LBS 2016
13th Conference on Location-Based Services
Vienna, 14–16 November 2016

Multimodal Location Based Services

Semantic 3D City Data as Virtual and Augmented Reality

ULPGC

José Miguel Santana
Agustín Trujillo
José Pablo Suárez

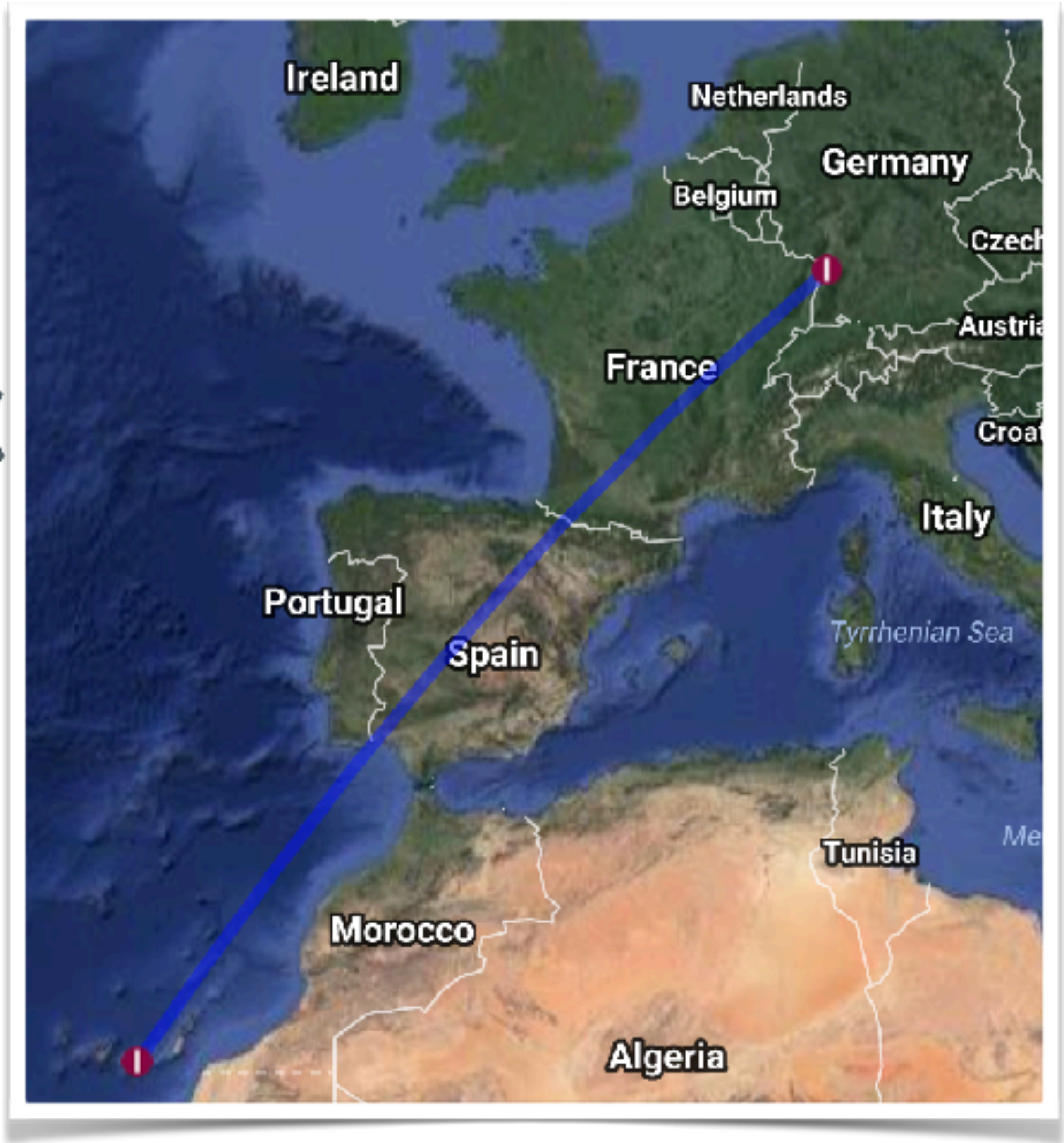
EIFER
EUROPEAN INSTITUTE FOR ENERGY RESEARCH

Jochen Wendel
Alexander Simons
Andreas Koch

Collaboration

ULPGC

CTIM
CENTRO DE TECNOLOGÍAS DE LA IMAGEN



EIFER
EUROPEAN INSTITUTE FOR ENERGY RESEARCH

eDF

KIT
Karlsruher Institut für Technologie

Outline

- Project Goals
- Urban and energy-related data models
- Tools: The Glob3 Mobile framework
- Representing a CityGML model in 3D
- Multimodal approach
  - Virtual Globe View
  - Virtual Reality Mono
  - Virtual Reality Stereo
  - Augmented Reality
- Use case: Visualising solar irradiation
- Conclusions

Project Goals

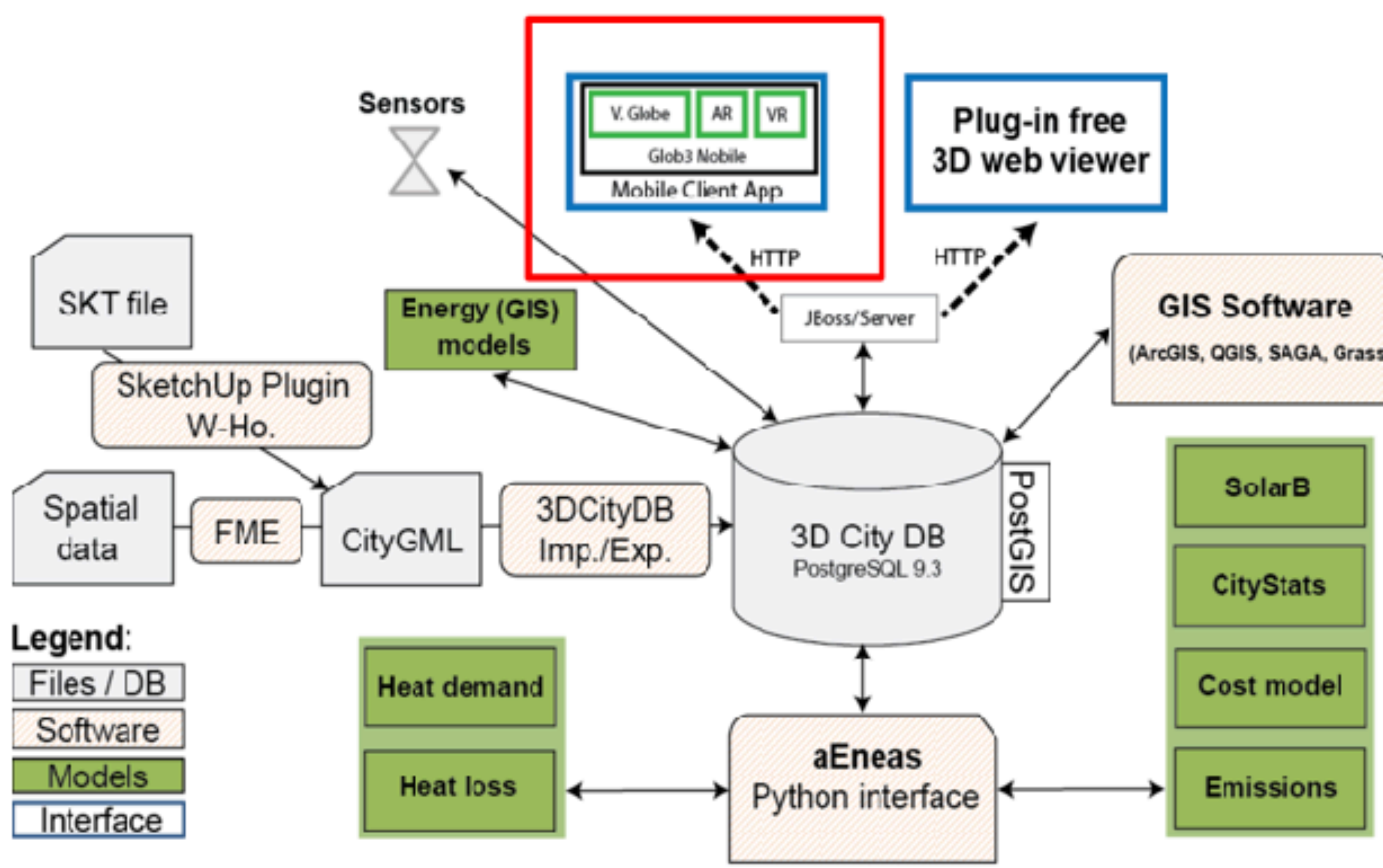
- Prototype an interactive and mobile system for exploring:
  - Semantic building / urban representational models (e.g. CityGML)
  - Energy related data sets.
- Explore the possibilities of multi-LoD maps, Virtual Reality and Augmented Reality for the visualisation of 3D urban models and temporal data-series.
- Create a iOS app, that serves as demonstration of the service.

