A Vrml97-X3D Extension for Massive Scenery Management in Virtual Worlds

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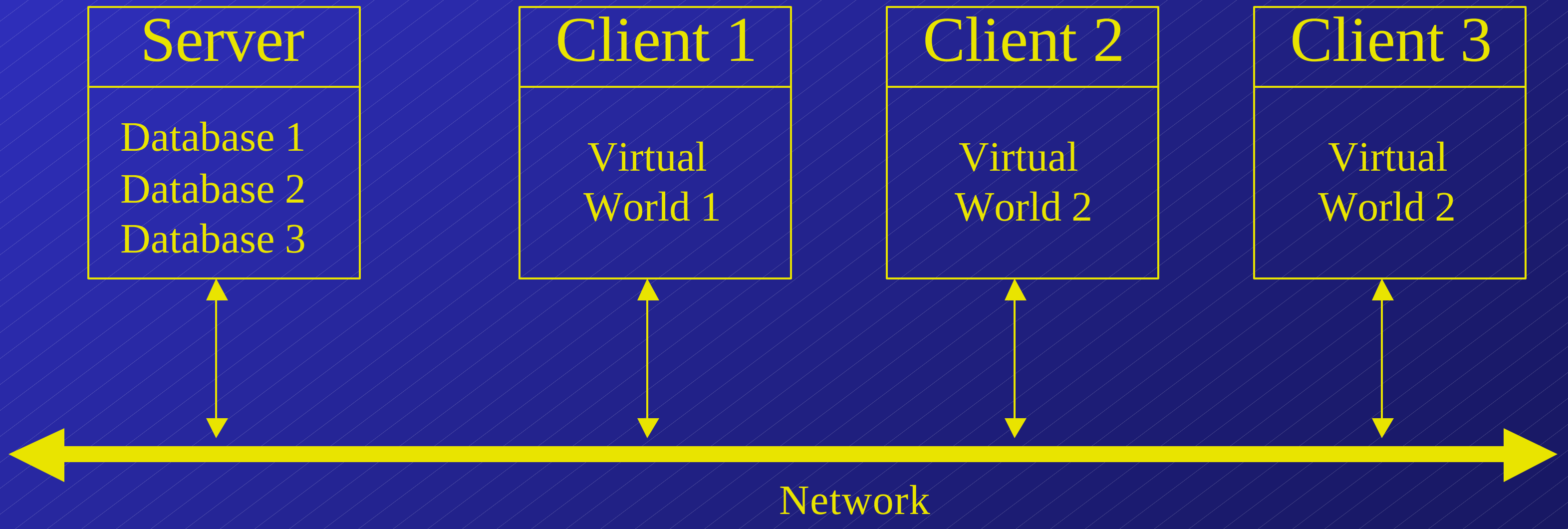
Objective

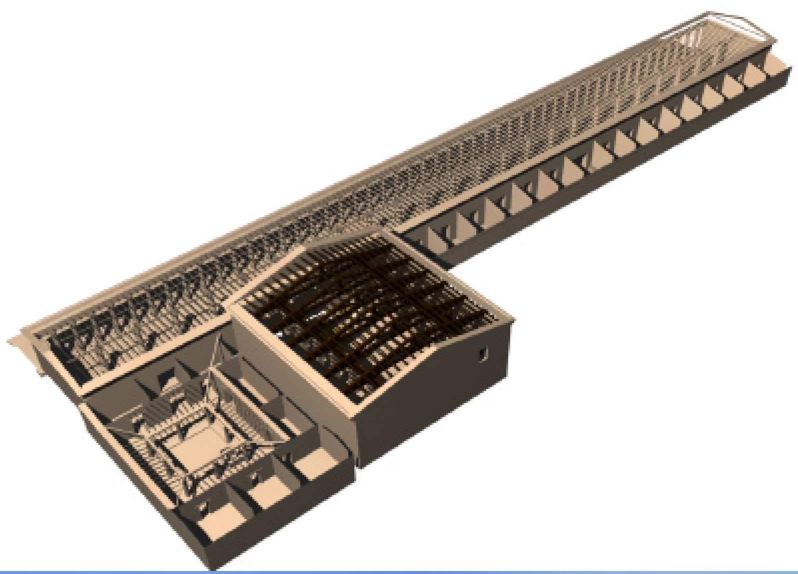
- Real time navigation
- Client-server architecture
- Applied to complex virtual worlds

