

# NewAgent: A Hybrid AI for Championship-Level Billiards

Combining Geometric Analysis, Noise-Robust Simulation,  
and Local Optimization for Superior Performance

Win Rate vs. BasicAgent

**88.2%**

(1,200 games)

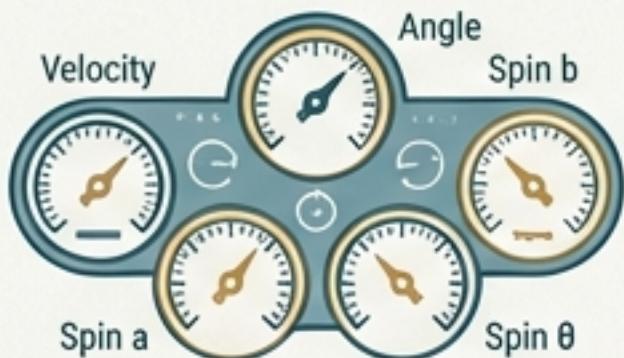
Win Rate vs. BasicAgentPro

**60.1%**

(9,600 games)



# Billiards Demands More Than Just Good Aim



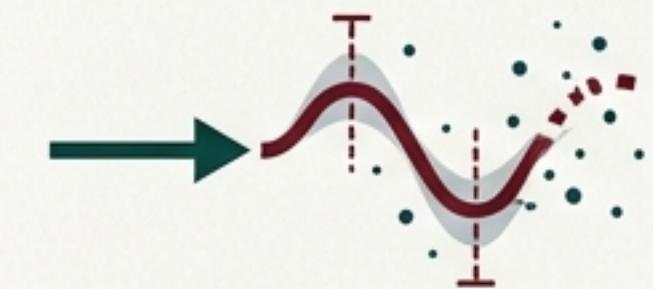
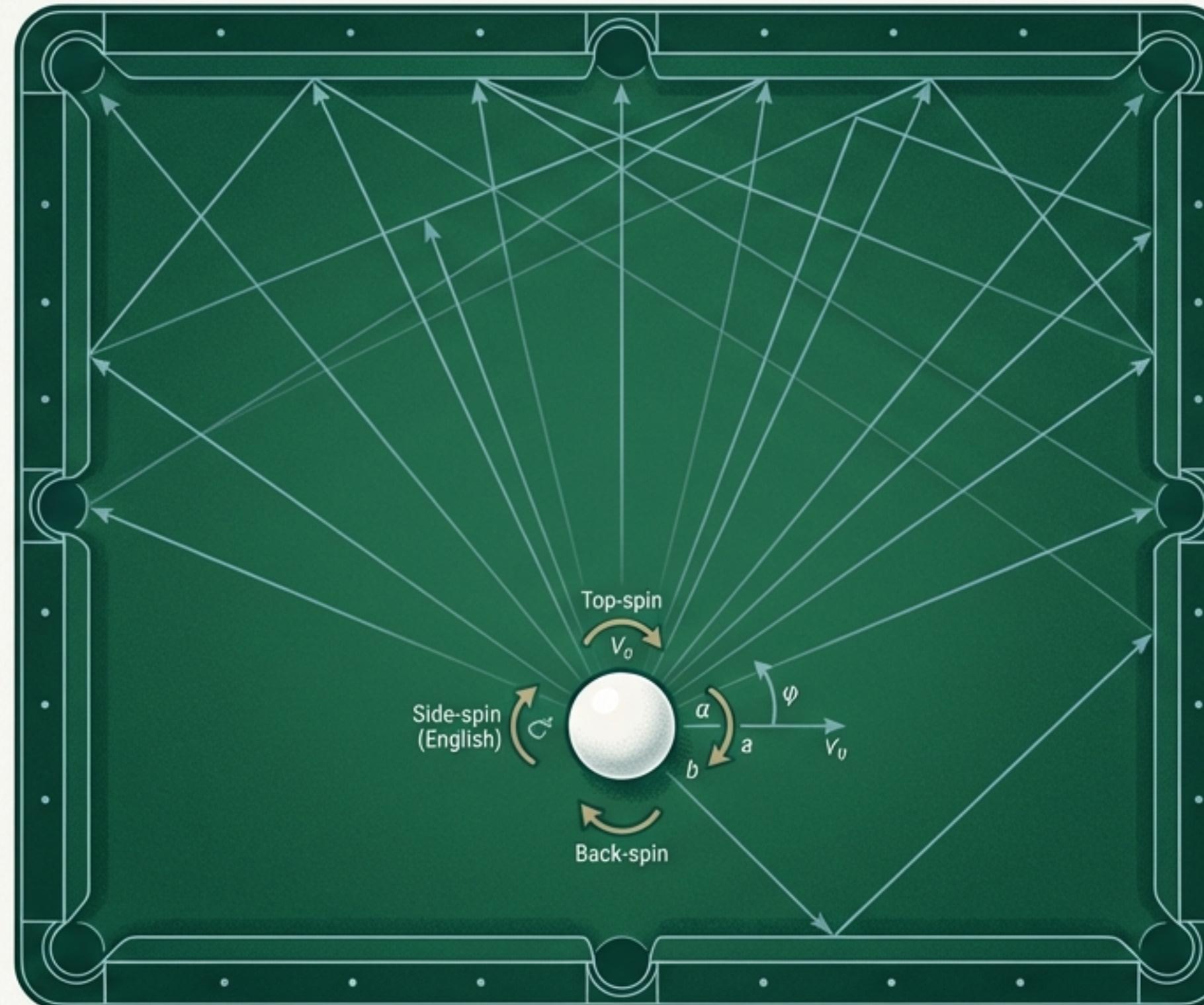
## 1. Vast Action Space

