8. Direction of maximal change

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Synthesize

Recall that we can write the dot product of two vectors as

$$\vec{v} \cdot \vec{w} = |\vec{v}||\vec{w}| \cos\theta$$

where θ is the angle between $\vec{v}$ and $\vec{w}$.

Let $\hat{u}$ be a unit vector and θ be the angle between ∇f and $\hat{u}$. Using the definition of the dot product, we have

$$D_{\hat{u}} f = \nabla f \cdot \hat{u} = |\nabla f||\hat{u}| \cos\theta = |\nabla f| \cos\theta. \quad (3.110)$$

We know $|\hat{u}| = 1$ because $\hat{u}$ is a unit vector.

Notice that when $\theta = 0$, the quantity $D_{\hat{u}} f\,(x, y)$ is maximal. This means that when $\hat{u}$ is parallel to ∇f, the directional derivative of f at (x, y) is maximal. In other words, **the gradient is the direction of the maximum rate of change of f**.

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