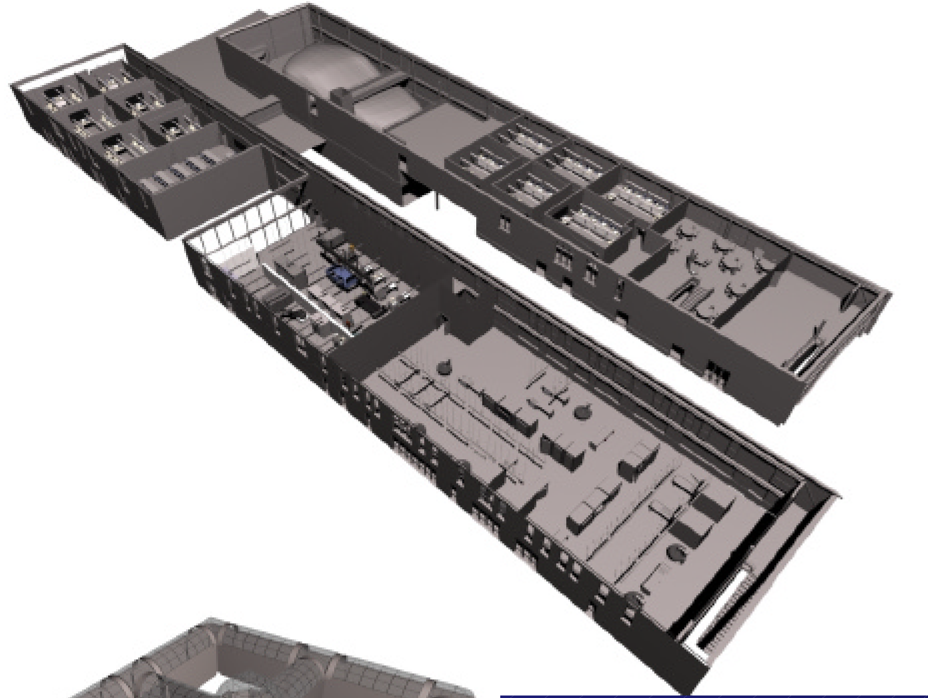


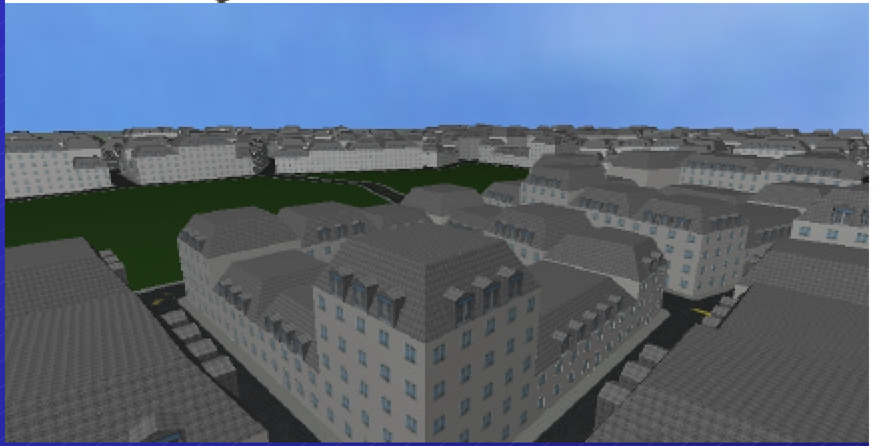
Virtual Worlds

- Three different parts
  - Globally dynamic: cars, pedestrians, …
  - Locally dynamic: doors, windows, …
  - Static: walls, roofs, …
- The scenery is made of
  - Locally dynamic and static parts

Sceneries: occlusion







VRML/X3D sufficent ?

- Inline, ProximitySensor, VisibilitySensor, Switch, …
- Insufficient
  - Only apply to parallelepipedic volumes,
  - Cannot tune downloading easilly,
  - No control on memory usage,
  - Etc.

Used solutions

- Database pre-processing
  - Spatial subdivision of the navigation space
    - Produces a set of cells (the navigation space),
  - Visibility preprocessing,
    - Cell-to-geometry, cell-to-cell or hybrid relationships
  - Database described using our VRML extention
- Streaming & visualization
  - Data streaming using partial visibility graphs
  - Data pre-fetching using motion prediction
  - Globally dynamic parts defined in root file

Overview

I – Basis concepts

II – Visibility relationships

III – Database optimisations

IV – Client side managements

V – Some videos

I – Basis concepts

Convex cell

Viewpoint tracking

Navigation space

I - Basis concepts

- Convex Cell

```
ConvexCell {
   field MFInt32  cadjIndex  []
   field MFString cellUrl    []
   field SFNode   coord      NULL
   field MFInt32  coordIndex []
   field MFInt32  cpvsIndex  []
   field MFNode   lpvs       []
   field MFNode   opvs       []
}
```

I - Basis concepts

- Convex Cell
  - Cell's volume described through fields:

```
field SFNode    coord       NULL
field MFInt32   coordIndex  []
```

  - Similar to the `IndexedFaceSet` node
  - Volume has to be **convex** and **solid**
  - Used to find quickelly
    - if a point is inside or outside the cell
    - If the cell has to be frustum culled

I - Basis concepts

- Linked viewpoint

```
# Viewpoint fields plus
eventOut SFString cellUrl ""
```

  - New field contains an **extended URL**
    - pointing to the **current cell**
  - If cell exists and its convex hull contains the viewpoint's position
    - both are said to be **linked**

I - Basis concepts

- Extended URL
  - Refer to a node located in another file
  - Similar to EXTERNPROTO
  - **Used to distribute the cells descriptions into 1 files**
  - Usage
    - "cells_0.wrl#c2"
      - refer to the cell c2 defined in the file cells_0.wrl
    - "#c2"
      - refer to the cell c2 defined in the current file

