierende Datenstrukturen (Szenengraph)
- Abstraktion von aktuell gegebenen Datenlieferanten; siehe dazu den Transfer von Maus zu Glove etc.
- Performanz im Hinblick auf ständige Triggerung

Prinzipielle Sensorenlage im Szenengraph

- Wird ein Knotenzugriff auf die beeinflußten Knoten benötigt?
- Wenn ja, Knotenzugriff per Traversierungsfunktionen (get-children, get-parent ...) oder per registrierter Referenz?
- Ist eine Position des Sensors von funktionaler Bedeutung (siehe Annäherung vs. Kollisionsengine)?

Datenaustausch zwischen den Komponenten (Field vs. Referenz)

- Fieldconnections durch das Scripting steuerbar aber bei großem Datenaustausch evt. langsam
- Funktion durch Knotenreferenz ist performant aber weniger flexibel und setzt nicht auf die eventuelle Kommunikationsfähigkeiten der Fields

Aufgaben

1. Entwickle zwei verschiedene Proximitysensoren, einen mit Box- und einen mit Sphereumgebung. Wie könnte man eine Staffelung verschiedener Umgebungen in einer Instanz umsetzen? -> Wer kann setzt dieses um!
2. Entwickle einen Touchsensor für mögliche Pointing-Devices.
3. Kopple den Touchsensor an einen Interpolator, so dass nach **`touch`** eine Interpolationsanimation ausgeführt wird.
4. Entwerfe ein eigenes Architekturkonzept für eine Kollisionsengine.
5. Stelle die Vor- und Nachteile unterschiedlicher Grapheinbettungen zusammen.

Universität Bielefeld

Animation durch Interpolation

Animation durch Interpolation

- „Animation verstehen wir als die Veränderung eines Attributs (einer Eigenschaft) im Zeitverlauf.“
- Eine Animation benötigt zwei Elemente:
  - 1. Einen Zeitgeber, um die Wiedergabe der Animation zusteuern
  - 2. Eine Beschreibung der Form der Veränderung während der Animation

Aufgaben

- Für die folgenden Aufgaben kann der bereits entwickelten Viewer benutzt werden. Alternativ dazu kann ebenfalls der aview ($(AV_HOME)/bin/aview.sh) verwendet werden.
- 1. Lade ein beliebiges Objekt und rotiere es unter Einsatz der Interpolatoren um eine Achse deiner Wahl.
- 2. Lade ein Objekt mit impliziten Ausrichtungen (vorne, oben, etc., also ein Auto oder eine humanoide Figur...) und positioniere es so über einem ebenfalls zu ladenden Boden (floor.iv) der virtuellen Welt, dass es realistisch Bodenkontakt erhält. Interpoliere die Position des Objekts in Form eines Vierecks.
- 3. s.2. aber lade nun ebenfalls ein statisches Hindernis (Baum, Tisch...) und umfahre das Hindernis durch Interpolation des Position und der Orientierung. Dabei soll „vorne“ immer der Bewegungsrichtung entsprechen.
- 4. Zusatz: Teste beliebige andere Interpolatoren (für Skalierung, Farbe, etc.).

and that‘s it...have fun...