Happy Elements

MAKE THE WORLD HAPPY

Generating the Best Game Experience through AI

Rein Houthooft

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Introduction

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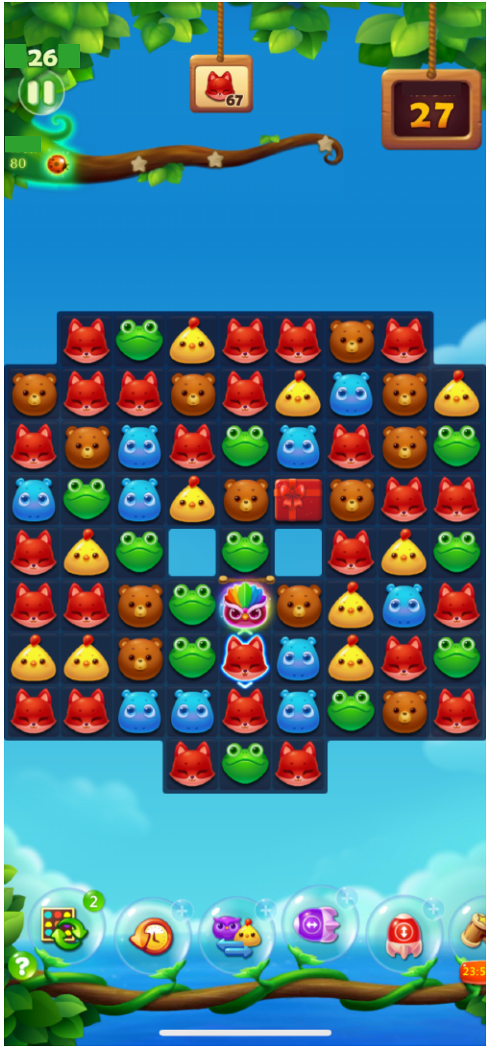

- Company focus: **casual** mobile games
- Main product: "**Anipop**" 
- Extremely popular (>**100M** users/month)
- Generates **TBs of data** each day
- **AI Lab** founded 1 year ago

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AI Lab: Goals & Strategy

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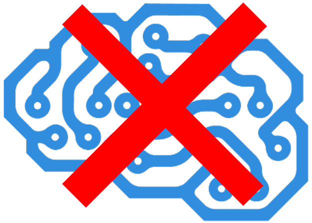
Open-loop to Closed-loop Game Design



Sparse feedback

<u>Little Optimization</u>

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Open-loop to Closed-loop Game Design

- Product-player preferences mismatch
- Designers slow in adapting to changing player behavior
- Lower player satisfaction

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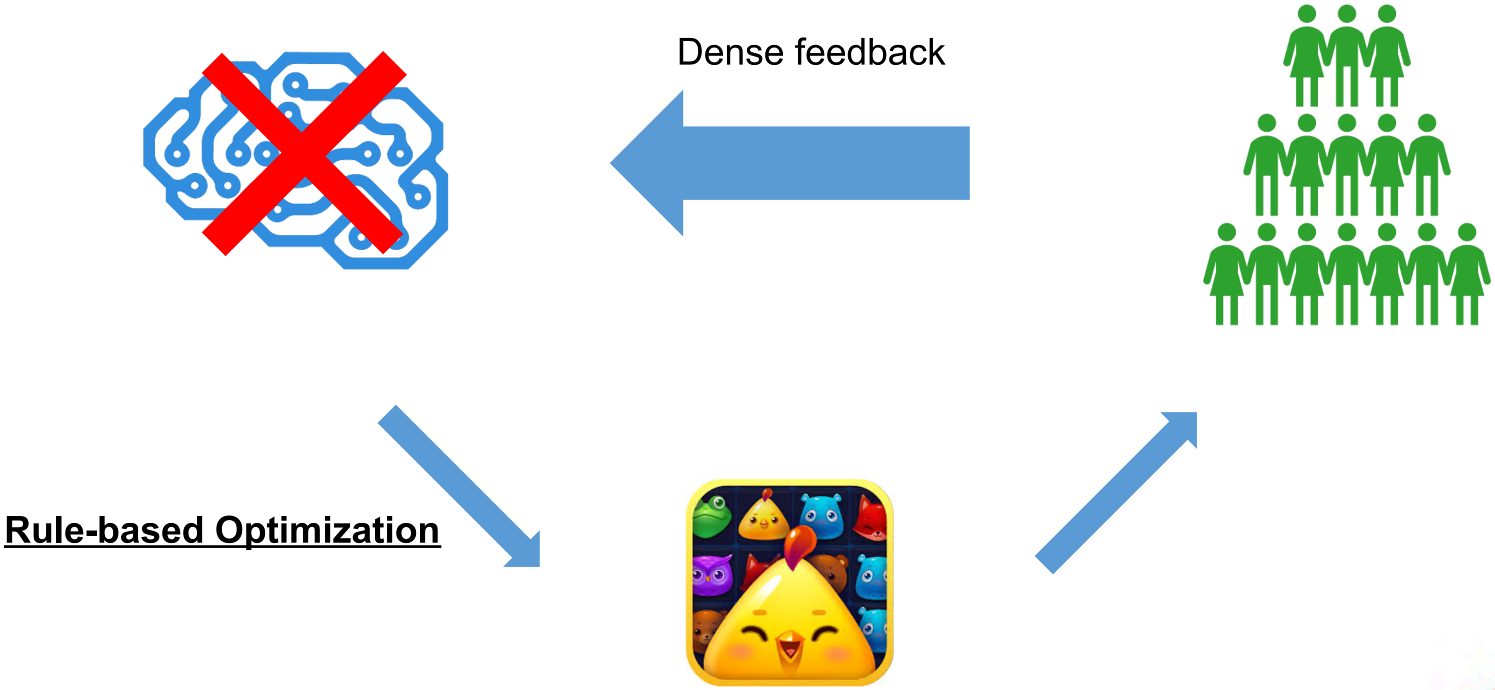
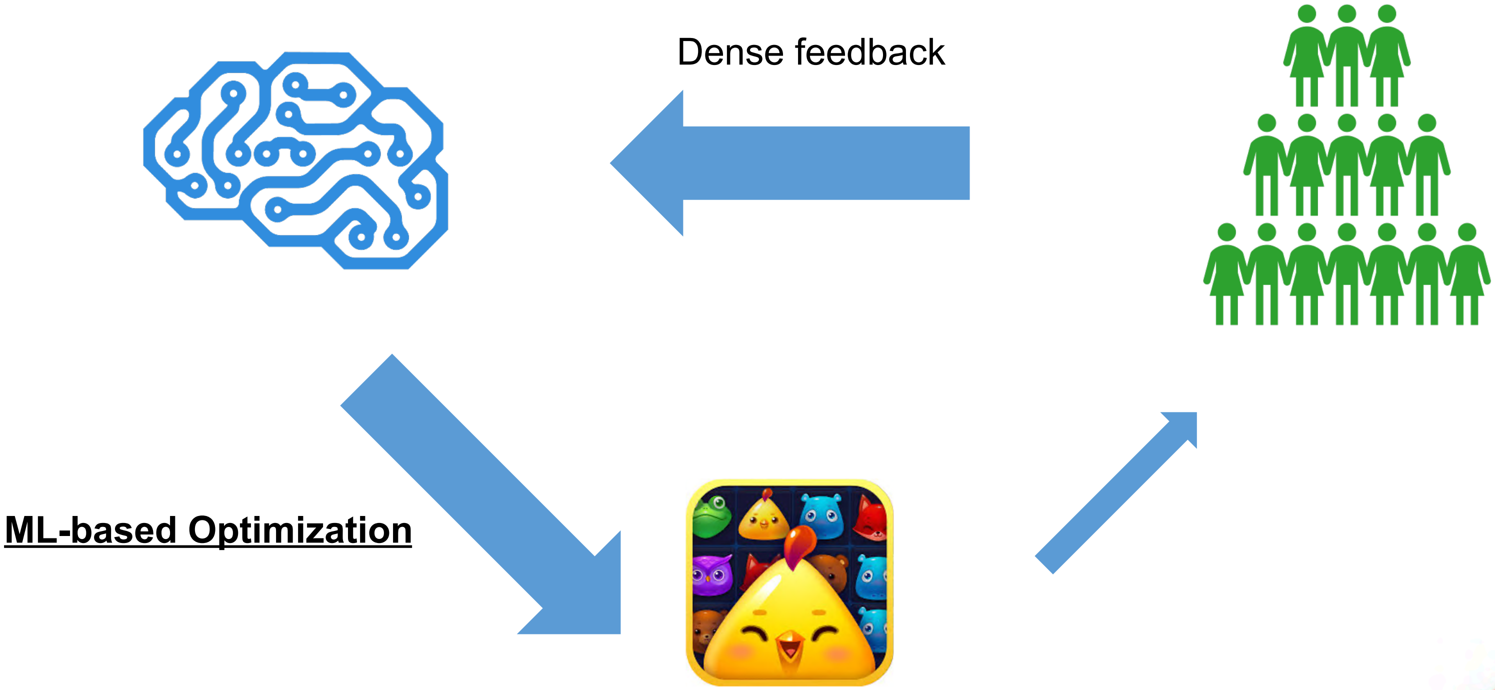
Open-loop to Closed-loop Game Design



Open-loop to Closed-loop Game Design

- Some adaptation to changing player preferences
- Low granularity
- Hard to maintain over time

Open-loop to Closed-loop Game Design



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Open-loop to Closed-loop Game Design

- Immediate adaptation to changing player preferences
- High granularity
- Maintains itself through objective function optimization

Sample AI Lab Project:

Deep Learning for Game Difficulty Adjustment

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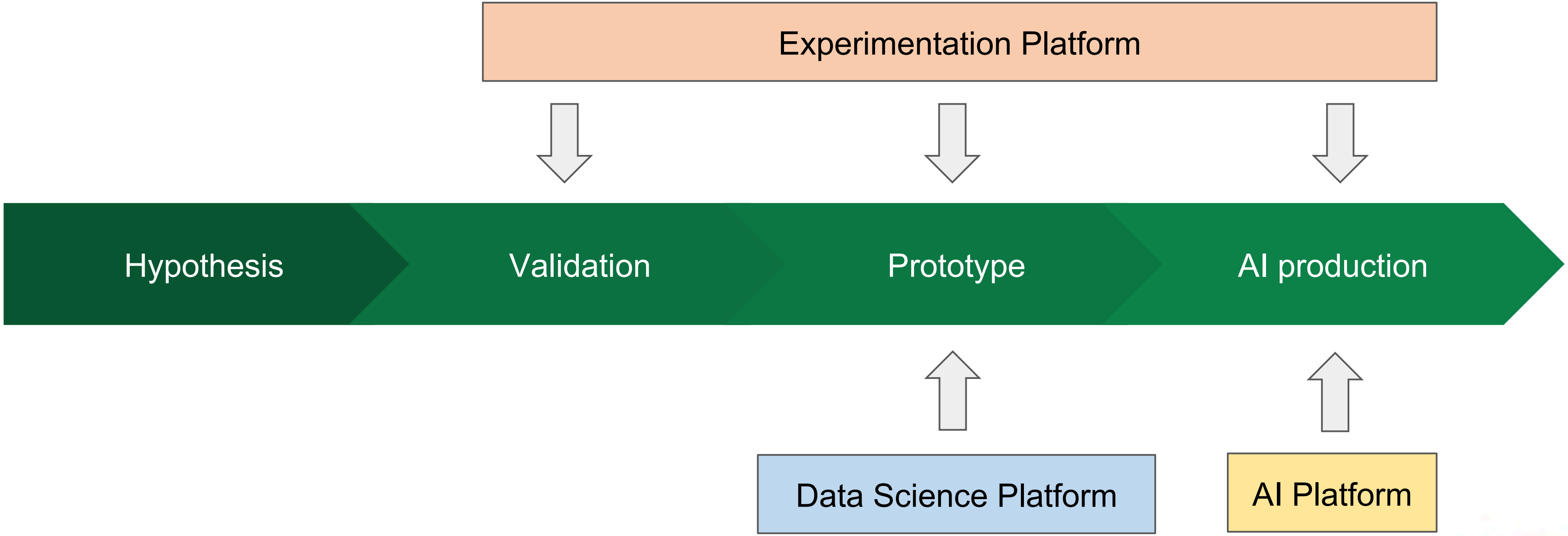
From Hypothesis to Production



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Game Difficulty Adjustment

- Hypothesis: **preferred** difficulty **varies** across users & time.
- Validation: difficulty correlates with **LTV/retention**.
- Prototype + Production: **adjust** difficulty dynamically via **ML**.

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Problem Formulation

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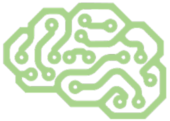
Problem Formulation

Fixed gameplay
for **all** users

manual rules

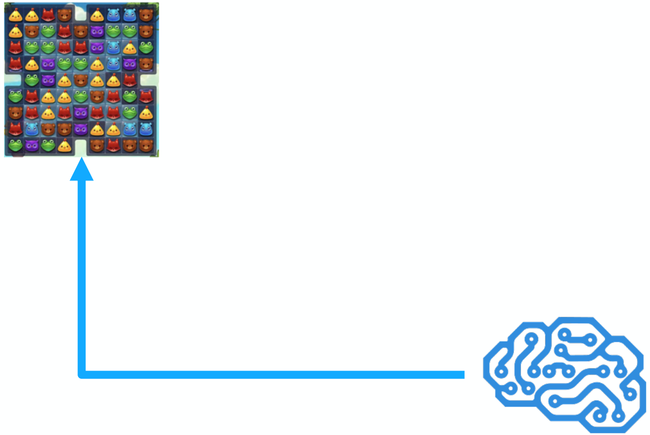
Personalized gameplay
for **each** user



machine learning

Problem Formulation

Gameplay modification: Action sequences



Objective: Rewards = player revenue/retention

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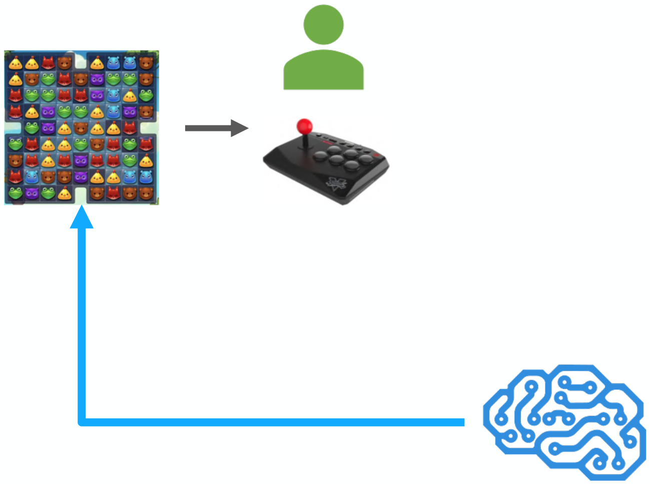
Problem Formulation

Gameplay modification: Action sequences



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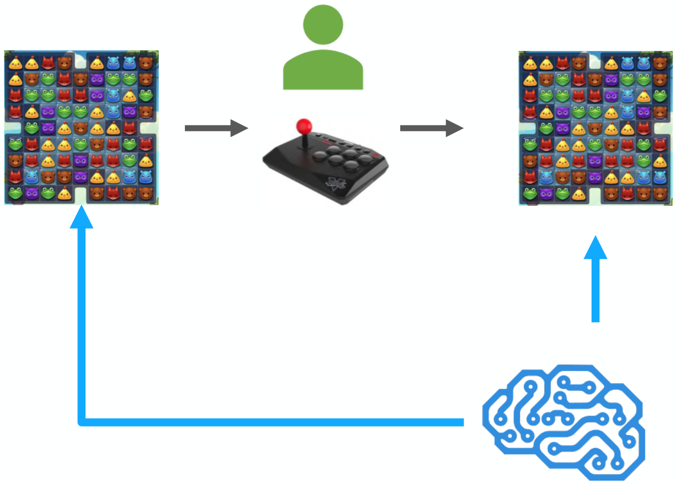
Gameplay modification: Action sequences



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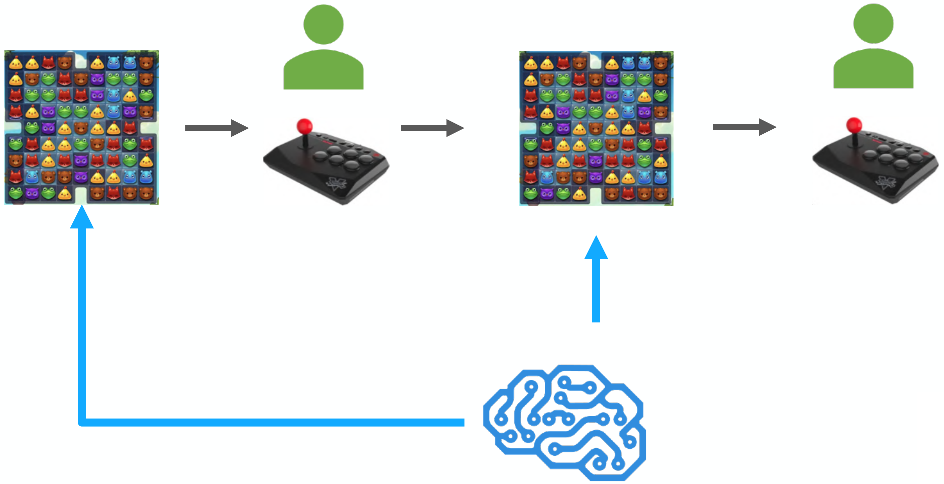
Gameplay modification: Action sequences



