Nebellum — A Semantic Signal Processing Framework

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1 | Introduction

Nebellum is a *semantic* signal processing framework. It levrages a multimodal large language model, Gemma [1], to decode pieces of intel, and a vectorized war game, Parabellum [2], to assign importance to said pieces

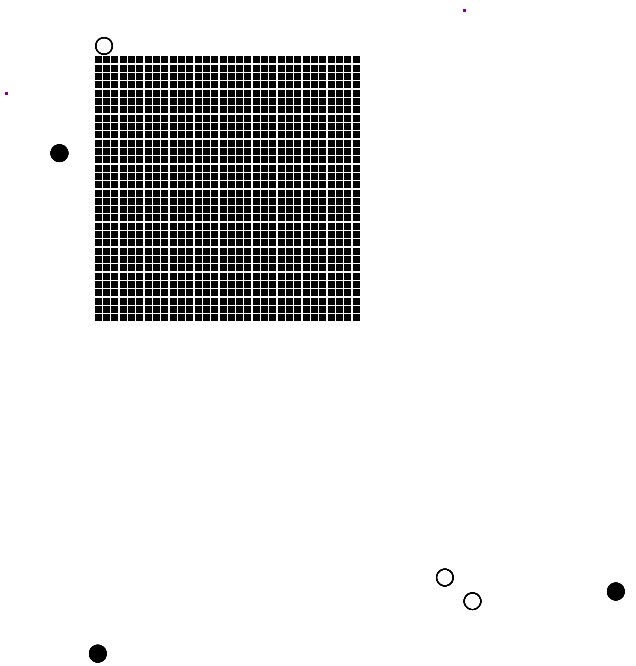

Figure 1: Parabellum simulation of Colosseo Quadrato in Rome

2 | Architecture

- Low level behavior is controlled by assigning behavior trees b and target positions
- Behavior trees map observations (info on units in sight range) to actions (move or shoot vector)
- Unit behavior (and target) is assigned by evaluating plan p at time t
- Plan evaluation happens m (evenly spaced) times throughout an n step episode

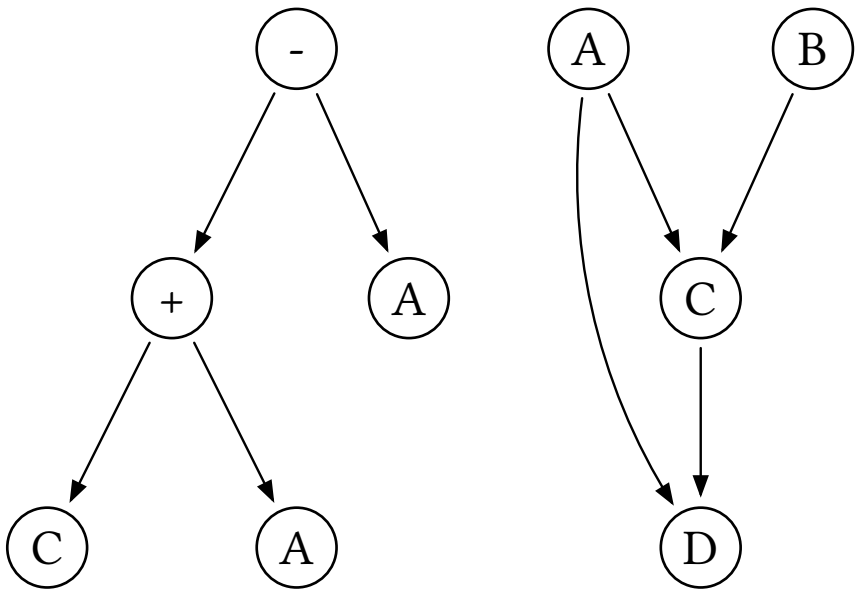

Figure 2: (left) Behavior that attacks if an enemy is in range and moves to target if not. (right) plan that waits for

2 | Architecture

Each of the m plan evaluations consits of:

1. Analysis: estimating the state $\hat{s}_t$ by combining unit observation o_t with intel i_t
2. Simulation: setting k simulations in motions based on $\hat{s}_t$ to gauge the importance of i_t

