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On Machine Learning

DeltaEvolve: Accelerating Scientific Discovery through Momentum-Driven Evolution

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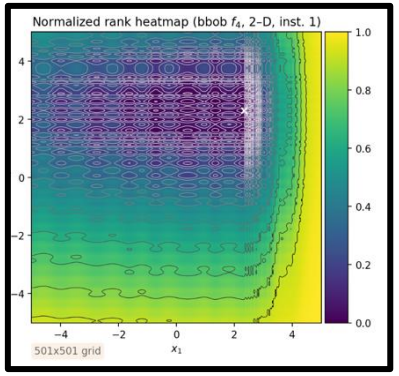
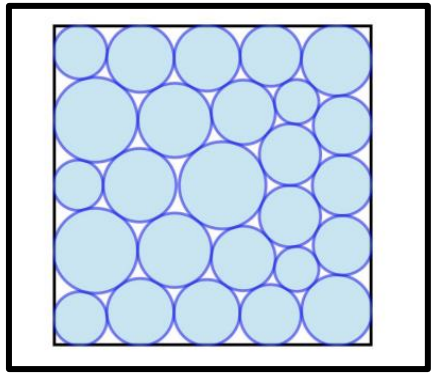
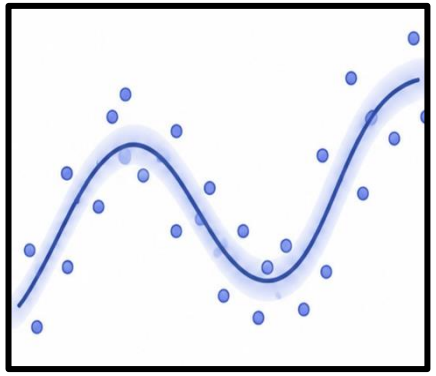
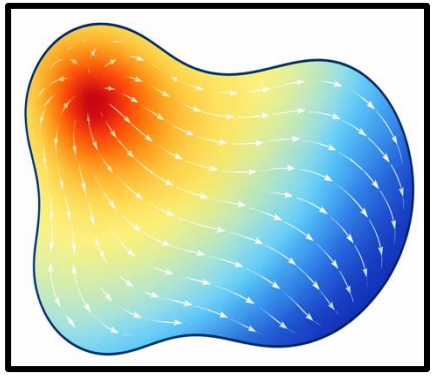
Open-Ended Discovery Tasks