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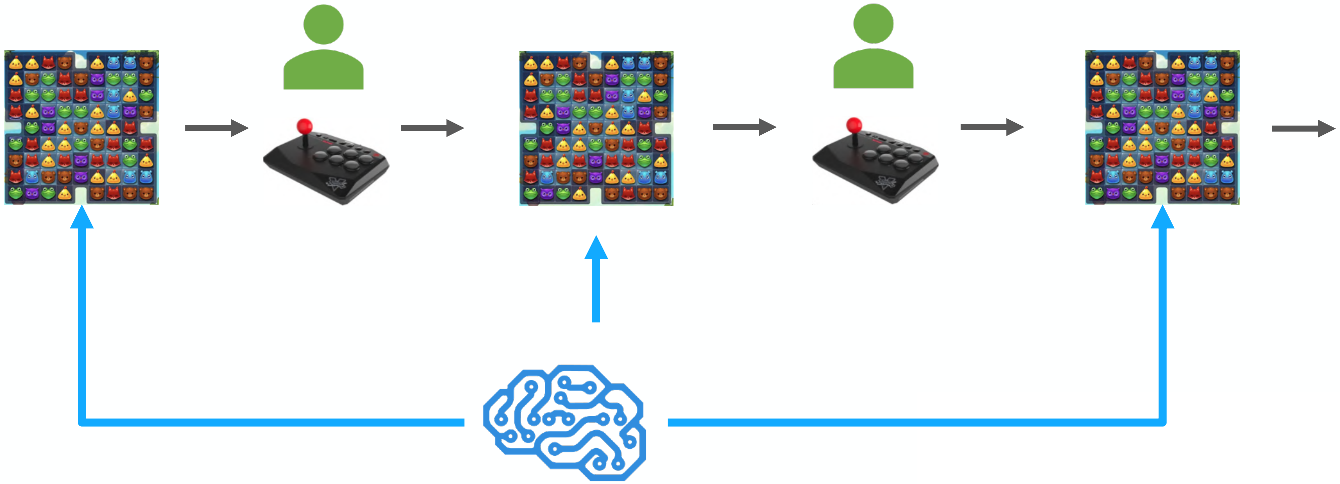
Gameplay modification: Action sequences



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Deep Reinforcement Learning

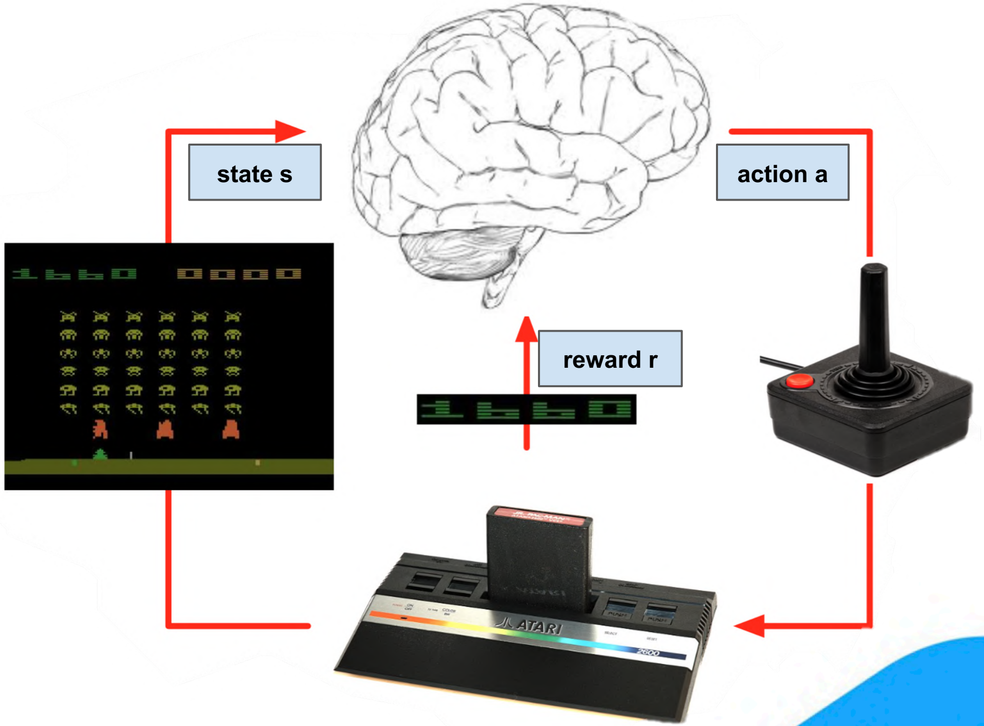
- **Reinforcement learning** defines problem via high-level **objective**
- **Deep learning** is a **paradigm** for building flexible **solutions**
- **Deep reinforcement learning** integrates both above points

Problem Formulation

Reinforcement Learning:

- What **action *a*** to take in **state *s*** to **optimize** the expected **reward E[*r*]**?

- For example, video game:
  - state s = screen
  - action a = controller
  - reward r = score



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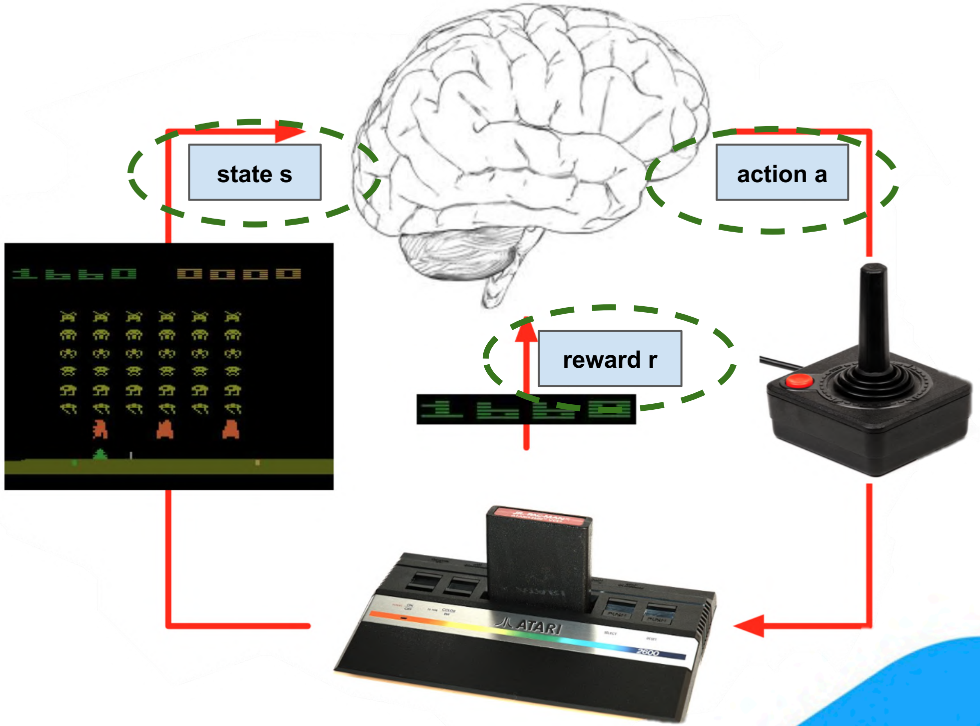

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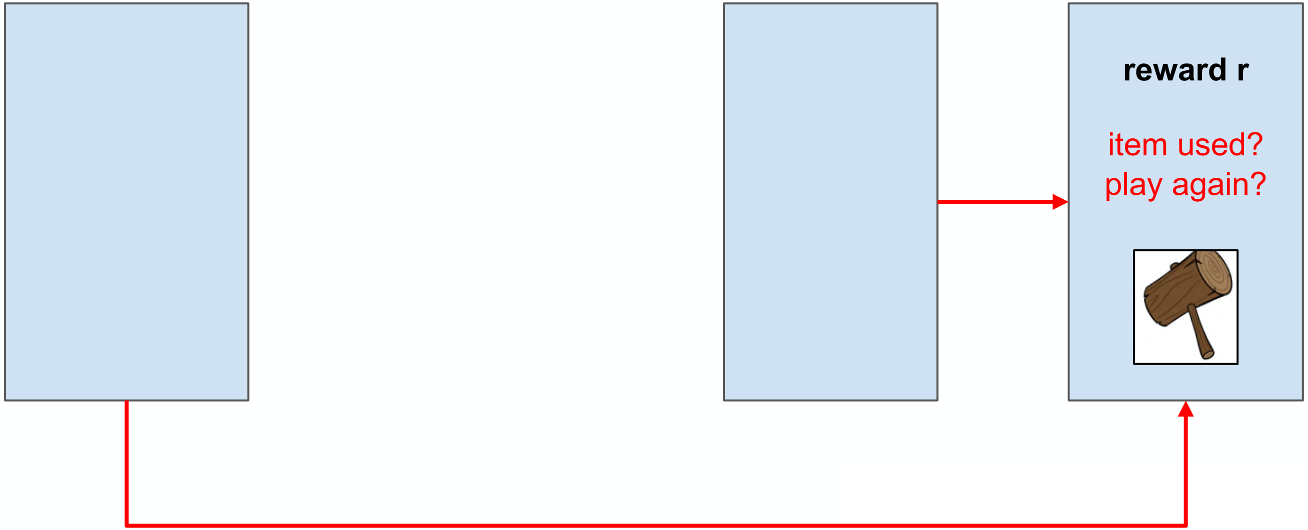
Reinforcement Learning



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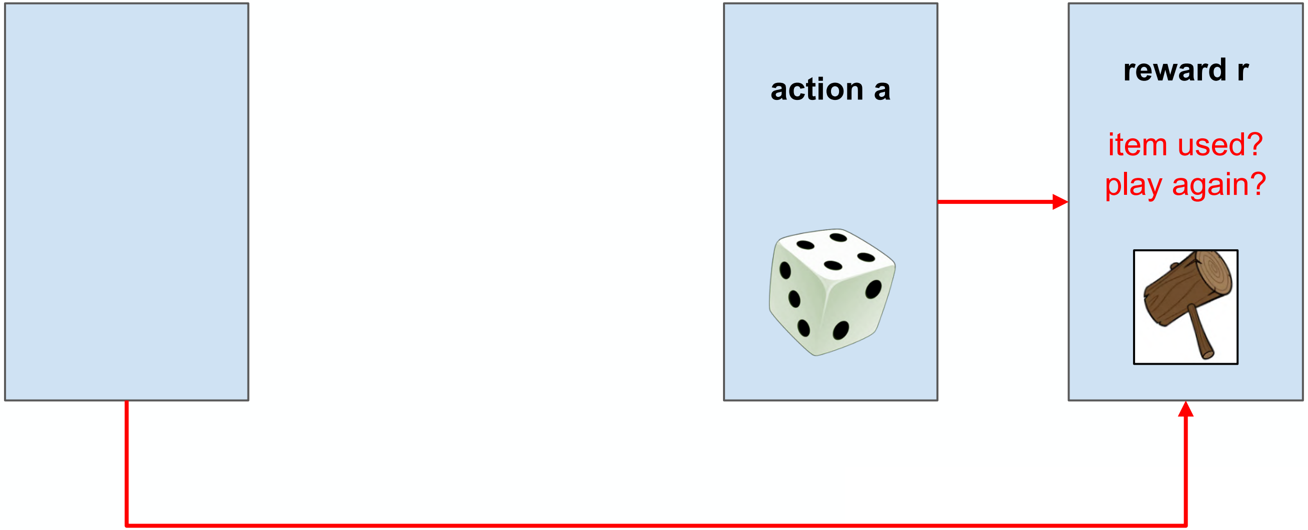

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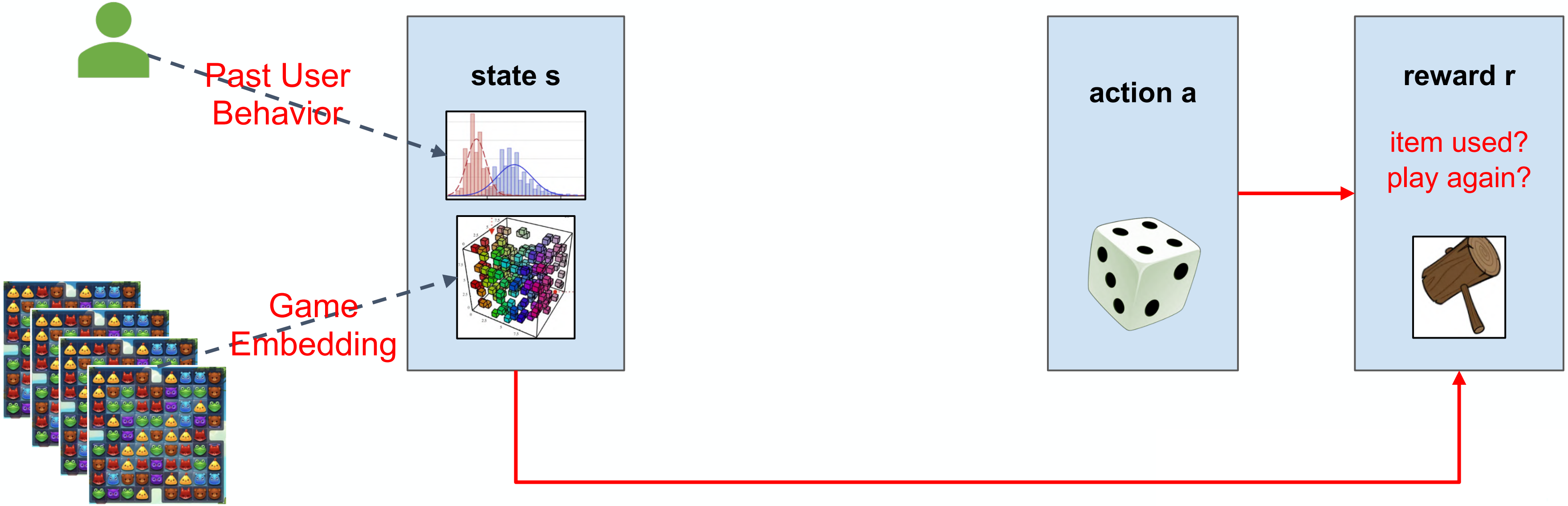
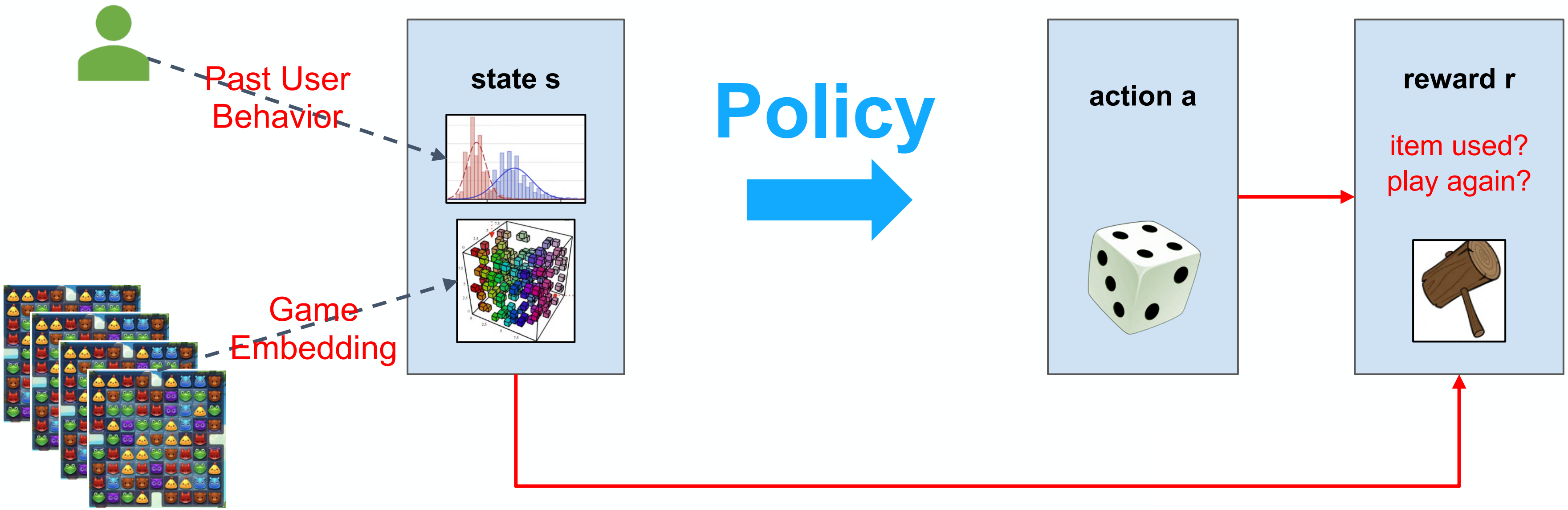


Reinforcement Learning



Deep Learning

- **Paradigm shift** rather than new technique
- Ability to **optimize any sort** of target using **any type** of data flow
- Extremely **flexible** in fusing and integrating **heterogeneous data**

