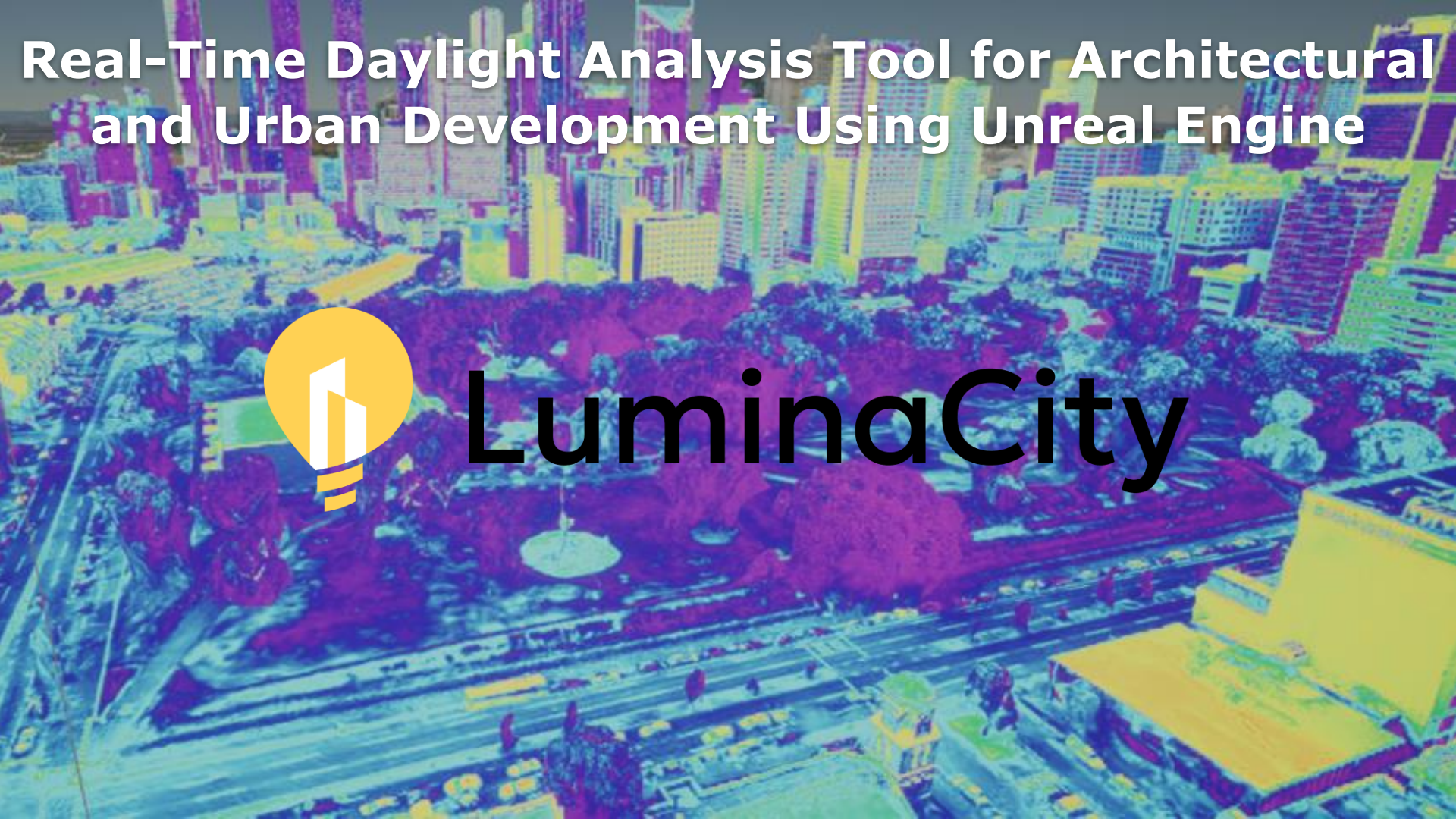
Real-Time Daylight Analysis Tool for Architectural and Urban Development Using Unreal Engine



Real-Time Daylight Analysis Tool for Architectural and Urban Development Using Unreal Engine

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Co-reader: Ken Arroyo Ohori

Delegate: Bastiaan van Loenen

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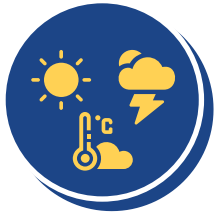
LuminaCity

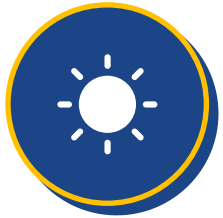


Climate Change

Emissions from Built environment

Housing Shortage

Lack of user-friendly tools



Daylight Analysis

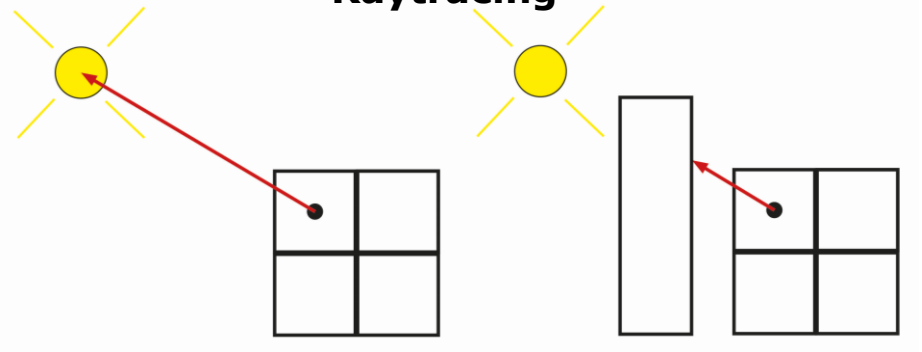
Health

Energy efficiency

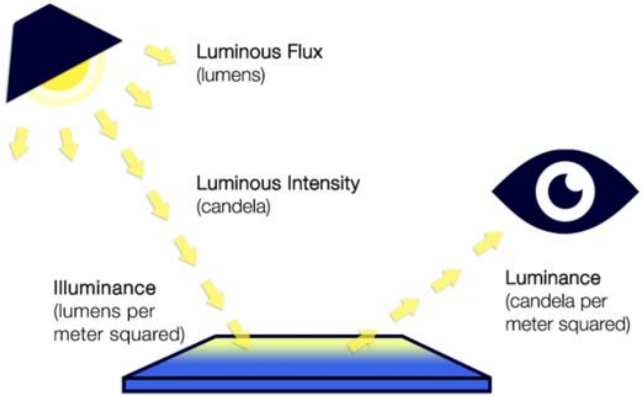
Temperature

- Mathematical representations of the sky
  - position
  - sky type
  - atmospheric conditions
- Components of Sky Models
  - Sunlight: Direct sun light
  - Skylight: Diffuse sky light
- Two main simulation techniques
  - Raytracing: shooting a ray
  - Probability based Monte Carlo Simulation
- Measurement Units
  - Luminance: Perceived Brightness
  - Illuminance: Amount of on surface

