A “Virtual Concert in Notre Dame”: An *Experimental* Production in Interactive Spatial Audio

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Context:

- The BiLi (Binaural Listening) project
  - Improving binaural 3D-audio for public use
  - Recording, synthesis, processing, diffusion, …
  - Impact on Binaural Audio Quality

➢ Content needed for project studies
  - Audio
    - Radio France & Conservatoire de Paris
  - Audio-visual
    - FranceTélévision
  - **Interactive / Virtual Reality … *Us!***

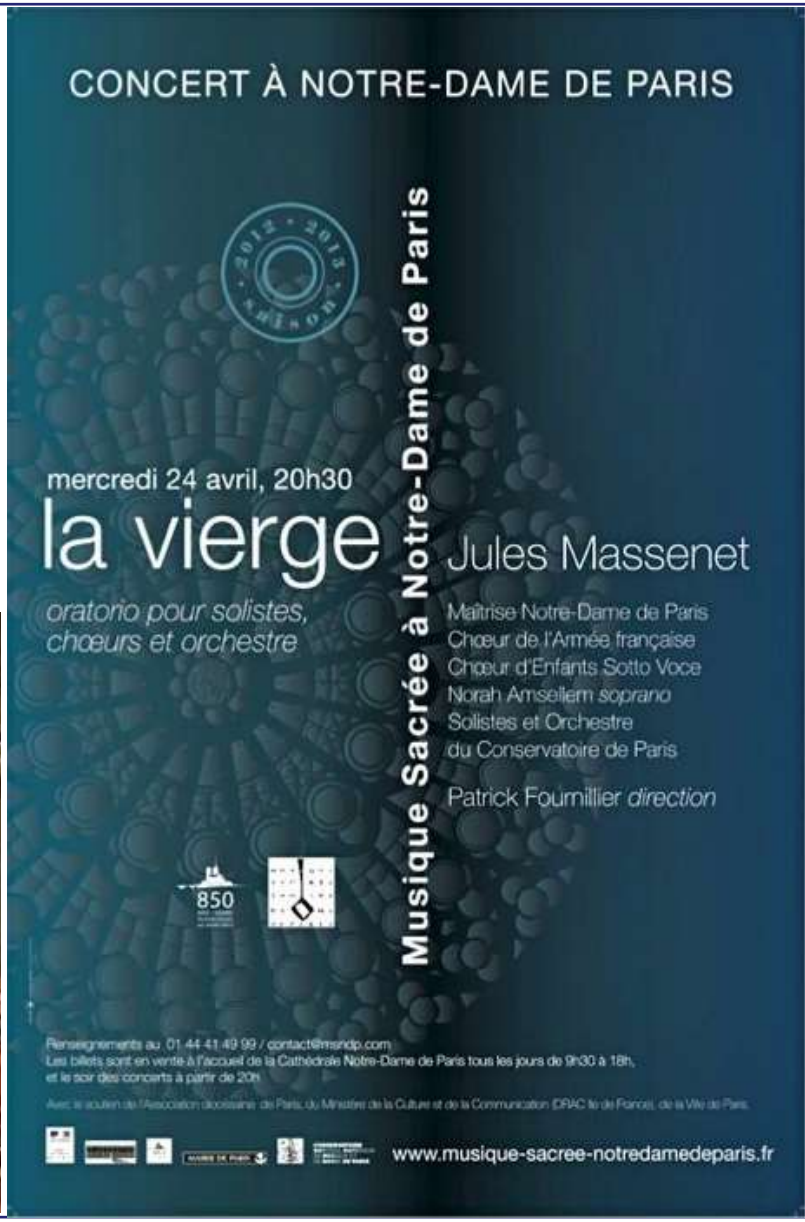
Project Concept

- Present a complex scene, with numerous sources, within which the listener can move about.
- Possibility to change HRTF processing to examine effects on appreciation

➢ Create an object-oriented musical performance where large displacements and various listener orientations are meaningful

An opportunity arises : Concert recording

- « La Vierge »
  - by Jules Massenet, 1880
  - Oratorio for orchestras, 2 choirs and 6 soloists
  - @ Notre Dame de Paris!