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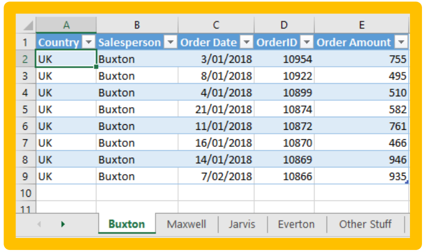
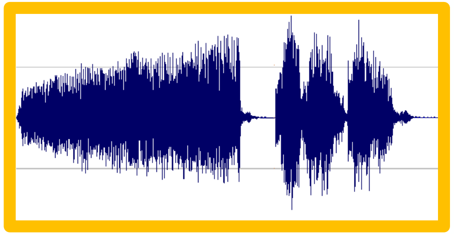
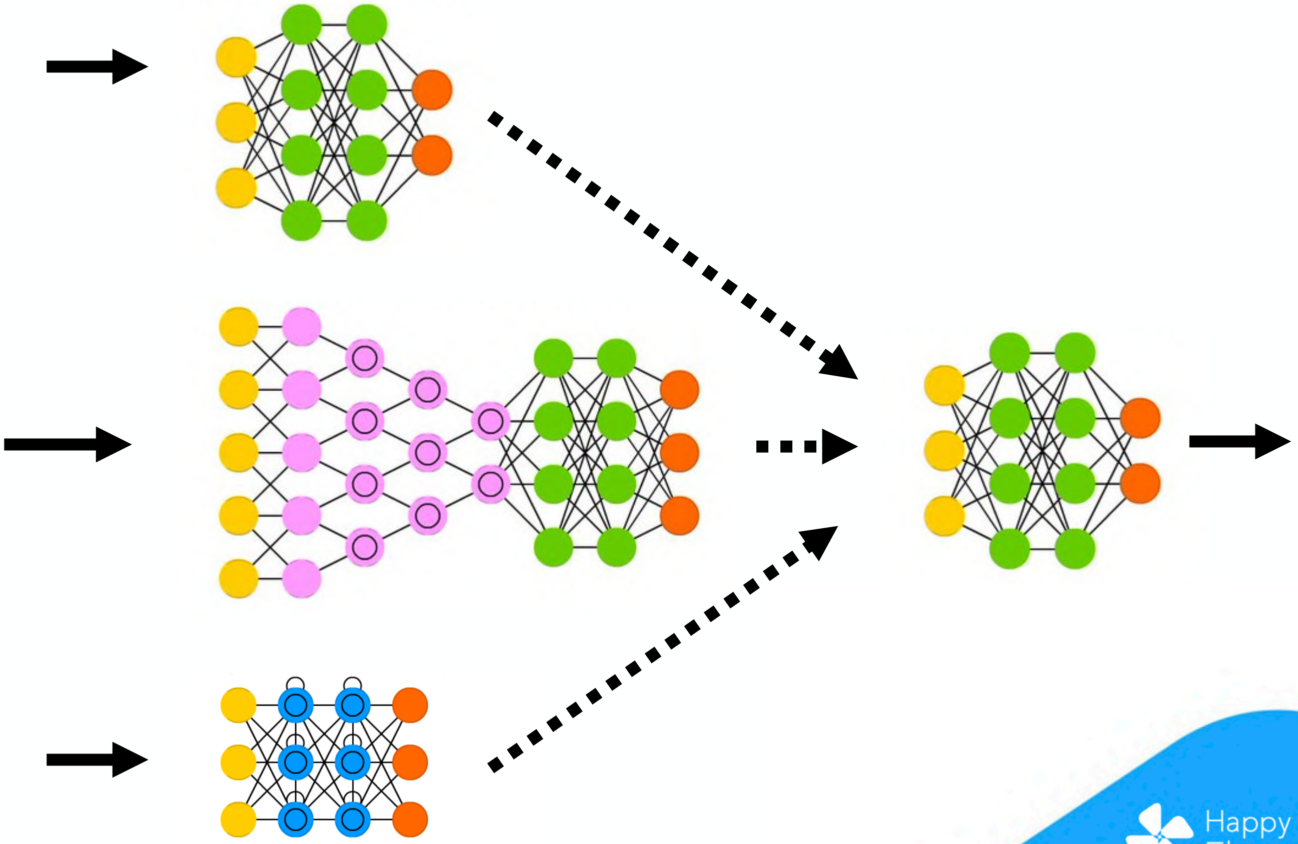
Deep Learning



	A	B	C	D	E
1	Country	Salesperson	Order Date	OrderID	Order Amount
2	UK	Buxton	3/01/2018	10954	755
3	UK	Buxton	8/01/2018	10922	495
4	UK	Buxton	4/01/2018	10899	510
5	UK	Buxton	21/01/2018	10874	582
6	UK	Buxton	11/01/2018	10872	761
7	UK	Buxton	16/01/2018	10870	466
8	UK	Buxton	14/01/2018	10869	946
9	UK	Buxton	7/02/2018	10866	935
10					
11					

Buxton | Maxwell | Jarvis | Everton | Other Stuff





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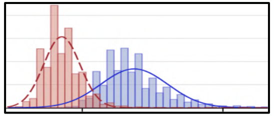

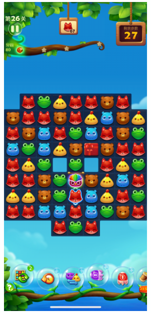

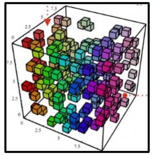

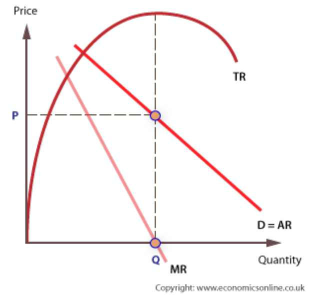

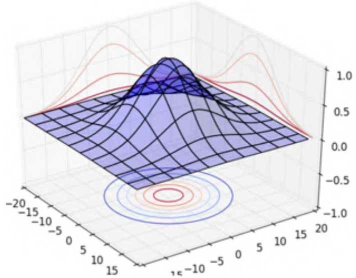

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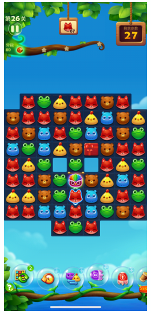

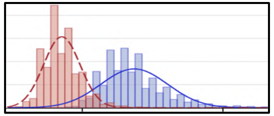

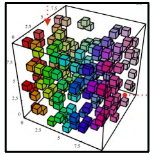

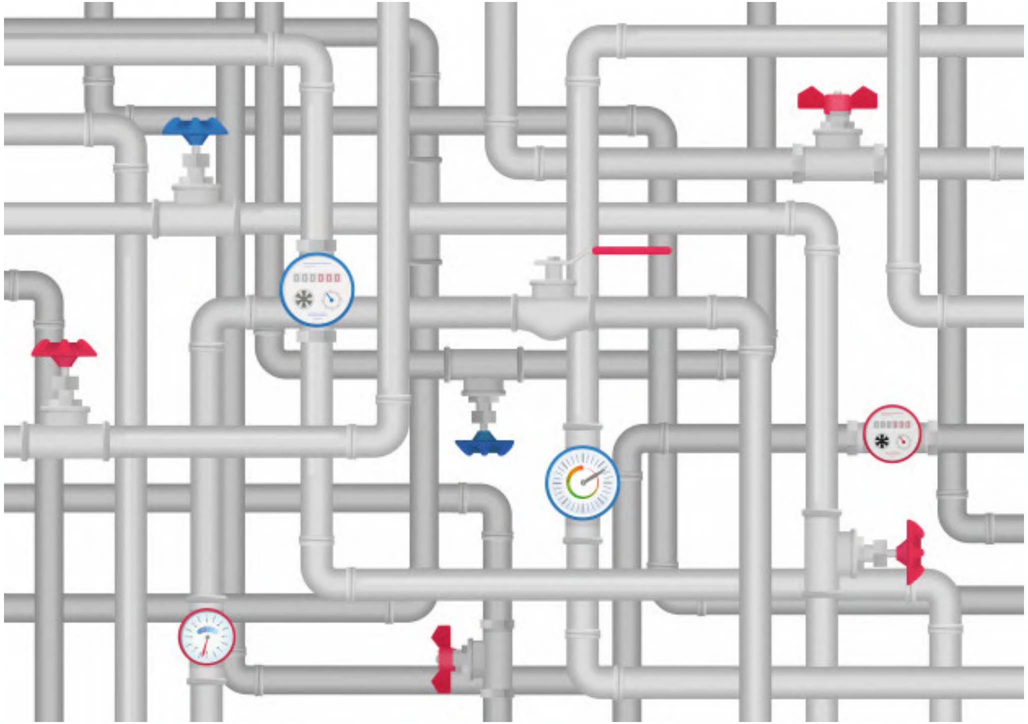

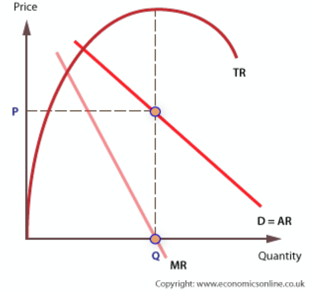

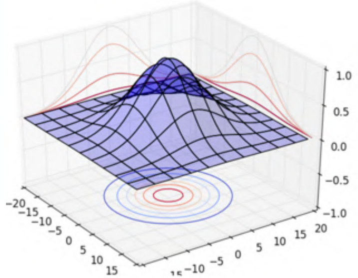

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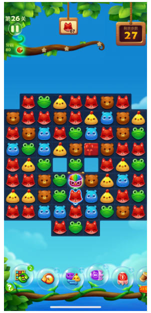

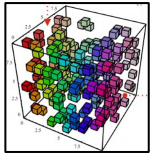

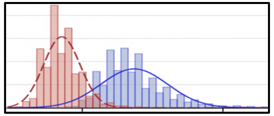

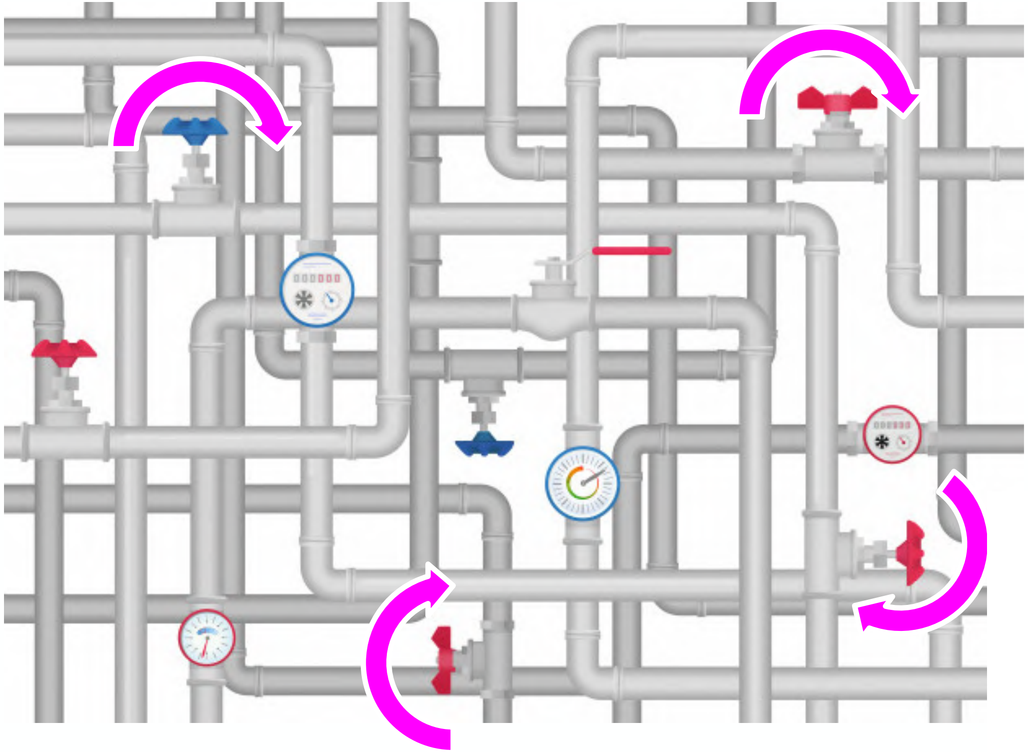

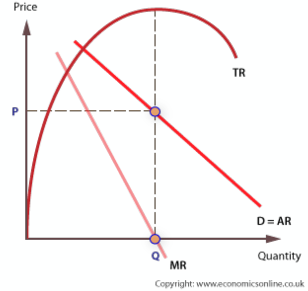

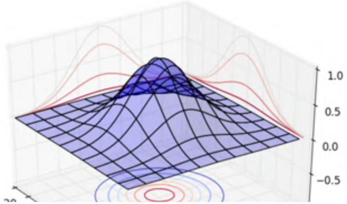

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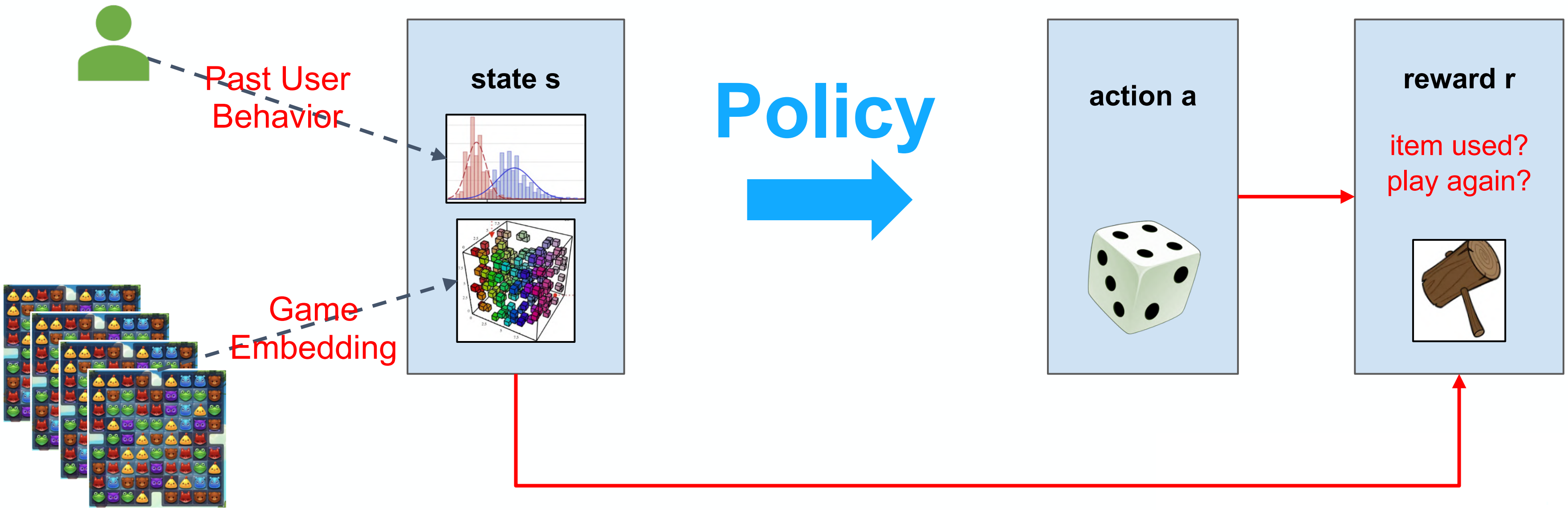
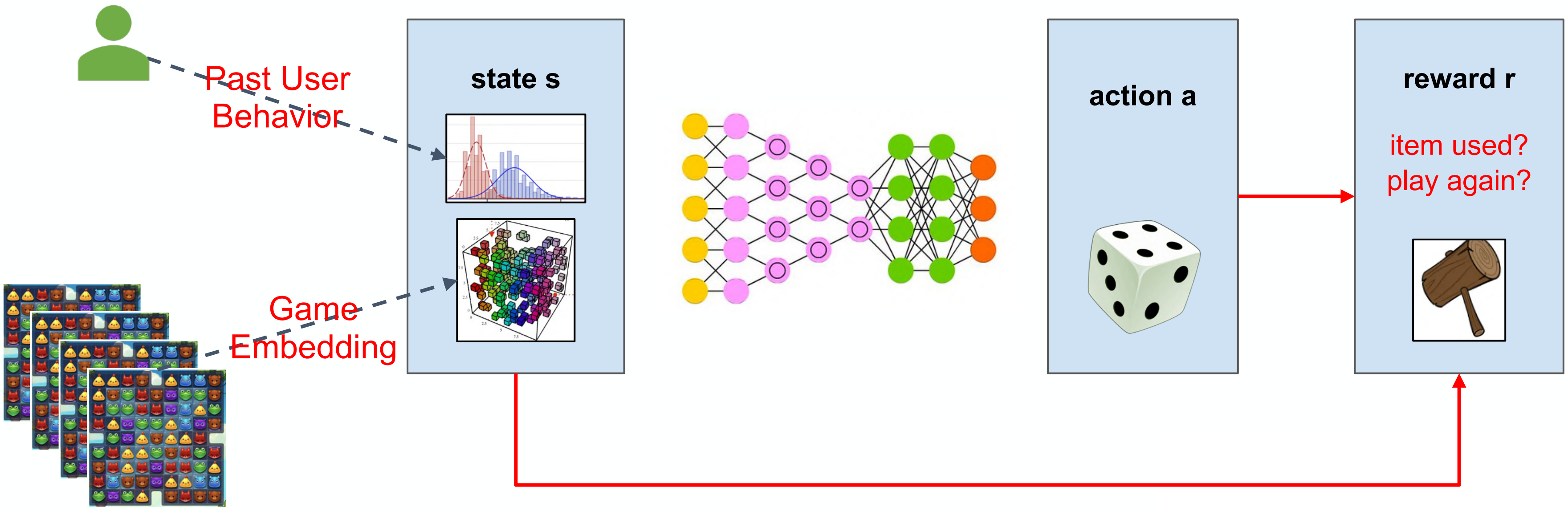
Reinforcement Learning



Deep Reinforcement Learning



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In Practice: Key Problems

- ML good at optimizing short-term targets:

  How do short-term targets relate to long-term objectives?