I - Basis concepts

- Adjacent cells
  - Refered to through the cell's fields

```
field MFInt32  cadjIndex  []
field MFString cellUrl    []
```

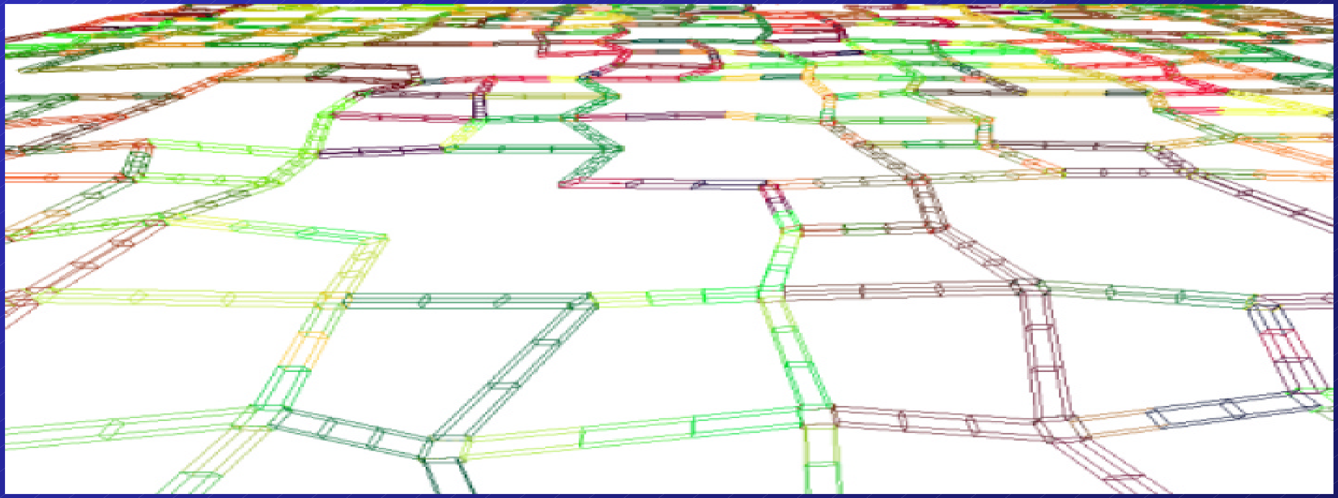
  - Can share some extended URLs with
    - The potentially visible cells (seen later)
  - The cells adjacent to the current cell
    - Are downloaded at once

I - Basis concepts

- Navigation space & current cell tracking
  - If viewpoint moves and is not in current cell
    - The adajacent cell that contains the new position becomes the new **current cell**
    - Otherwise it is handled as a collision with the cell's volume
  - Navigation space
    - The set of cells that can be accessed through this mechanism

I - Basis concepts

- Navigation space
  - Can be the rooms of an indoor scenery
  - Or the streets of an urban scenery



II – Visibility relationships

Cell-to-geometry

Cell-to-cell

Hybrid

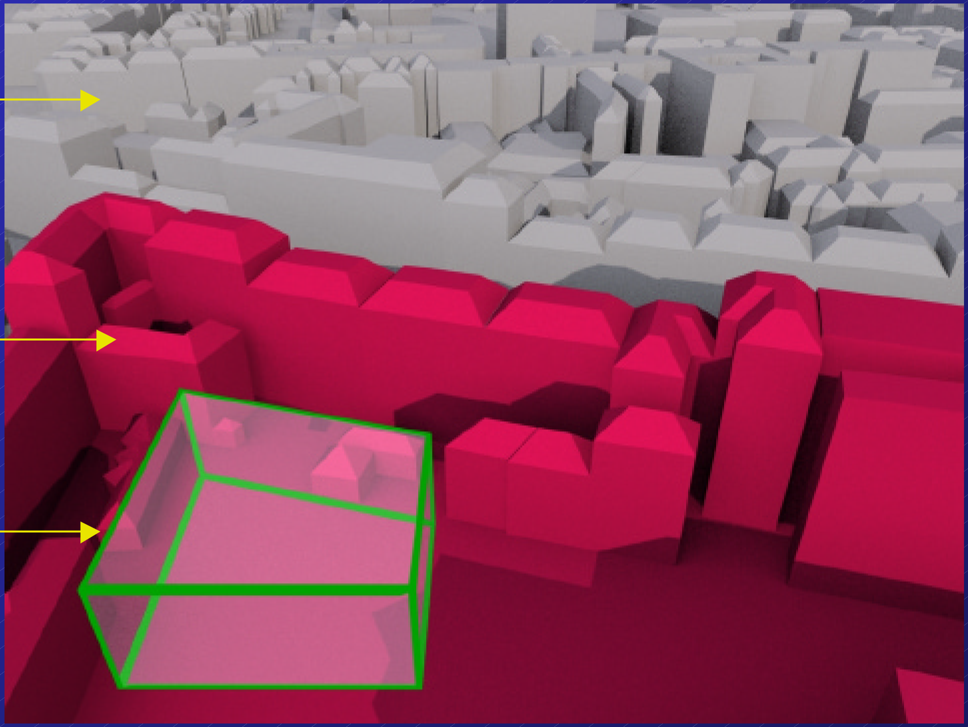
II - Visibility relationships

- Cell-to-geometry

Hidden objects

Potentially visible Objects (OPVS)