The agent must select from a continuous 5-dimensional action space: velocity ( $V_0$ ), angle ( $\phi$ ), and spin parameters ( $a, b, \theta$ ).



## 3. Strategic Traps

The agent must avoid illegally pocketing the 8-ball at all costs while strategically clearing its own set of balls.



## 2. Execution Noise

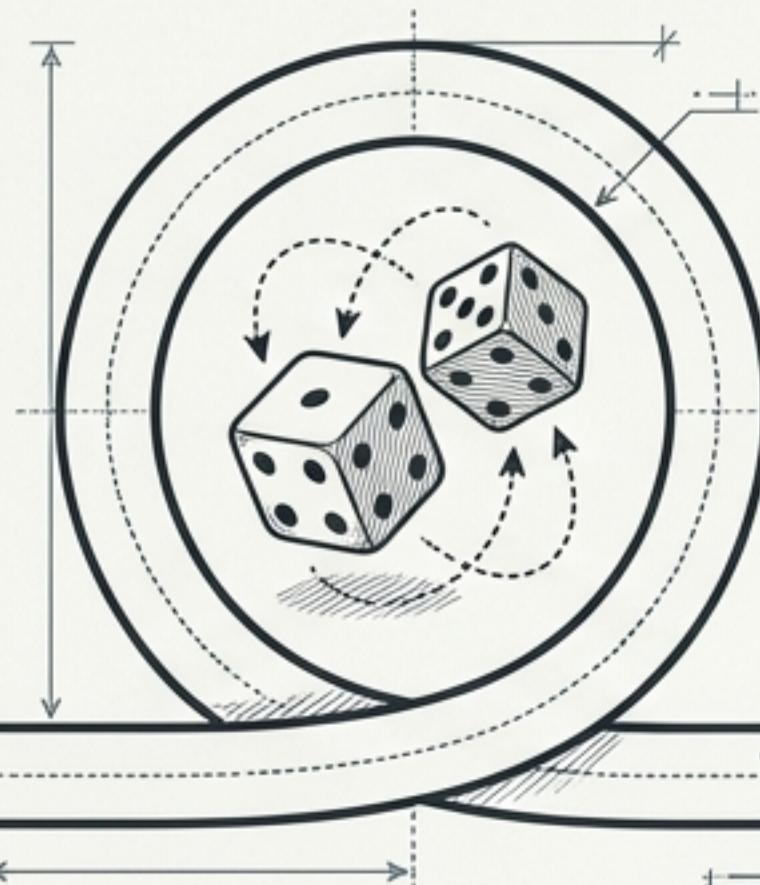
Every action is subject to Gaussian noise, mirroring real-world uncertainty. A theoretically perfect shot can easily fail.