- ML good at optimizing on fixed dataset:

  What when the data regime is highly non-stationary?

Optimization Horizon

- Often it is easy to define **short-term targets**:

  Did the user play another in-game level?
  Did the user make an in-app purchase?

- But how does this lead to **long-term objectives**?

  User engagement over the next year
  Life-time value of player

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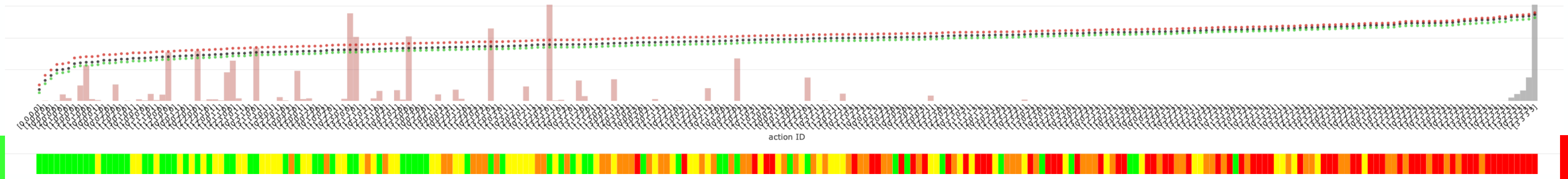
Optimization Horizon

Retention

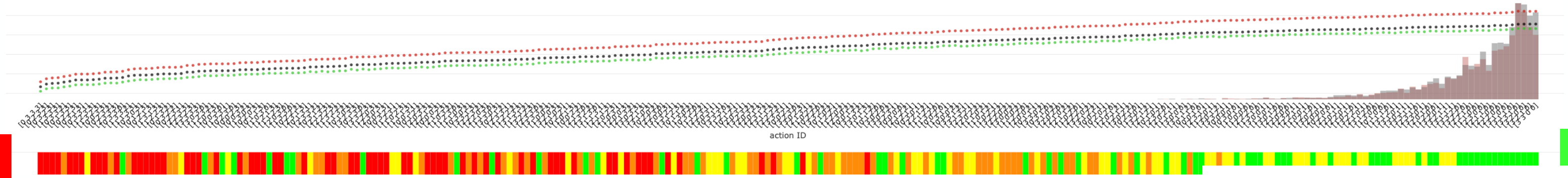
HARD



EASY

Revenue

EASY



HARD

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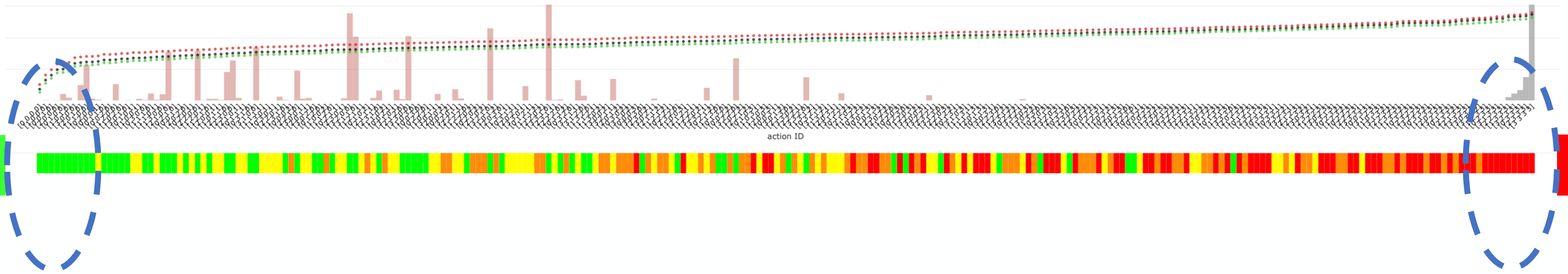
Optimization Horizon

Retention

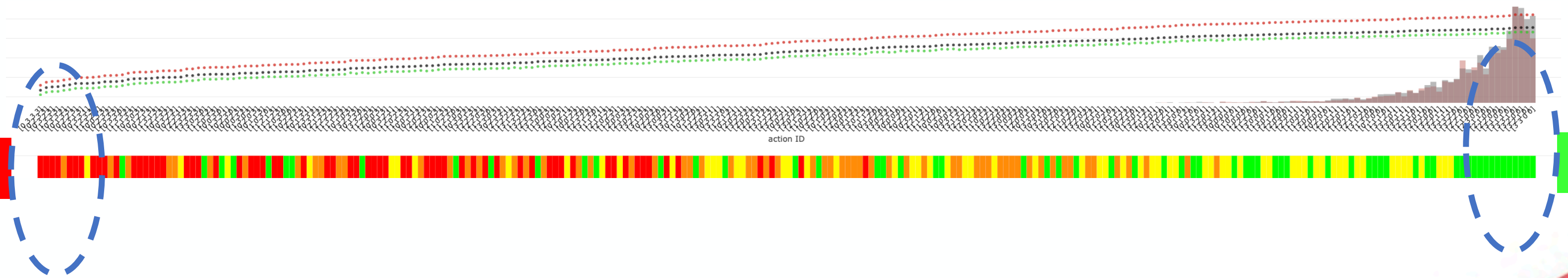
HARD



EASY

Revenue

EASY



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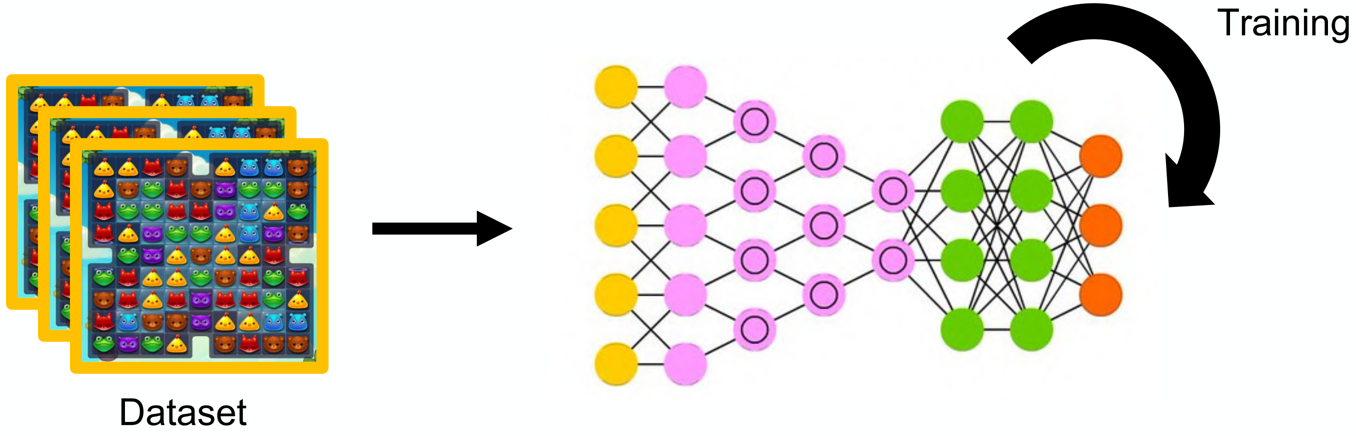
Optimization Horizon

- This can be solved through **RL** by **formulating the right objective**
- Objective is a **sum of individual short-term targets** over a time horizon
- However problem remains in **how to accurate model** this objective

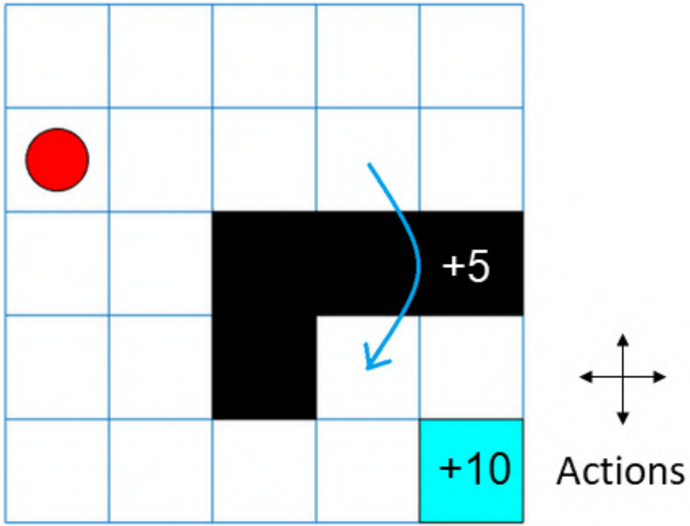
Exploration – Exploitation Duality



- Traditionally, ML works on a **fixed dataset**
- Practical RL in **constant motion**: model generates

Exploration – Exploitation Duality

- Rewards might be **sparse**: learn from long-term signal
- + **dynamic interaction** with players: inherently **nonstationary** data regime
- Core problem: trading off **exploration vs exploitation**



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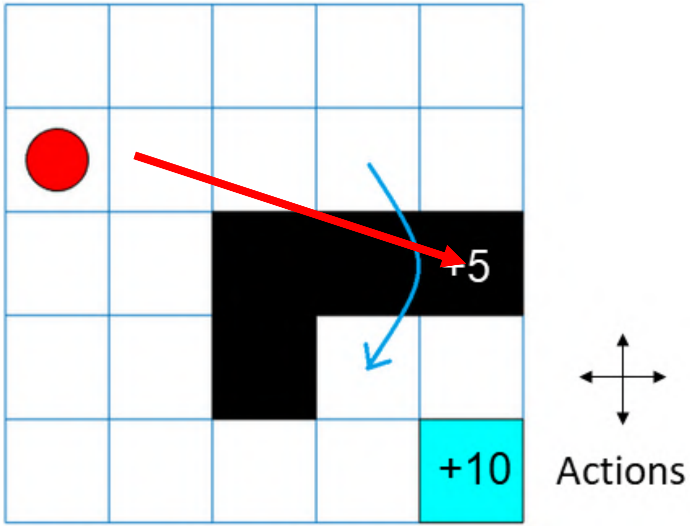

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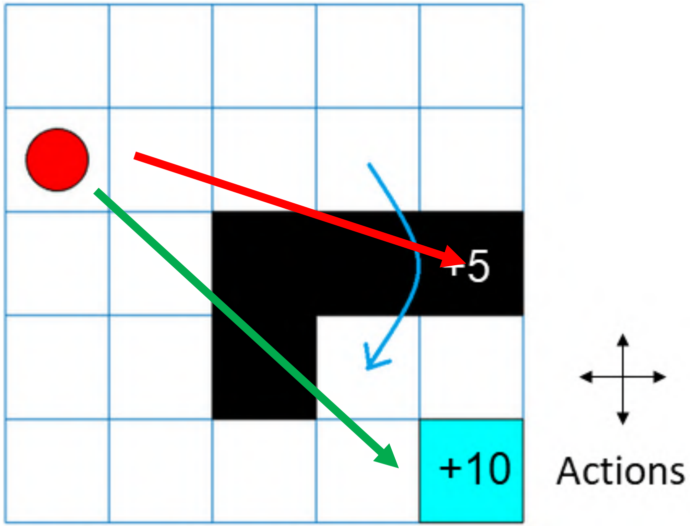

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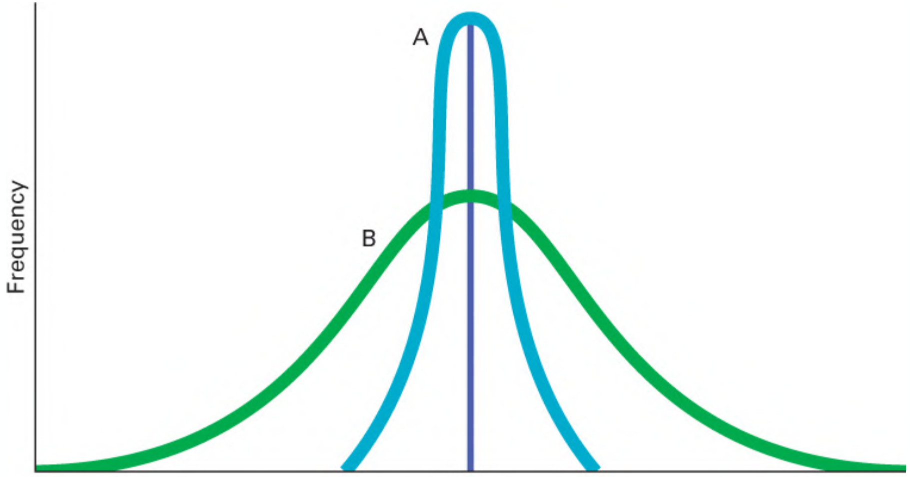
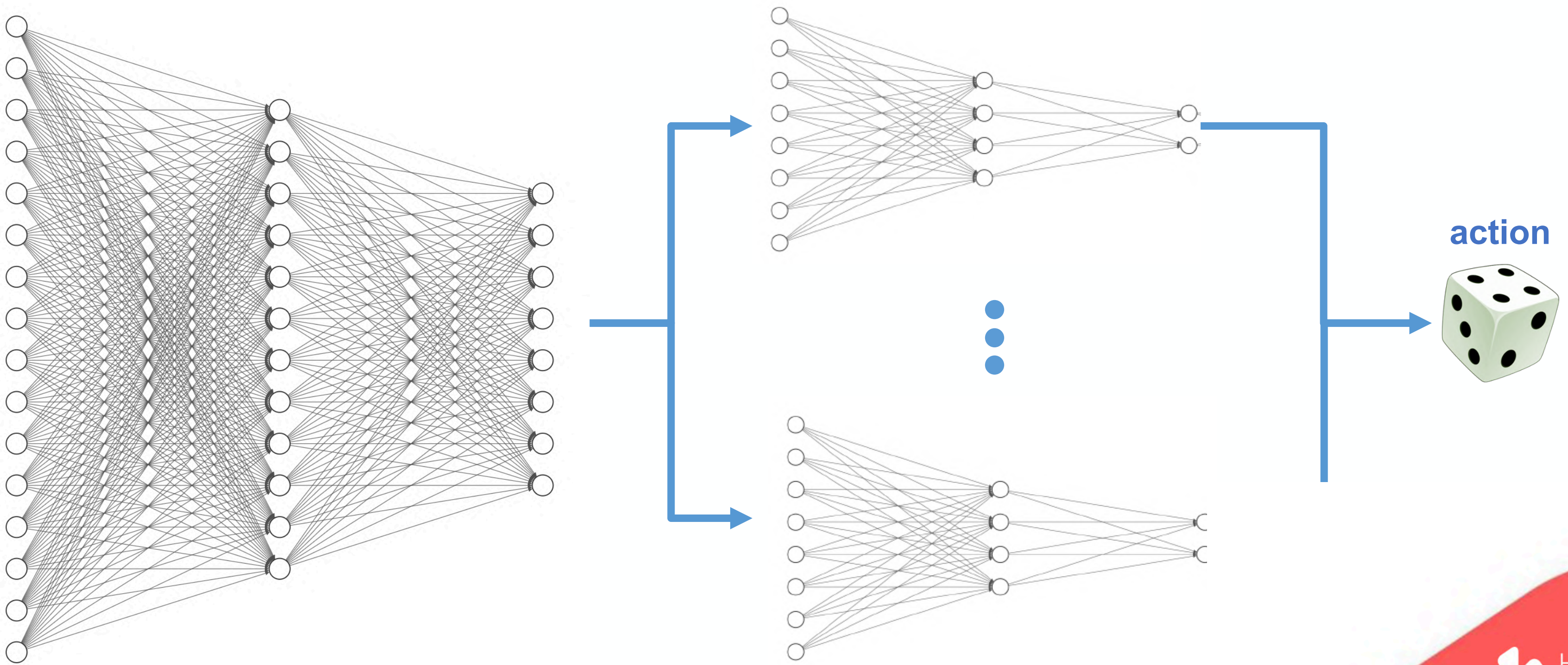
Exploration – Exploitation Duality

- Approximate Bayesian approach to capture **model uncertainty**
- Solving exploitation (A) vs. exploration (B) problem.