Current cell



II - Visibility relationships

- Cell-to-geometry
  - Objects can be defined into separated files
  - And refered to in the cell's field

```
field MFNode    opvs          []
```

  - Using either `Inline` nodes (bad idea)
  - Or **`SharedInline`** nodes (seen later)
  - Thus, an object can be refered to by several cells

II - Visibility relationships

- Cell-to-geometry
  - During the navigation,
    - the OPVS of the current cell
      - Is first downloaded if not present
    - At each new frame rendering
      - The nodes of the OPVS are then frustum culled
      - And only visible ones are rendered

Recall that objects described in the root file are also rendered classically

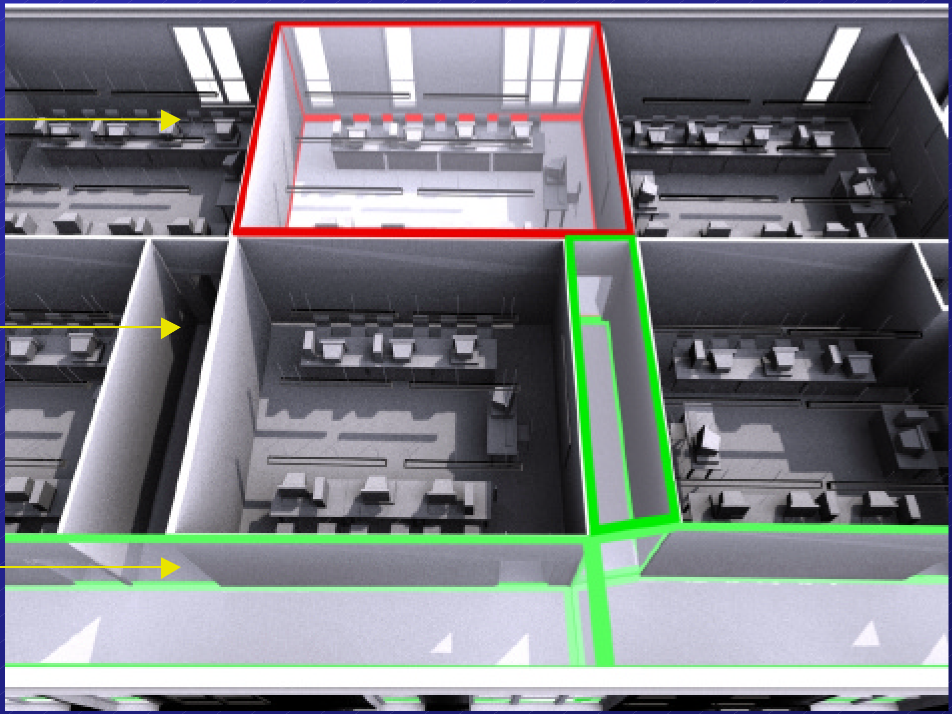
II - Visibility relationships

- Cell-to-cell

Current cell &
local objects (LPVS)

Hidden cells

Potentially visible
Cells (CPVS) &
local objects (LPVS)



II - Visibility relationships

- Cell-to-cell
  - Cells can be described into separated files
  - And referred to through the cell's fields

```
field MFString cellUrl    []
field MFInt32  cpvsIndex  []
```