Raytracing

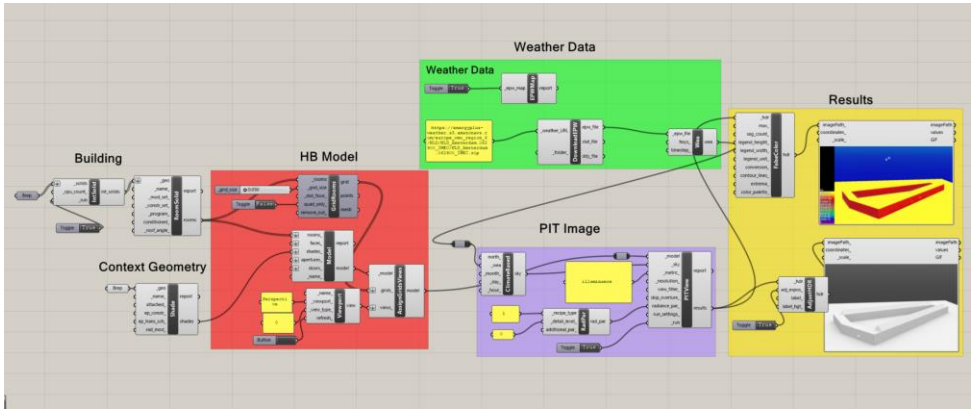


Light Units



Sky & Daylight models

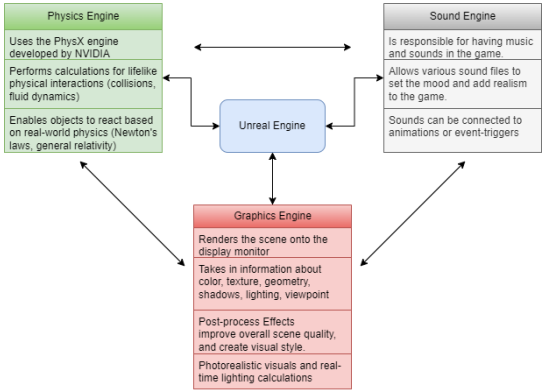
- Radiance
  - Validated daylight model
  - Combines deterministic raytracing and Monte Carlo simulation
- Honeybee
  - Integration with Radiance within Grasshopper
  - Graphical interface
  - Tools for simulating daylighting conditions
  - Slow & complex



Honeybee Grashopper script

- Traditionally used for game development
- Real-time realistic rendering
- Build in Tools
- 3 main components
- Development vs. Runtime
- Development
  - Blueprints: Visual scripting system
  - C++ coding
  - Hybrid approach

Components of Unreal Engine



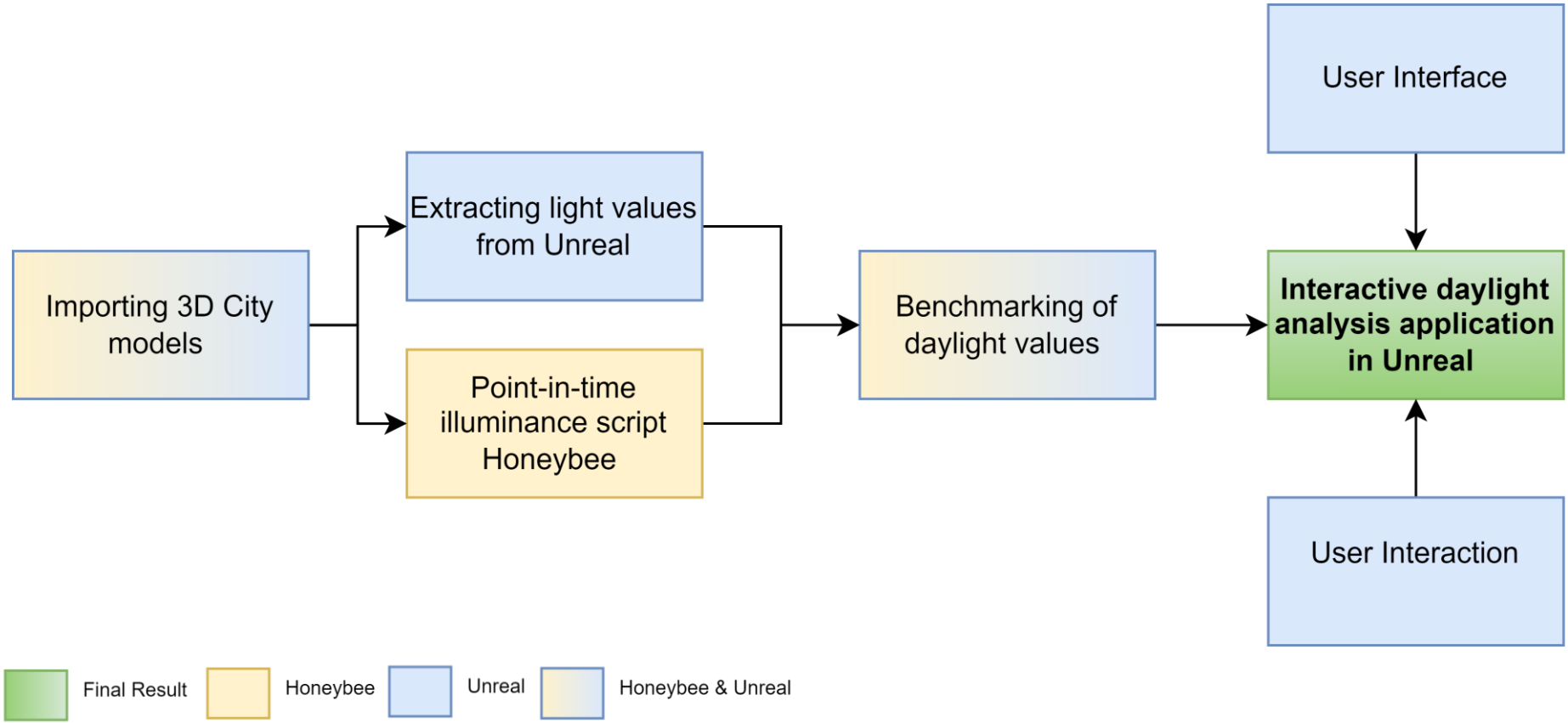
Realistic Rendering

- Validating Game Engines as a Quantitative Daylighting Simulation Tool (Hegazy et al., 2021):
  - Better accuracy compared to traditional rendering techniques.
  - Realistic and interactive virtual daylit spaces without sacrificing quantitative accuracy.
  - Perception differences between real-life and virtual spaces.
  - Game engines have potential as valuable tools for daylighting simulation and should be further validated and adopted in research.

To what extent is the Unreal engine suitable to scale-up physically accurate daylight simulation tools?