Model: Bootstrapped Contextual Bandits



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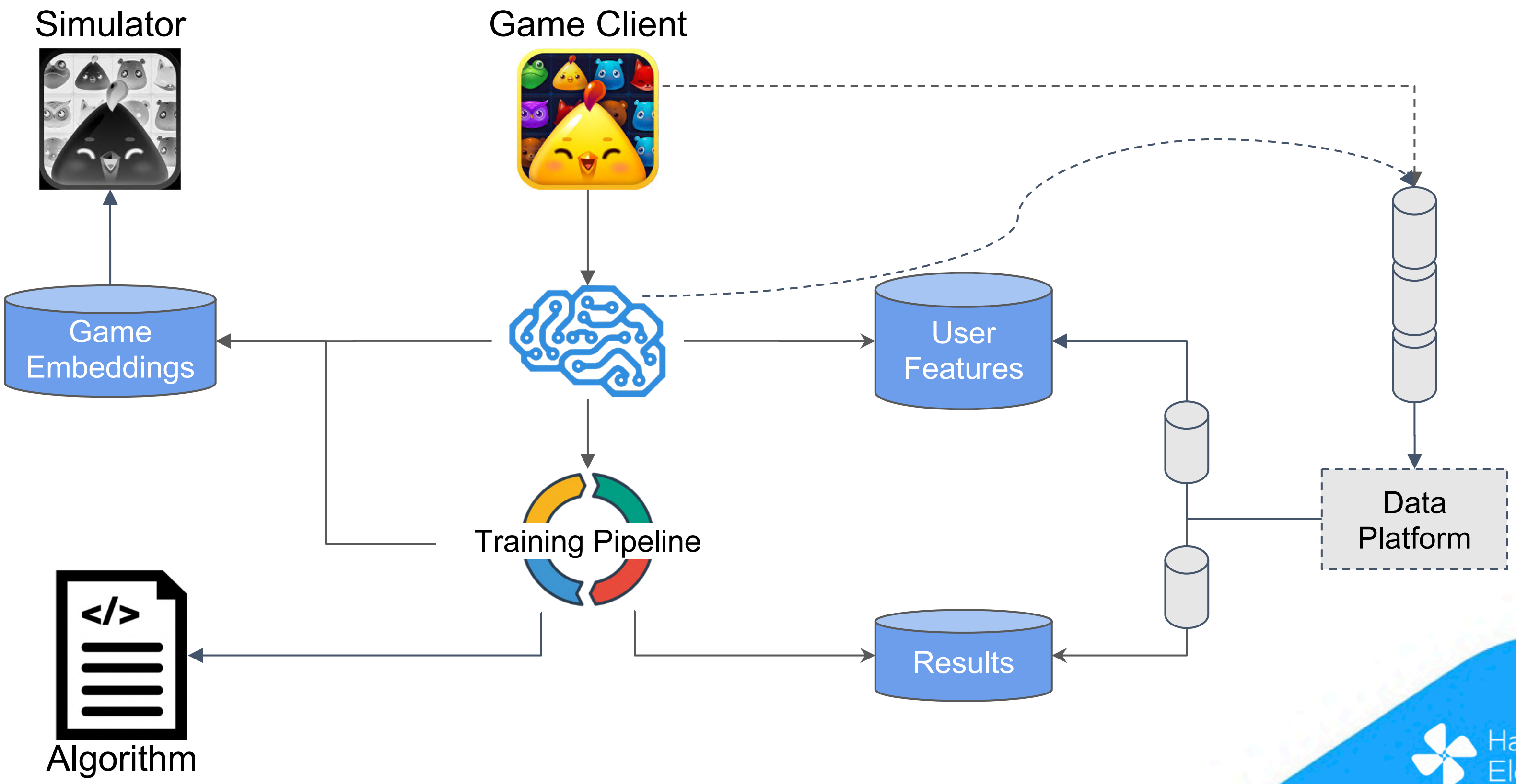
System Architecture



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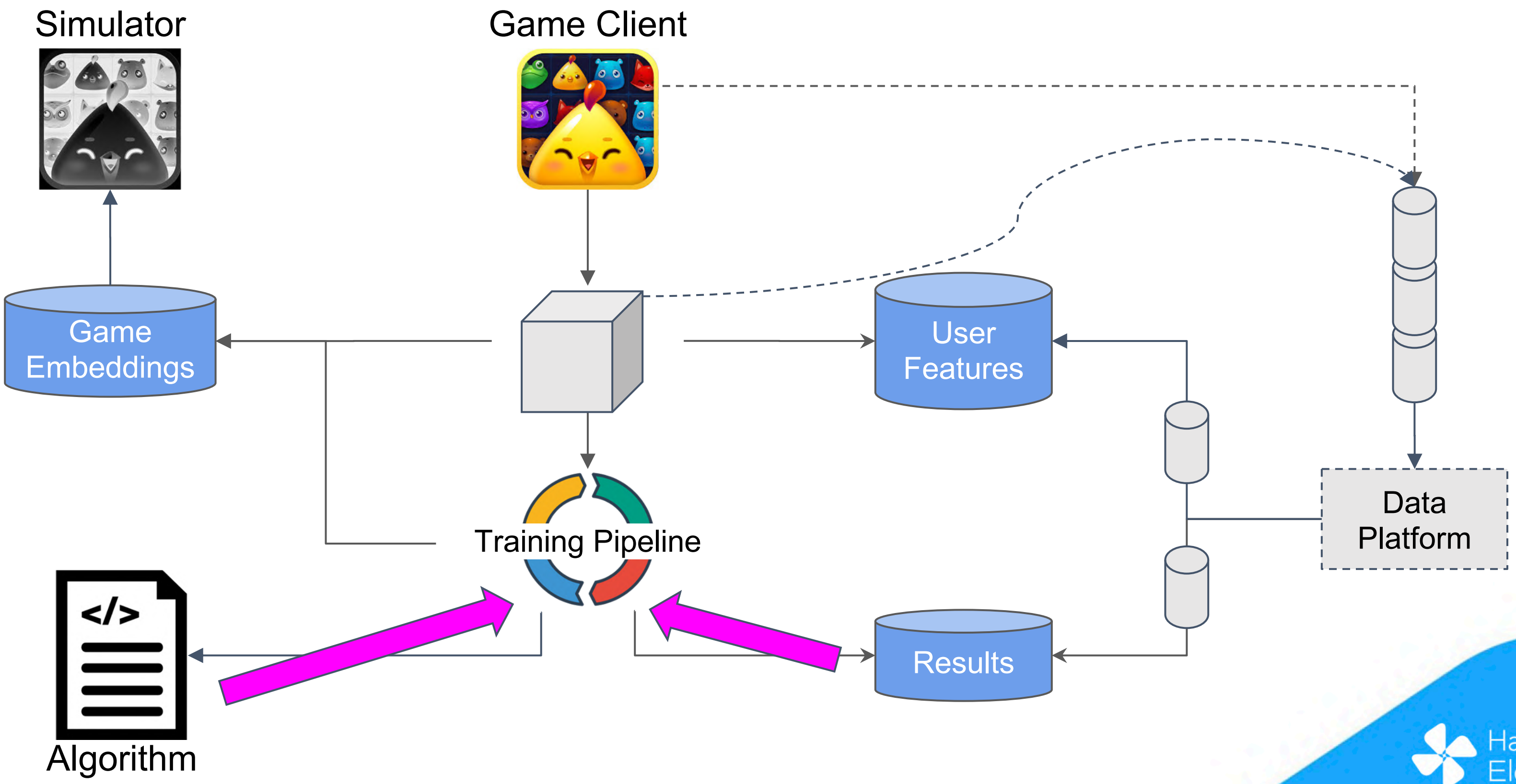

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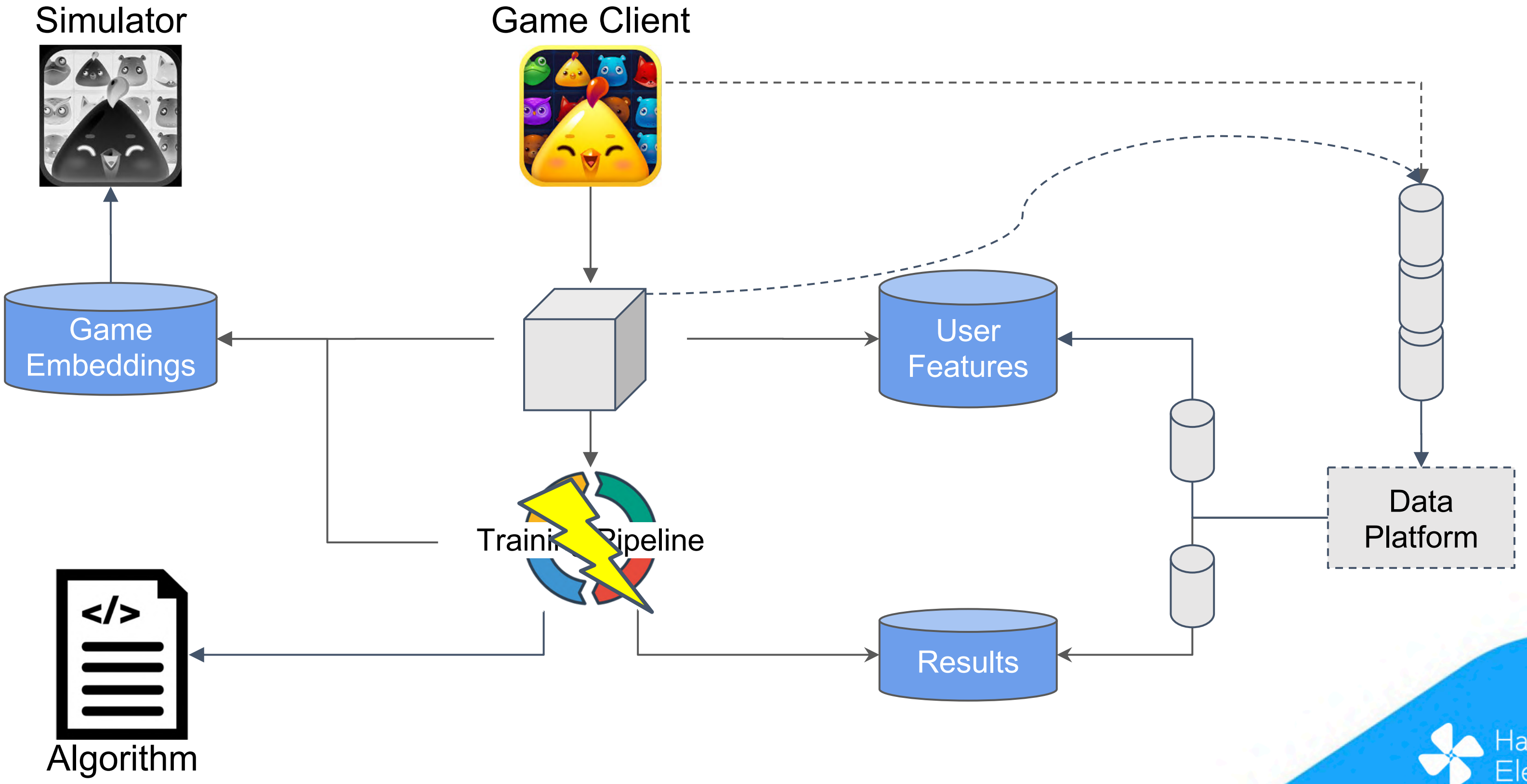

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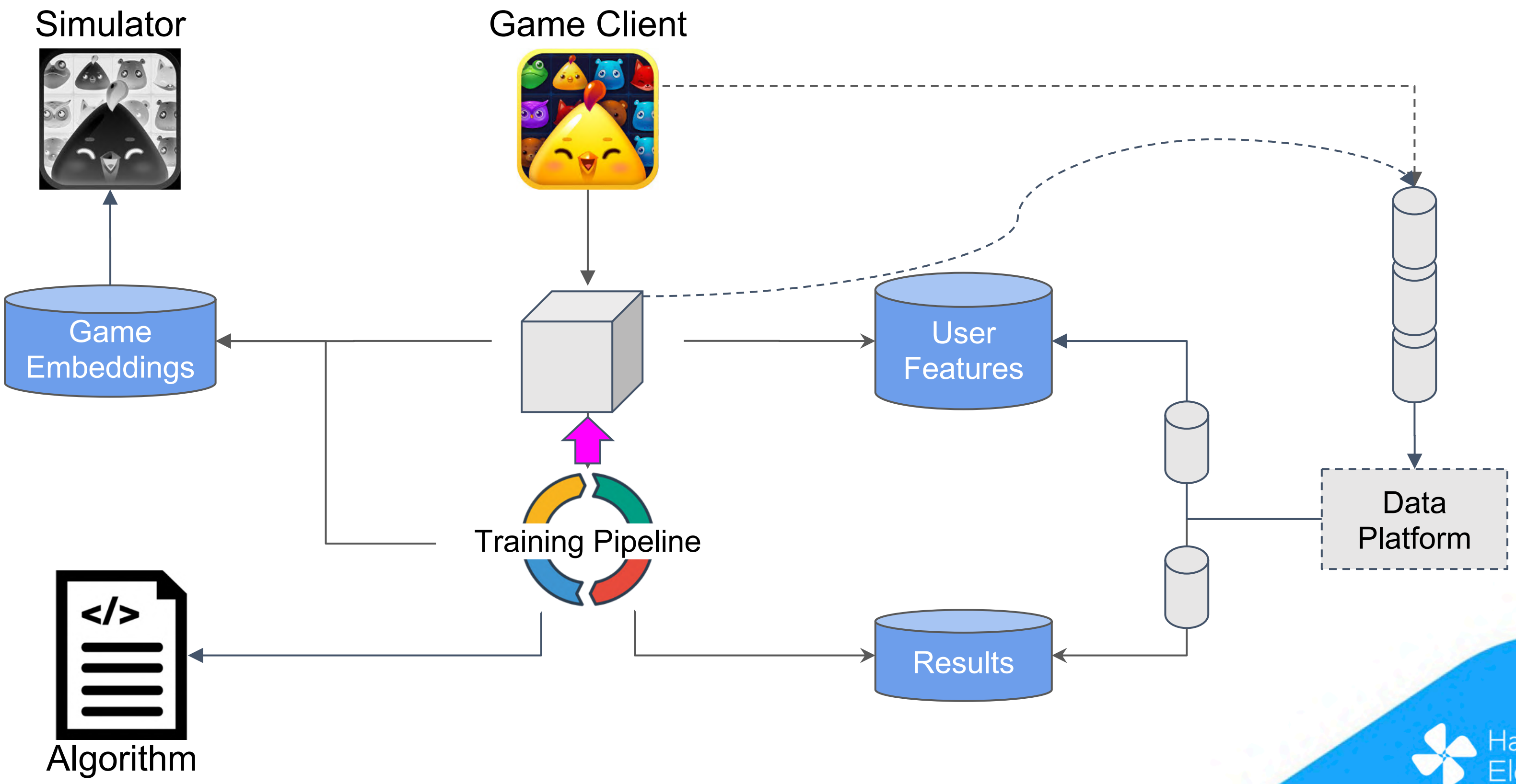

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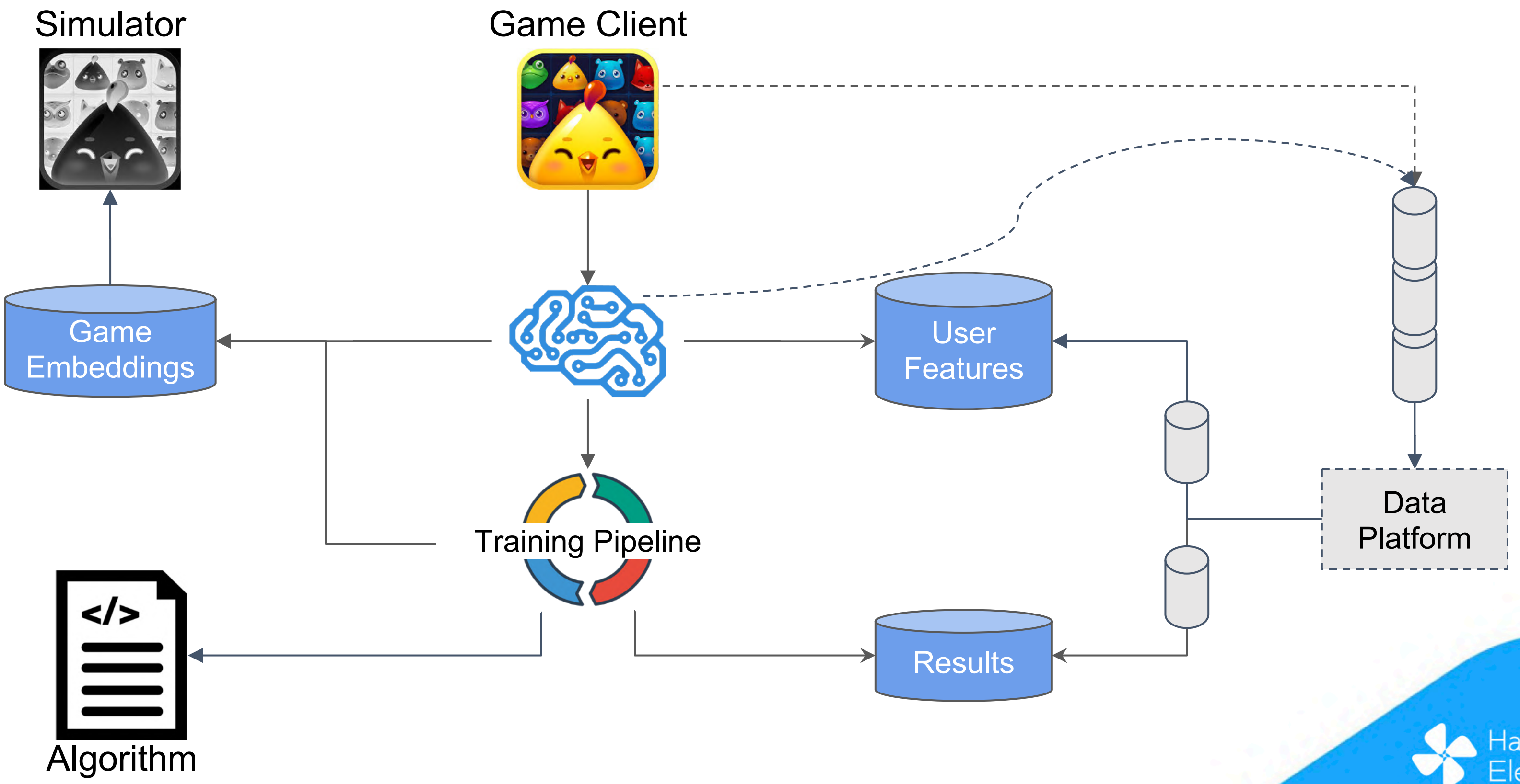