  - Objects of the LPVS are described or referred to in the field

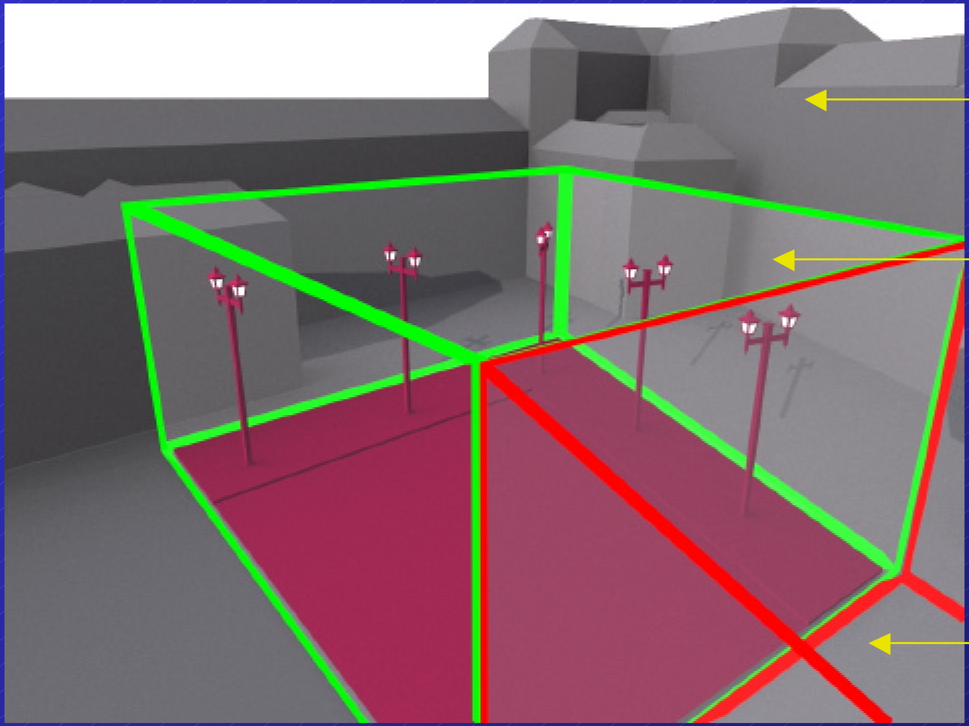
```
  field MFNode   lpvs       []
```

II - Visibility relationships

- Cell-to-cell
  - During the navigation,
    - the LPVS and the CPVS of the current cell
      - Are first downloaded if not present
    - then, the LPVSs of the cells of the CPVS
      - Are also downloaded if not present
    - At each new frame rendering
      - The cells of the CPVS are frustum culled
      - The nodes of the LPVS of the visible cells are then frustum culled
      - The nodes of the LPVS of the current cell are also frustum culled

II - Visibility relationships

- Hybrid (HPVS = OPVS + CPVS)



OPVS

Potentially visible Cell (CPVS) & local objects (LPVS)

Current cell

II – Visibility relationships

- Hybrid
  - Uses all the fields depicted for previous relationships
  - Uses downloading and visualization mechanisms presented before
  - Is a first optimisation to reduce the database size
    - Especially the number of references used to describe each PVS