## 4. Computational Budget

All decisions must be made efficiently to complete a game in under 3 minutes.

# Our Initial Approaches Revealed Key Lessons



## Attempt 1: Pure Random Search

~30% win rate vs. BasicAgent

Very low hit rate; inefficient use of simulation budget.

Lesson: Geometric guidance is essential.

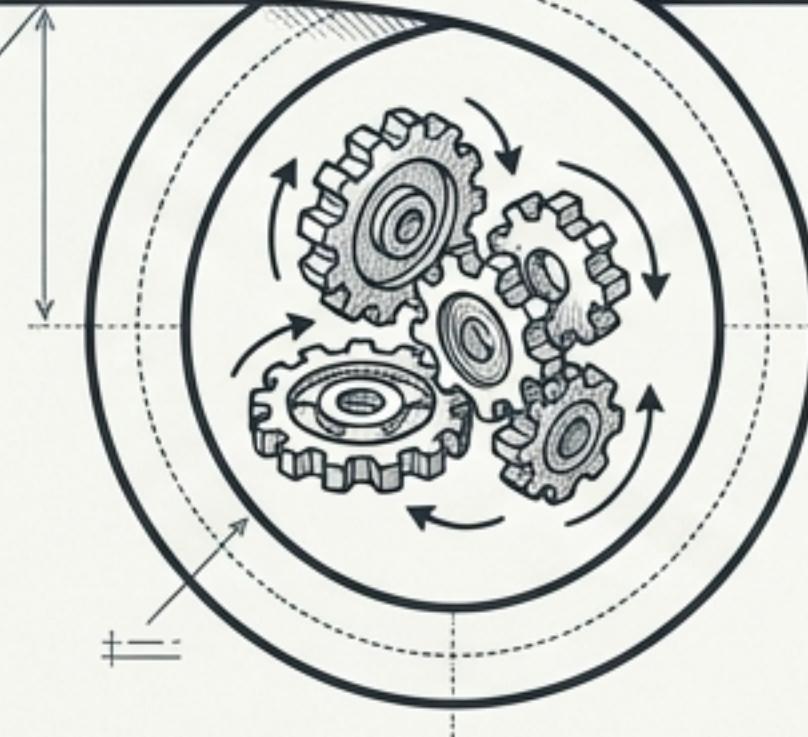


## Attempt 3: MCTS without Pre-filtering

~55% win rate vs. BasicAgent

Wasted simulation effort on obviously poor actions.

Lesson: The search must be focused on promising candidates.