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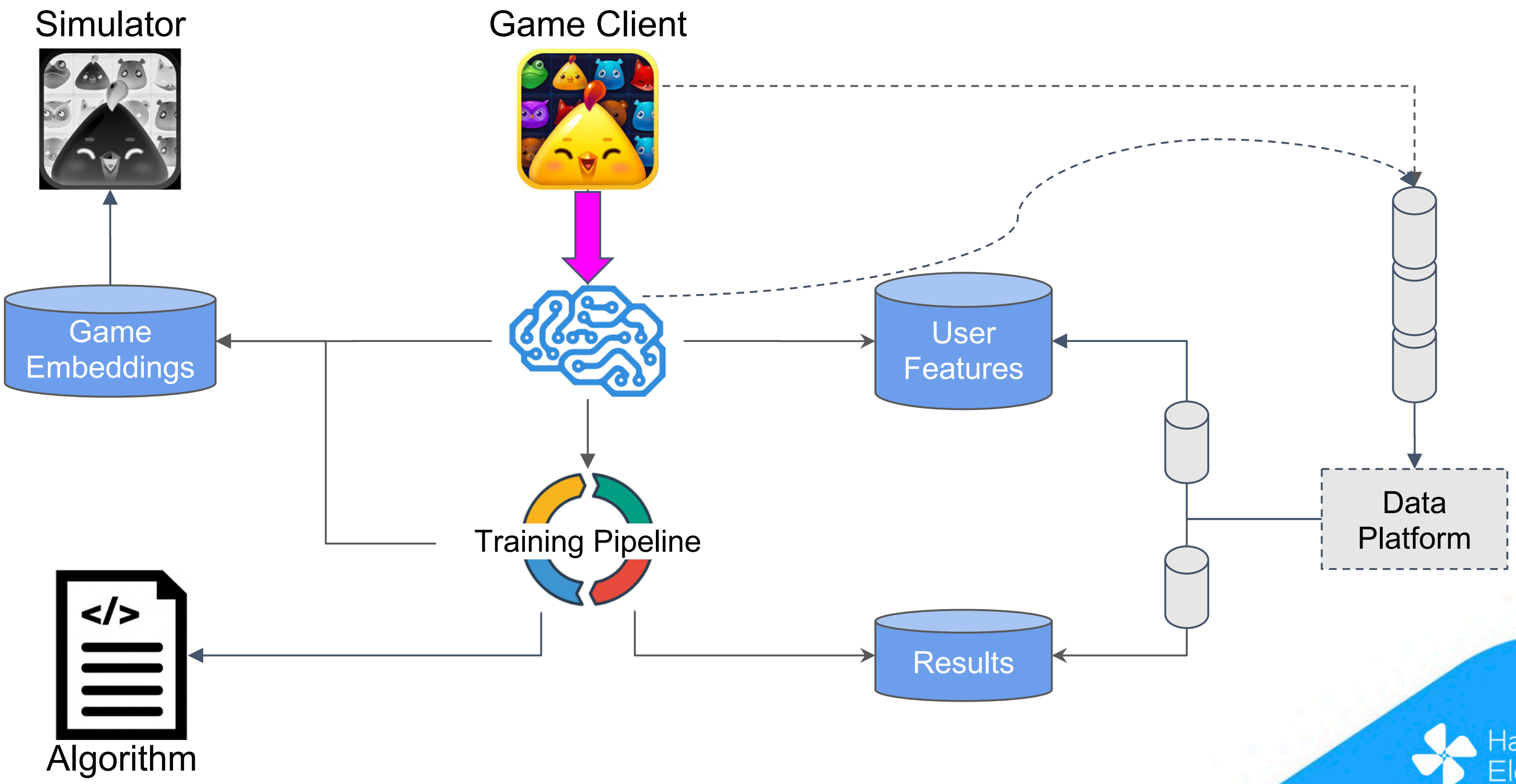

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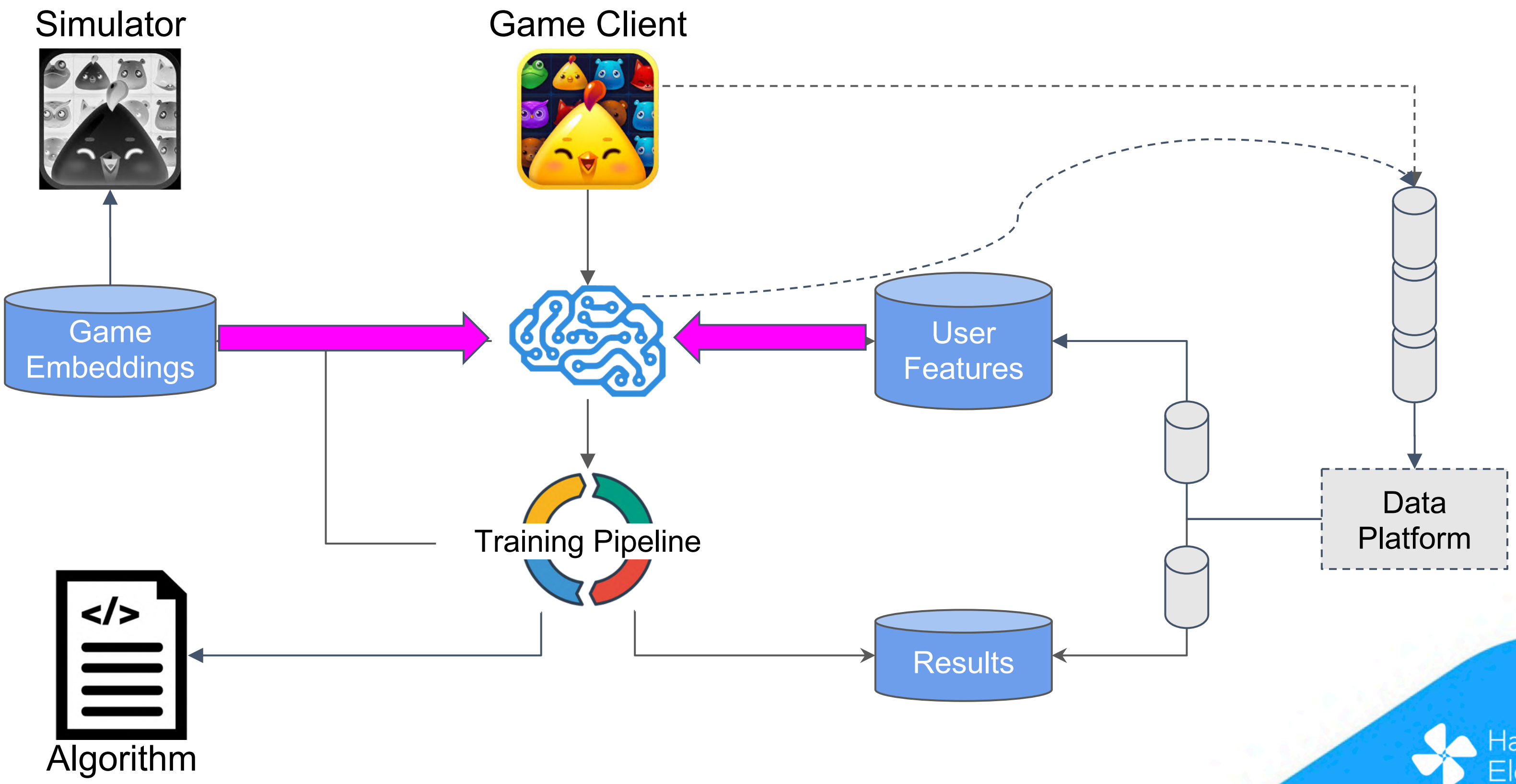

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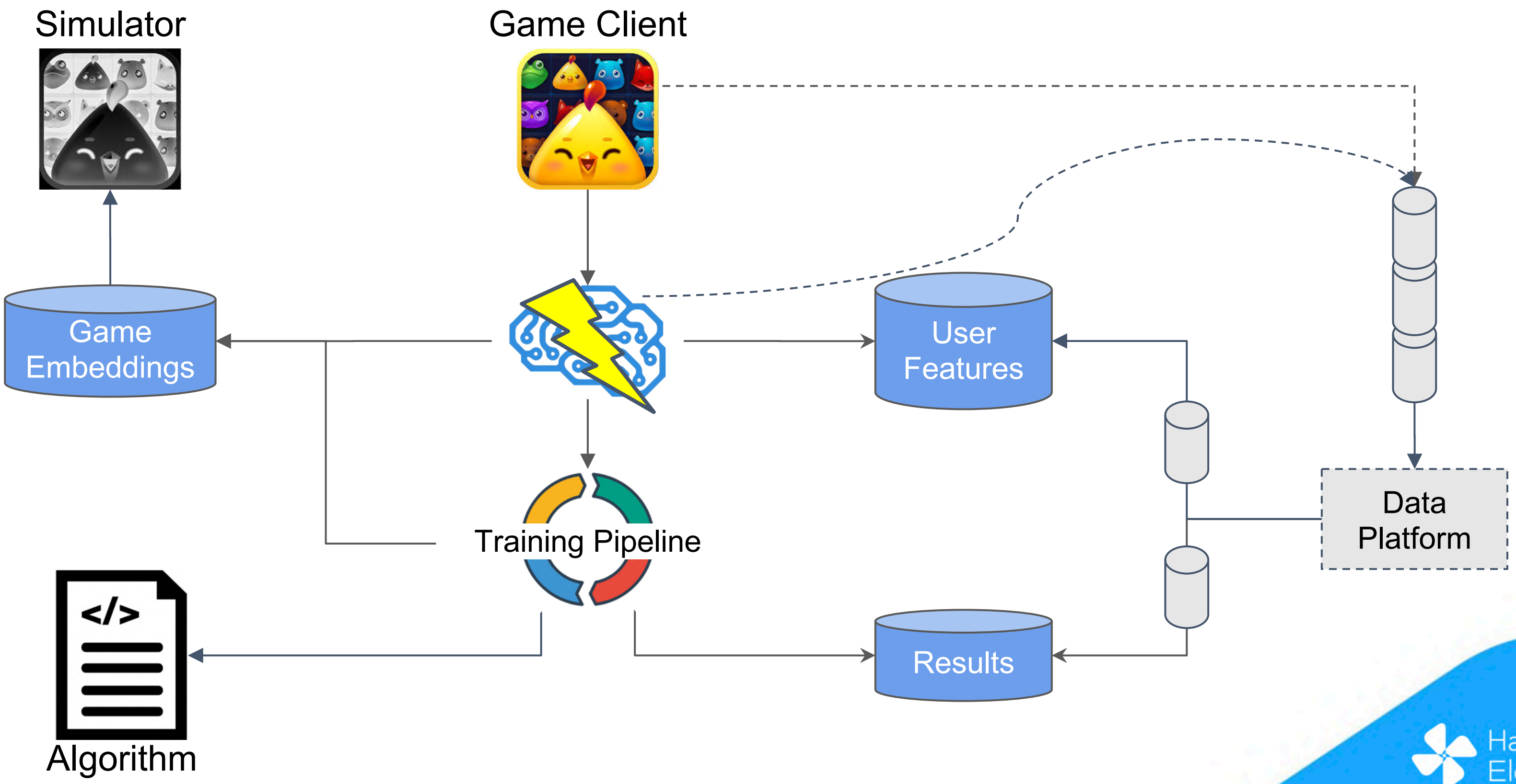

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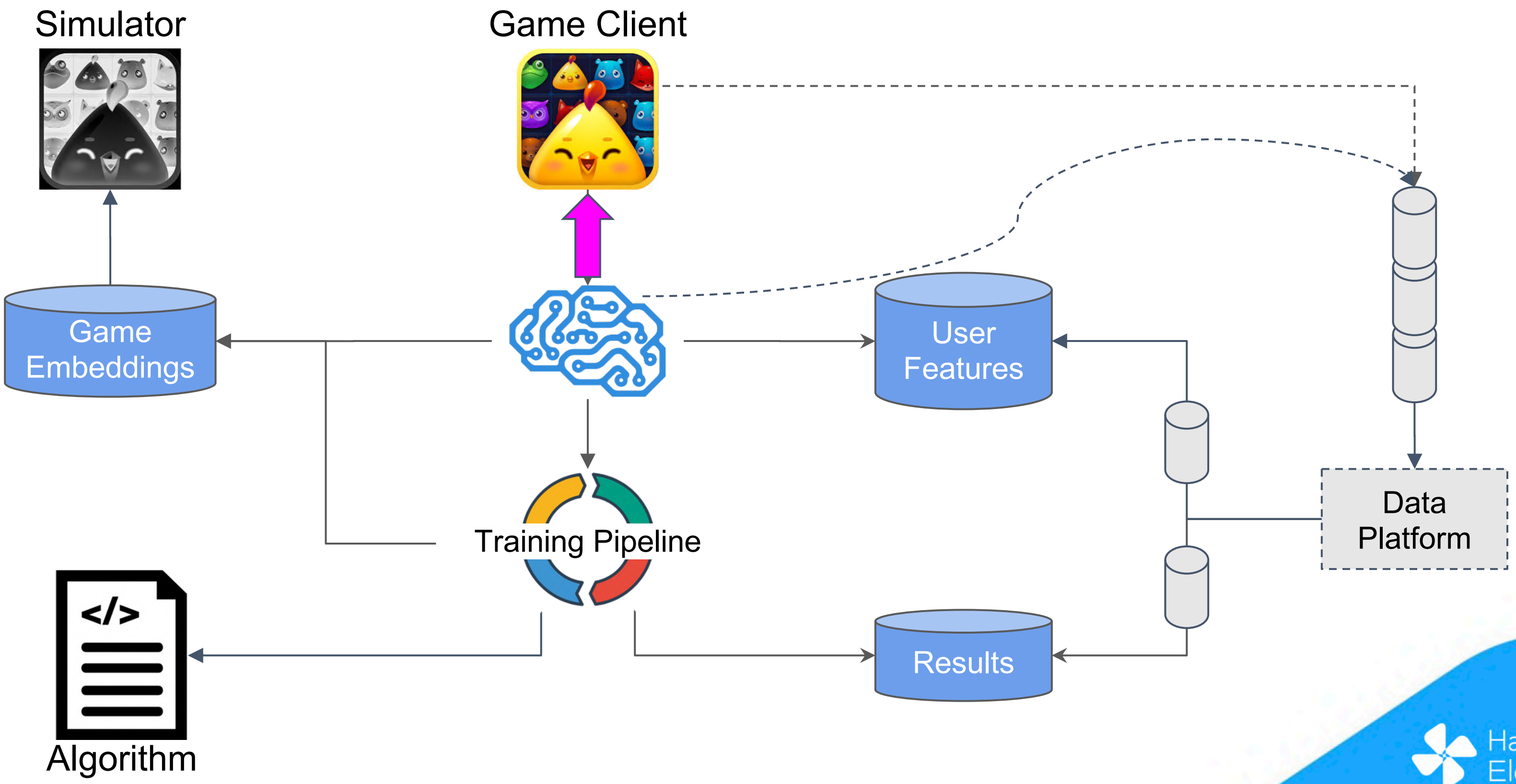

