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6. Interlude: Minimizing and Maximizing Functions

Concavity in 1 dimension

Handwritten mathematical derivations on a chalkboard:

$$L(\theta, \lambda) = \lambda \log(-\lambda \sum_{i=1}^n x_i)$$

$$f(x) = \frac{1}{b} 1(0 \leq x \leq b)$$

$$L(\theta) = \frac{1}{b} 1(\max(x_i) \leq b)$$

Video player controls: 7:09 / 7:09, 1.50x, volume, full screen, and other standard video controls.

Video

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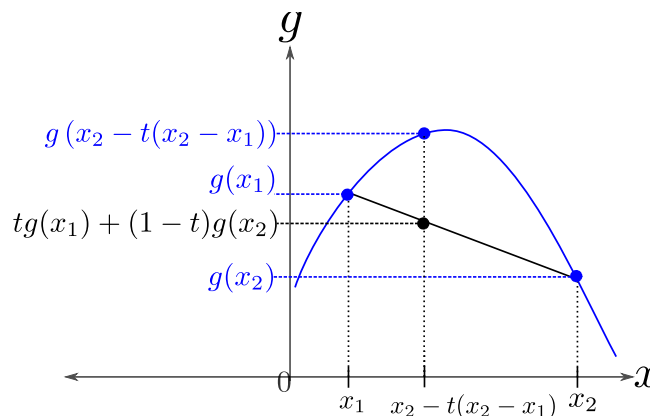
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A function $g : I \rightarrow \mathbb{R}$ is **concave** (or concave down), where I is an interval, if for all pairs of real numbers $x_1 < x_2 \in I$

$$g(tx_1 + (1-t)x_2) \geq tg(x_1) + (1-t)g(x_2) \quad \text{for all } 0 < t < 1.$$

Geometrically, this means that for $x_1 < x < x_2$, the graph of g is **above** the secant line connecting the two points $(x_1, g(x_1))$ and $(x_2, g(x_2))$.



At $x = x_2 - t(x_2 - x_1) = tx_1 + (1-t)x_2$, the y -value of the graph of g is $g(x) = g(tx_1 + (1-t)x_2)$, while the y -value of the secant line is $tg(x_1) + (1-t)g(x_2)$.

If the inequality is strict, i.e. if

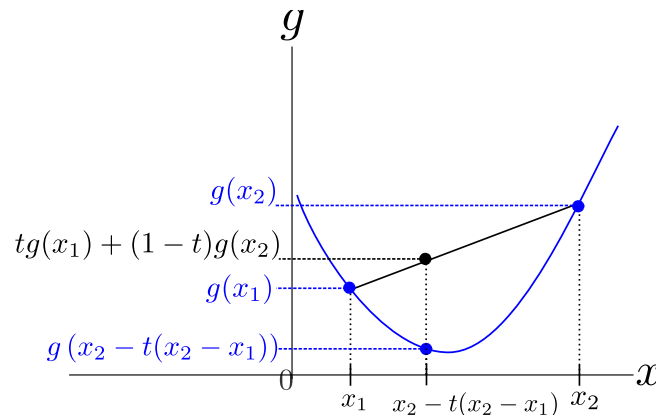
$$g(tx_1 + (1-t)x_2) > tg(x_1) + (1-t)g(x_2) \quad \text{for all } 0 < t < 1.$$

then g is **strictly concave**.

The definition for **(strictly) convex** is analogous. A function $g : I \rightarrow \mathbb{R}$ is **convex** (or concave up), where I is an interval, if for all pairs of real numbers $x_1 < x_2 \in I$

$$g(tx_1 + (1-t)x_2) \leq tg(x_1) + (1-t)g(x_2) \quad \text{for all } 0 < t < 1.$$

Geometrically, this means that for $x_1 < x < x_2$, the graph of g is **below** the secant line connecting the two points $(x_1, g(x_1))$ and $(x_2, g(x_2))$.



At $x = x_2 - t(x_2 - x_1) = tx_1 + (1 - t)x_2$, the y -value of the graph of g is $g(x) = g(tx_1 + (1 - t)x_2)$, while the y -value of the secant line is $tg(x_1) + (1 - t)g(x_2)$.

If the inequality is strict, i.e. if

$$g(tx_1 + (1 - t)x_2) < tg(x_1) + (1 - t)g(x_2) \quad \text{for all } 0 < t < 1.$$

then g is **strictly convex**.

If in addition g is twice differentiable in the interval I , i.e. $g''(x)$ exists for all $x \in I$, then g is

- **concave** if and only if $g''(x) \leq 0$ for all $x \in I$;
- **strictly concave** if $g''(x) < 0$ for all $x \in I$;
- **convex** if and only if $g''(x) \geq 0$ for all $x \in I$;
- **strictly convex** if $g''(x) > 0$ for all $x \in I$;

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