Sub questions:

1. Integration of 3D city models
2. Extracting light values
3. Benchmarking
4. Design Functionality



Methodology

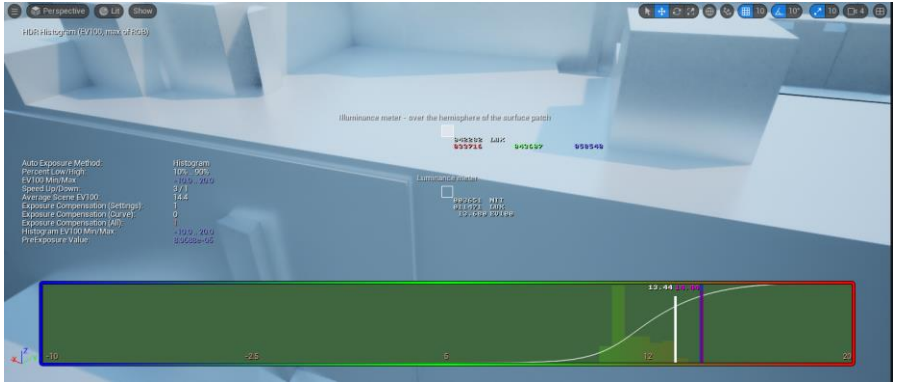
- 3D City model = 3D digital model of City
- Different models
  - CityGML
  - CityJSON
  - Cesium 3D Tiles
  - Etc.
- Usage in Netherlands
  - 3DBag CityJSON
  - Rotterdam/Hague CityGML
  - Amsterdam Cesium 3D Tiles

3D City Model

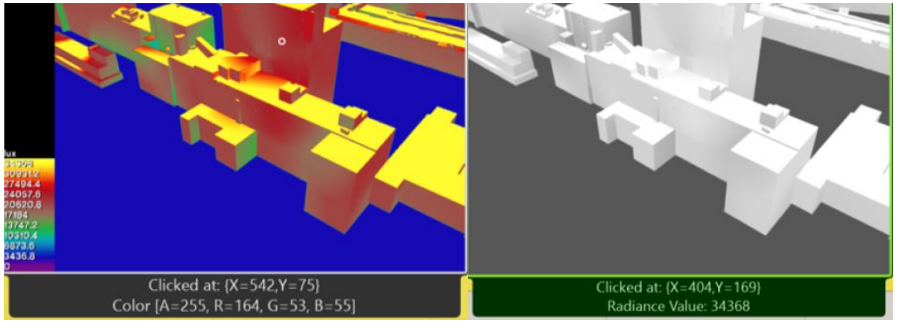
- Not directly loadable in Unreal or Honeybee
- Cesium Ion
  - Georeferencing
  - OGC 3D Tiling standard
  - Smooth rendering
- Implementation in research:
  1. Convert CityJSON to Cesium tile using FME
  2. Load CityGML directly into Cesium ion.
  3. Convert CityJSON to CityGML using FME
  4. Convert CityJSON to CityGML using citygml-tools
  5. Cesium OSM Tileset
  6. Google Maps API.

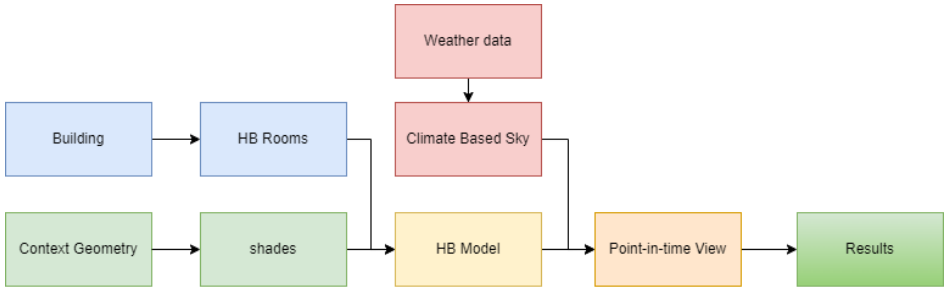
- Unreal
  - Accessing from build in functionality
  - Custom C++ actor
  - HDR eye adaptation tool
  - False Colour Material
- Honeybee
  - Point-in-time Illuminance script