Urban and energy-related data models

- **CityGML**: Information model for urban objects representation.
  - Extension of GML (from OGC)
  - Classes, hierarchies, aggregations, relations, and properties.
  - Used on 3D virtual cities, analysis, simulation…
  - Extendable via Application Domain Extensions (ADE)
  - Buildings represented in different levels of detail.

Urban and energy-related data models

- **Karlsruhe Model**: CityGML LoD 2
- **CityStats, Heat D./ L.**:Energy-related data per building
- **SolarB**: Temporal data-series representing energy simulations



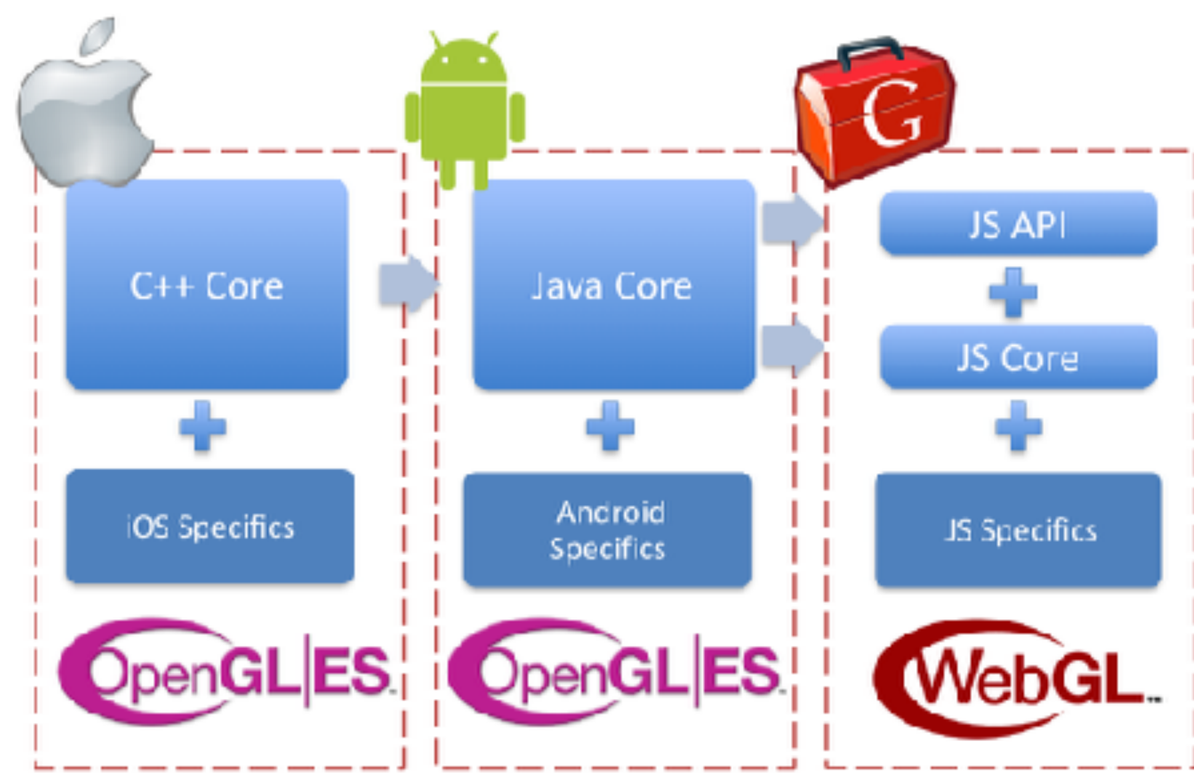
Based on Nichersu and Simons (2014) and extended by Wieland et al. (2015), Saed and Wendel (2015)

Urban and energy-related data models

- **Karlsruhe** model
  - +30.000 buildings [LoD2] (from a total set of 80.000).
  - +230.000 surfaces [Grounds, Walls and Rooftops]
  - Building parameters:
    - Heat demand, Volume, GHG Emissions, solar gains, 50 demographic variables…
  - High resolution textured models of emblematic buildings and monuments.

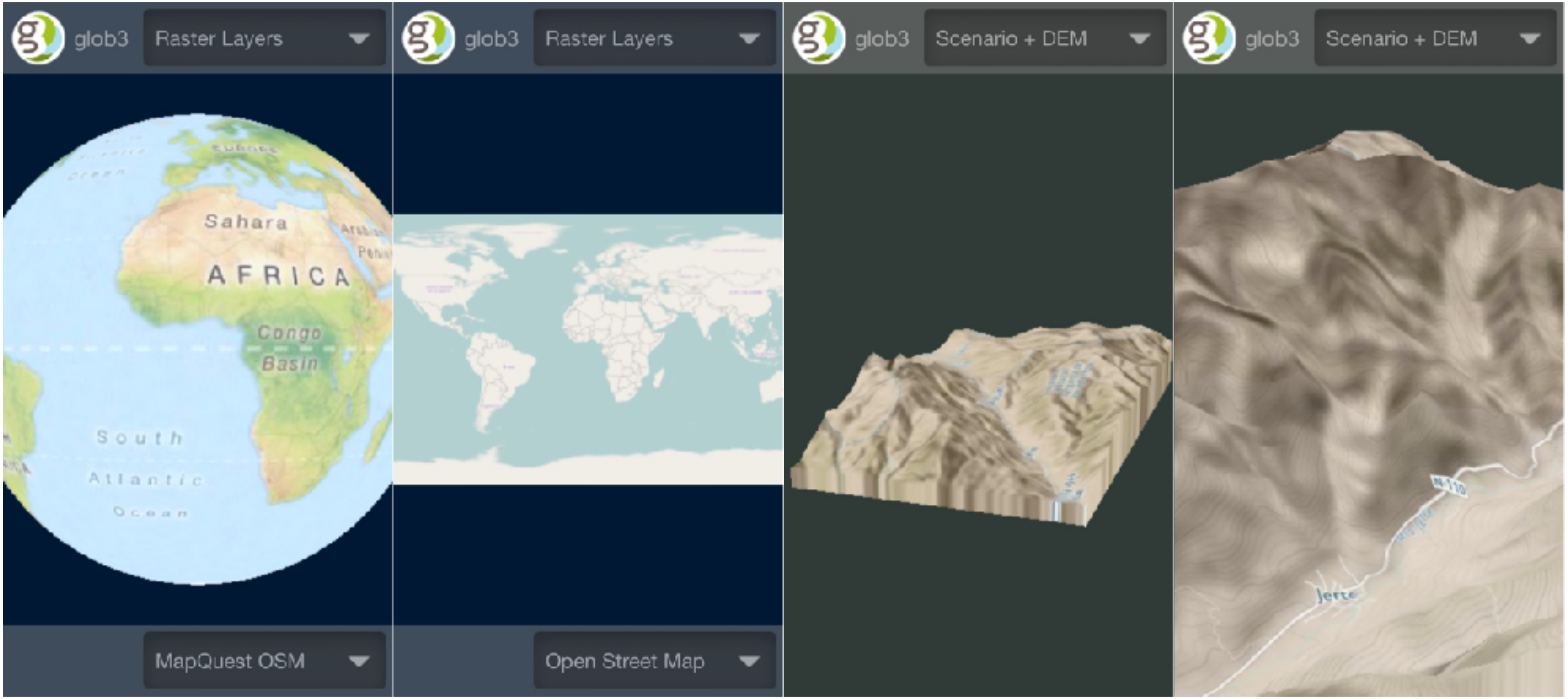
Glob3 Mobile

- Open-source framework for Map & Virtual Globe Applications.
- Native implementations for iOS, Android and Web.
- Developed by CTIM (ULPGC) and IGO Software.
- Available: https://github.com/glob3mobile/g3m
- Automatic Multiplatform Porting



