Reinforcement Learning for Simulation: Business Advantages and Use Cases
Introduction
pathmind | Agenda

- **Pathmind: Reinforcement Learning for Simulation**
  - Introduction to RL
  - RL vs. Heuristics and Optimizers
  - Identify RL Use Cases and Examples
  - Integrate RL into Business Applications

- **Real-Life RL Use Cases**
  - **Engineering Group**: Flexible Manufacturing System Model
  - **Accenture**: Warehouse Putaway and Picking Model

- **Q&A**
You can think of RL and simulation as a chess game.

**Reinforcement learning** is the player. It makes decisions based on its training to achieve a desired outcome.

A **simulation** is the game board. It provides the environment for the reinforcement learning to take actions and defines the rules of the game.
**pathmind | RL vs. Heuristics and Optimizers**

- **Data** → **Decisions/Actions** → **Outcomes**

  - **Heuristics**: Static rules and equations based on best practice
  - **Optimizers**: Solvers using separate runs and weights for outcomes
  - **Signals**
  - **Predictions**
  - **Rewards**
  - **Simulation**: ‘Digital Twin’ to replicate actions and outcomes

- **Data-driven trained AI decision agent**
- **Simulation-driven trained AI decision agent**
Identifying RL Applications

- **High Variability and Randomness**: Data that changes frequently and can be random or difficult to predict.
- **Large State Spaces**: Environments with a large number of possible outcomes.
- **Multiple Contradictory Objectives**: Optimizing for more than one metric simultaneously.
Examples: Business Values of RL and Simulation

- **Multi-Echelon Inventory Management**: 34% increase in total profits
- **Interconnected Call Center Optimization**: 9.6% reduction in caller wait time
- **Energy System Operation & Maintenance**: 30% increase in total revenue
- **Maximizing Output With Factory Order Sequencing**: 16% reduction in processing time
- **Supply Chain Inventory Level Optimization**: 20% improvement over optimizer
- **Open-Pit Mine Site Haul Truck Routing**: 19% increase in total ore produced
- **Metals Processor Energy Optimization**: 10% reduction in electricity spending
- **Factory AGV Fleet Optimization**: 78% improvement over heuristic

For complete case studies, visit pathmind.com/blog.
pathmind | Deploy Policy Predictions

- Consume RL predictions in real-world business processes in 3 ways:
  - Call RL predictions from an **Excel worksheet**.
  - Use Pathmind’s REST API to integrate RL in **web applications**.
  - Directly deploy RL **offline** (i.e. no internet access) in physical machines.
Using Pathmind With AnyLogic
Engineering Group: Flexible Manufacturing System Model
Flexible Manufacturing Systems & Industry 4.0

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12
45
43
%
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- Strategic Global Partnerships with Customers.
# Use Case: A Flexible Manufacturing Order Handling System

<table>
<thead>
<tr>
<th>Industry &amp; Company:</th>
<th>Mechanical Manufacturing Plant</th>
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<tbody>
<tr>
<td>Process We Want to Optimize:</td>
<td>Production Order Management, Assignment, Sequencing &amp; Execution in a machining Manufacturing Plant</td>
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| Background: | - Orders generated dynamically;  
- Each order has **4 Production Phases** until finished product;  
- For each product, there are **24 Possible Sequences**;  
- Each phase requires a: **Machine, Tool, Pallet**;  
- **Load/Unload Area** used for Pallet Association;  
- Uncertainty present. |
| Objectives: | - Avoid **bottlenecks**.  
- Minimize total order processing time.  
- Enable automated order handling and sequencing. |
| Achievements: | Optimized line **load balancing** reducing the frequency of bottlenecks and Deep Reinforcement Learning effective **job insertion strategy** beat out heuristic |
Insights: Flexible F&B Manufacturing Order Scheduling

**Simulation Set-Up:**
- Each scheduling task includes:
  - Product to transfer;
  - Eventual current holding station;
  - Task type (load, unload, next phase).
- Statistical distributions for stations:
  - Failure rates;
  - Repair times.
- Tool-shuttle to move tools:
  - Addressing phase requests;
  - Needing maintenance.

**Reinforcement Learning Set-Up:**
- Single Agent: pallet-shuttle
- Actions:
  - Insert a new job on the production line
  - Reach a station to move placed job to next phase
- Observations:
  - Station utilization and status
  - Waiting orders
  - Time passed
  - Palette and tool availability
  - Next-phase for each job in the line

**Reward Function**

\[ R \leftarrow (after.\texttt{produced} - before.\texttt{produced}) \times 300 \]
\[ R \leftarrow (after.\texttt{timePassed} - before.\texttt{timePassed}) \times 0.1 \]
\[ R \leftarrow \text{Math.pow}(after.\texttt{stationsWorking} - 3, 2) \times 2.5 \]
\[ R \leftarrow after.\texttt{invalidOrderTypeInserted} \times 0.5 \]
\[ R \leftarrow after.\texttt{invalidLoad} \times 0.5 \]
\[ R \leftarrow (before.\texttt{lineTaktTime} - after.\texttt{lineTaktTime}) \times 0.25 \]
Findings: Flexible F&B Manufacturing Order Scheduling

Line Load Balancing

• RL to find the optimal line load to avoid deadlocks
• Improved the heuristic by RL strategy mimic

Job Insertion Strategy

• Heuristic rule based on the job completion percentage
  • Waiting orders uniformly inserted.

RL agent found a strategy to consume orders faster.
Highlights: Flexible F&B Manufacturing Order Scheduling

Deep Reinforcement Learning policy strategy reveals to be better than heuristic in term of results:
The Business Value

1. Enables “true” decision automation: from data to action!
   
   Business Value: Data-driven, more optimal decisions compared to heuristics and gut feel result in real savings.

2. Essential for “true” digital twin and Industry 4.0 automation!
   
   Business Value: Less labor needed to make repetitive, mundane decisions. Can refocus labor to other tasks gaining efficiency.
   
   Business Value: Reduce knowledge drain and maintain know-how embedded in models.
Accenture: Warehouse Putaway and Picking Model
ABOUT US

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Examples: Business Values of RL and Simulation

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- **Factory Fleet Optimization**: 28% improvement over heuristic

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pathmind | Use case: Fulfillment center

- 4 products, 5 hallways, 15 workers
- RL for put-away process – hallway selection
- Focus in optimizing put-away and pickup processes

Inbound – put-away
One type of product per truck
One truck every 30’

Outbound – pickup
Mix of products per truck
One truck every 60’
**Industry:** Factory Fleet Optimization

**Process We Want to Optimize:** Hallway selection for put-away

**Background:**
- IB trucks enter with one specific product
- OB trucks exit with a combination of different products
- All products have different characteristics

**Objectives:**
- Minimize distance traveled by workers
- Minimize trucks’ waiting time

*Use case:* Fulfillment center
**Use case: Results**

- **With RL**
  - 28% distance reduction
  - 6% time reduction in docks
  - Easy to follow decisions with great impact

- **Without RL**

![Graphs comparing delivery closeness, delivery ratio, average time in docks, and picking values with and without RL.](image-url)
Why didn’t we use common optimization algorithms?

- Time dependence
- Complexity
- Uncertainty
Identifying RL Applications

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Why did we use Pathmind?

- Intuitive AnyLogic integration
- Parallel experiments
- Action Masking
- Production-ready REST API
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Ready to get started with RL for simulation?  
Visit app.pathmind.com/sign-up to create a free account.