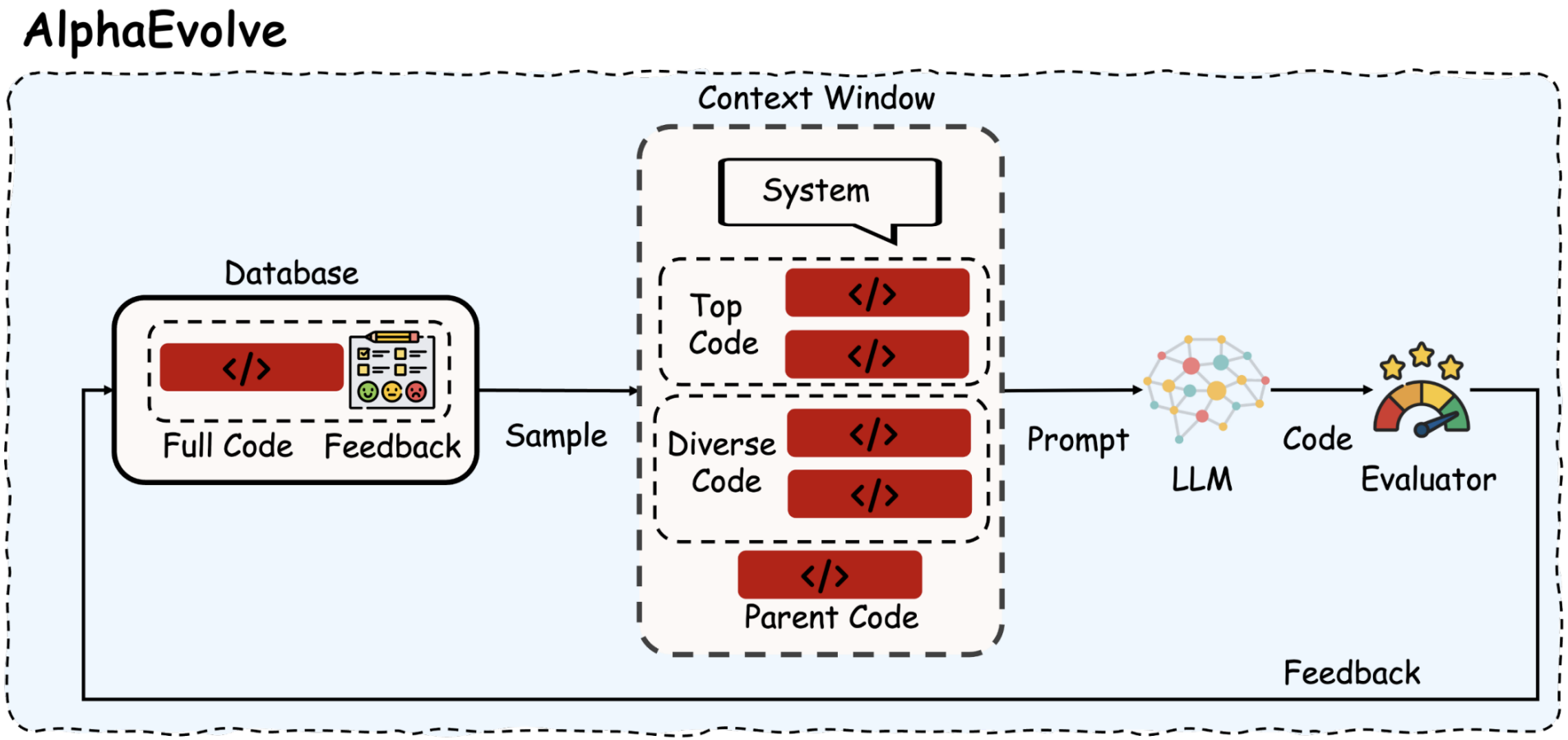






BlackBox Optimization	Combinational Optimization	Symbolic Regression	PDE	Algotune
• Bbob_f1 • Bbob_f2 • ... • Bbob_f24	• Aircraft landing • Bin Packing • ... • Travelling Salesman	• Population Growth • Chemistry Reaction • ... • Physics	• Advection • ... • Burgers	• Convolve 2d • Eigenvector • ... • Affine Transform

AlphaEvolve



AlphaEvolve[1]

[1] Novikov A, Vũ N, Eisenberger M, et al. Alphaevolve: A coding agent for scientific and algorithmic discovery[J]. arXiv preprint arXiv:2506.13131, 2025.