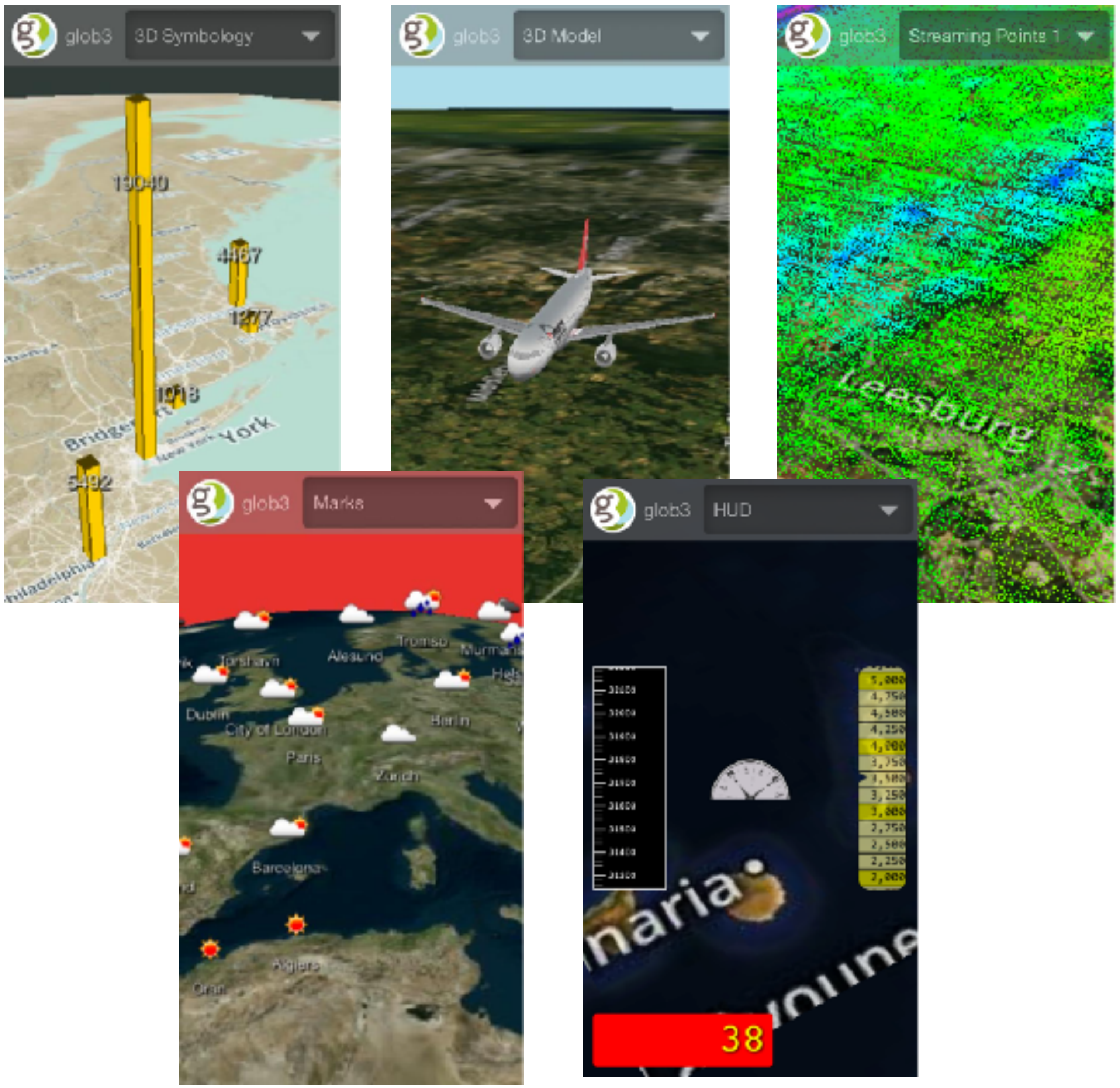
G3m Features

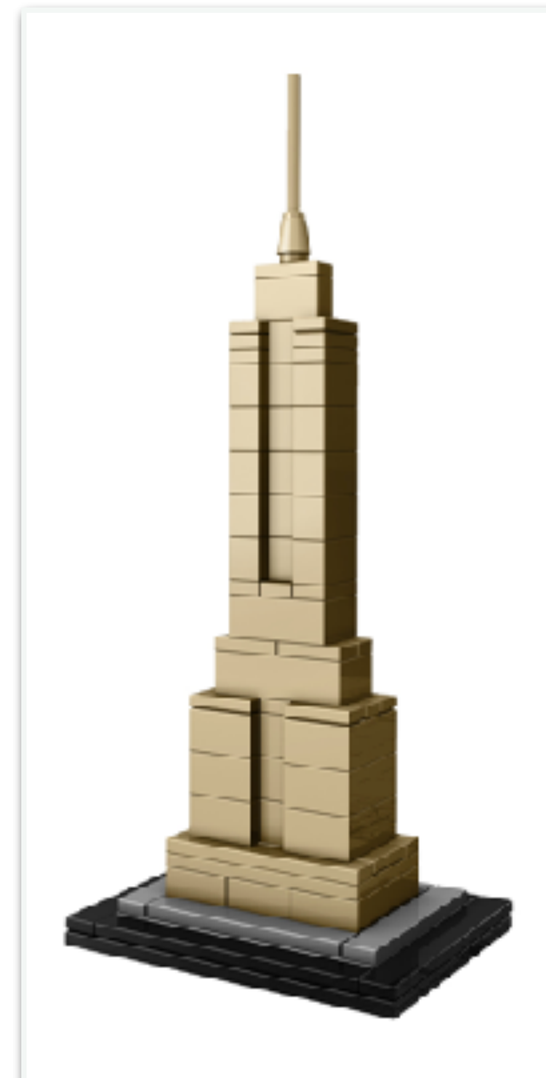
Many kinds of scenario



G3m Features

2D/2.5D/3D Interactive Symbology



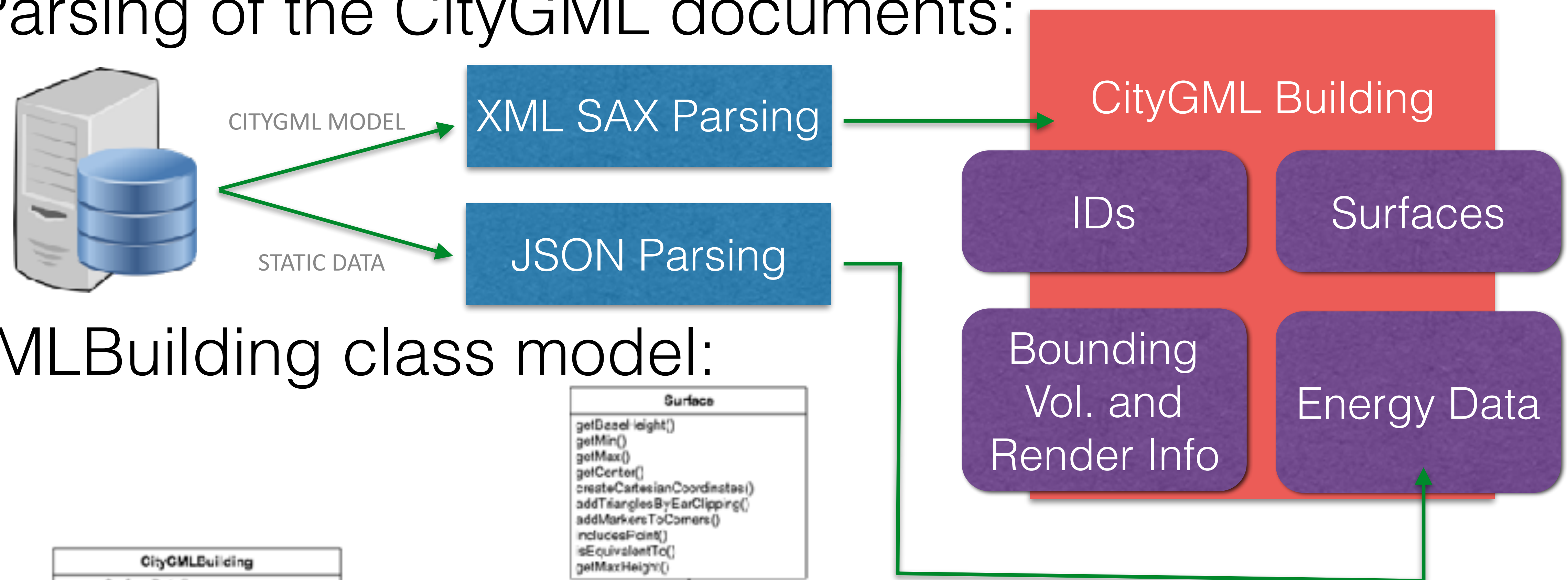


CityGML to 3D

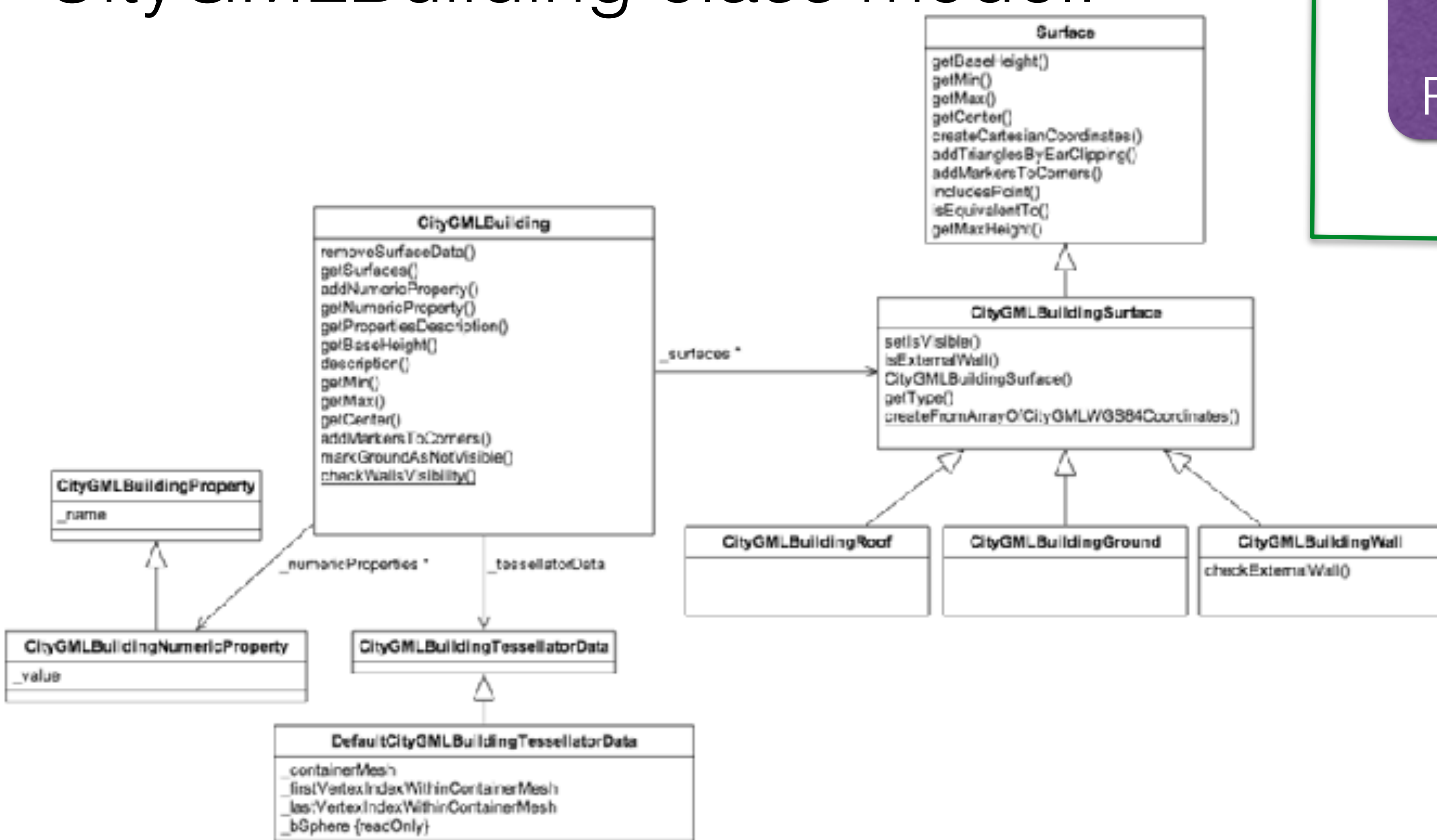
- OpenGL / WebGL only understand triangles!