Recording layout

- Recording by the

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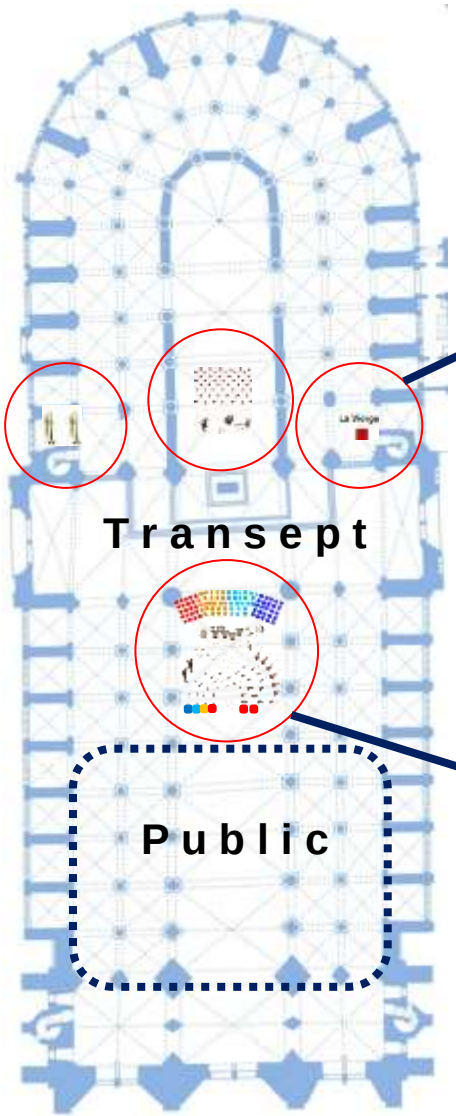
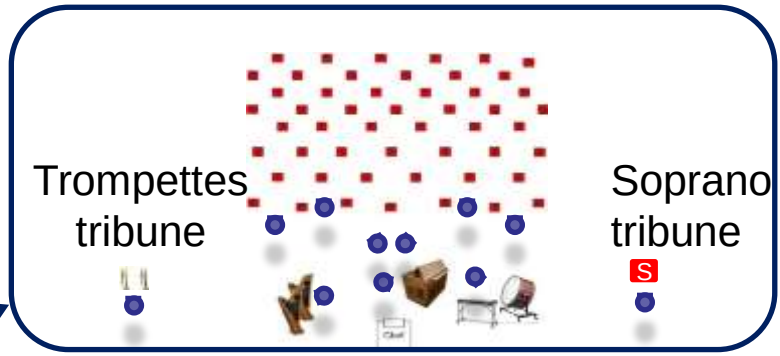