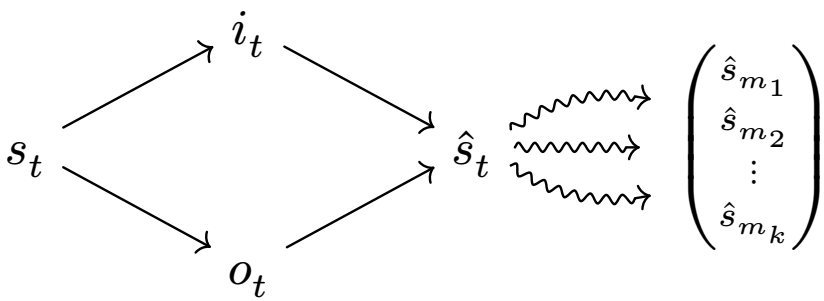

Figure 3: At time t we have state s_t, intel i_t and observation o_t. These are combined into $\hat{s}_t$, the basis k different m step trajectories

2.1 | Analysis

- Intel i_t is generated on all units in s_t encoding position and health in natural language
- Each piece of intel is fed to Gemma for analysis and combination into state estimate $\hat{s}_t$
- For each team, k intel subsets are made from a random masking of enemy units out of sight
- For each intel subset $i_{tj} : j \in [1, k]$ state $\hat{s}_{tj}$ is made by masking info in $\hat{s}_t$ from intel *not* in i_{tj}

2.2 | Simulation

- The plan p is evaluated for each of the k states $\hat{s}_{tj} : j \in [1, k]$ yielding the k behaviors b_j
- From $\hat{s}_t$, k trajectories (one for each behavior b_j) of length $\left\lfloor \frac{n}{m} \right\rceil$ are run and recorded

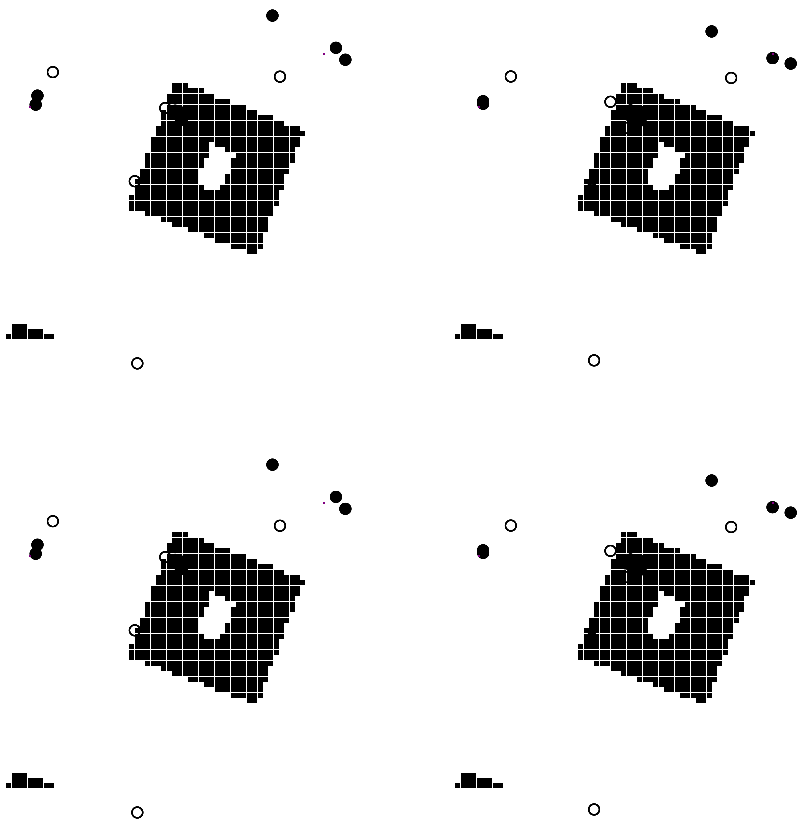

Figure 4: Simulated futures based on would be behaviors based on different pieces of intel

3 | Performace

- Test

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[1] G. Team *et al.*, “Gemma 3 Technical Report,” no. arXiv:2503.19786. arXiv, Mar. 2025. doi: 10.48550/arXiv.2503.19786.

[2] N. Syrkis, T. Anne, and S. Risi, “Parabellum.” Jun. 2025.