- The data received via CityGML needs to be translated into a triangulated mesh model to be displayed.
  - Model storage can be local or on a remote server.
    - Karlsruhe model ~= 400 MB.
  - Fetching, parsing and tessellation are executed on parallel threads.

CityGML to 3D: Parsing

- SAX Parsing of the CityGML documents:

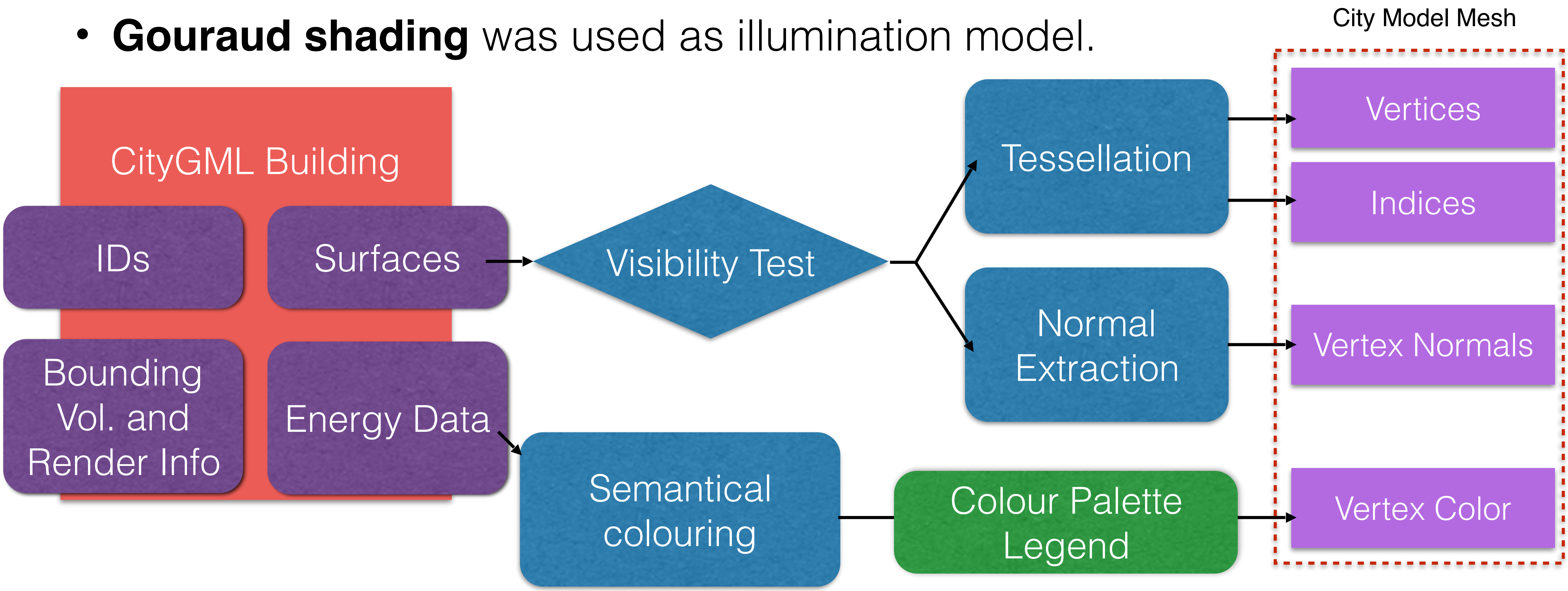


- CityGMLBuilding class model:



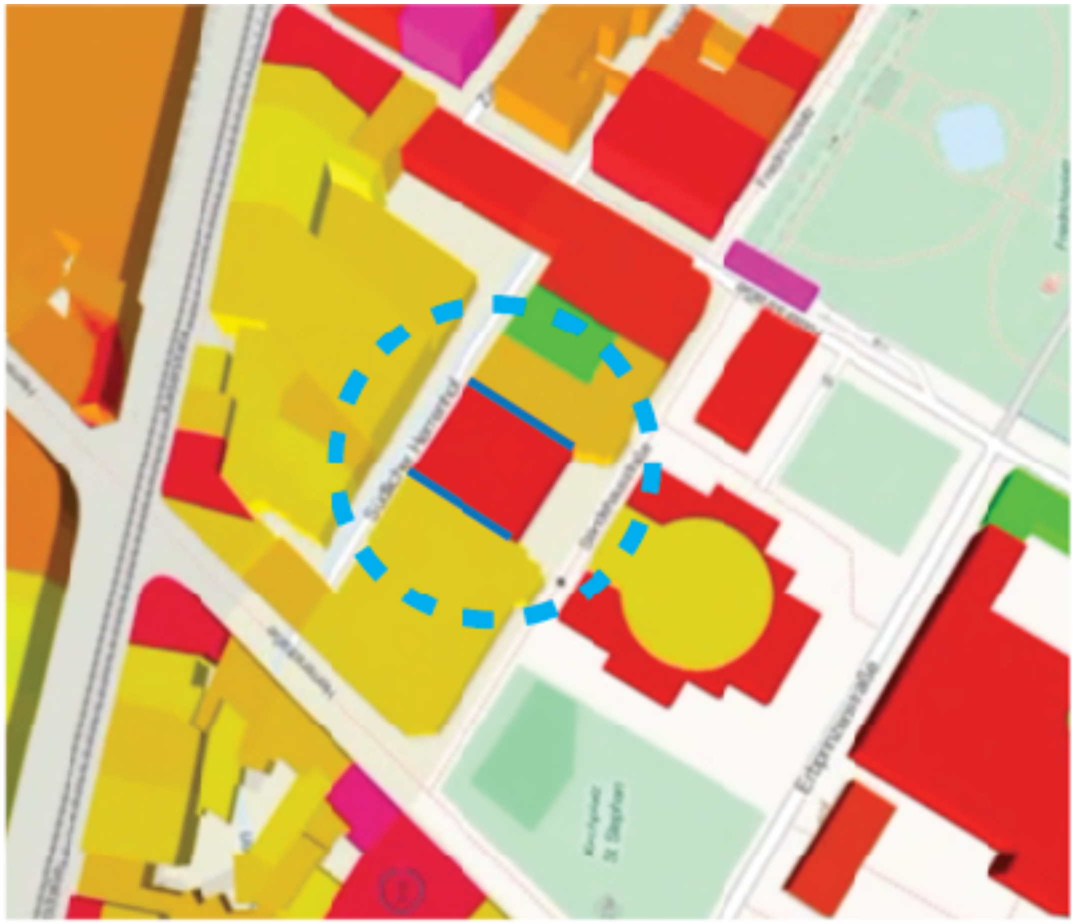
CityGML to 3D: Tessellation

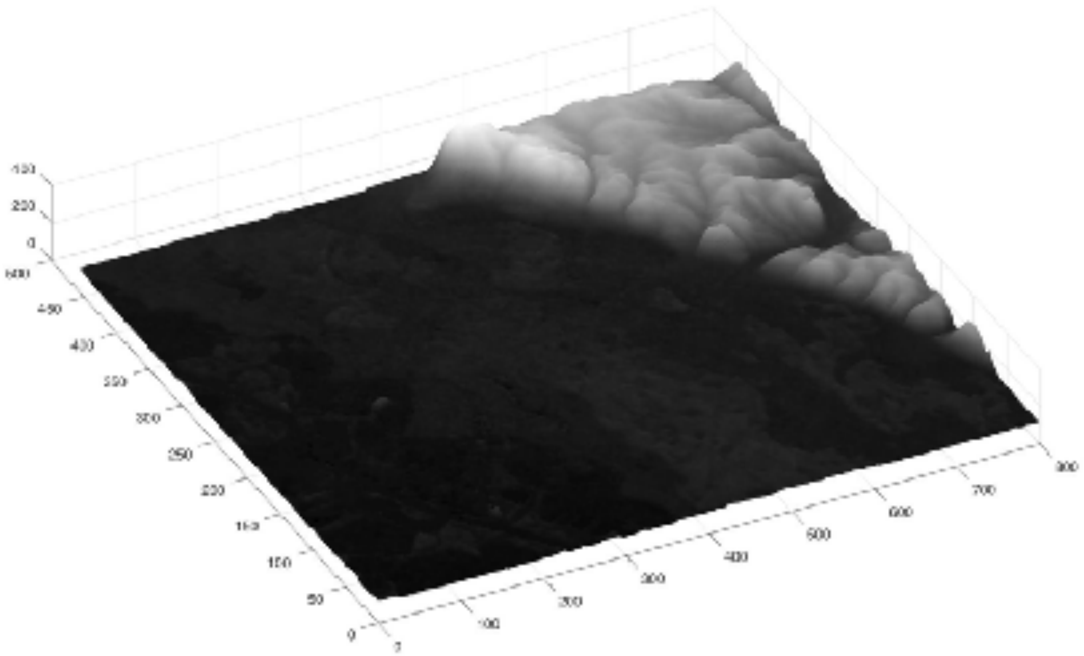
- Creating a single triangular mesh of buildings.
    - For a high number of models, batched drawing is essential [x49]
- **Gouraud shading** was used as illumination model.

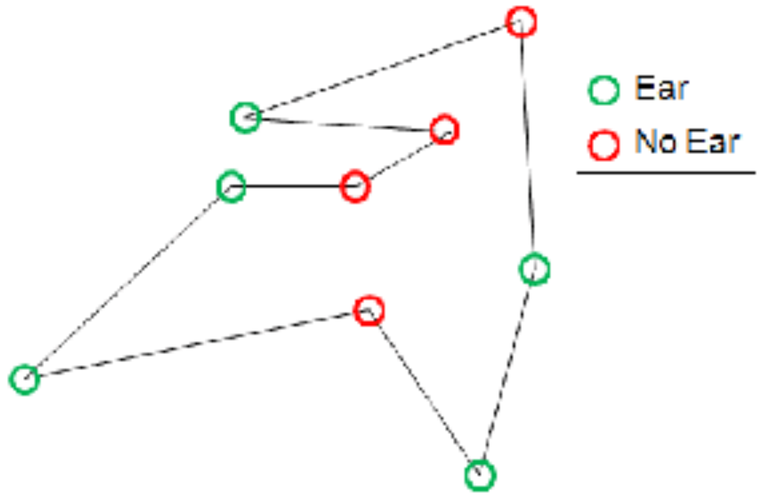


CityGML to 3D: Tessellation

- Visibility test, eliminating shared walls.
  - Proximity based limiting the O(n!) complexity.
- EPSG:4326 to Cartesian World Coordinates
  - Addition of DEM displacement
- **Ear Clipping Algorithm** for wall tessellation
  - Computationally expensive algorithm [$O(n^2)$]
    - 91% of tessellated surfaces are 4 edged.

