

Developing a Computational Tool to Assess Shadow Pattern on a Horizontal Plane, Preliminary Results

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1. Abstract

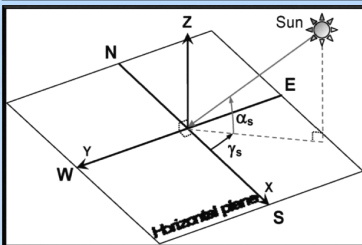
BIPV (Building Integration of PV) plays an important role in dense urban environments since there most of the energy consumption takes place. Nevertheless, this integration is difficult because of the shadows projected onto the PV by surrounding buildings and objects, mismatching the electrical performance of the modules. This paper presents the preliminary results obtained with a computational model developed in the Mathematica Programming Environment to evaluate the shading patterns on the horizontal plane of urban environments. This knowledge allows locating the PV panels in such a way to minimize their shading losses.

2. Objectives

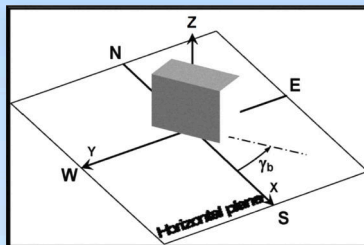
- Developing a ray tracing model in Wolfram Mathematica to analyze the shading on the horizontal plane caused by a building.
- Simulating and comparing the shadow patterns generated by a building in different localities throughout the world.

3. Ray tracing model

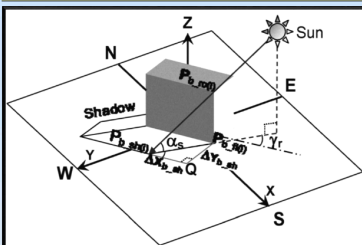
• Sun position angles



• Buildings orientation angle



• Shaded area on the ground



• Ray tracing equations

Vertex of the shadow:

$$\vec{P}_{b_sh}(i) = \vec{P}_{b_fl}(i) - (\Delta X_{b_sh}, \Delta Y_{b_sh}, 0)$$

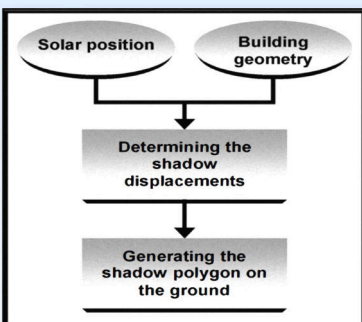
With:

$$\Delta X_{b_sh} = H \cot[\alpha_s] \cos[\gamma_r]$$

$$\Delta Y_{b_sh} = H \cot[\alpha_s] \sin[\gamma_r]$$

$$\gamma_r = \gamma_s - \gamma_b$$

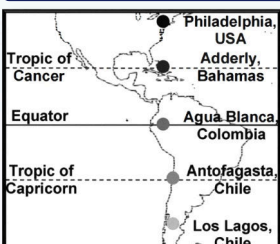
4. Computational model



```

TimeInstantsShadowPolygonVertices:=
Compile[{{SunPos_?Real}, {ObjectDimensions_?Real}, {p_?Real}},
(*Determining the vertices of the shadow projected onto the horizontal plane*)
HorVertices=TimeInstantShadowPointsConstrains[SunPos, ObjectDimensions, p];
(*Transforming the shadow vertices from the horizontal coordinates to the building ones*)
RotVertices=Table[HorizontalToBuildingSystem[HorVertices[[i]], :p],{i,1,Length[HorVertices]},{i,1,2}];
(*Generating the final list with the vertices of the shadow polygons at an instant*)
FinalVertices={If[Length[RotVertices]==2,{RotVertices},{Most[RotVertices],Rest[RotVertices]}}];
(*Returning the obtained results*)
FinalVertices
{{HorVertices_?Real}, {RotVertices_?Real}, {FinalVertices_?Real}}];
    
```

5. Input parameters



Site	Latitude [°]	Longitude [°]
Philadelphia	39° 57'	75° 9'
Adderly	23° 36'	75° 18'
Agua Blanca	-0° 2'	75° 12'
Antofagasta	-23° 39'	72° 0'
Los Lagos	-39° 51'	72° 50'

6. Results

Shaded horizontal plane at 9:30 hrs. on 21/03/2008

• Building's geometry

Length = 4 m, width = 4 m, height = 8 m, orientation = 45° S (South).

	3D view point (26 m,61 m,64 m)	Horizontal view	Sun position (azimuth, elevation)	Shaded area [m ²]
Philadelphia (temperate zone)			(-52.1° S, 36.1°)	71
Adderly (tropical zone)			(-64.2° S, 44.7°)	57
Agua Blanca (tropical zone)			(-89.8° S, 50.3°)	47
Antofagasta (tropical zone)			(-118.3° S, 47.5°)	41
Los Lagos (temperate zone)			(-123° S, 37.7°)	47
Parameters	Radius = 16 m			
Legend				

- The largest shaded area on the ground is observed in the temperate zone of the northern hemisphere due to the lower solar elevation at that time of the year.
- PV systems should be installed outside the shadow patterns to limit both the decrease in their maximum delivered power and the occurrence of hot spots on their PV panels.

7. Conclusions

- A flexible program has been developed in Wolfram Mathematica to assess the shadow projected by a building on the horizontal plane.
- The developed tool allows to identify urban areas unsuitable for installing ground-mounted PV systems.
- Future work will be addressed to include mutual shading among buildings and shading of arbitrary oriented and tilted surfaces.

8. References

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