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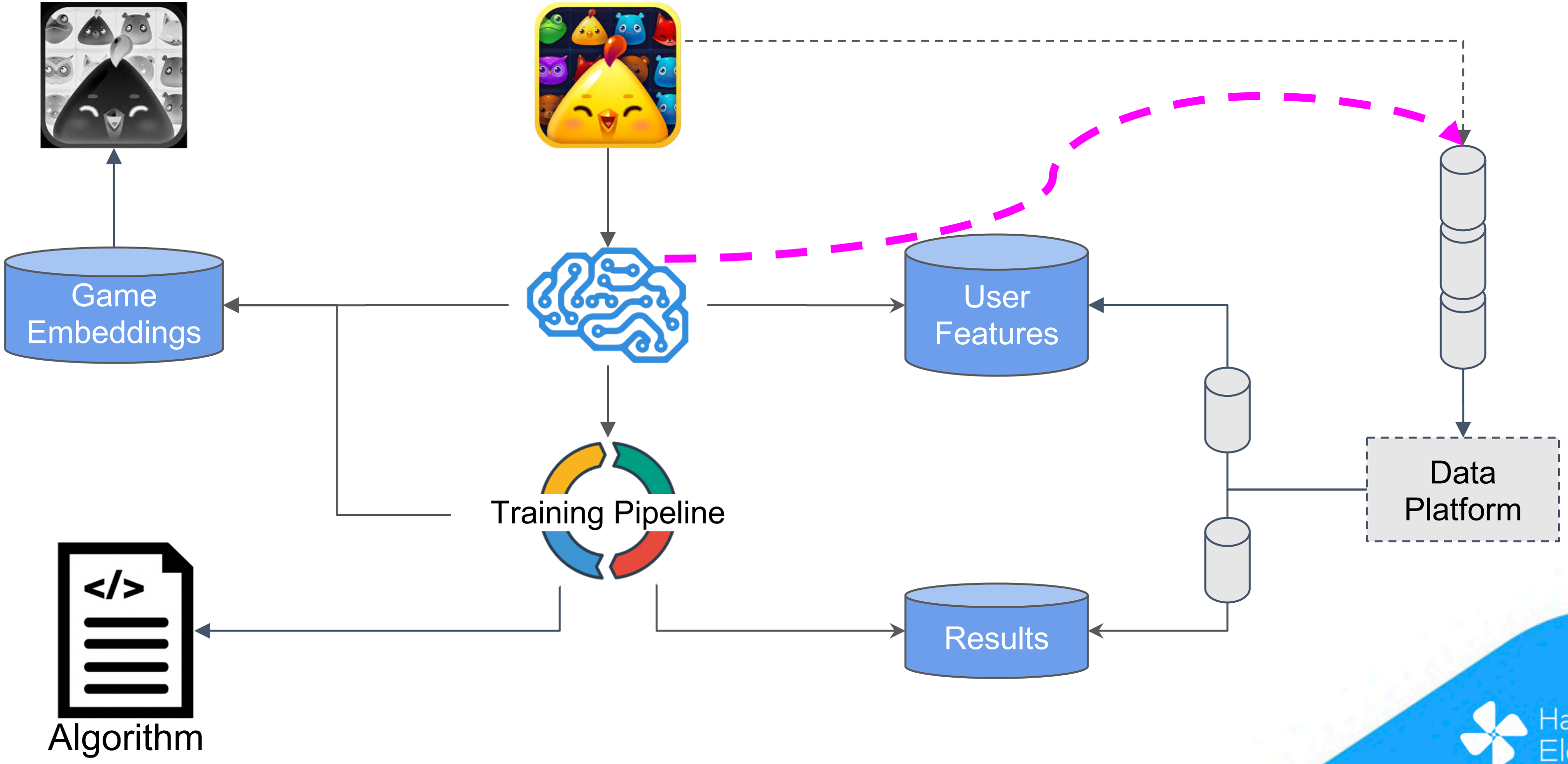

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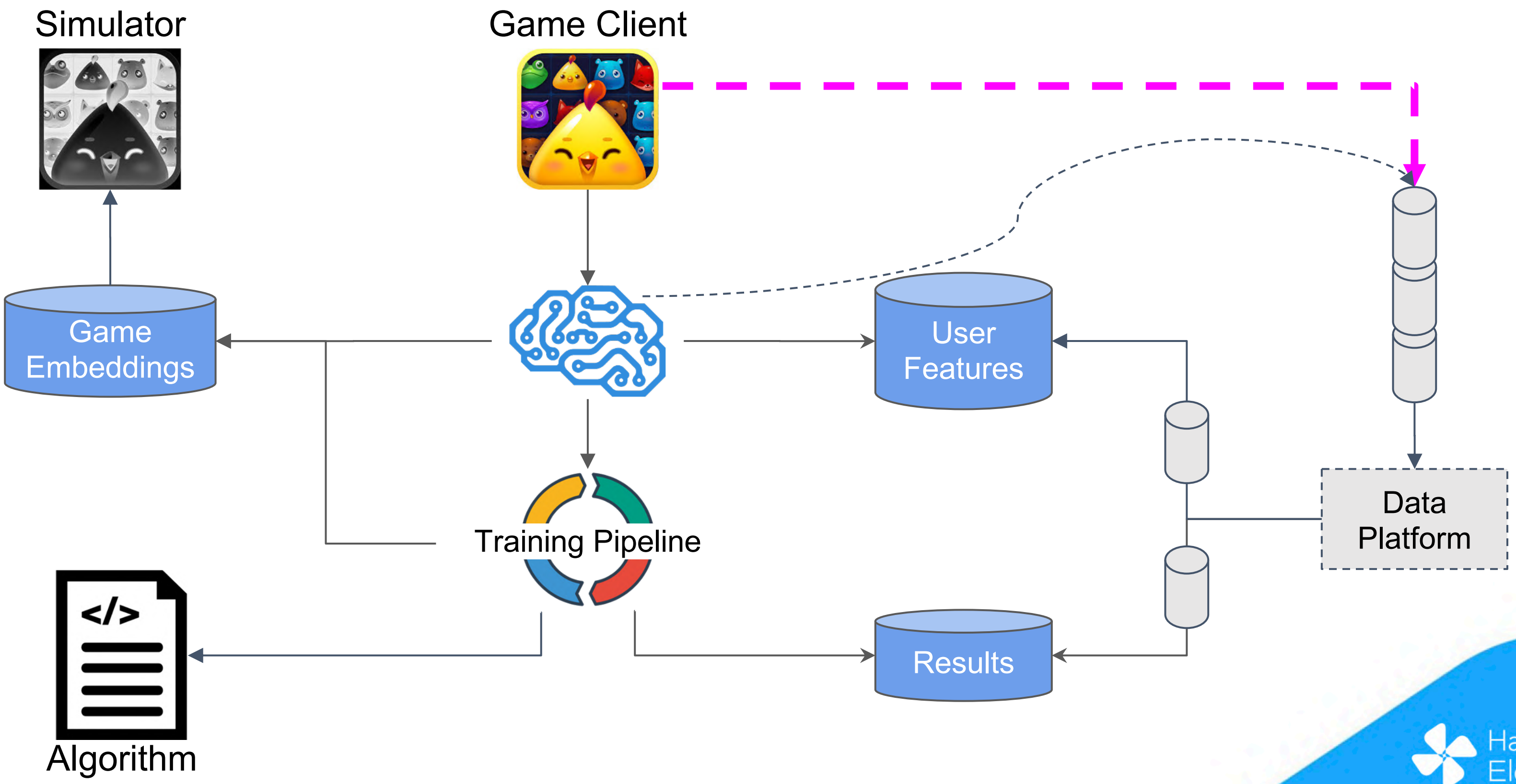

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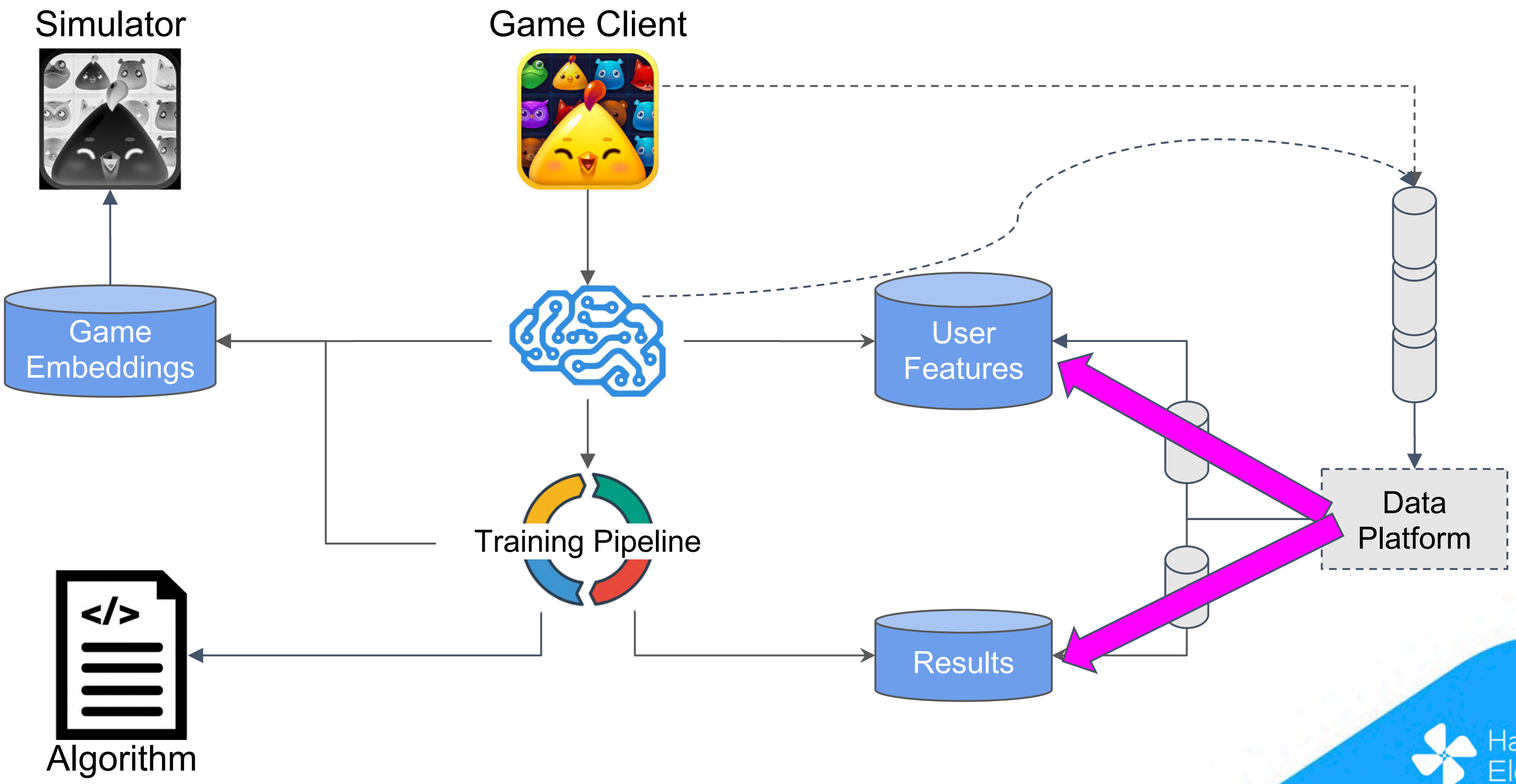

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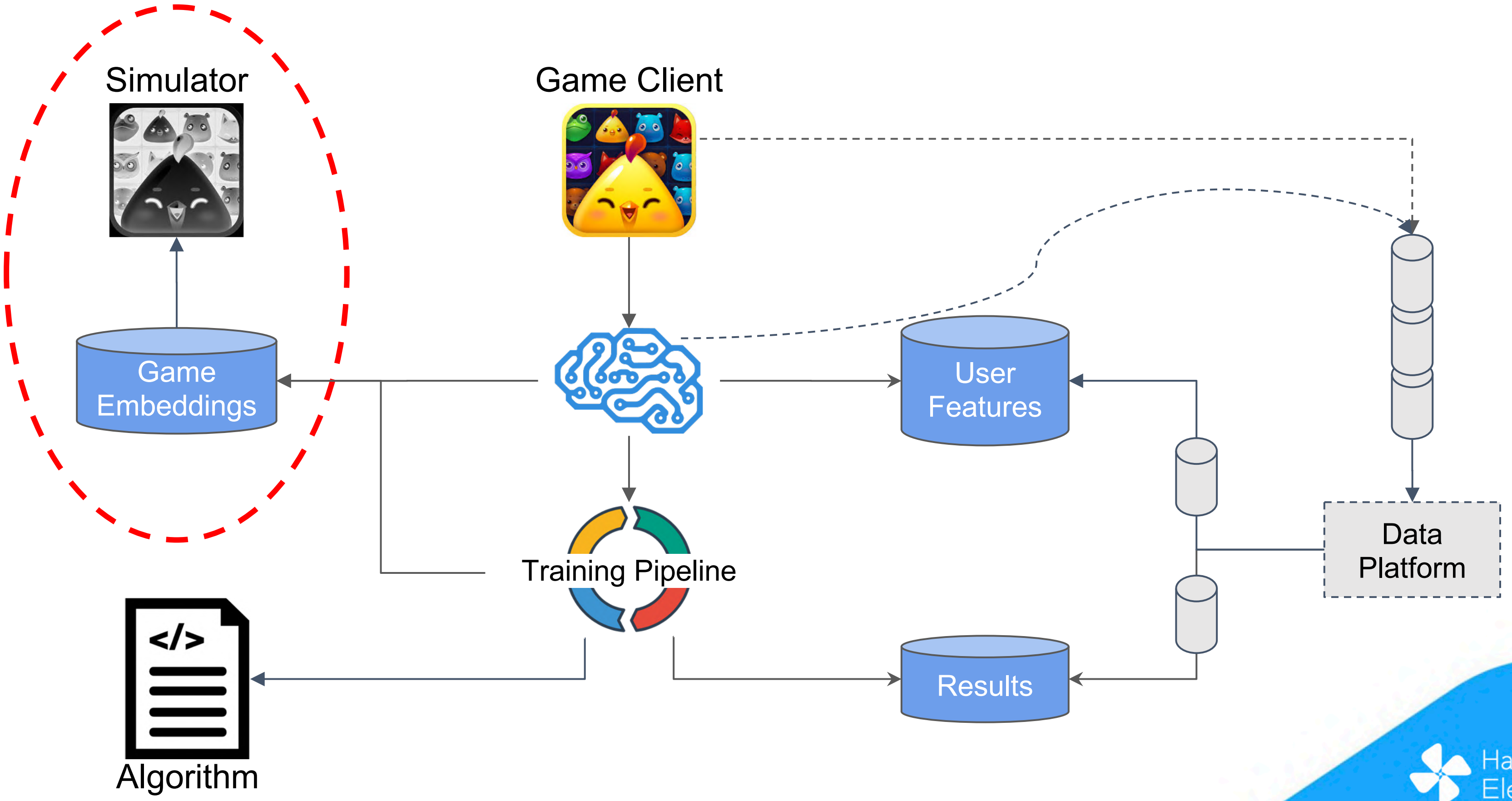
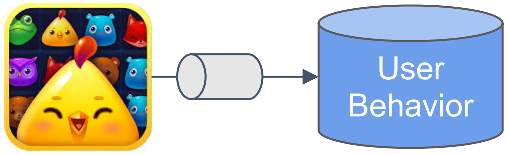
System Architecture



Happy Elements

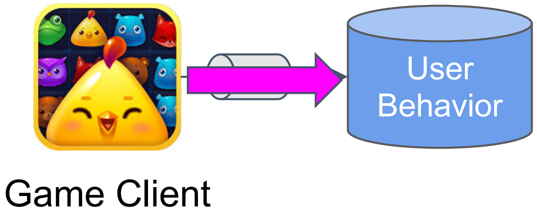
System Architecture: Gameplay Embeddings