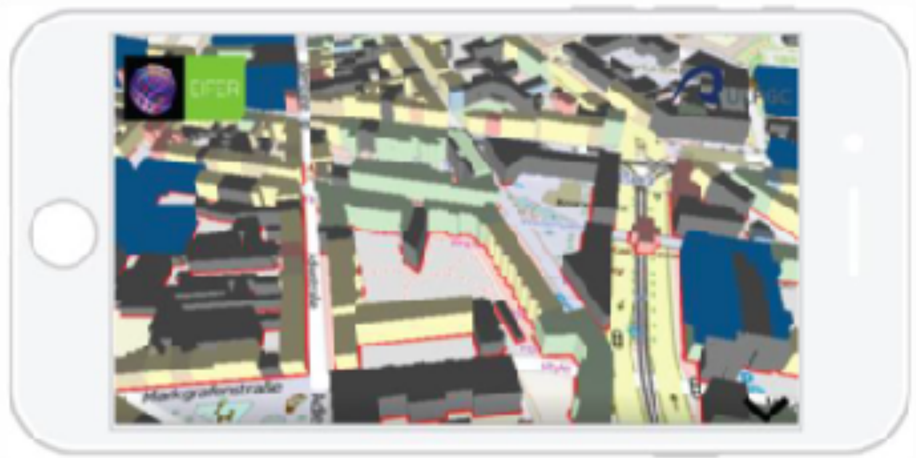




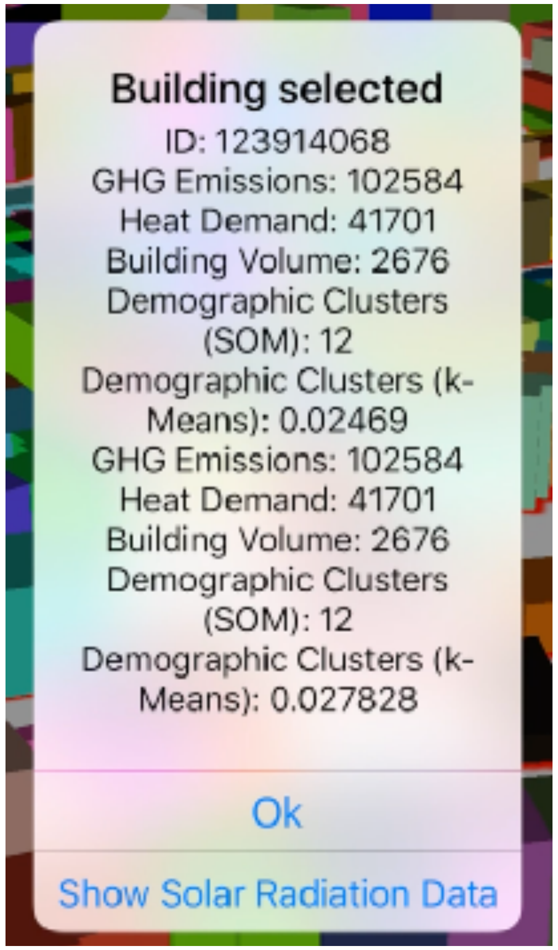


http://www.sunshine2k.de/coding/java/Polygon/Kong/Kong.html

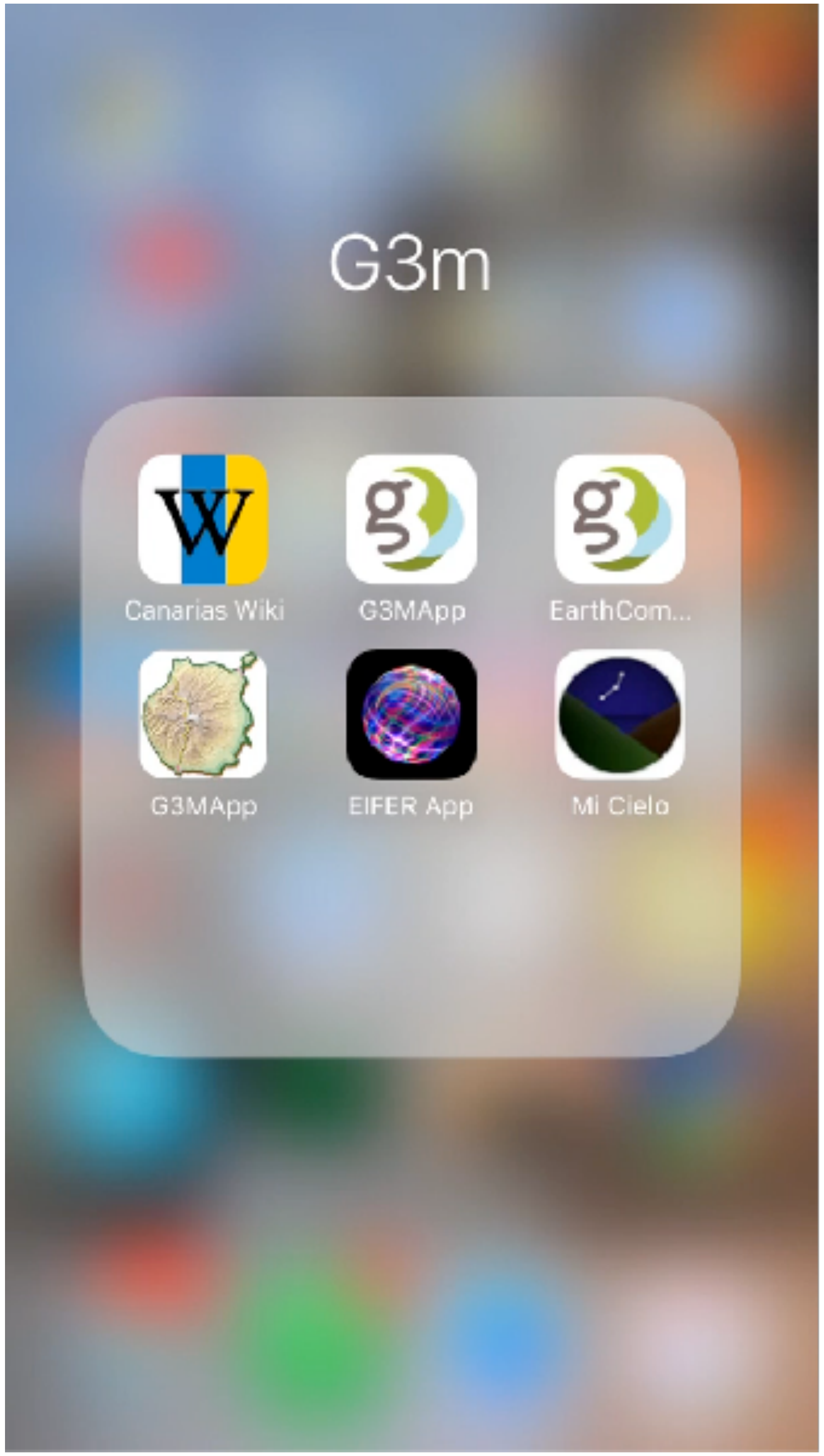
Multimodal App: Virtual Globe



- Classic GIS 3D map approach.
- Multitouch navigation.
- Buildings are selectable showing their associated data.
- OpenStreet Map as base layer. [Mapnik]



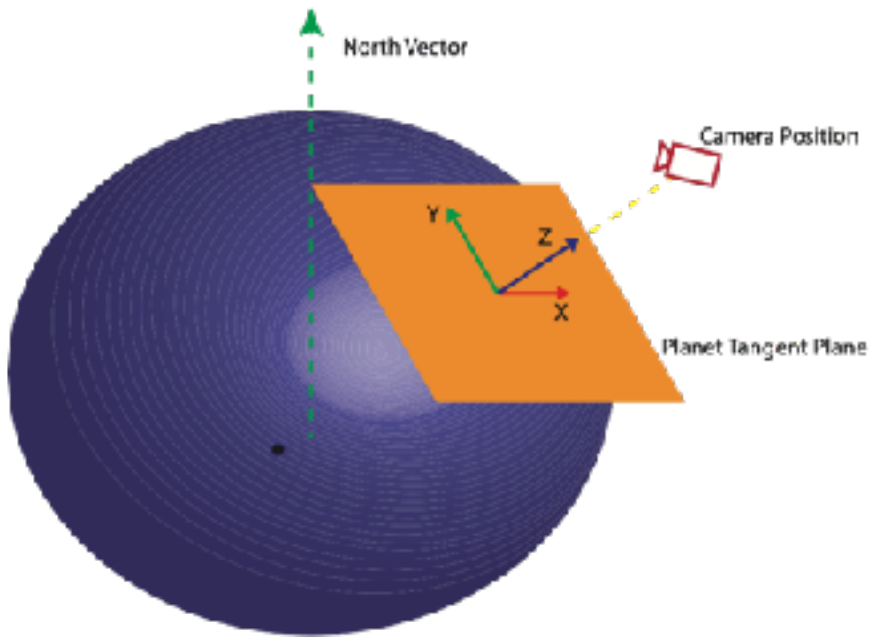
Multimodal App: Virtual Globe



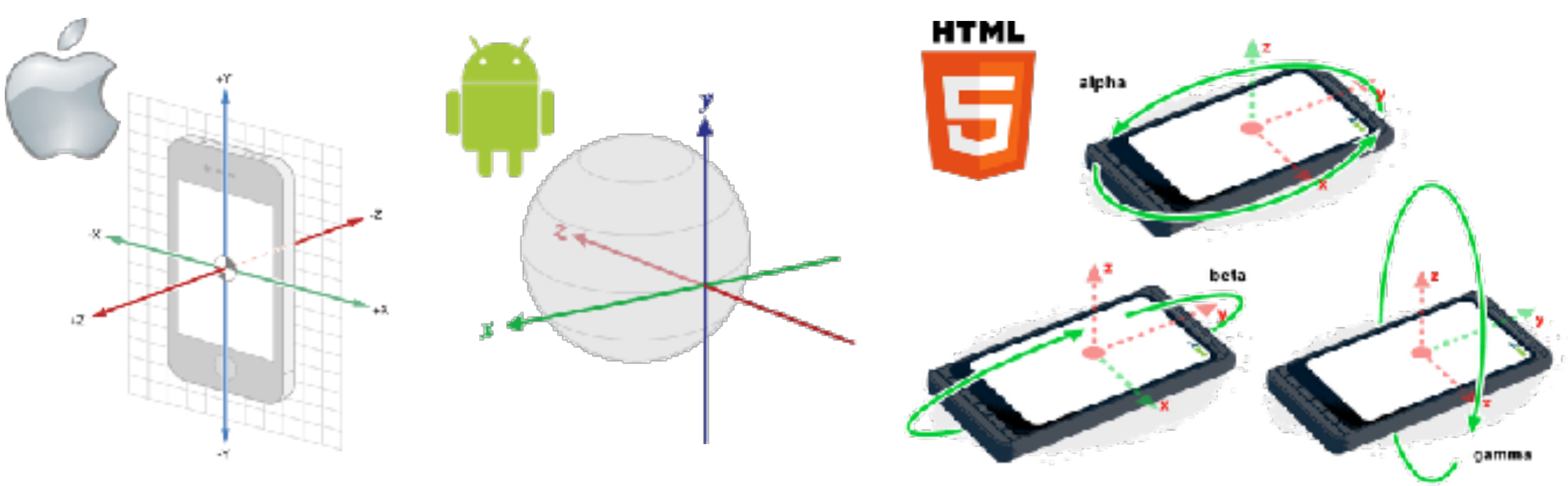
Multimodal App: Virtual Reality

- Sensors output of iOS, Android and Javascript.
- Control the UI rotations.
- Device location given by GPS.