Measurement in Unreal



Measurement in Honeybee





Simplified Honeybee Script

Methodology - Extracting light values

Building blocks

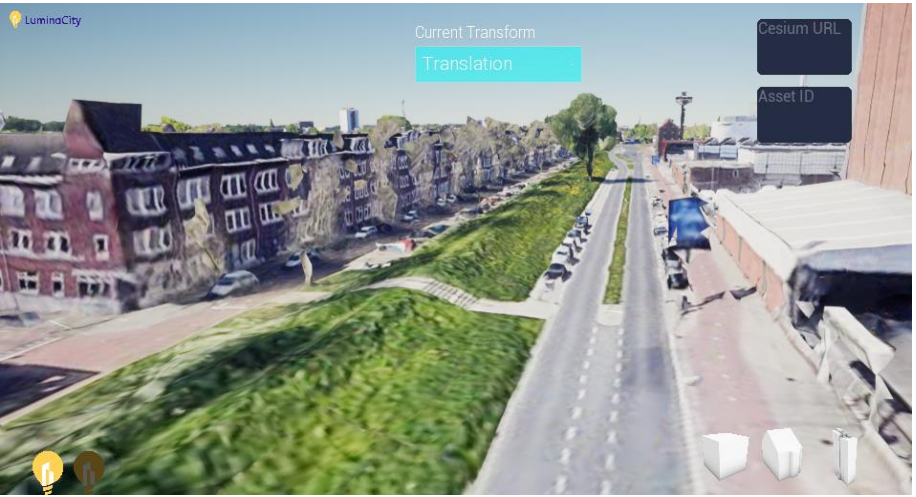
Import tilesets

Change render

Change date & time

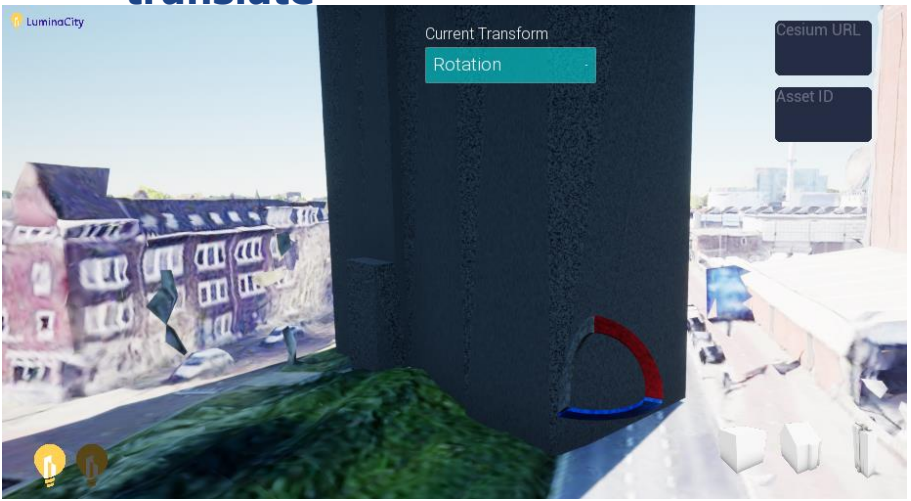
Rotate, scale, translate

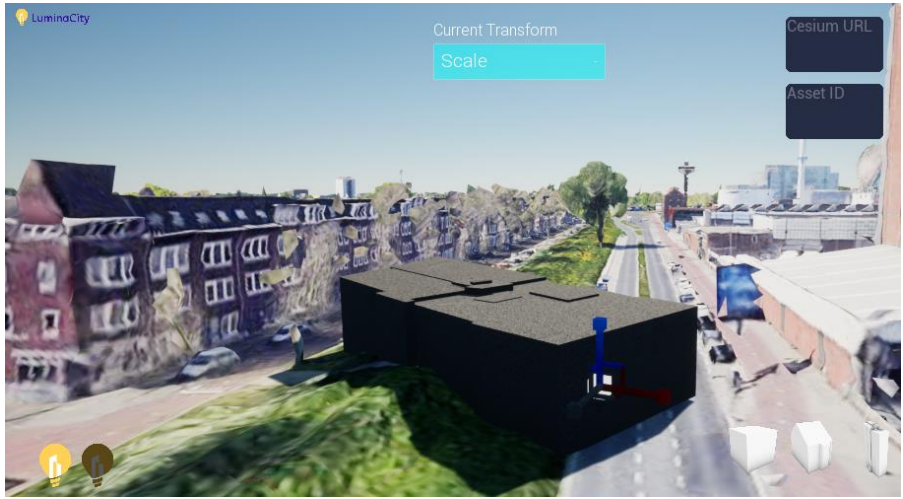
Building blocks



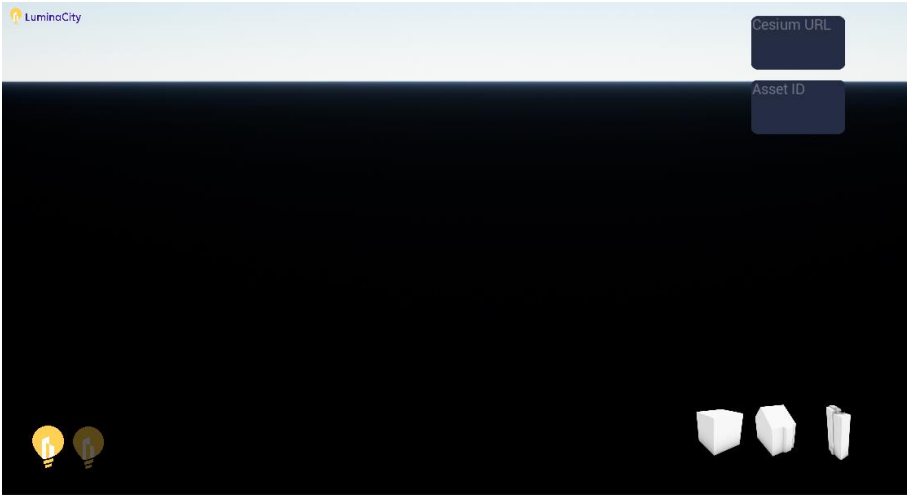
Scale

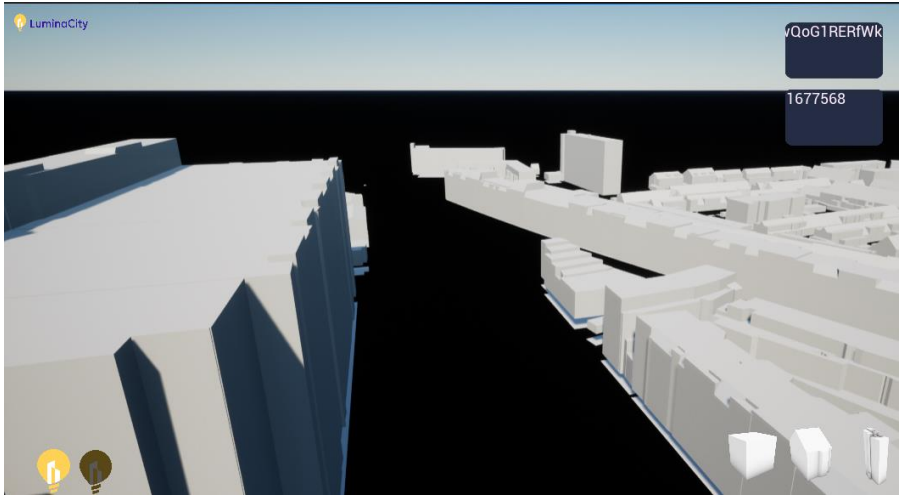
Rotate, scale, translate





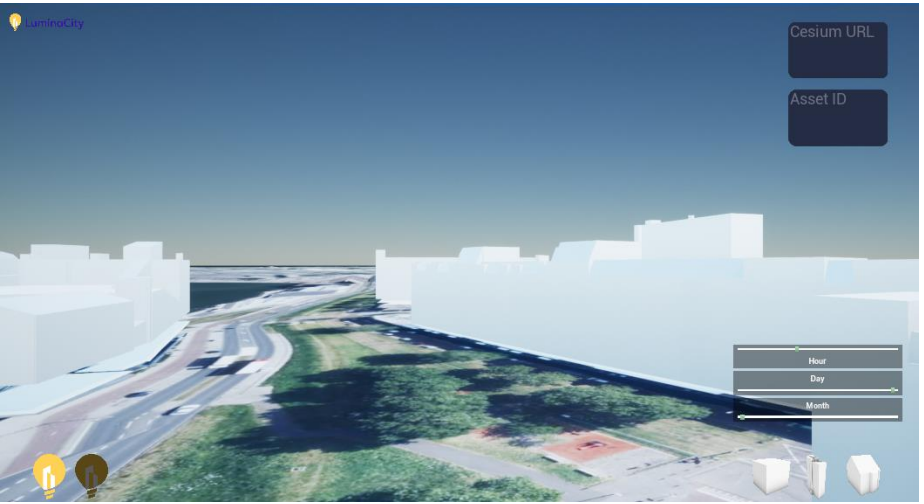
