Algorithm 1 CAPO: Context-Aware Prompt Optimization

Require: Dataset $\mathcal{D} = \{(X_i, y_i)\}_{i=1}^{n}$, Meta-LLM $\Phi(x)$, Downstream LLM $\phi(x)$, Cost function $\ell(y, \hat{y})$, Initial prompts ν, Population size p, Block size b, Number of iterations n

Divide dataset $\mathcal{D}$ into blocks $\mathcal{B} = \{B_1, ..., B_k\}$ where $|B_i| = b$
Create $d \in \mathbb{R}^x$ for fewshot examples
for $i = 1$ to n **do**
    $P \leftarrow$ random_selection(ν)
    $\nu \leftarrow \nu$.update(P)
    $\nu \leftarrow$ mutate(ν)
    prepend few-shot examples to ν
    $\nu \leftarrow$ do_racing(ν, top_k $= p$)
end for
best_prompt $\leftarrow$ do_racing(ν, top_k $= 1$)
return best_prompt

Algorithm 2 do_racing

Require: Prompts ν, Top-k p, cost function $\ell(y, \hat{y})$, blocks $\mathcal{B}$, Downstream LLM $\phi(x)$

survivors $\leftarrow \nu$
$i \leftarrow 0$
scores $\leftarrow [0] * \text{len}(\nu)$
shuffle $\mathcal{B}$
while len(survivors) $>$ top_k **do**
    $i \leftarrow i + 1$
    scores $\leftarrow \frac{1}{i}$ (evaluate$(\nu, B_i) + (i-1) *$ scores)
    survivors $\leftarrow$ racing_elimination$(\nu, \text{scores}, i, \alpha)$
end while
return survivors

Algorithm 3 Confidence-based Racing Elimination

Require: Prompts P, scores S, current round n, confidence level α, total blocks B

$z_\alpha \leftarrow \Phi^{-1}(1 - \alpha/2)$ ▷ Critical value
survivors $\leftarrow P$
for $p_i \in P$ **do**
    for $p_j \in P \setminus \{p_i\}$ **do**
        if $s_j > s_i$ **and** $(s_j - s_i)\sqrt{n} > z_\alpha$ **then**
            survivors $\leftarrow$ survivors $\setminus \{p_i\}$
            break
        end if
    end for
end for
return survivors