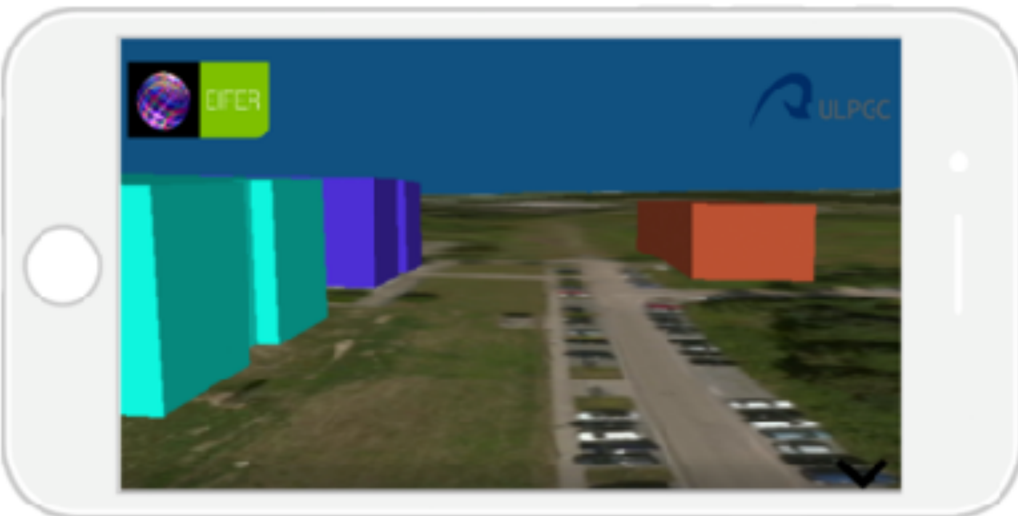
Geolocalized Reference System

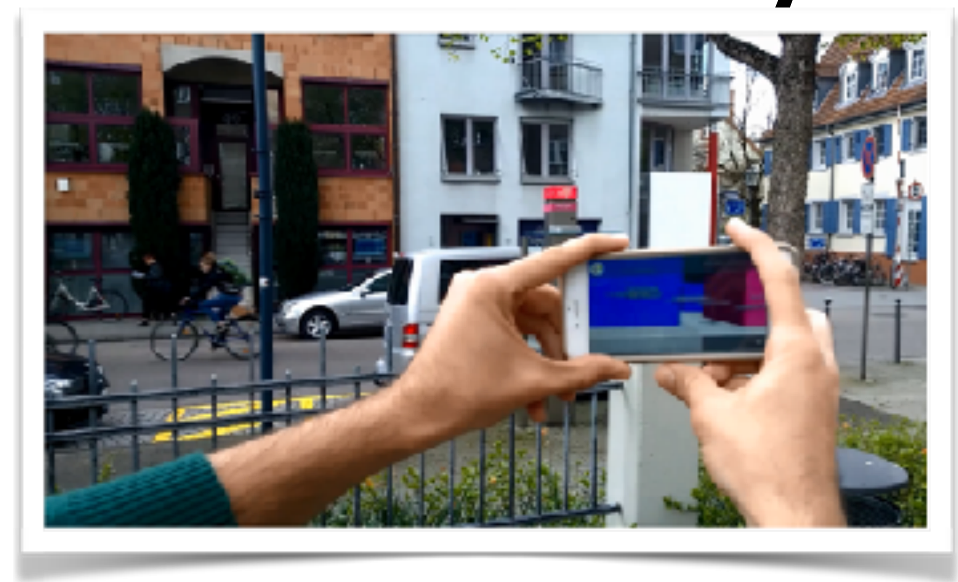


Multiplatform device-attitude representations



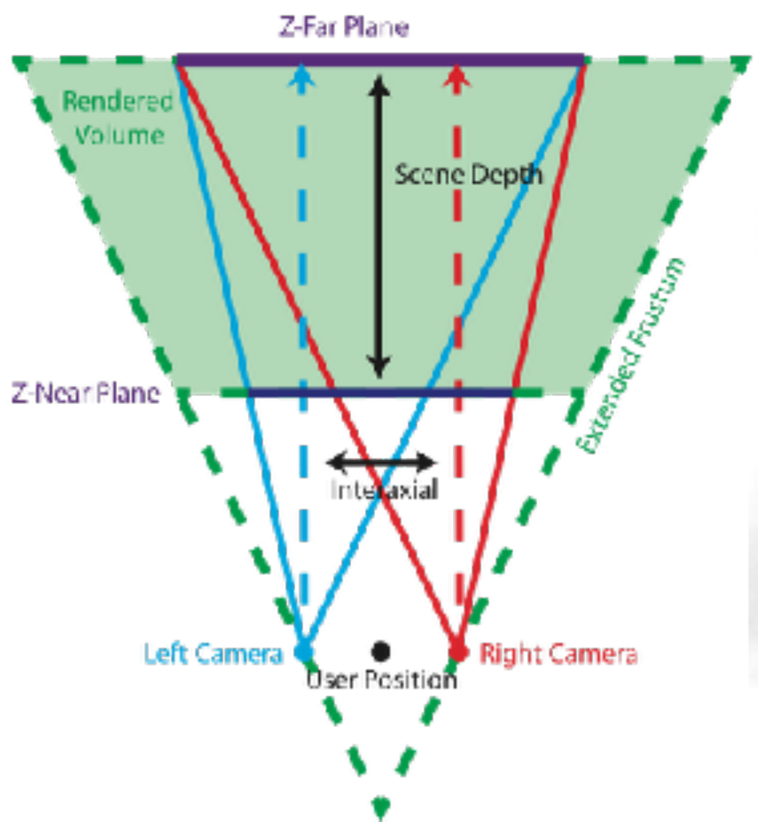
Multimodal App: Virtual Reality

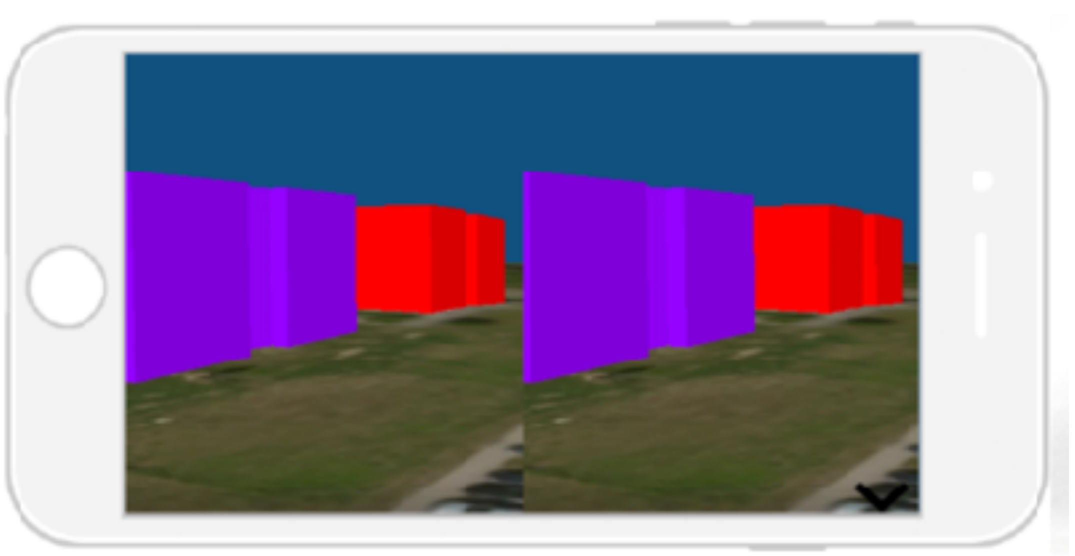




Multimodal App: VR Stereo

- Stereo rendering of the scene
  - Low-level OpenGL coding from scratch.
  - Stereo parallel projection.
  - Using a 1:1 scale for the interaxial.
  - Stereo frustum culling to improve performance.





Multimodal App: VR Stereo

- Use of Cardboard-like VR headsets.

Multimodal App: Augmented Reality

- Device Attitude Tracking + Real Image Merging
- Phone's camera has to be mathematically represented.
  - Intrinsic parameters obtained with OpenCV.