Import tilesets

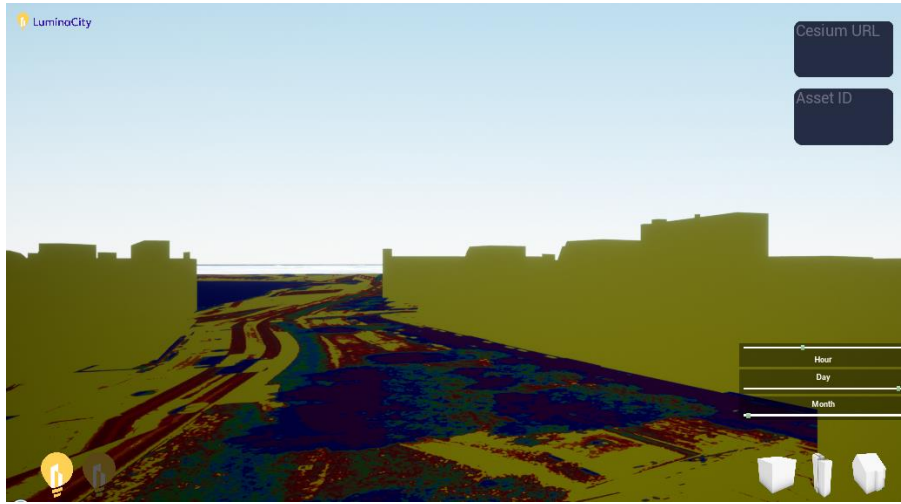




Functionality – import tilesets

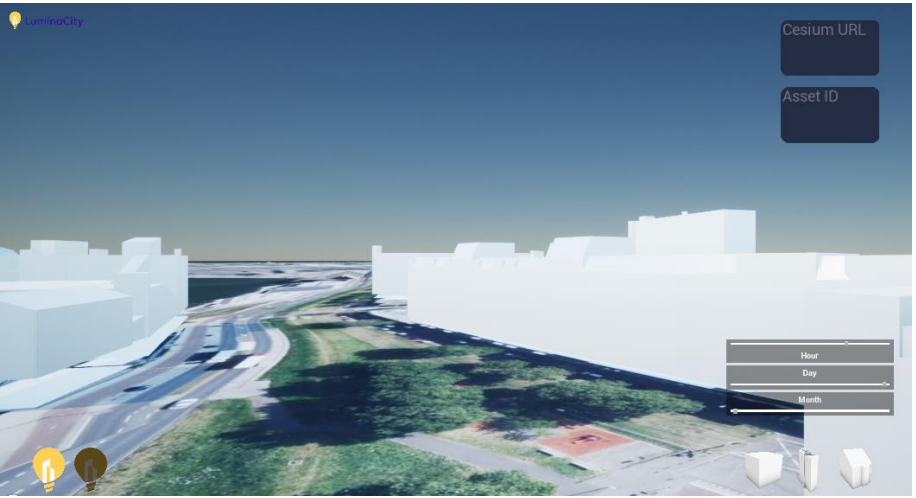
Change render

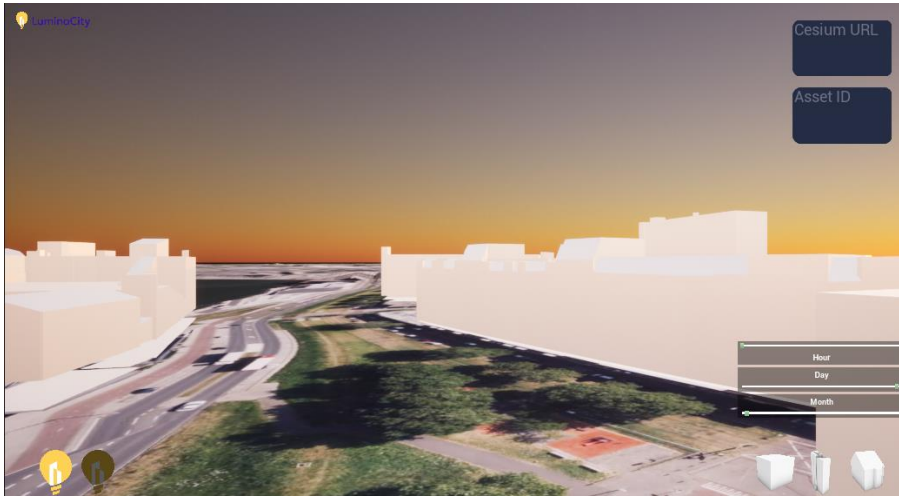




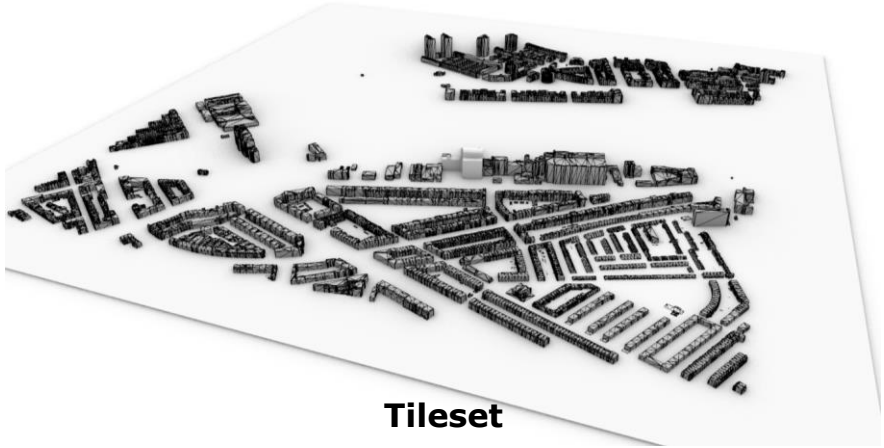
Functionality – change render

Change date & time



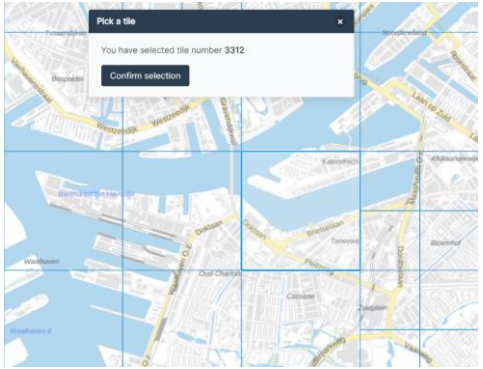


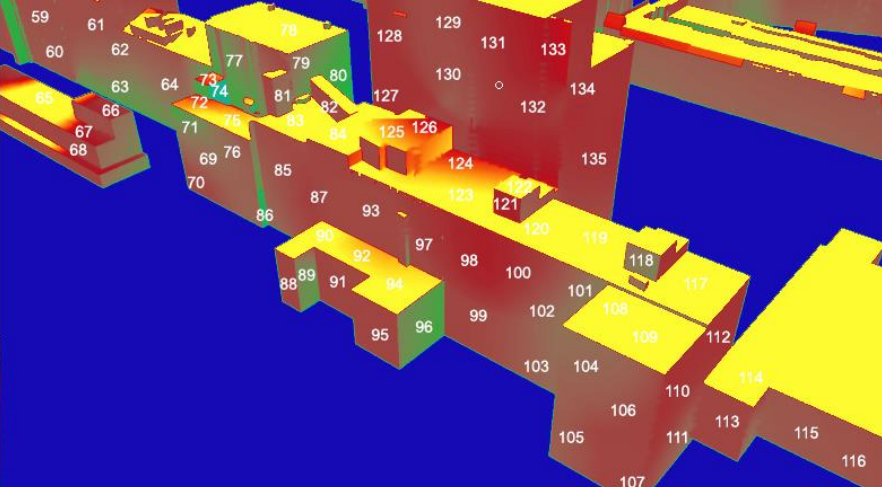
- Benchmarking 3D City Models Unreal vs. Honeybee Script
- Tile 3312 from 3DBAG.
  - 3010 buildings
  - Rotterdam, the Netherlands
  - area of 1.75 km²