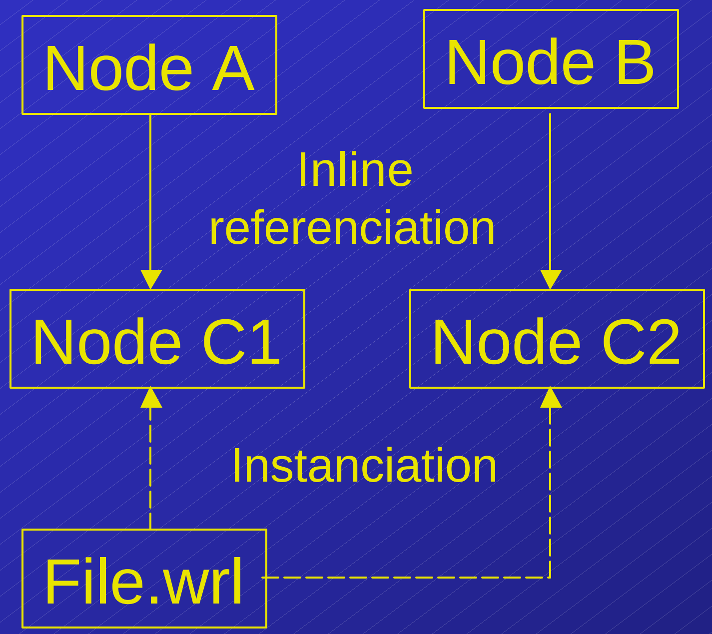
III – Database optimizations

`SharedInline`

`SharedTransform`

III – Database optimizations

- Shared inline: motivation

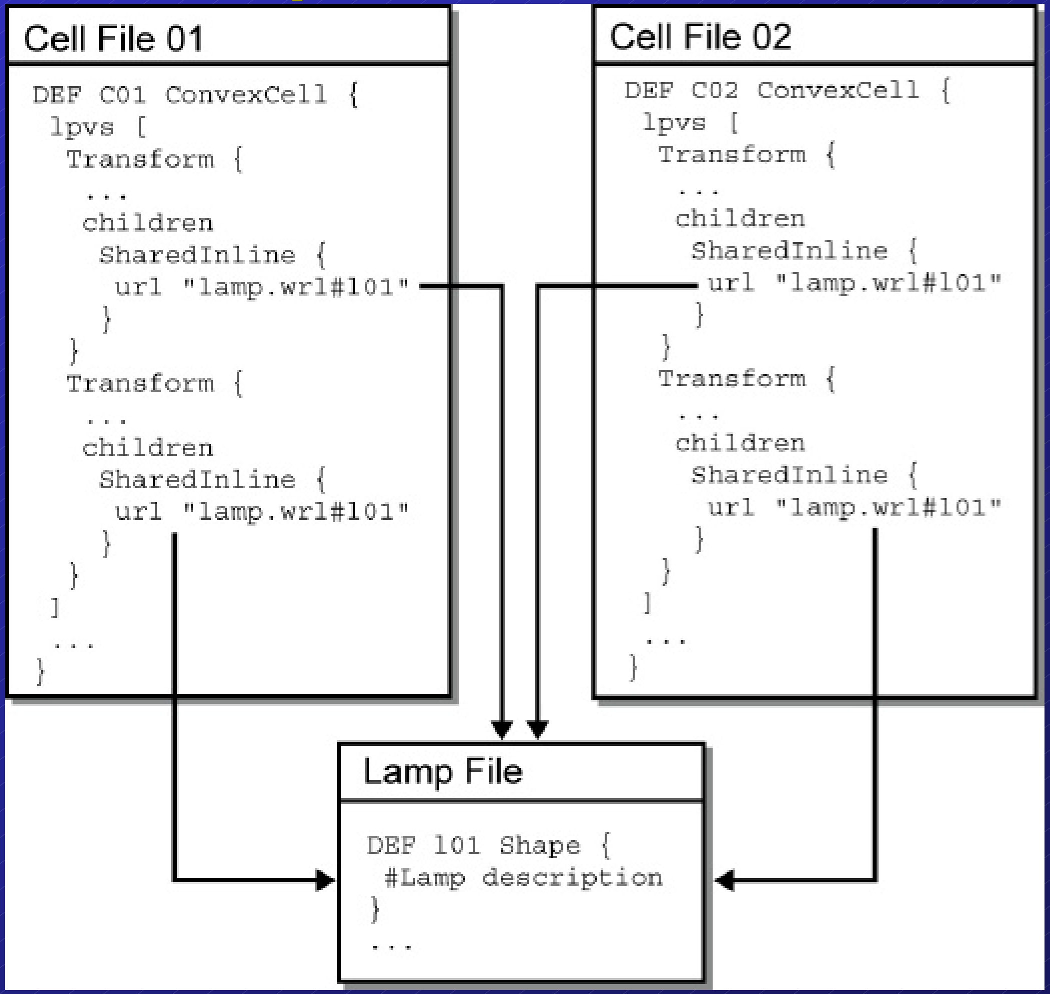


III – Database optimizations

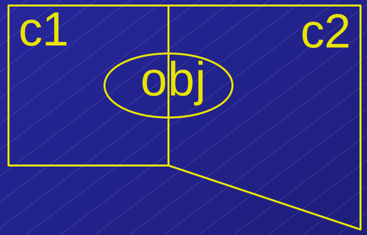
- Shared inline
  - Same prototype as `Inline` node
    - but the name: **`SharedInline`**
  - Can be used anywhere
  - Must be used
    - to refer to the external objects in the **`opvs`** field
  - Especially interesting
    - to refer to some external objects in the **`lpvs`** field
    - reduces the memory used on client side
  - The URL can be an extended URL

III – Database optimizations

- Shared inline
  - Example: Sharing in **`lpvs`** field



III – Database optimizations



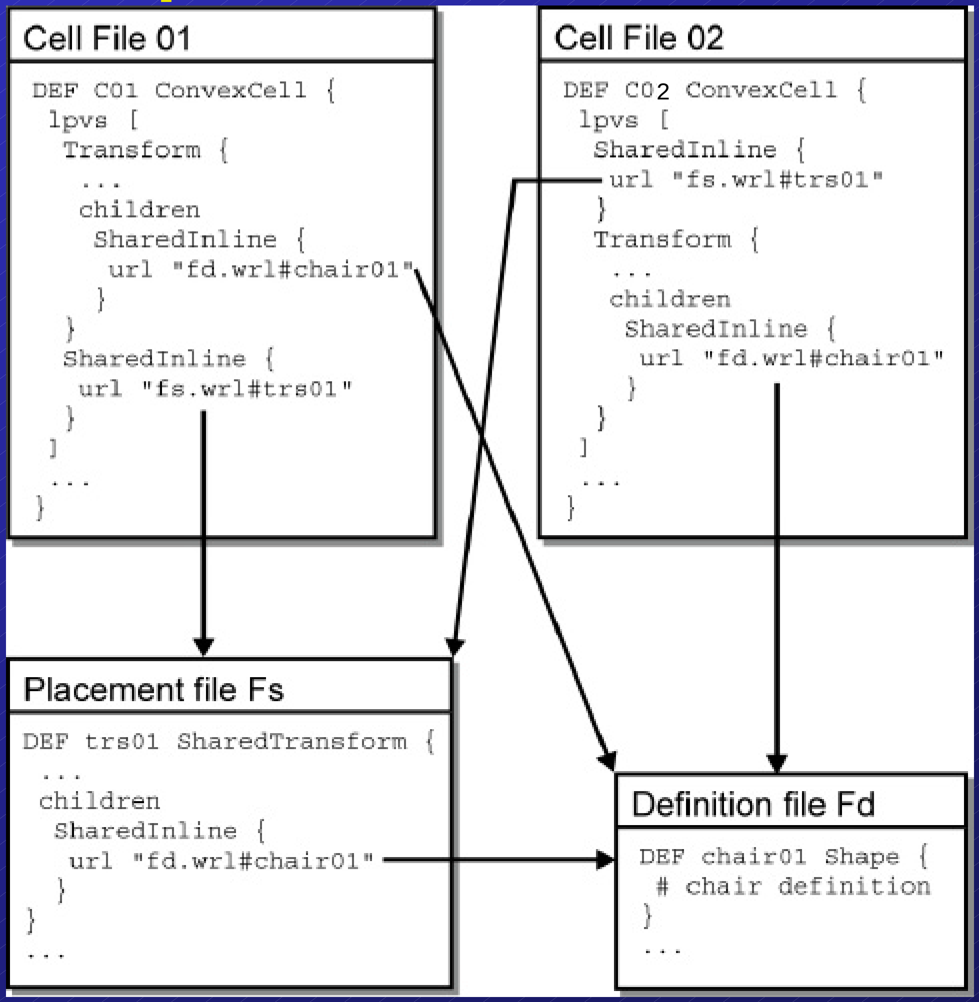
- Shared transform: motivation
  - Objects of the LPVS have to be
    - Contained by the convex hull of the cell
  - If object is partially in two cells
  - Shared tranform prevents from cutting the object
  - Object is referred to by the two cells but **rendered only once**