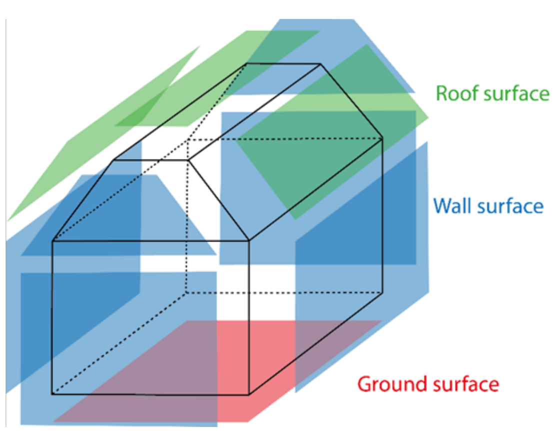
$$\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \underbrace{\begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix}}_{\text{Intrinsic C. Matrix}} \underbrace{\begin{bmatrix} r_{11} & r_{12} & r_{13} & t_1 \\ r_{21} & r_{22} & r_{23} & t_2 \\ r_{31} & r_{32} & r_{33} & t_3 \end{bmatrix}}_{\text{Extrinsic Camera Parameters}} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix}$$

Multimodal App: Augmented Reality

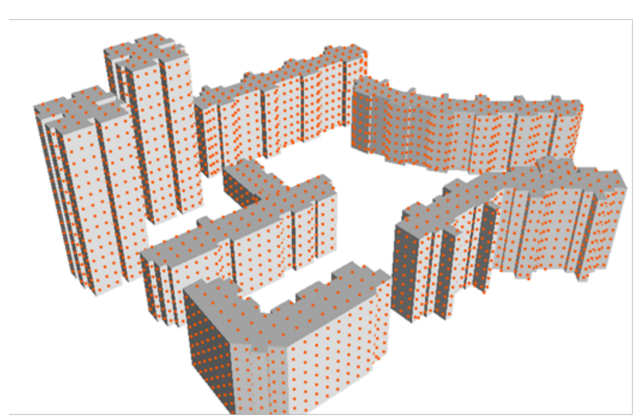
MULTI FRAMEBUFFER RENDERING

Use case:
SolarB – Solar irradiance model

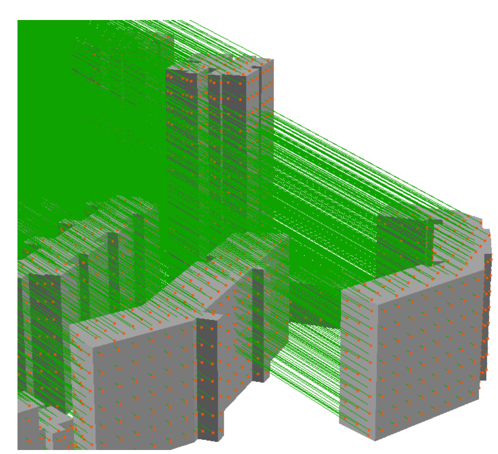
- Numerical simulation of the amount of sunlight captured by the building surfaces.
  - Based on Šúri, M. and Hofierka, J. (2004)
- Final result: Temporal data series of Solar radiation per time interval for surfaces and buildings [kWh]
  - Surfaces represented as point sets with a resolution of 1 p/m^2.



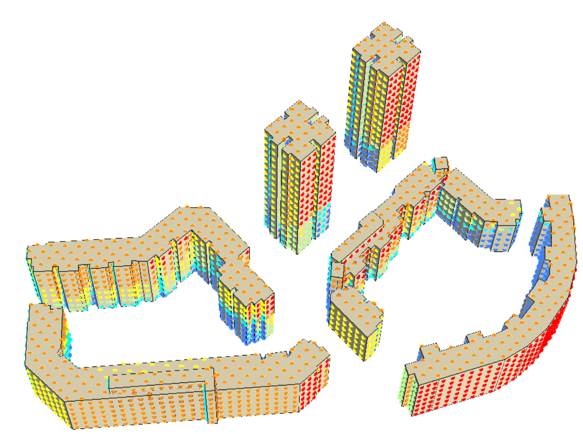
a) Building part classification



b) Point grid generation



c) Shadowing analysis

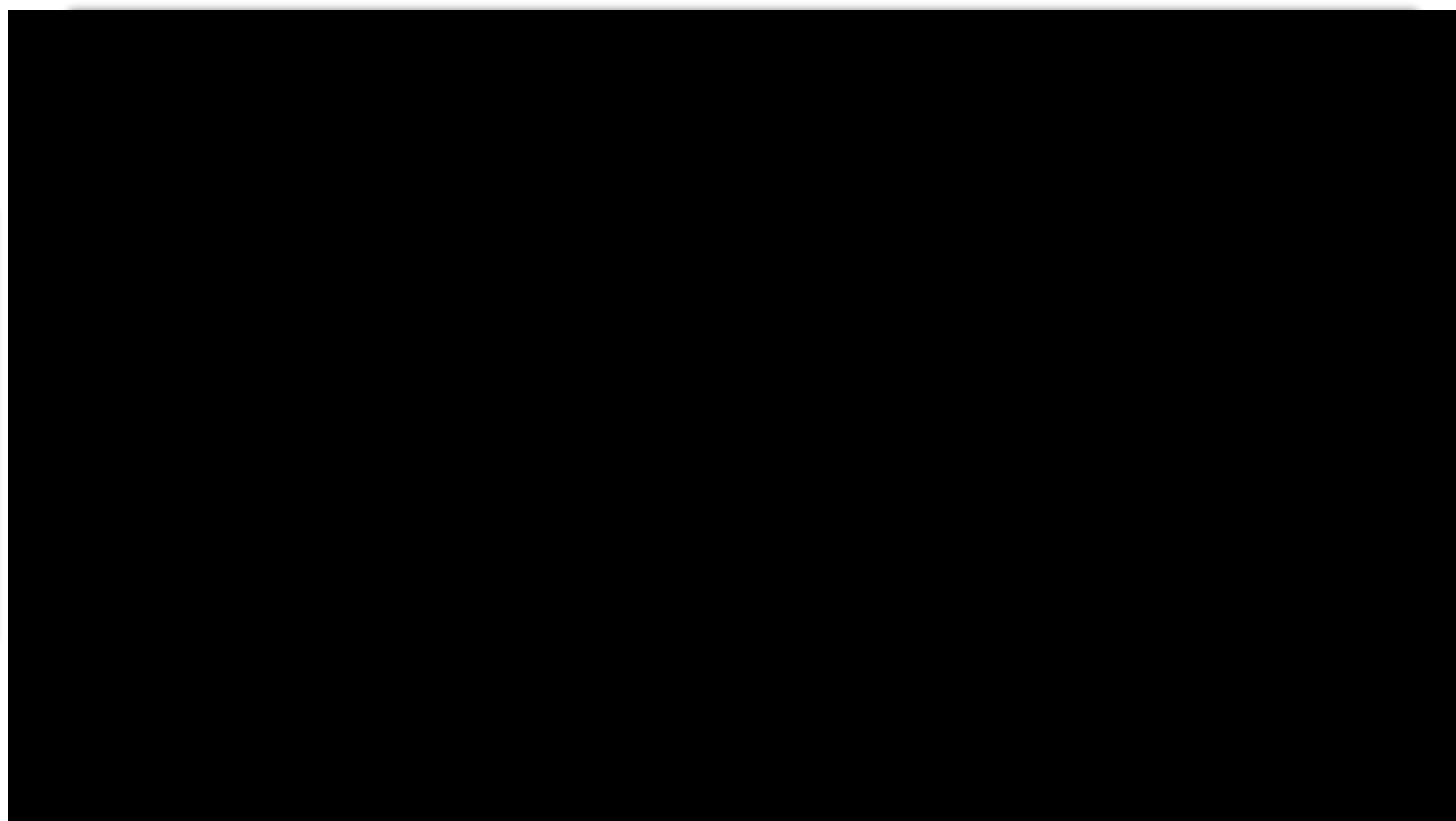


d) Aggregation of results

Use case:

SolarB – Solar irradiance model

- Example: The EIFER offices in Karlsruhe (7 stories)
  - 14 surfaces [3071 points]
  - 1 year of solar irradiation data [8760 timestamps]



Conclusions

- The prototype demonstrates feasible to apply mobile computer graphics technologies to the study of massive urban datasets.
- The app is able to directly retrieve semantic building data from energy simulations/models in a standardised way (OGC, CityGML structure).
- VR and AR are useful techniques for field experts on energy research and infrastructure maintenance.
- For medium sized cities, multi-level-of-detail is not necessary.
- GPS & Compass accuracy for VR and specially for AR is still unreliable on many urban situations.
  - Alternative positioning techniques could achieve better results.

LBS 2016
13th Conference on Location-Based Services
Vienna, 14–16 November 2016

Thanks for your attention

ULPGC

José Miguel Santana
Agustín Trujillo
José Pablo Suarez

EIFER
EUROPEAN INSTITUTE FOR ENERGY RESEARCH

Jochen Wendel
Alexander Simons
Andreas Koch