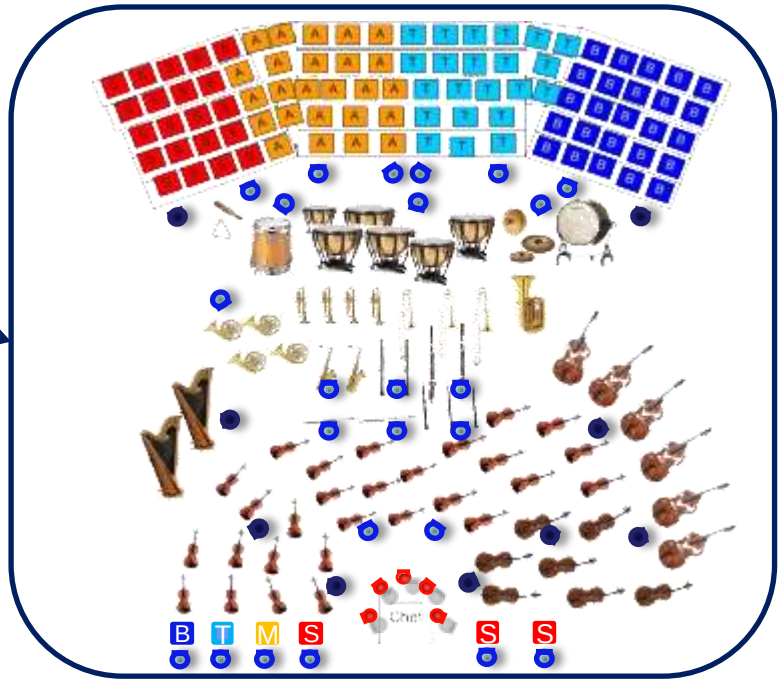
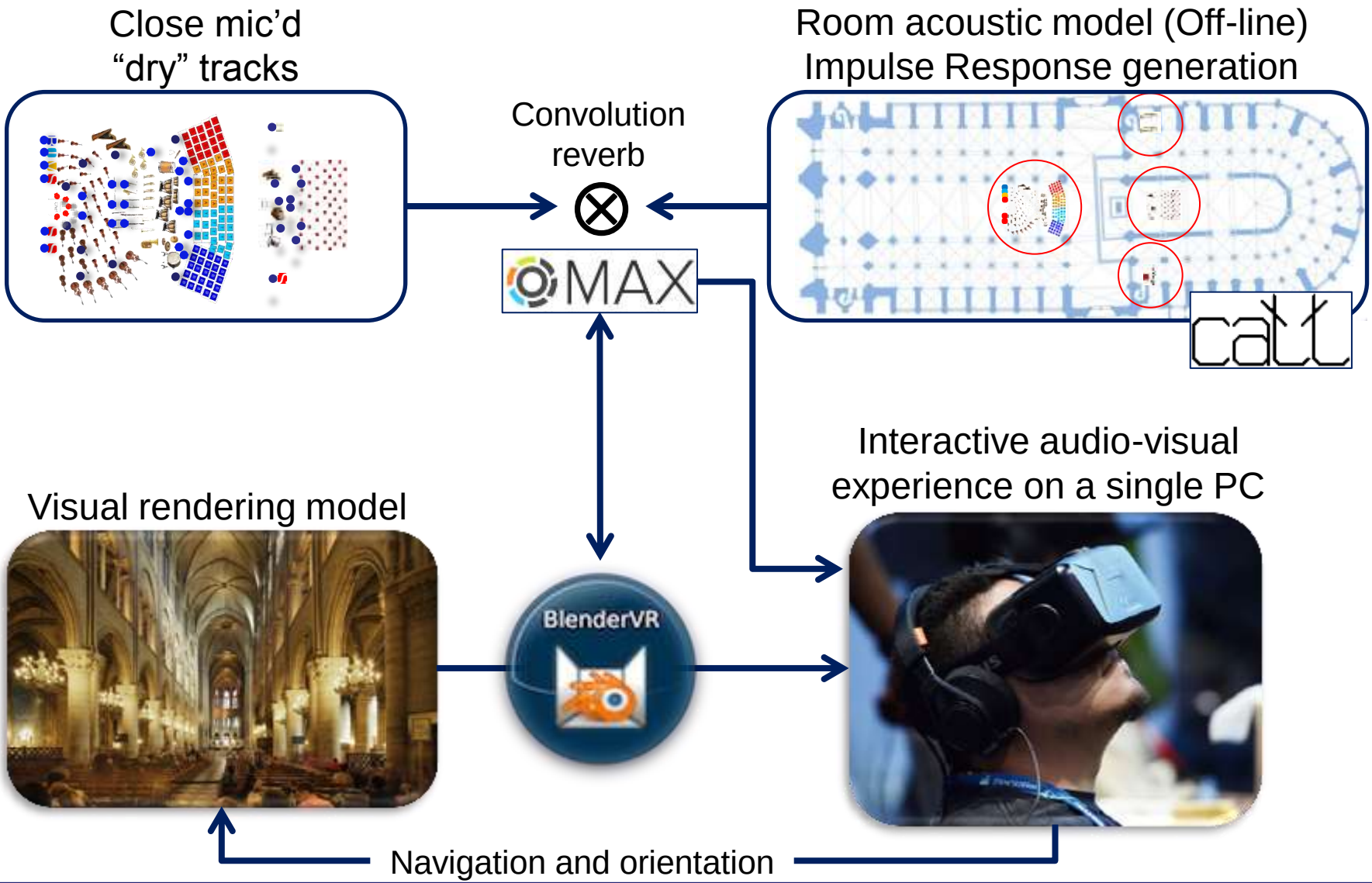
- 45 proximity mics + ambiance mics
- Microphones by section and soloists





