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Design of heliostat fields

Sun path, cone optics and staggered layouts

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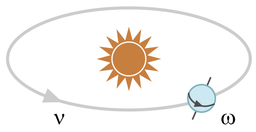
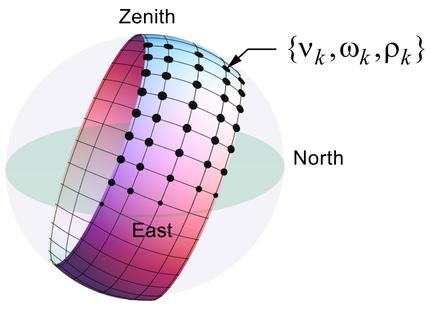
A systematic approach is presented to sample the motion of the sun and to simplify the computation of annual efficiency. The focusing properties of heliostats are described with the fast algorithms of cone optics. A new layout of heliostat fields is proposed which has smooth transitions between heliostat zones.

Fourier sampling of sun path

Orbital and axial rotation of Earth



Apparent motion of Sun



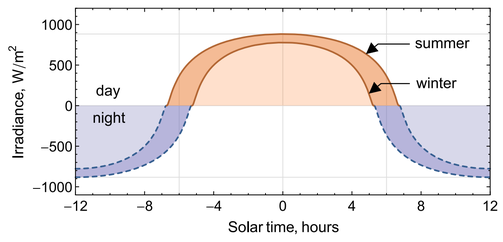
Fourier series

$$f(\nu,\omega) = \sum_{n=-\infty}^{+\infty} \sum_{m=-\infty}^{+\infty} F_{nm} \exp(in\nu + im\omega)$$

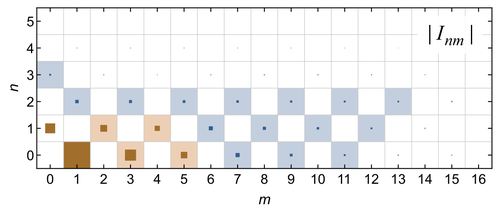
Example: Irradiance

$$I = I_0 \exp\left(-\frac{\tau}{\sin^p \alpha}\right) \qquad [1]$$

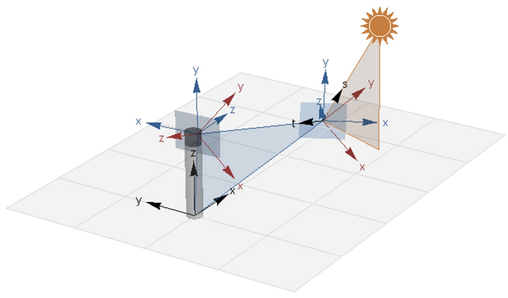
Function



Spectrum



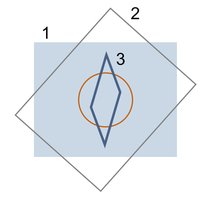
Cone optics for flux distribution



Principal image

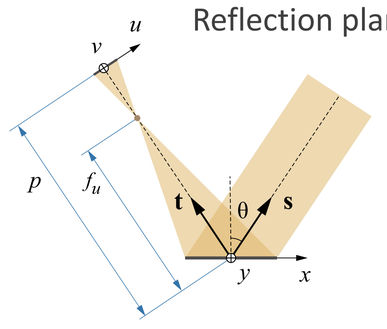
$$u = \left(\cos\theta - \frac{p}{f}\right)x$$

$$v = \left(1 - \frac{p\cos\theta}{f}\right)y$$

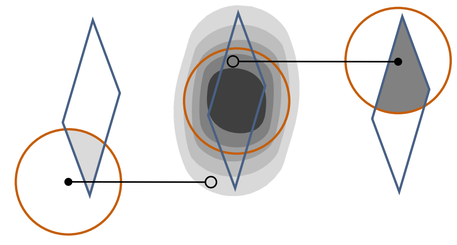


rotation + scaling

Reflection plane

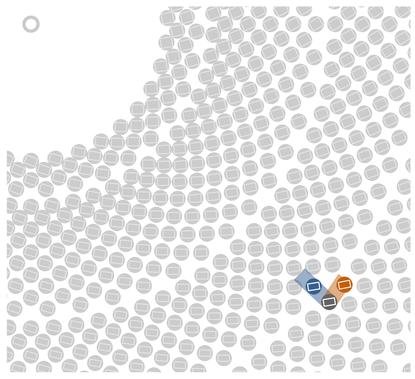


Convolution with sun shape [3]

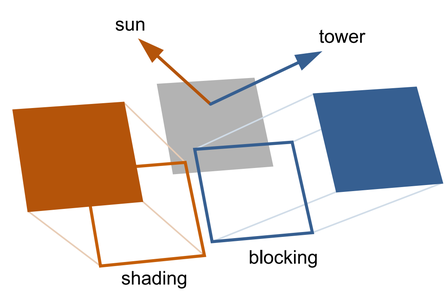


Shading and blocking

Top view



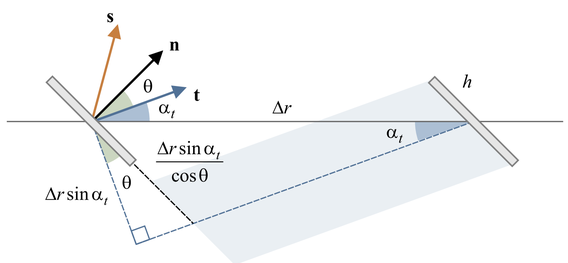
Perspective



parallel projection + polygon clipping [4]