III – Database optimizations

- SharedTransform
  - – Example:

    Sharing in **`lpvs`**

    Between two cells



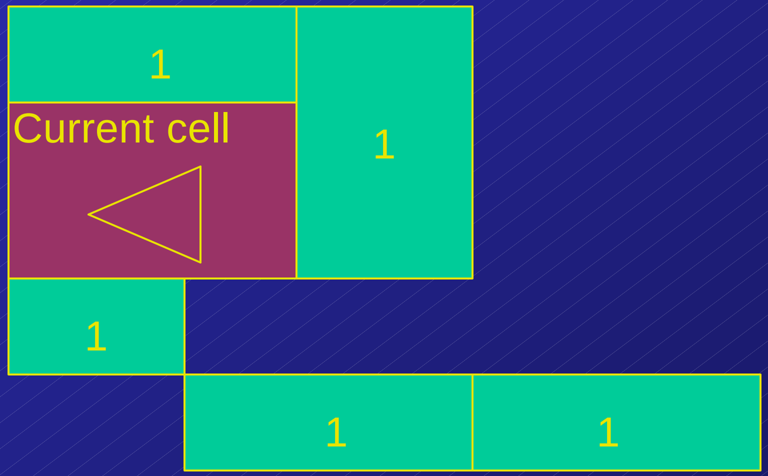
IV – Client side managements

Pre-fetching

Memory management

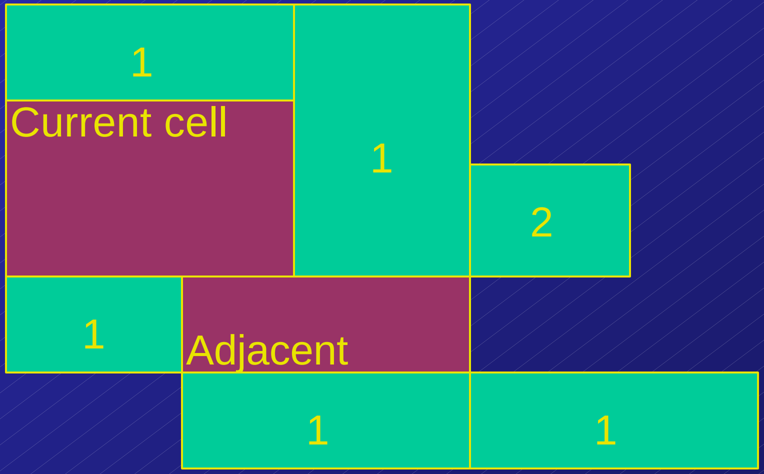
IV – Client side managements

- Fetching and pre-fetching
  - – Example with cell-to-object
  - – Step 1: **fetch** the current cell and its OPVS.



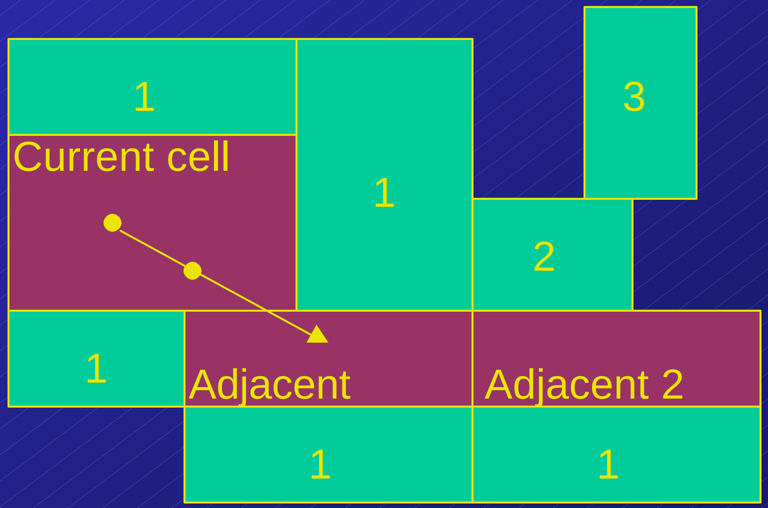
IV – Client side managements

- Fetching and pre-fetching
  - Step 2: **pre-fetch** the adjacent cells and their OPVS.