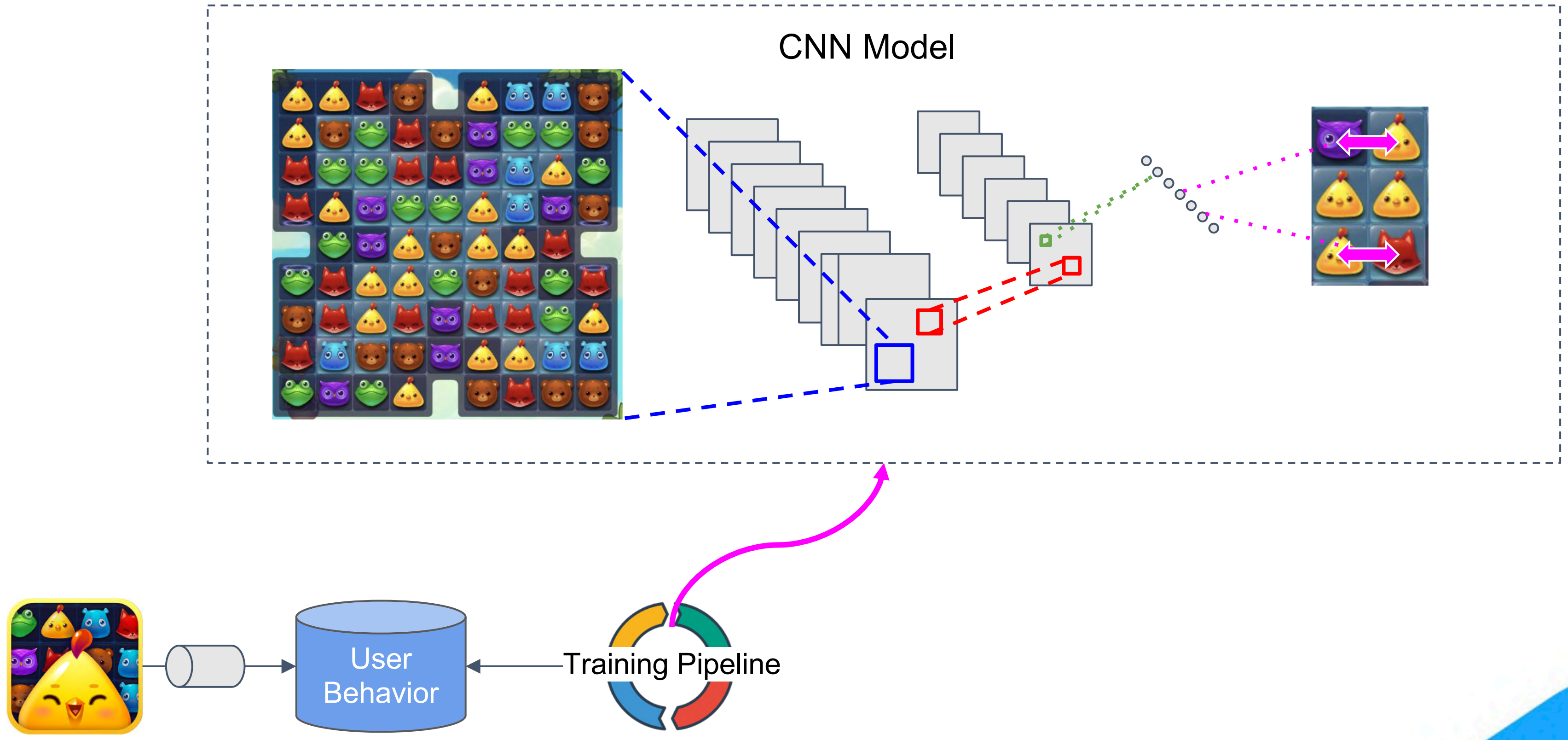
Game Client

Happy Elements

System Architecture: Gameplay Embeddings



System Architecture: Gameplay Embeddings



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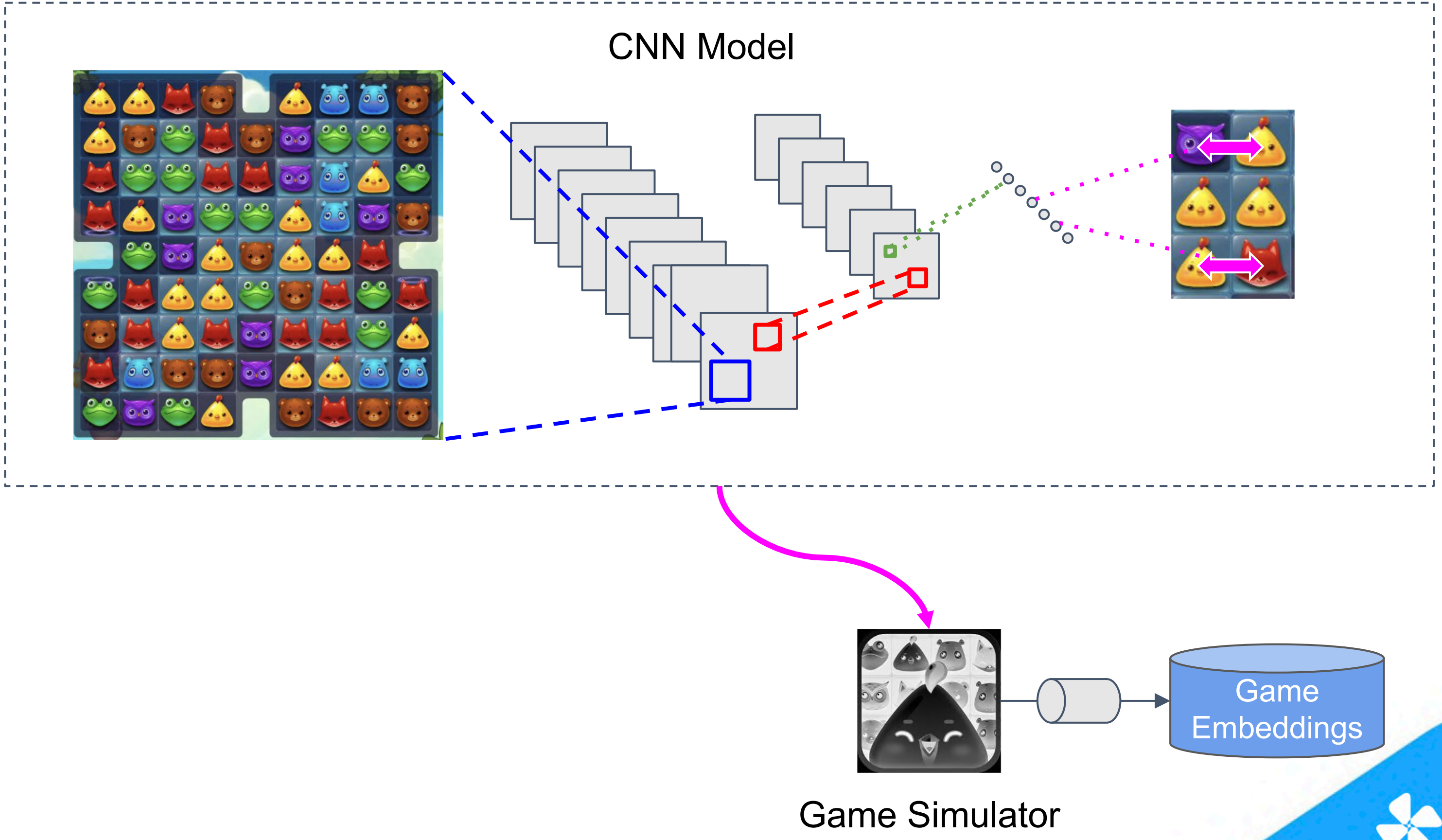
System Architecture: Gameplay Embeddings



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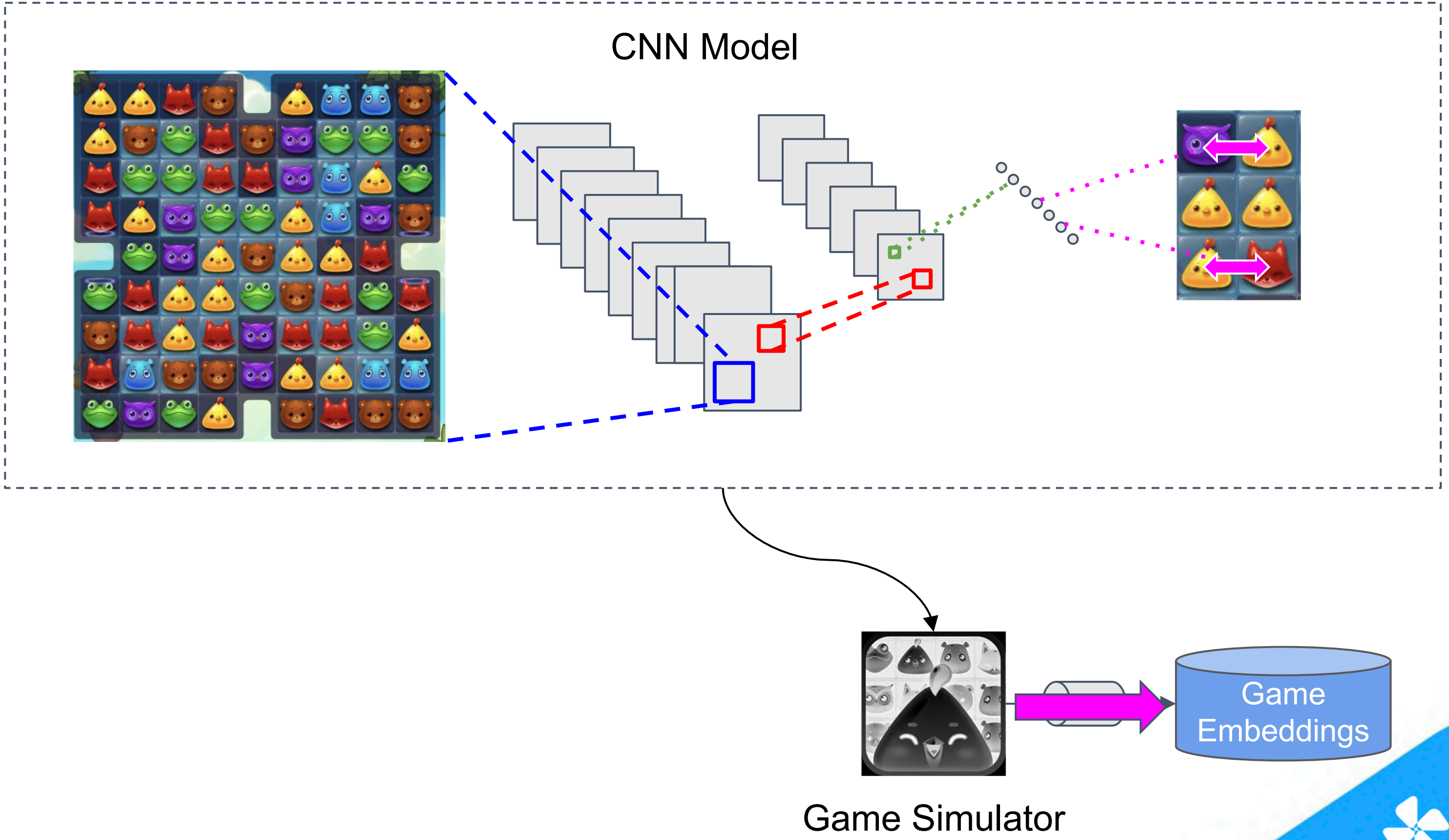
System Architecture: Gameplay Embeddings



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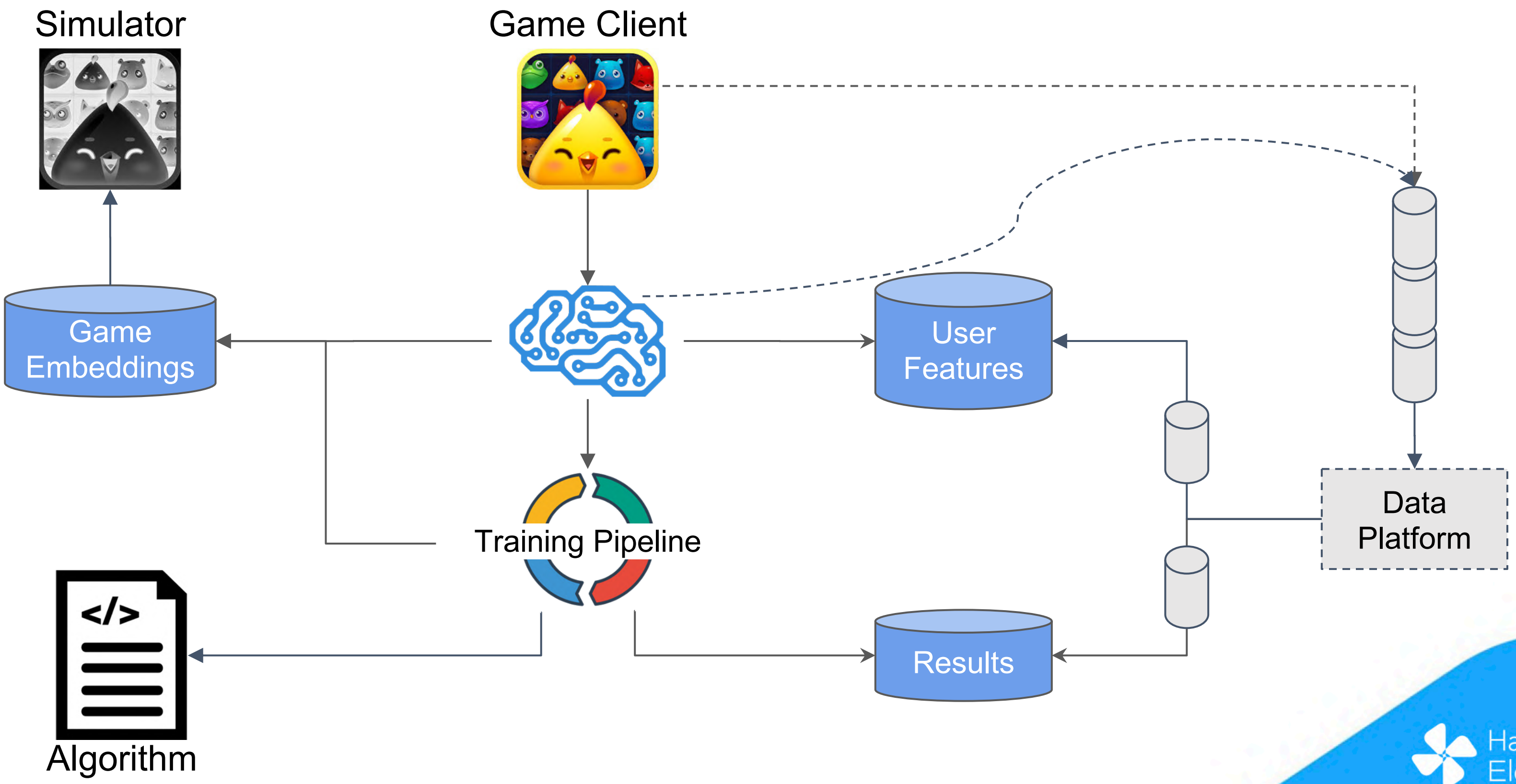
System Architecture



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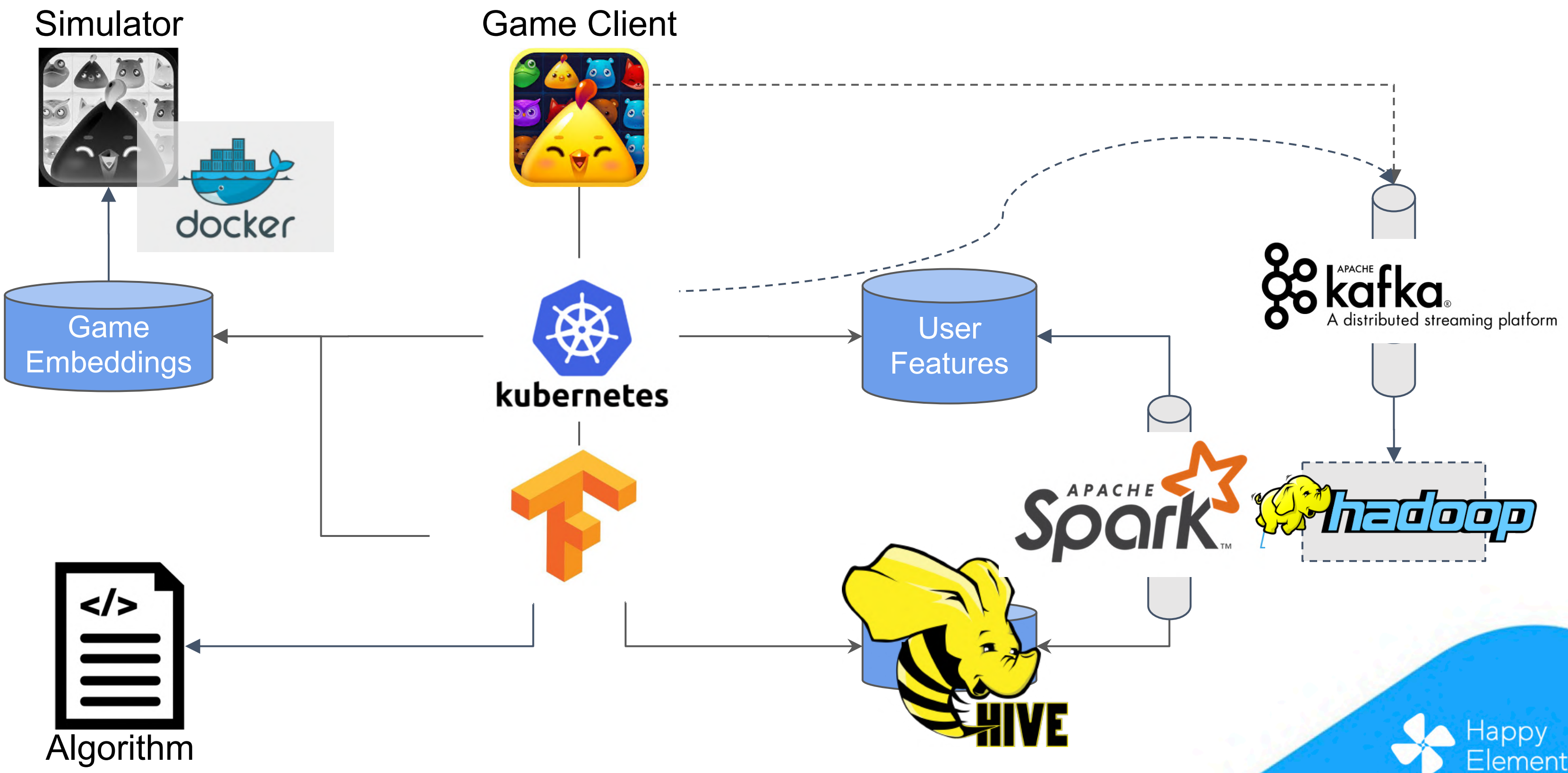
Technology Stack Samples



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Conclusions

- Deployment of ML can **significantly improve revenue** and **engagement**
- **Nonstationary** data presents **difficult optimization** problem
- **Relationship** between **short**-term and **long**-term **metrics** hard to identify

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THANKS

http://en.happyelements.com/ai