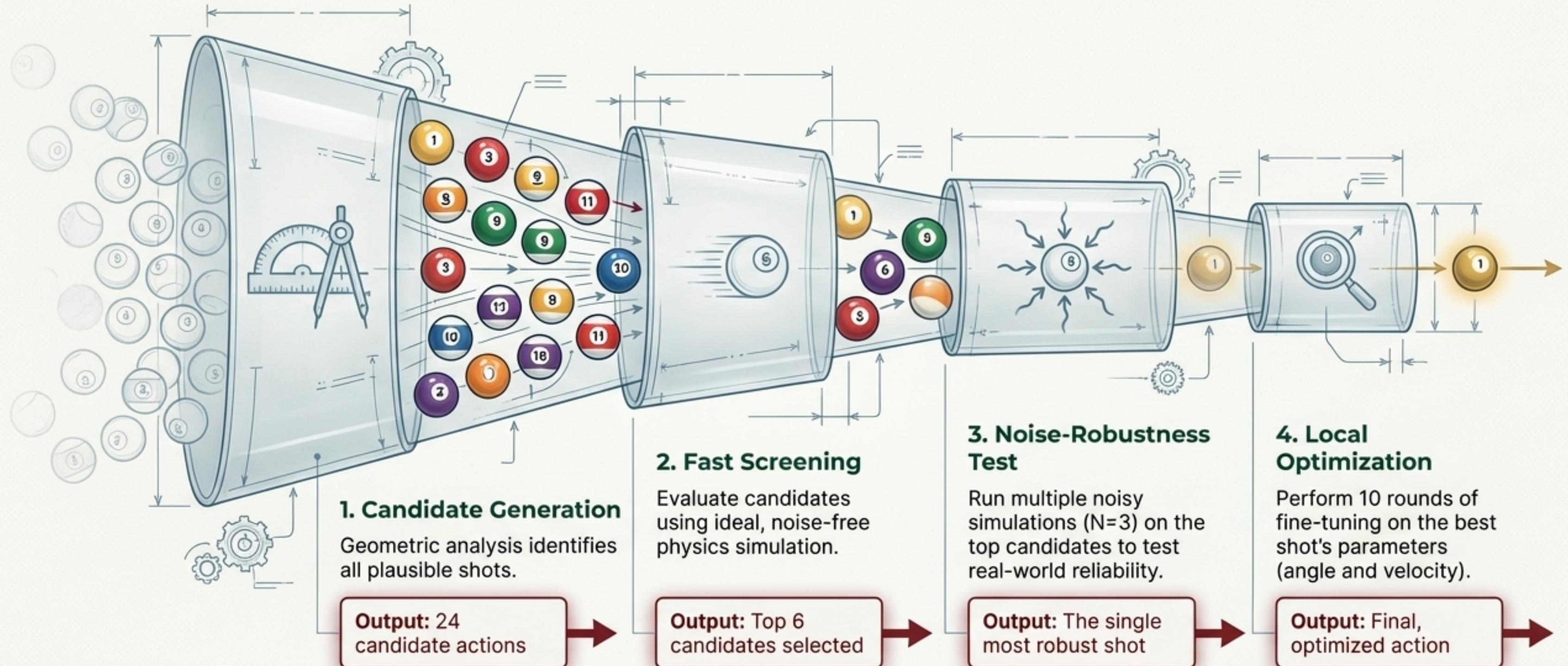
## Attempt 2: Bayesian Optimization Only

High computational cost and sensitivity to hyperparameters.

Lesson: Efficiency and robustness are critical.