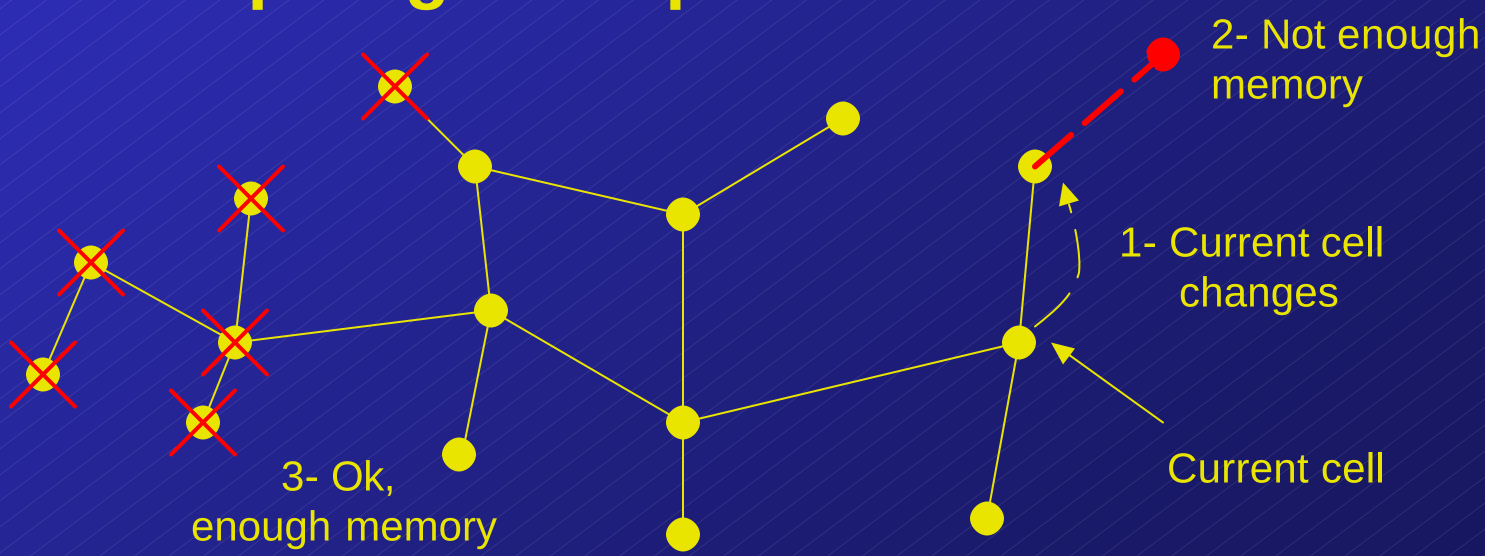
IV – Client side managements

- Fetching and pre-fetching
  - Step 3: **pre-fetch** the cells adjacent to the ray-casted cell and their OPVS.



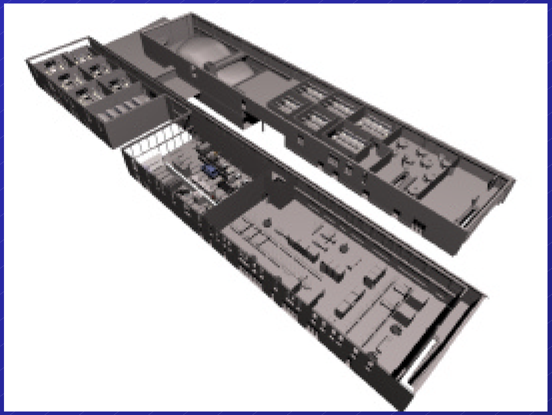
IV – Client side managements

- Memory management
  - Uses the **partial adjacency graph** to perform **topological replacements**.



V - Videos

V - Videos



- Cell-to-cell relationships
  - University of Kerlan scenery (370 000 polygons)
- Navigation space
  - Model subdivided using a constrained BSP
- Visibility pre-processing
  - Shooting,non-conservative but fast to compute
- Bandwidth
  - Test performed on a LAN (100Mbit/s)
  - Pre-fetching disabled

V - Videos

- Cell-to-geometry relationships
  - City scenery with procedural geometry
    - (1 million polygons)
  - 1GBytes model encoded using 540KBytes.
- Navigation space
  - Streets generated together with the model.
- Visibility pre-processing
  - Shooting,non-conservative but fast to compute.
- Bandwidth
  - Test performed on a modem (56Kbit/s).

V - Videos

- Cell-to-cell relationships
  - Museum scenery (17 000 polygons)
  - 90MBytes of progressive texture maps
- Navigation space
  - Model subdivided using a constrained BSP
- Visibility pre-processing
  - Shooting,non-conservative but fast to compute
- Bandwidth
  - Test performed at several bandwidths
    - 128Kbits/s, 256Kbits/s, 1Mbits/s and 100Mbits/s.

VI – Conclusion

Contribution

- **Streaming** in VRML97 thanks to visibility
  - Simple and efficient **pre-fetching** and **memory management** solutions.
- Support all types of relationships
  - **Cell-to-cell, cell-to-geometry, hybrid**.
- Complete specification in VRML97
  - With **a single node**,
  - Plus two optimization nodes.

Questions ?

- More details at:

www.irisa.fr/siames/jean-eudes.marvie