Bi-Mind Engine: A Data-Oriented Architecture and Token-Efficient Expression Compiler for Real-Time LLM-Driven Physics Simulations

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Abstract- As Large Language Models (LLMs) are integrated into real-time web applications and metaverse environments, transmitting verbose JavaScript application code (~380-400 tokens per update) creates massive bandwidth overhead and V8 Garbage Collection (GC) latency spikes. We present the Bi-Mind Engine by Alatus Info. Ltd, a Data-Oriented Design (DOD) particle engine paired with BEX (Bi-Mind Expression) - a stack-based RPN language. AI agents stream 40-token BEX strings, achieving >90% token reduction and 100% GC-free off-main-thread execution on 160 KB Float32Array buffers.

Index Terms- Data-Oriented Design (DOD), Reverse Polish Notation, LLM Token Cost, SharedArrayBuffer, Web Workers.

I. INTRODUCTION & MOTIVATION

Modern AI agents dynamically alter environmental physics, buoyancy, and force fields in client-side web simulations. Traditional approaches stream complete JavaScript source code encapsulating animation loops and boundary checks, resulting in 350-400 tokens per transition. At scale, LLM API costs grow quadratically while V8 heap allocations trigger GC frame drops.

II. SYSTEM ARCHITECTURE & MEMORY LAYOUT

The Bi-Mind Engine enforces a strict Data-Oriented Design (DOD) structure. Entity state is organized into contiguous Float32Array memory buffers containing 4 floats/particle:

Offset	Attribute	Data Type	Bytes
`data[i]`	Position X	`Float32`	4 B
`data[i+1]`	Position Y	`Float32`	4 B
`data[i+2]`	Velocity X (vx)	`Float32`	4 B
`data[i+3]`	Velocity Y (vy)	`Float32`	4 B

Memory Footprint = N * 4 attributes * 4 bytes = 160 KB. By operating on typed array pointers, V8 property lookup overhead drops to 0, ensuring deterministic cache locality.

III. BEX (BI-MIND EXPRESSION) RPN GRAMMAR

BEX uses Reverse Polish Notation (RPN) stack evaluation. The grammar separates static engine infrastructure from dynamic runtime formulas. Listing 1 shows a canonical BEX statement:

Listing 1: Antigravity Buoyancy Rule (~40 Tokens)

```
vy g - =vy | vx f * =vx | vy f * =vy |
x vx + =x | y vy + =y | y 0 < vy -0.8 * vy ? =vy
```

IV. MULTI-THREADED EXECUTION & WORKER TICK

The physics update loop runs off the main thread inside a Dedicated Web Worker. Using SharedArrayBuffer zero-copy transfer, the worker executes the JIT-compiled BEX formula on the pointer buffer, while the main thread renders at locked 60/120 FPS with 0 allocations.

V. EMPIRICAL BENCHMARKS & EVALUATION

TABLE I. PERFORMANCE DIFFERENTIAL MATRIX (10,000 PARTICLES)

Metric / Parameter	Classic JS	Bi-Mind Engine	Gain
LLM Token Cost	~380 Tokens	**~40 Tokens**	**90% Savings**
RAM (10k Entities)	~640 KB	**160 KB**	**4.0x Less**
V8 Property Lookups	600,000/sec	**0 lookups/sec**	**Zero Lookup**
Garbage Collection	High GC Stutter	**0 Allocations**	**100% GC-Free**
Thread Architecture	Single Thread	**Worker Physics**	**Non-Blocking**
Frame Throughput	Frame Drops	**60 / 120 FPS**	**Deterministic**

VI. CONCLUSION & OFFICIAL PLATFORM

The Bi-Mind Engine demonstrates that combining Data-Oriented Design with stack-based BEX expressions solves token cost and execution latency barriers for real-time LLM systems. Developed by Alatus Info. Ltd, **the platform is accessible at https://www.bi-mind.com/**

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