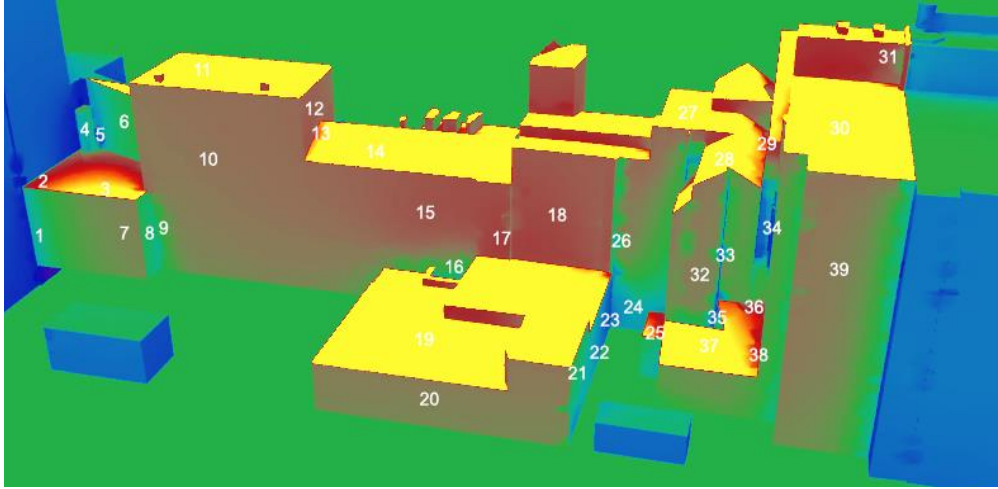


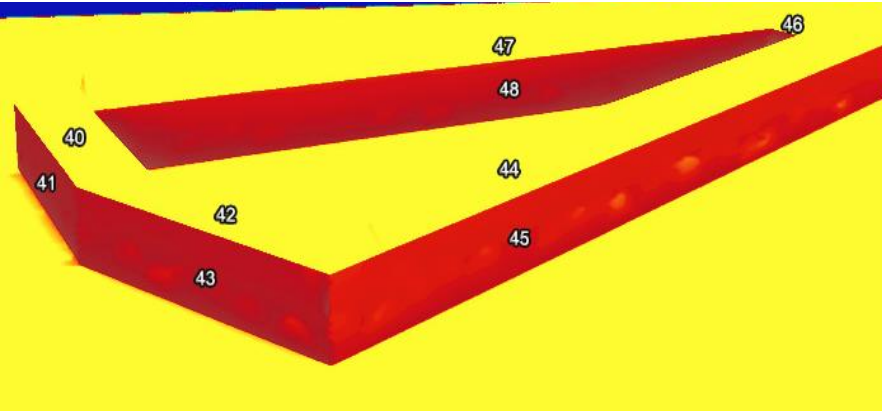
Tileset

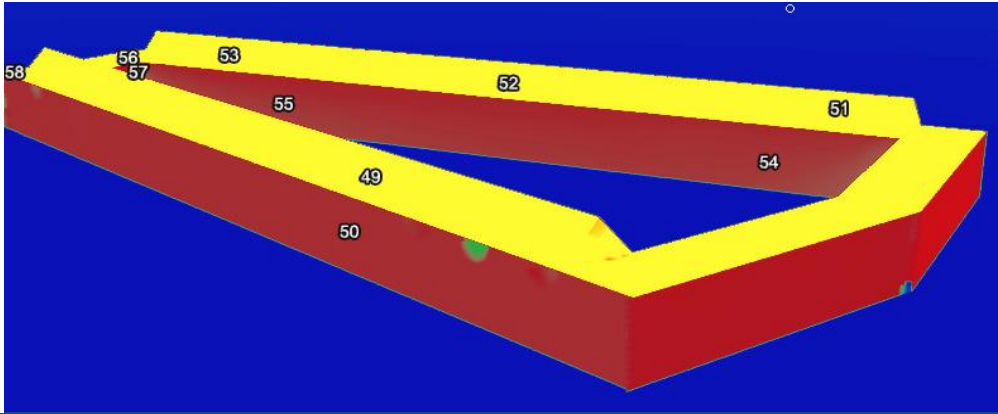
Tileset location



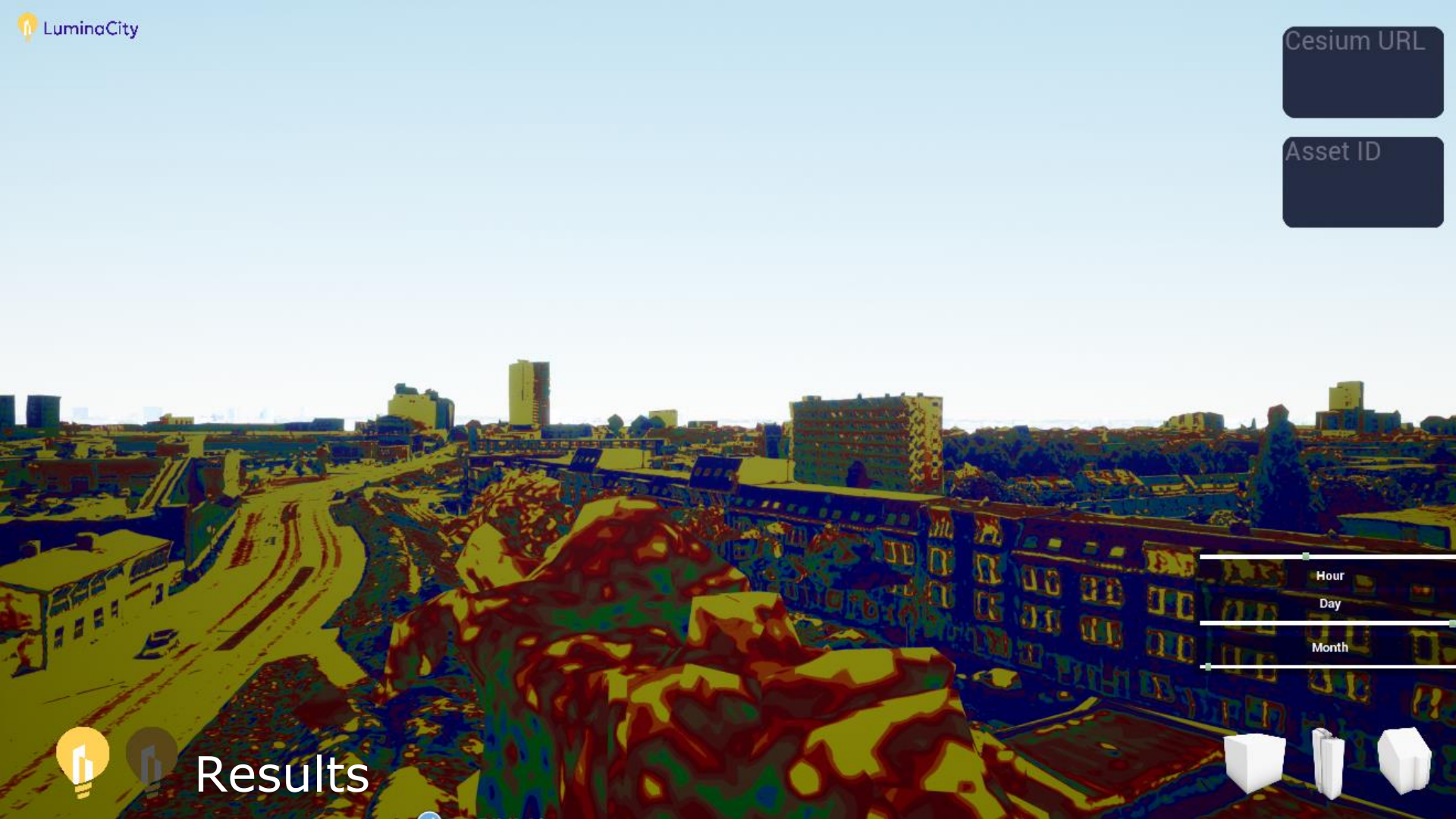




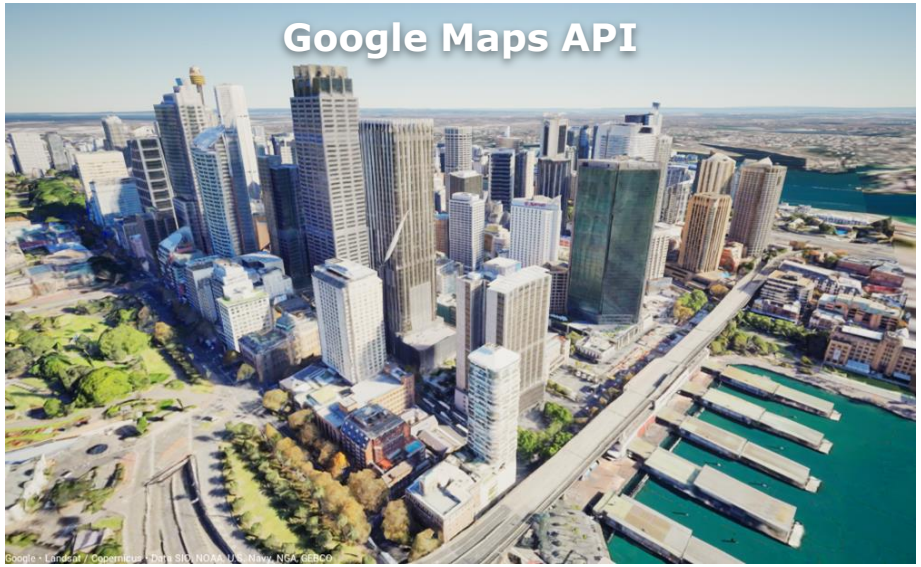




Benchmarking – points

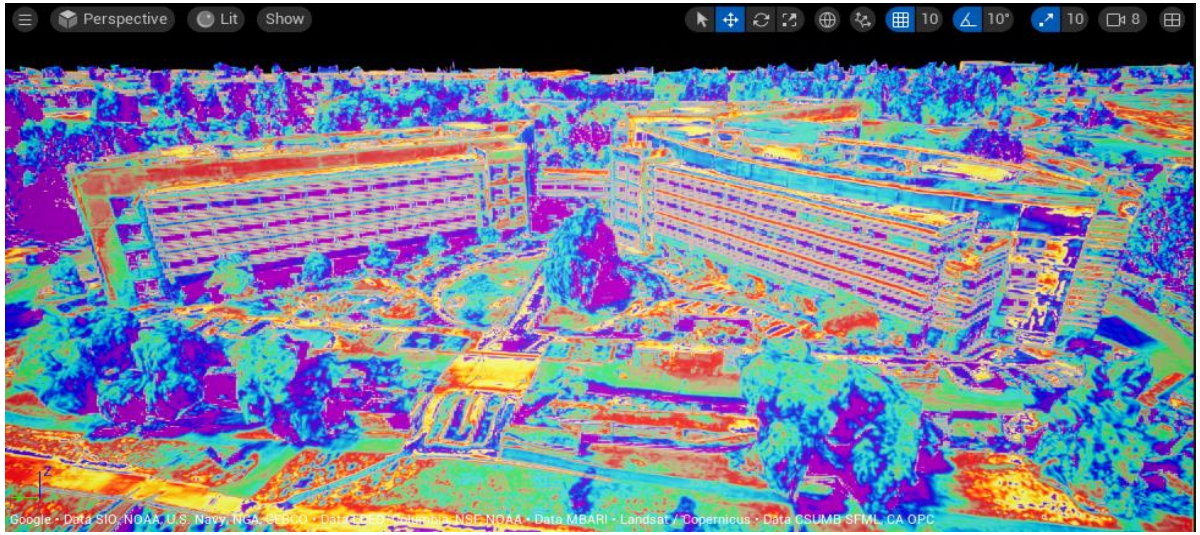

LuminaCity
Cesium URL
Asset ID
Hour
Day
Month
Results

- Height issue CityJSON
- Not all Formats of CityGML accepted



Results - 3D City Models

- **Accessing build in functionality** - required custom engine build
- **Custom C++ actor** – calculate luminance values at runtime
- **HDR eye adaptation tool** – measure Illuminance and luminance values in development mode
- **False Colour Material** - visually represent Illuminance and Luminance