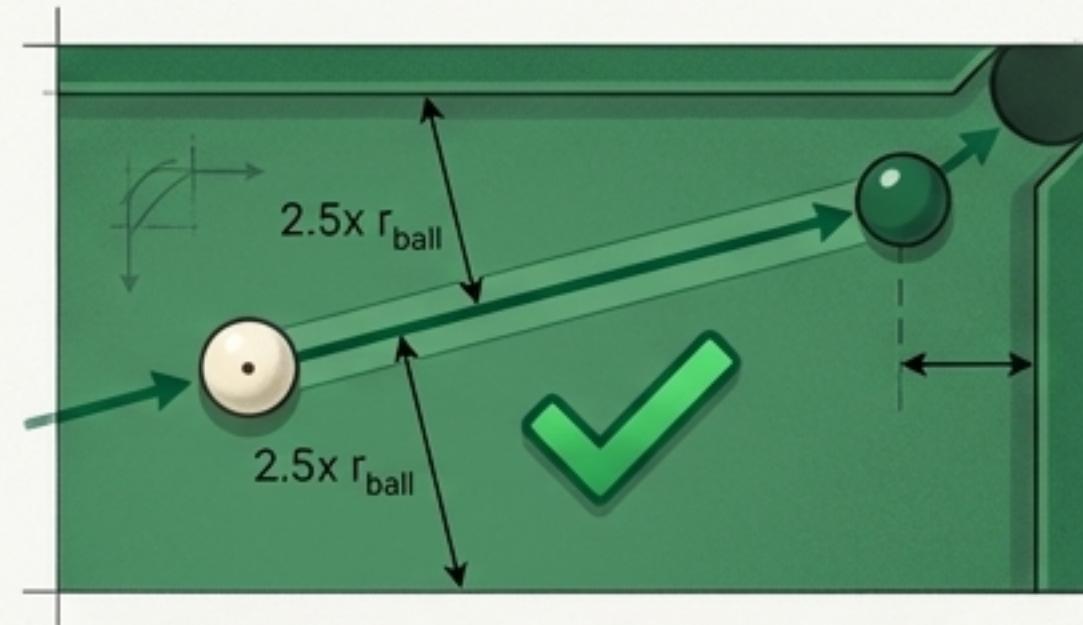
**The Hybrid Approach**

# Our Solution: A Four-Stage Pipeline for Smart, Robust Decisions

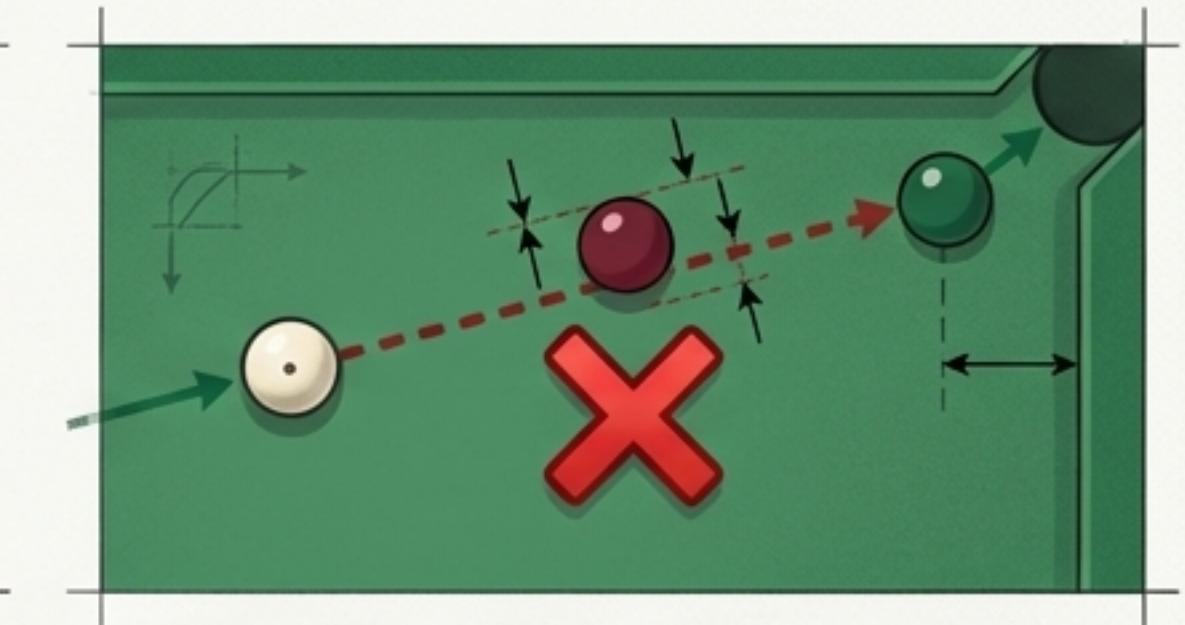


# We Start with Geometry to Avoid Blunders and Think Fast

**Function:** Geometric pre-analysis rapidly finds plausible shots and ranks them without slow physics simulations.



**Key Feature 1: Path Clearance Detection.**  
Any path with an obstacle closer than  $2.5 \times$  the ball's radius is penalized.



A blocked path receives a low score.