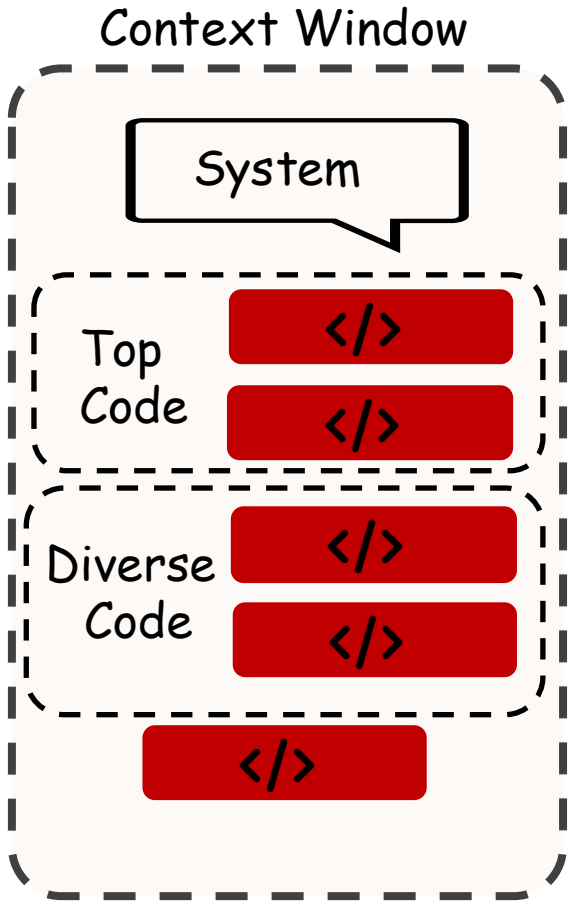
Issue of Full Code

1. Limited context window

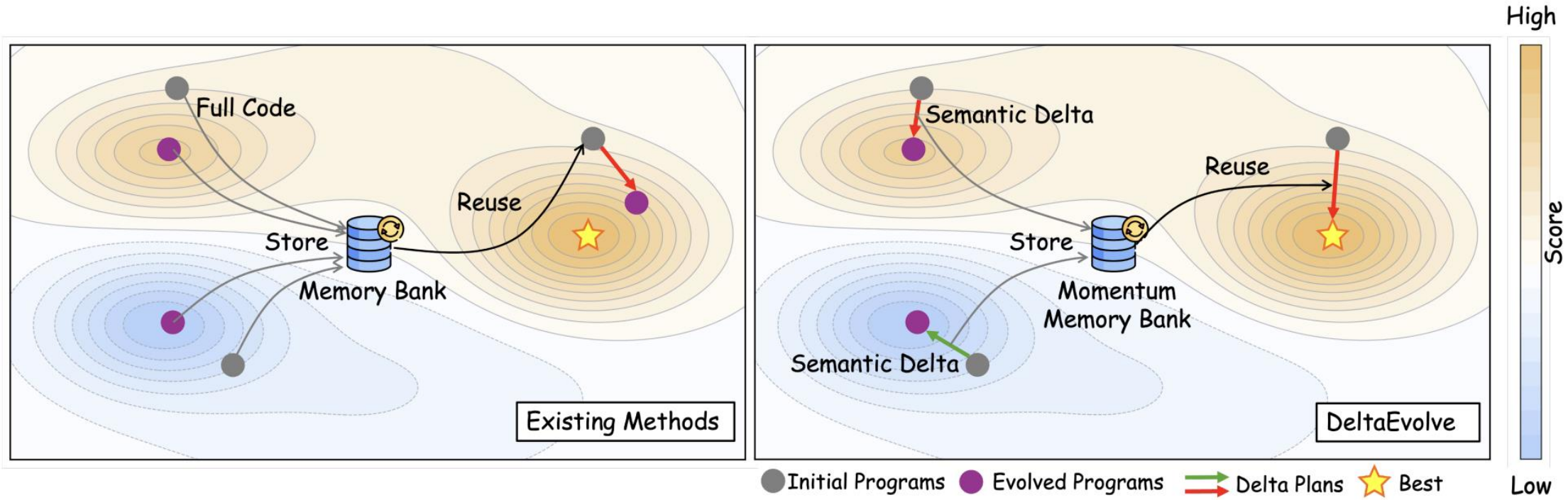
Programs are long, context is finite — only a handful survive, most history is discarded.

2. Insufficient evolutionary guidance

A full program buries the idea under detail. The model can't tell which change raised the score, or why.



DeltaEvolve



Semantic delta Δ

A short, plain-language note of **what changed** from parent to child, and whether it **improved or degraded** the score.

Momentum memory

Like momentum stacks differences between iterates, stacked deltas point in the **direction of improvement** — and transfer across programs.