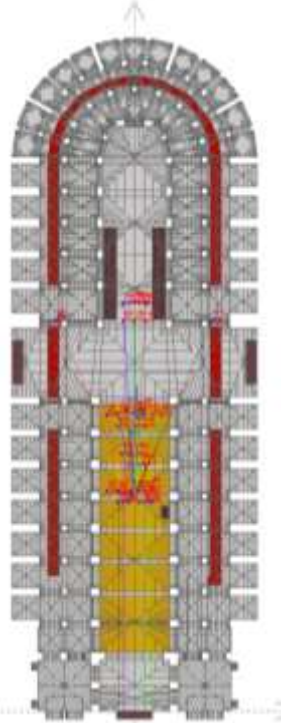


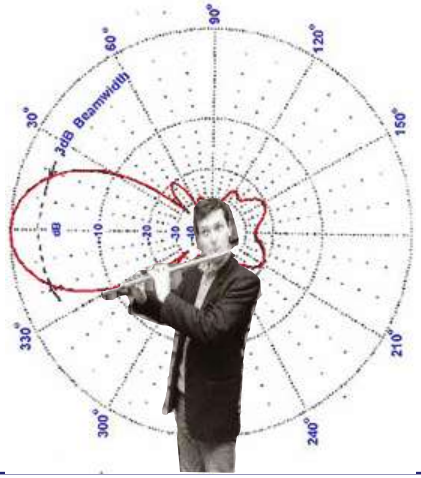
Conceptual architecture overview



Acoustic Model of Notre Dame

- **Geometrical acoustical model** created from plans and laser scan data
- **Impulse response measurements** carried out to establish acoustic conditions
- Acoustic material props. estimated and fine-tuned to **calibrate** model to measured parameters within 1 JND
  - reverberation (T20) & clarity (C80)
- **Directivity patterns** (Octave-bands) for each section/track were estimated and included in the simulation
- RayTrace RIR simulations
  - Necessary to predefine listener path early on
  - Path defined with 88 positions, 1 every 3 m
  - ~3 weeks computation for all sources & receivers





Visual rendering model

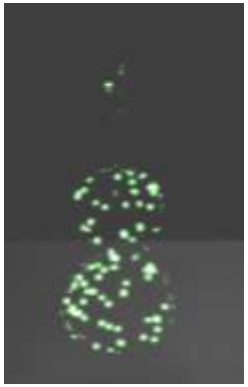
- 3D model created based on plans, laser scan data, and site visits
- Lighting, mesh, and textures optimized for real-time rendering
- 500 000 triangles
- Textures from *on-site* photos
- Created in 3DSMax, ported to Blender

Visual animation design

- To have a bit of “life” in the Cathedral fly through
  - Animating a full orchestra too much work
  - ➢ ***“Ghost Orchestra”*** metaphor
- Animations driven by individual audio track analysis → level env.
- Real-time impact of complex animations on CPU
  - Need to be able to support “dozens or more” instruments as well as the Cathedral model

- Vu-meter concept from previous Organ project transformed into dynamic cylindrical vu-meter → Too “techno”

- Ghostly sprite instruments
  → Too unequal for different instrument sizes
- Ghostly sprite cylindrical vu-meters playing instruments → ***Looking good !***



Real-time audio rendering

- 3rd order Ambisonic → Binaural (w/ head tracking) (18 virt. spkr.)
- Predefined trajectory path
- Amplitude panning between nearest neighbors
- Nearest 5 are kept in buffers to avoid artifacts when switching active elements during panning as listener is **free** to drive on path
- CPU limitations
  - 45 instr. x 16 ch HOA x 5 receivers at any instant (***3600 conv!***)
  - Too much for real-time convolutions on 1 machine
  - Solution : All convolutions performed **off-line**
    - HOA **downmix prerendered** for each receiver (88 pos)
    - Large storage requirements : 16ch HOA for all positions
      - Only a short extract of performance for demo purposes today
      - 3 min extract, 88 positions, 16ch HOA, 24bit = **500 GB!**