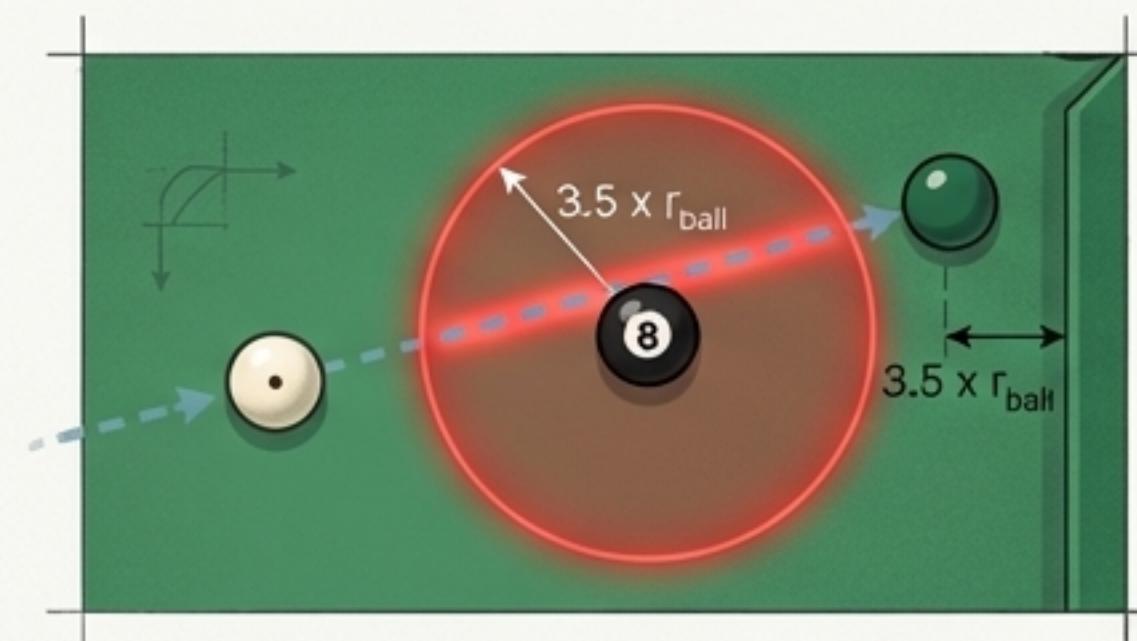
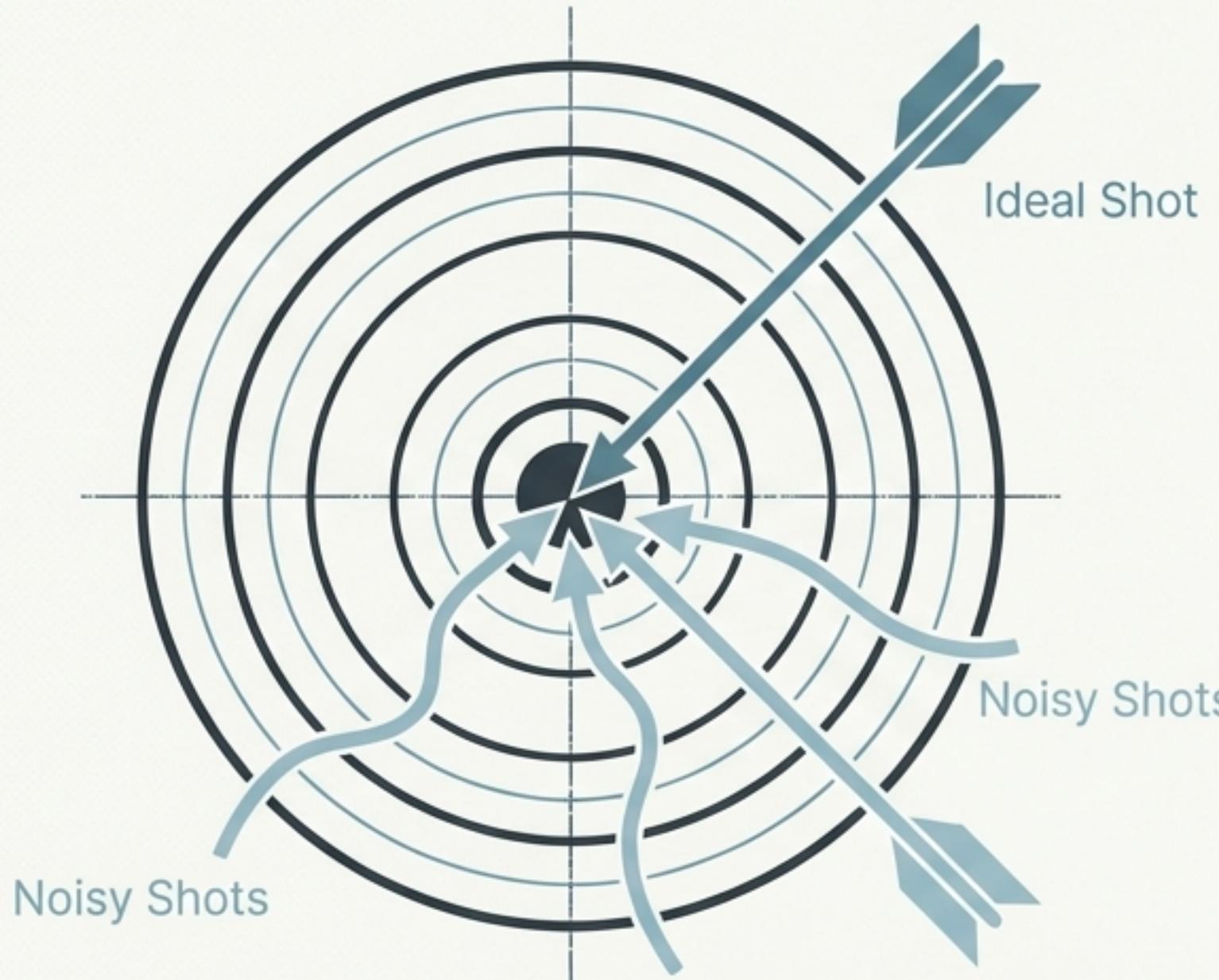


