Optimization: Maximize the Solar Panel Output for a Fixed Area

Objective

Use MATLAB to formulate and solve an optimization problem: Given a fixed area, determine the optimal tilt angle and aspect ratio of a solar panel to maximize the total energy output.

Background

Solar panel efficiency depends on:

- The tilt angle with respect to the sun
- The shape (aspect ratio) of the panel
- The available area for installation

The goal is to apply numerical optimization techniques in MATLAB to find the best configuration that maximizes energy output under simplified assumptions.

Problem Description

You have a total area of 2 square meters to place a solar panel. The panel can have any rectangular shape but must stay within this total area.

The total energy output (in simplified units) can be approximated as:

$$E(\theta, r) = A \cdot \eta(\theta) \cdot sunIntensity(\theta) \cdot f(r)$$

Where:

- A= 2 m^2 (fixed area)
- $\theta \in [0^o, 90^o]$ is the tilt angle (in degrees)
- r is the aspect ratio (length/width), with $r \in [0.5,4]$
- $\eta(\theta) = \cos(\theta - 30^o)$ (efficiency function)
- $sunIntensity(\theta) = 1000 \cdot \cos(\theta - 45^o)$ (sunlight variation with tilt)
- $f(r) = \exp(-0.1 \cdot (r-1)^2)$ (efficiency drops for extreme shapes)

Your task: Find the optimal θ and r that maximize $E(\theta, r)$

Tasks

1. Define the objective function in MATLAB: E = @(x)... where x(1)=theta, x(2)=r.
2. Use fmincon to find the values of theta and r that maximize the energy output.
    - Hint: Minimize -E(x) instead.
3. Constrain the values:
    - $0 \leq \theta \leq \frac{\pi}{2}$
    - $0.5 \leq r \leq 4$
4. Plot the objective function using fsurf or a mesh plot to visualize E(θ,r).
5. Print the optimal angle, ratio, and corresponding energy output.

Sample Output

Optimal Tilt Angle: 39.8 degrees

Optimal Aspect Ratio: 1.2

Maximum Energy Output: 1895.3 units

Learning Outcomes

- Formulate a real-world problem as a mathematical optimization problem
- Use MATLAB's fmincon for constrained nonlinear optimization
- Visualize and interpret multivariable objective functions

Background Material

- MATLAB Onramp
- Optimization Onramp