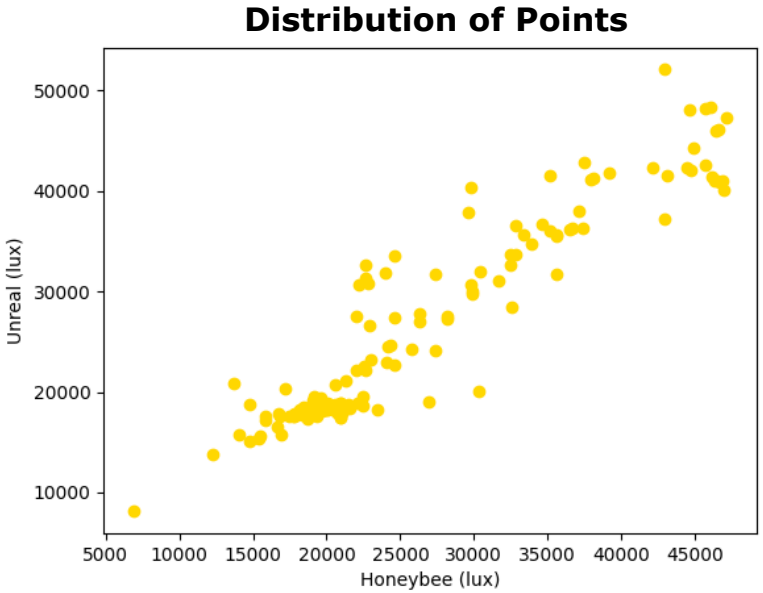


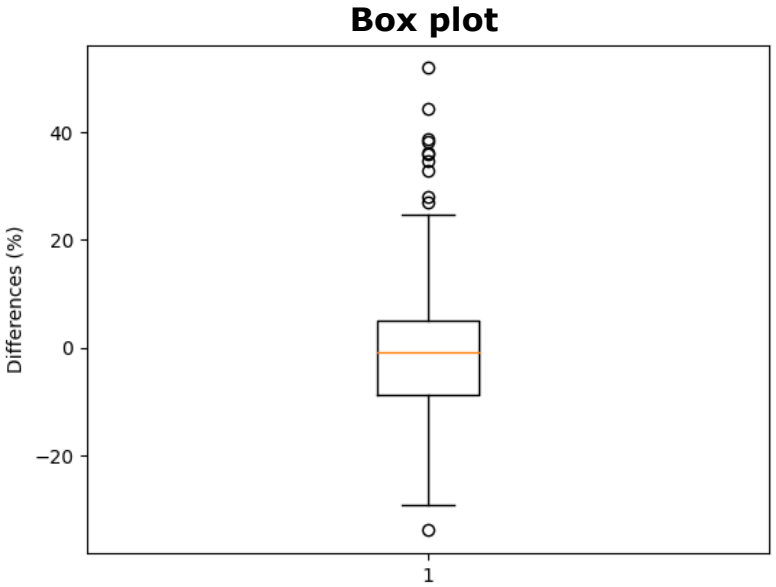
False Colour Rendering

Results - Extracting Light values

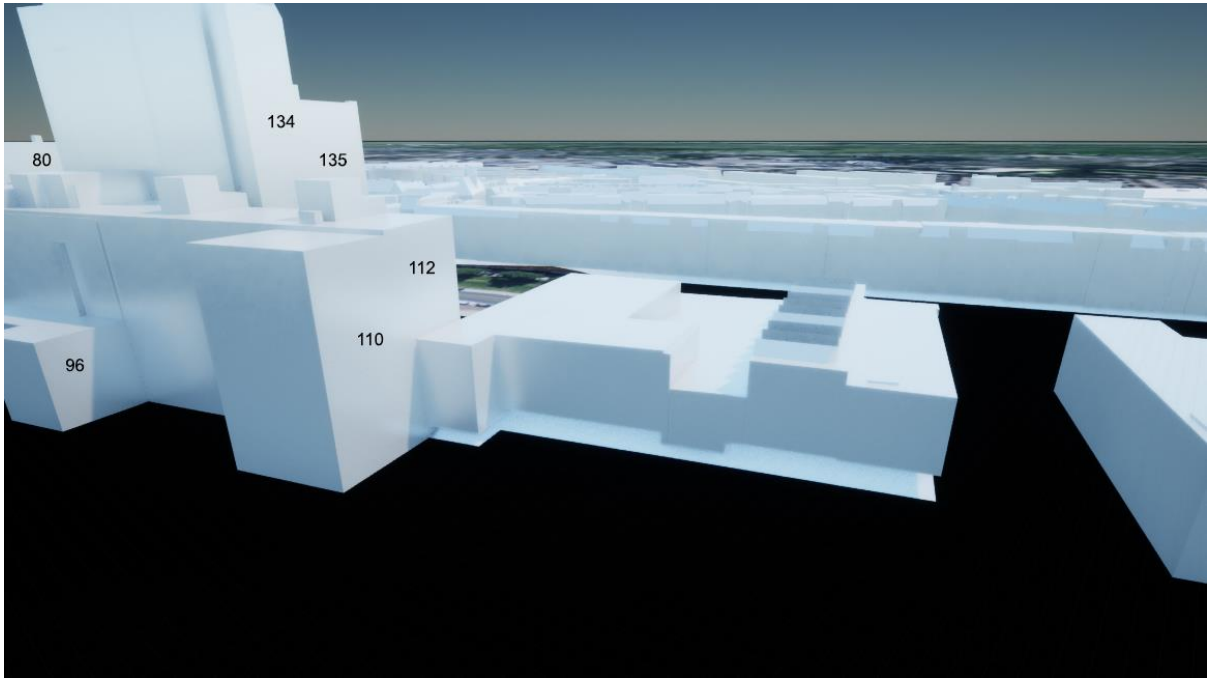
3D City Model Benchmark

	Runtime new angle	Runtime Complete script	Runtime adding new geometry	Illuminance values
Unreal	0.6 msec	0.6 msec	0.6 msec	9.78% difference with Radiance
Radiance Honeybee	645sec	93 min	93 min	-





Results – Benchmarking



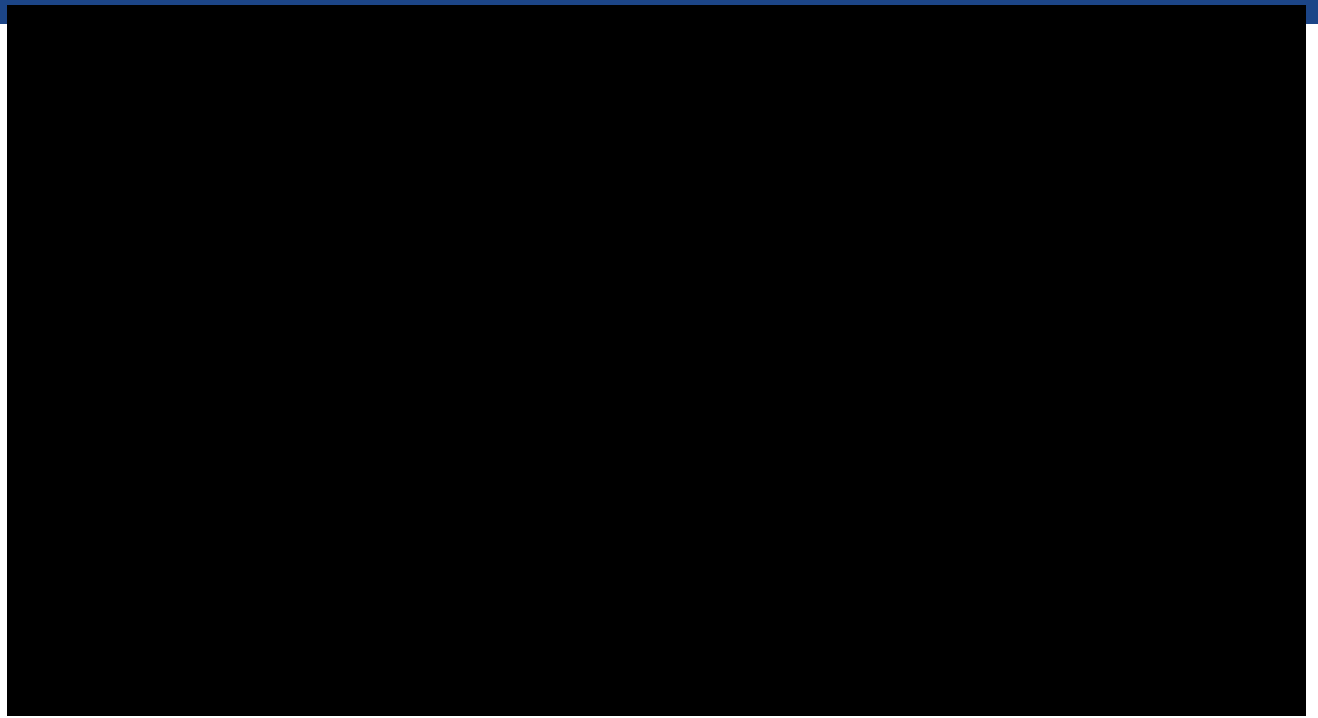
Outliers in lit Surfaces

Values of outliers

Point	Honeybee	Unreal	Difference(%)
80	13691	20800	51,92
96	14762	18744	26,97
110	22607	31381	38,81
112	22607	32631	44,34
134	22858	30779	34,65
135	22213	30693	38,18

Demo

https://youtu.be/HoYp9HjSBtY



- **User Functionality:**
  + Initial massing studies
  - Refined and detailed design
  + Import designs made in other tools.
  + Collaborative Design
  - Detailed Daylight analysis

- Improved comparison and extraction methods
  - Exporting data
  - Manual vs. Automatic measurement
- User testing and feedback
- Validation across different scenarios
  - Different times and locations
- Connection to weather data in Unreal
  - Sun & Sky light settings according to data.
  - Sun position alignment
- Extended functionality
  - Daylight analysis
  - Design functionality

- Great potential to use Unreal Engine to scale-up physically accurate daylight simulation tools that is:
  1. **Physically accurate** - average deviation of 9.04% with Radiance
  2. **Efficient** - 0.6ms calculation times
  3. **User-friendly** - speed, accuracy & design functionality
- Proof of concept for an architectural & urban development platform with built-in geospatial analysis.

The Future of Daylight analysis is bright!

LuminaCity