SceneGen - automated 3D scene generation for psychophysics

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Why SceneGen?

SceneGen is a tool to produce large numbers of virtual interior scenes. It provides us with the prerequisites for investigating the perception and experience of architectural space with psychophysical methods.

- Photo textures & a physics-based radiosity lighting allow high pictorial realism.
- All scene properties are easily adjustable whilst totally controlled.
- An automated generation process allows for large sets of similar scenes that are necessary for systematic evaluations of architectural space.
- The application of SceneGen is not limited to architectural research: its ability to hide the manipulation of experimental parameters by varying scene features makes it very useful for exploring virtual reality (VR) parameters and perceptual psychophysics in general.

▲▼ the same structural components and materials but different room proportions

▲▼ the same scene with and without scale objects

▲▼ the same scene in different context

What does it provide?

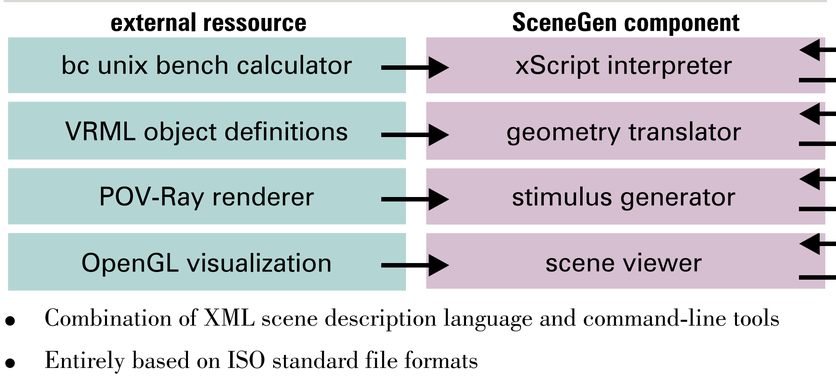
SceneGen allows for an automated generation of an unlimited number of scenes from a component-based scene description that can contain freely definable variance constraints and mathematical interdependencies between parameters.

- The generation process implements a complete scene description that is directly available for further analysis.
- The plain text file format simplifies adjusting and editing by hand.

SceneGen parameters:

- Size, position and quantity of all constituent components
- Surface properties (color, texture, reflectivity, bumpiness etc.) widely definable
- Lighting model from simple color shading to physics-based radiosity rendering
- Real-time-capable multi-textured scenes, panorama and perspective images

How does it work?



- Combination of XML scene description language and command-line tools
- Entirely based on ISO standard file formats
- Makes extensively use of established free open-source software

How is it applied?

SceneGen is designed to provide suitable stimuli for a field of empirical research linking architecture, perceptual psychophysics and virtual reality (VR). Currently we see three main directions:

- A systematical investigation of the perception and experience of architectural space under controlled laboratory conditions. We want to study the effect of varied single scene parameters, for example room proportions, configuration, context, colors, surfaces etc.
- The influence of virtual reality setup properties (e.g., screen size, resolution, screen curvature) on the experience and appearance of virtual environments.
- The influence of VR simulation parameters (e.g., geometrical field of view, eyepoint height, freedom of movement, lighting models and texture quality) on the experience and appearance of virtual environments.

Example application

The influence of eyepoint height on perceived distances in VR

INTRODUCTION. Simulated virtual environments generally convey a poor impression of natural scale, dimension, and ego-location. Many setup and simulation parameters are assumed to affect this. We currently focus on the influence of view parameters (here eyepoint height), because they are ubiquitous and easy to adjust, and therefore offer a good way of improving the quality of VR simulations.

EXPERIMENTAL QUESTION. How does the virtual eyepoint height influence the perceived dimensions and the experience in virtual environments?

METHOD. For the perceptual experiment we used a 130x90 degree wide-angle spherical projection system. Nine subjects in two groups estimated seven different distances and dimensions in 20 virtual rooms made by SceneGen. In addition, the experience of four interiors was rated in seven principal experiental categories, using a scaling technique derived from the semantic differential.

The stimuli were radiosity-rendered 360 degree panoramic images of vacant rectangular interiors. To hide the main experimental parameter of eyepoint height, all dimensions of the structural components (walls, windows, doors) were varied within the normal range of real buildings. All other properties (e. g., surfaces, illumination, context) were constant across all scenes.

RESULTS.