Diagram 3: 8-Ball Risk Detection

**Key Feature 2: 8-Ball Risk Detection.** If the 8-ball is inside the danger zone of a shot path, the shot receives a massive penalty.

**Pweight = 300**

# We Plan for Imperfection to Succeed in a Noisy World



We choose the shot with the best *cluster*, not just the single perfect outcome.

## The Problem

The game engine applies Gaussian noise to every action parameter (velocity, angle, spin). A shot that seems perfect in an ideal simulation might consistently fail in reality.

## Our Solution

We test the top candidate shots with multiple noisy simulations to find the most consistently successful one.

## The Scoring Formula

We select the best action using a weighted score that balances ideal performance with real-world reliability. This prioritizes actions that perform well on average under noisy conditions.

$$S_{\text{combined}} = 0.4 * S_{\text{ideal}} + 0.6 * S_{\text{noisy}}$$

# Dominating the Baseline: 88.2% Win Rate vs. BasicAgent

## 88.2% WIN RATE

1,058 WINS



NewAgent

142 WINS

BasicAgent

### Key Takeaway

**Total Games Played:** 1,200

**Key Takeaway:** Our hybrid pipeline of geometric filtering and noise-robust evaluation **consistently and overwhelmingly outperforms** the standard Bayesian Optimization baseline.

# Holding Our Own Against a Stronger Foe: 60.1% Win Rate vs. BasicAgentPro

**60.1% WIN RATE**



**\*\*Tested Across 9,600 Games\*\***  
A testament to rigorous,  
statistically significant testing.

## Key Takeaway

Total Games Played: 9,600

**\*\*Key Takeaway:** Even against a stronger MCTS-based agent, our efficient and robust approach **maintains a significant winning edge** over a very large sample of games.

# Our Agent Excels in Offense but Can Improve in Defensive Strategy

## Key Strengths



**Efficient Pocketing:** Frequently clears multiple balls in a single shot.



**Excellent 8-Ball Safety:** The 'Peight' penalty successfully prevents most premature game-losing shots.



**Capitalizes on Fouls:** Effectively uses "ball-in-hand" opportunities after opponent errors.

## Areas for Improvement



**Sub-optimal Break Shots:** The opening break is not optimized and can concede an early advantage.



**Lacks Defensive Plays:** When no good offensive shot exists, the agent does not have a dedicated "safety" strategy.



**Struggles with Clutter:** Performance degrades on highly cluttered tables with many blocking balls.

# A Winning Hybrid Design with a Clear Path Forward

**Conclusion:** NewAgent's hybrid pipeline—combining fast geometric filtering with robust, noise-aware simulation—is a highly effective strategy for 8-ball pool, proven by win rates of **88.2%** and **60.1%** against strong benchmarks.

## Future Work