Progressive Disclosure Sampler

Multi-Level Database

$$N_t = \left(\delta_t^{(1)}, \delta_t^{(2)}, p_t\right)$$

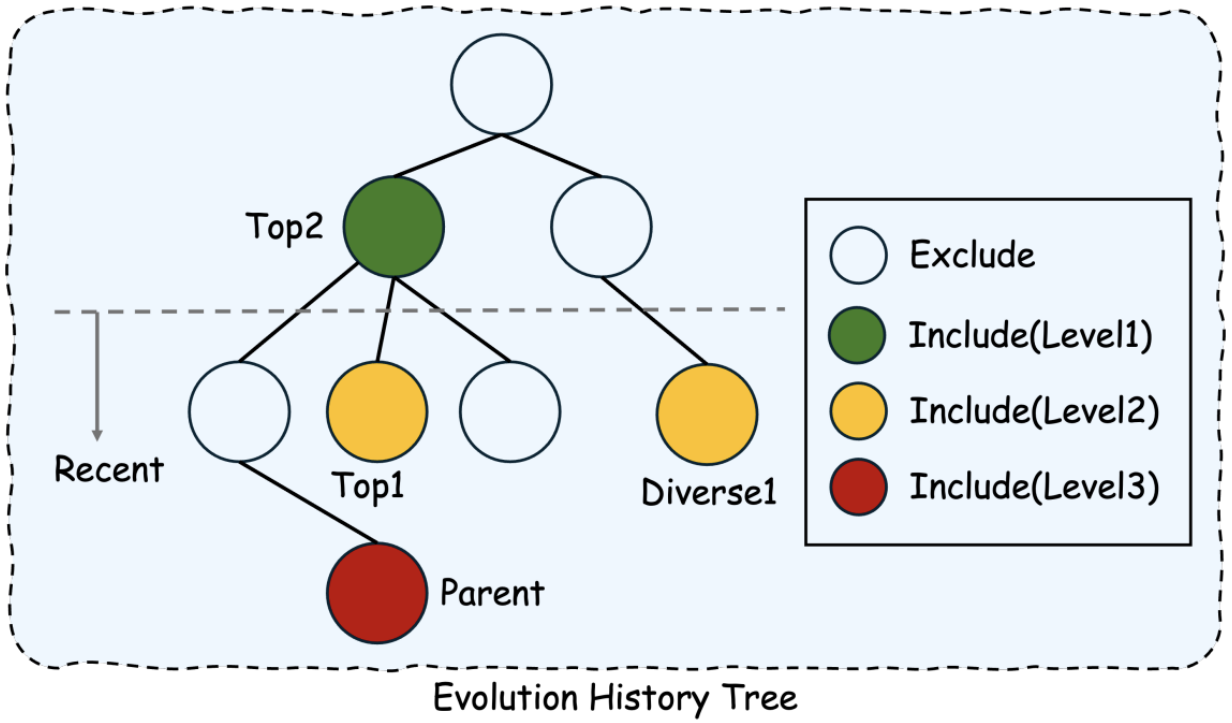
- **L1: Delta Summary**

$$\delta_t^{(1)} := \langle \texttt{FROM: } s_{t-1} \quad \texttt{TO: } s_t \rangle,$$

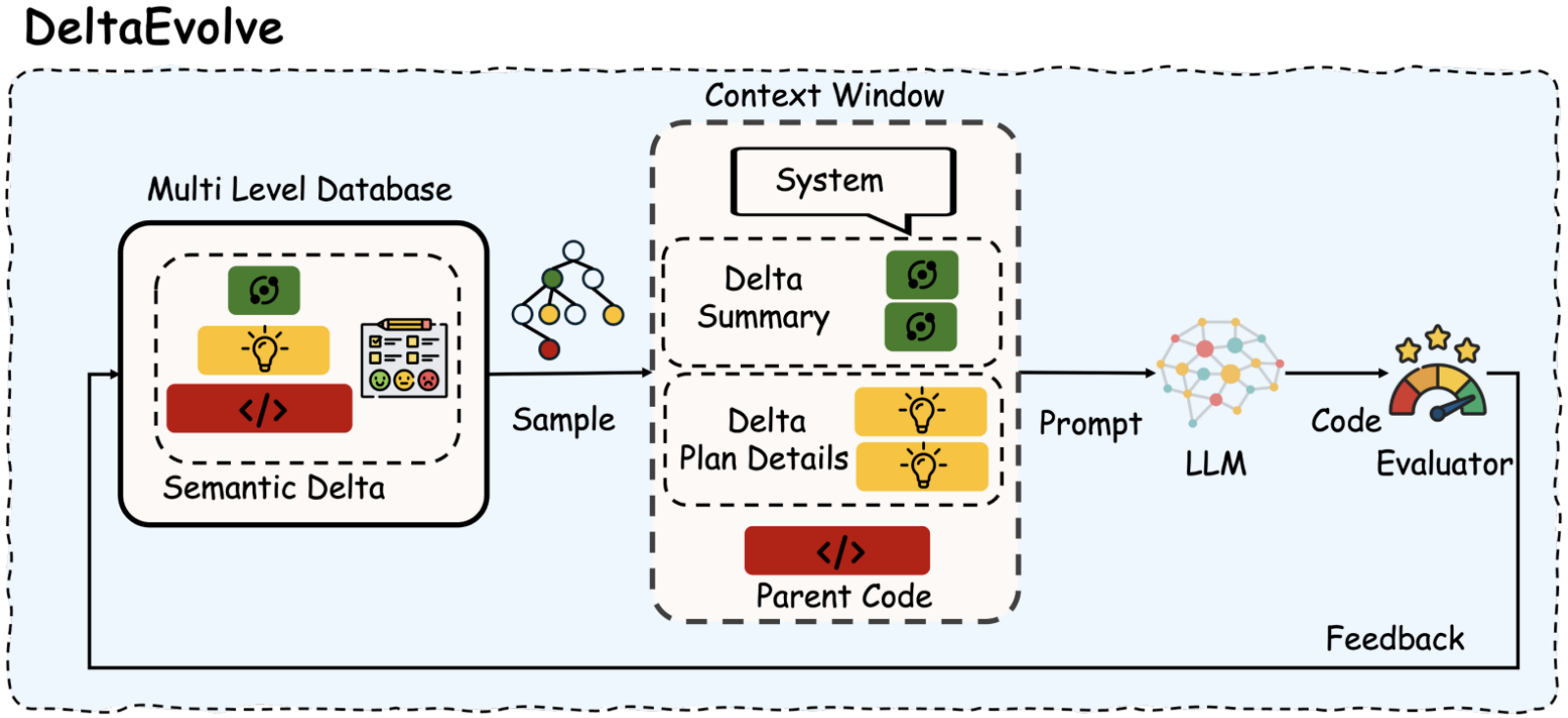
- **L2: Delta Plan Details**

$$\delta_t^{(2)} := \{(\ell_{t-1}^{(j)}, \ell_t^{(j)}, \texttt{hyp}_t^{(j)})\}_{j=1}^{J},$$