- Most distance and dimensions estimates negatively correlated with eyeheight.
- Significant effect of eyepoint height is strongest on perceived egocentric distances, followed by allo-centric distances perpendicular to gaze direction.
- Allo-centric distance estimates parallel to gaze direction are not significantly influenced.
- No ideal eyeheight, best approximation differs between experimental tasks.
- No significant interaction between eyepoint height and experience of space.

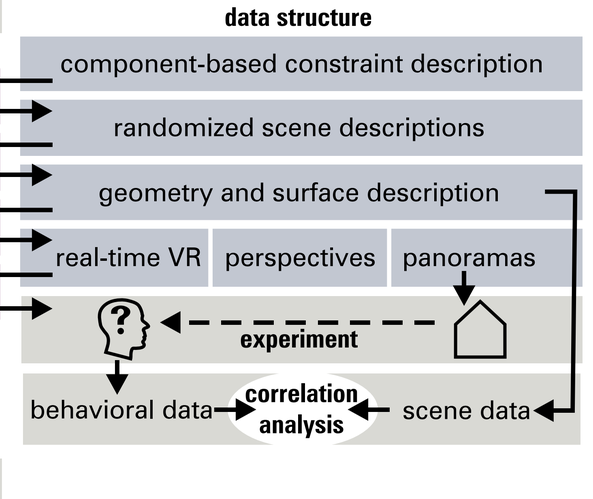
```
<scene>
  <materials>
    <material id="ingrain" color="#rnd(0.5,1.0)# #rnd(0.5,1.0)# #rnd(0.5,1.0)#"
              texture="textures/ingrain06.tga" sX="0.5" sY="0.5" finish="diffuse 3.0"/>
    <material id="parquet_ship" color="1.0 1.0 1.0" texture="textures/parquet_ship.tga"
              sX="1.5" sY="1.5" finish="diffuse 3.0 reflection { 0.03, 0.1 }"/>
    <material id="parquet_sqr" color="1 1 1" texture="textures/parquet_square02.tga"
              sX="0.6" sY="0.6" finish="diffuse 3.0 reflection { 0.03, 0.1 }"/>
    <material id="wood_beech" color="1.0 1.0 1.0"  texture="textures/wood_beech.tga"
              sX="0.25" sY="0.25" finish="diffuse 2.5 ambient 0"/>
    <material id="window_glass" color="0.95 0.97 0.97 0.05" />
    <material id="window_sill" color="1.0 1.0 1.0"  texture="textures/stone_jura.tga"
              sX="0.25" sY="0.25" finish="diffuse 3.0 ambient 0"/>
  </materials>

  <var l="#rnd(4,8)#" w="#rnd(3,6)#" h="#if(((Sl+Sw)/2)<4) (Sl+Sw)/2 else 3+rnd(0,1)#"
       wBrick="0.125"/>
  <room id="0" form="rect" pos="#-Sl/2# #-Sw/2# 0.0" l="Sl" w="Sw" h="Sh">
    <walls material="ingrain" d="#rnd(0.2,0.4)#" wBrick="SwBrick"
           wLedge="#rnd(0.01,0.025)#" hLedge="#rnd(0.04,0.10)#"/>
    <var doorH="#rnd(2.05,2.25)#"/>
    <doors material="wood_beech" quantity="1;2" w="#rnd(0.875,1.125)#" h="SdoorH"
           wFrame="#rnd(0.03,0.06)#" dFrame="#rnd(0.1,0.4)#"/>
    <var winZ="# tmp=rnd(0.6,1.0); if(tmp<0.75) 0 else tmp #"/>
    <var winW="#rnd(0.875,2.0)#" winH="#if(SwinZ<0.75) rnd(SdoorH,Sh-SwinZ-SwBrick)
                                       else rnd(1,Sh-SwinZ-SwBrick)#"/>
    <var nWin="#1+(Sl*Sw*0.28)/(SwinW*SwinH)#"/>
    <windows material="window_glass" quantity="SnWin" w="SwinW" h="SwinH" z="SwinZ"
             nBeams="#if((SwinH>SwinW)&&(SwinW>1.2)) 1 else 0#">
      <frame material="wood_beech" w="#rnd(0.04,0.07)#" d="#rnd(0.04,0.07)#"/>
      <sill  material="window_sill" exist="1" />
    </windows>
    <floor   material="parquet_ship;parquet_sqr"/>
    <ceiling material="ingrain"/>
  </room>
</scene>
```