Nonblocking distance [5]

$$\frac{\Delta r}{h} = \frac{\cos\theta}{\sin\alpha_t}$$



Computation of annual efficiency

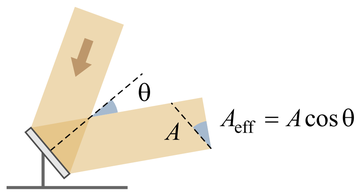
Definition

$$\langle f \rangle = \frac{\int_{\text{year}} f(t)I(t)dt}{\int_{\text{year}} I(t)dt}$$

Gaussian quadratures

$$\langle f \rangle = \sum_{k=1}^{K} \rho_k f_k$$

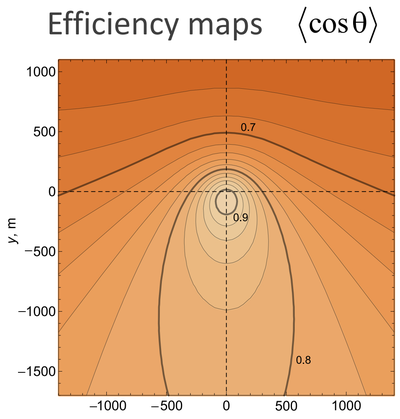
Example: Cosine factor



Each sampling point in the sky has a weight ρ_k

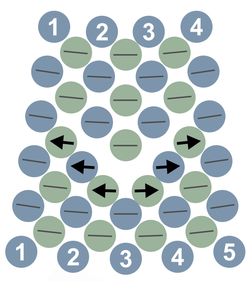
Gemasolar (2011)

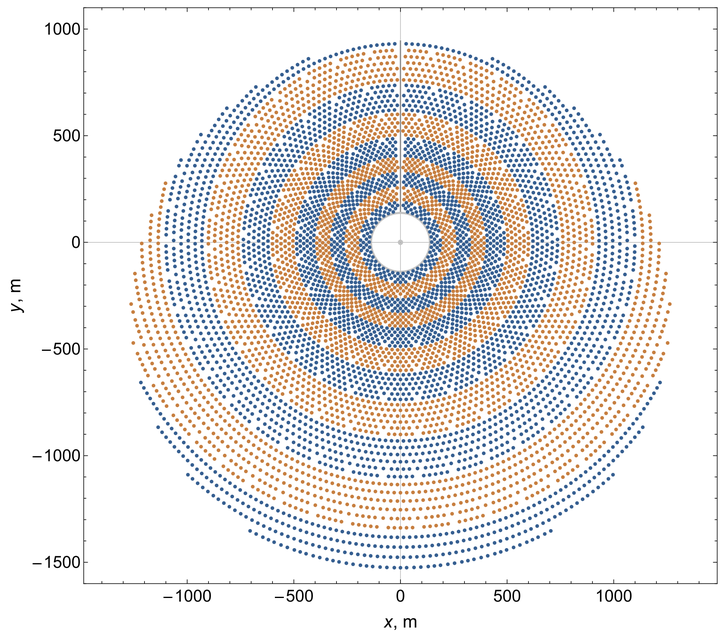
Efficiency maps $\langle \cos\theta \rangle$



Gear-staggered layouts

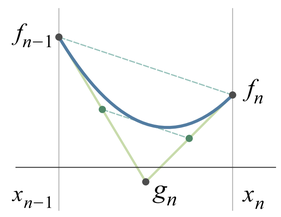
Smooth transitions between zones



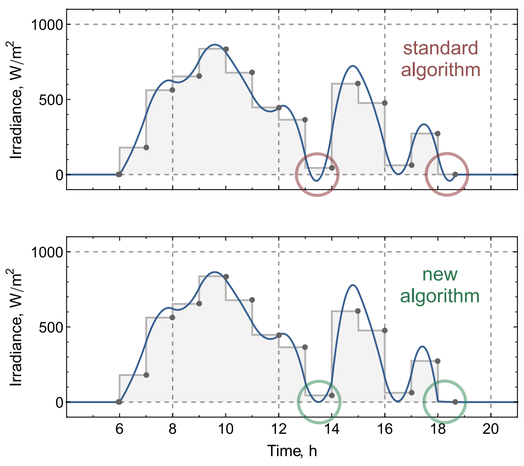


Interpolation of irradiance

Positive Bézier splines [2]



$$f(u) = (1-u)^2 f_{n-1} + 2u(1-u)g_n + u^2 f_n$$



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REFERENCES
[1] P. Ineichen, "A broadband simplified version of the Solis clear sky model," Sol. Energy **82**, 758 (2008).
[2] G. Wolberg and I. Alfy, "An energy-minimization framework for monotonic cubic spline interpolation," J. Comput. Appl. Math. **143**, 145 (2002).
[3] F. J. Collado, "One-point fitting of the flux density produced by a heliostat," Sol. Energy **84**, 673 (2010).
[4] G. Greiner and K. Hormann, "Efficient clipping of arbitrary polygons," ACM Trans. Graph. **17**, 71 (1998).
[5] F. J. Collado and J. A. Turégano, "Calculation of the annual thermal energy supplied by a defined heliostat field," Sol. Energy **42**, 149 (1989).

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