- **L3: Full Code**



DeltaEvolve



Longer history, same budget

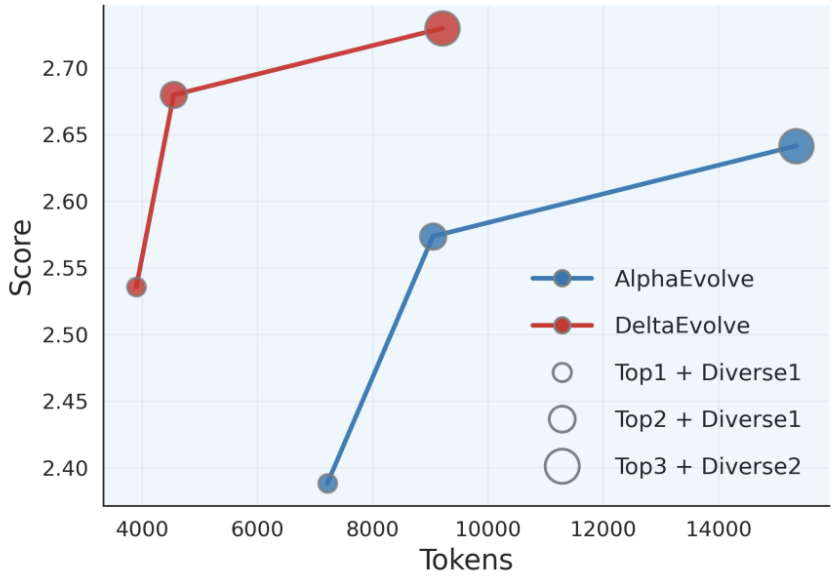
A delta is far shorter than a program, so much more history fits in context.

Sharper signal

The model sees the direction of improvement directly, so the search is more focused.

Experiments

- **RQ1 (Solution Quality):** *Can* `DeltaEvolve` *discover solutions with superior objective scores compared to state-of-the-art evolutionary baselines across diverse scientific domains?*
- **RQ2 (Token Consumption):** *Does* `DeltaEvolve` *reduce the computational cost (input tokens) required to discovery high-quality solutions?*



Task Domain	Method	GPT-5-mini + o3-mini		Gemini-2.5-flash-lite + Gemini-2.5-flash	
		Best Score(↑)	Token Consump.(↓)	Best Score(↑)	Token Consump.(↓)
1. BlackBox Optimization	Parallel Sampling	0.4161	390872	0.4161	390872
	Greedy Refine	2.2618	555430	2.3403	1054566
	AlphaEvolve (Full Code)	2.6415	1852841	2.5221	1894890
	DeltaEvolve (Ours)	**2.7297**	1390709	**3.9372**	1227388
2. Hexagon Packing	Parallel Sampling	0.4913	565016	0.4913	565016
	Greedy Refine	0.8508	717697	0.4913	814092
	AlphaEvolve (Full Code)	0.9721	905249	0.7859	1334339
	DeltaEvolve (Ours)	**0.9821**	827884	**0.8804**	893749
3. Symbolic Regression	Parallel Sampling	1.8527	503098	1.8535	503098
	Greedy Refine	2.9553	811404	2.9550	756762
	AlphaEvolve (Full Code)	3.2657	1660699	3.2174	1545091
	DeltaEvolve (Ours)	**3.4174**	810354	**3.2198**	832164
4. PDE Solver	Parallel Sampling	0.7506	154016	0.7506	154016
	Greedy Refine	0.7506	375186	0.7506	255332
	AlphaEvolve (Full Code)	0.8850	711298	0.9901	595094
	DeltaEvolve (Ours)	**0.8915**	562848	**0.9931**	253719
5. Efficient Convolution	Parallel Sampling	0.8035	139958	0.8036	139958
	Greedy Refine	0.8035	240473	0.8037	305334
	AlphaEvolve (Full Code)	0.8974	683439	0.8219	885592
	DeltaEvolve (Ours)	**0.9067**	348539	**0.9032**	517281

Acknowledge & Thanks

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Thanks for Listening !

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