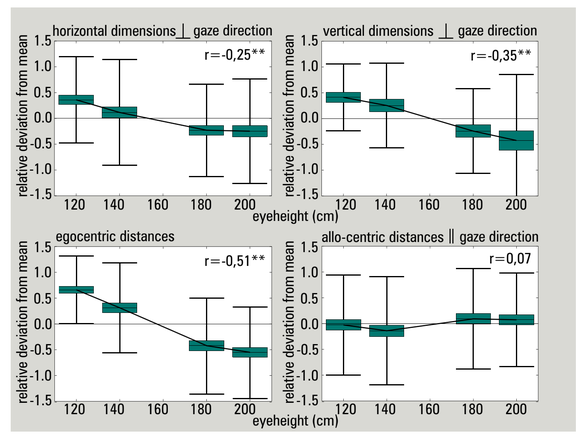
▲ sample of a component-based scene constraint definition

▼ a randomized and evaluated scene description

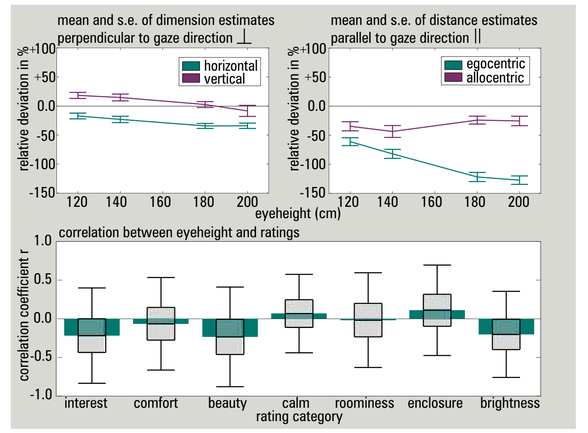
```
<scene>
  <materials>
    <material id="ingrain" color="0.77 0.93 0.8"
              texture="textures/ingrain06.tga" sX="0.5" sY="0.5" finish="diffuse 3.0"/>
    <material id="parquet_sqr" color="1 1 1" texture="textures/parquet_square02.tga"
              sX="0.6" sY="0.6" finish="diffuse 3.0 reflection { 0.03, 0.1 }"/>
    <material id="wood_beech" color="1.0 1.0 1.0"  texture="textures/wood_beech.tga"
              sX="0.25" sY="0.25" finish="diffuse 2.5 ambient 0"/>
    <material id="window_glass" color="0.95 0.97 0.97 0.05" />
    <material id="window_sill" color="1.0 1.0 1.0"  texture="textures/stone_jura.tga"
              sX="0.25" sY="0.25" finish="diffuse 3.0 ambient 0"/>
  </materials>

  <room id="0" form="rect" pos="3.61 1.84 0.0" l="7.32" w="3.68" h="3.51">
    <walls material="ingrain" d="0.35" wBrick="0.125" wLedge="0.022" hLedge="0.65"/>
    <doors material="wood_beech" quantity="2" w="1.03" h="2.07"
           wFrame="0.044" dFrame="0.35"/>
    <windows material="window_glass" quantity="5" w="1.17" h="2.31" z="0.00"
             nBeams="0">
      <frame material="wood_beech" w="0.063" d="0.057"/>
      <sill  material="window_sill" exist="0" />
    </windows>
    <floor   material="parquet_sqr"/>
    <ceiling material="ingrain"/>
  </room>

  <camera pos="2.928 0 1.6 15.7 0 0"/>
  <background url="textures/marktplatz.tga"/>
</scene>
```

data structure





▲ effect of eyepoint height on distance estimates, data z-transformed per subject



▲ effect of eyepoint height on relative distance estimate deviations and on rated experience

CONCLUSION. Our experimental paradigm based on stimuli generated by SceneGen allowed us to investigate spatial perception under fully controlled but comparatively natural conditions. We were able to observe a significant influence of the virtual eyepoint height on the appearance of spaces without asking participants directly about this parameter. That eyeheight differences particularly affect egocentric distance estimates, reveals a strong task-dependency, and moreover, it suggests that a shift of the vertical position also changes the perceived horizontal ego-location of observers in VR.

the same room geometry but different colors and materials ▲▼

▲▼ the same room but different lighting and surface models

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