Reality hits the audio…

- **“Dry” track assumption not valid** enough, too much cross-talk
  - Direct sound hard to perceive, blurred source position
- Selected audio extract which is most coherent musically for the demo duration time does not include the full orchestra & choir
  - **Demo therefore presents the concept only**, not the most dynamic moments in the piece
  - **Not all orchestral elements are present** in current demo
- RIR simulation and HOA panning step size misses some details for events in near proximity
  - Direct sound precision localization blur
  - **Lack of expected variations** when passing behind pillars
- Predefined path not well synchronized with **musical interests** of the selected extract

Reality hits the graphics…

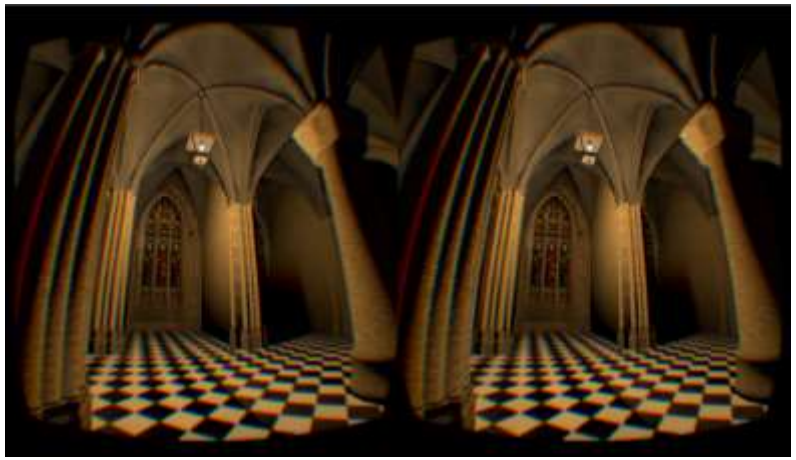
- "Dry" track assumption not valid enough for coherent visual animations, too much cross-talk → all instruments active when loud
- "Ghostly sprite vu-meters exciting instruments" looks great on screen
  - But… Oculus pixelization issues
  - Propose new **"Ghostly shadow"** last Wed.

- Full visual model, with animations, still to heavy
  - Reduce lighting, limit visible elements
    - Reduces pixelization issues
- Create "back-up" demos in case of "demo effect"
  - Pregenerated movements of work in progress stages
  - Blender's off-line 360° rendering engine not the same at interactive renderer → More last minute modifications
- 25 fps OK for screen/tablet → **75 fps** for Oculus with head tracking

Results on different platforms

- Multiple demos presented in demo area *(still time to listen!)*
  - Full interactive navigation + HOA audio + 3D Oculus (DK2)
  - Orientation AV interaction + horiz plane audio + Tablet
  - Orientation AV interaction + HOA audio + Tablet
  - Orientation Audio interaction + horiz plane audio + Tablet

Oculus 3D



360° Equirectangular

Conclusions … *A work in Progress*

- An experiment in interactive production
- A ***real*** learning experience in 3D graphics, DSP, and CPU limitations for the team
- Necessity to redefine selected musical extract and trajectory path prior to any subjective experiments
  - Need to **optimize audio & visual impact**
- Prioritize degree of interaction
  - Full navigation interaction (real-time) ***vs.***
  - orientation only (off-line)

Production Credits

• Producer	Brian FG Katz
• Artistic director, animations, audio & visual software architecture	David Poirier-Quinot
• Audio recording supervision	Jean-Marc Lyzwa
• Acoustic measurements, model, & calibration	Bart N. Postma Julie Meyer
• Visual model of the Cathedral	Cyril Verrecchia
• Oculus & 360° rendering code	Dalai Felinto Martins Upitis

Special thanks to the Cathedral of Notre Dame de Paris for letting us do recordings and measurements in the wee hours