2025 USA-NA-AIO Round 1, Problem 3, Part 12

USAAIO

Mar 2025

Part 12 (5 points, non-coding task)

In this part, you are asked to compute $\nabla_\beta \, L\left(\beta\right)$ and express your solutions in two forms. Reasoning is not required.

1. Write $\nabla_\beta \, L\left(\beta\right)$ in the following summation form:

$$\nabla_\beta \, L\left(\beta\right) = \sum_{n=0}^{N-1} \cdots .$$

2. Denote

$$\mathbf{X} = \begin{bmatrix} \mathbf{x}^{(0),\top} \\ \mathbf{x}^{(1),\top} \\ \vdots \\ \mathbf{x}^{(N-1),\top} \end{bmatrix}$$

and

$$\mathbf{y} = \begin{bmatrix} y^{(0)} \\ y^{(1)} \\ \vdots \\ y^{(N-1)} \end{bmatrix}$$

and

$$\mathbf{z} = \begin{bmatrix} \sigma\left(\mathbf{x}^{(0),\top}\beta\right) \\ \sigma\left(\mathbf{x}^{(1),\top}\beta\right) \\ \vdots \\ \sigma\left(\mathbf{x}^{(N-1),\top}\beta\right) \end{bmatrix}$$

Write $\nabla_\beta \, L(\beta)$ in terms of $\mathbf{X}$, $\mathbf{y}$, $\mathbf{z}$ with matrix operations (the summation symbol is not allowed).

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Misplaced '#'

We have

$$\begin{aligned} \nabla_\beta \, L(\beta) &= \boxed{\sum_{n=0}^{N-1} \left(\sigma\left(\mathbf{x}^{(n),\top}\beta\right) - y^{(n)}\right)\mathbf{x}^{(n)}} \\ &= \boxed{\mathbf{X}^\top(\mathbf{z}-\mathbf{y})}. \end{aligned}$$

""" END OF THIS PART """

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