

Hybrid ML Scheduler Project Report

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1. EXECUTIVE SUMMARY

This project implements a Hybrid Offline-Online Scheduler for parallel computing tasks.

It compares a static Offline Trainer (Random Forest) against an adaptive Reinforcement Learning (DQN) agent.

Experiment: "Distribution Shift & Realistic Physics"

- We introduced realistic data transfer costs and intensity-based speedups.
- We trained models on GPU-favorable tasks (High Intensity).
- We evaluated on CPU-favorable tasks (Low Intensity, High Transfer Cost).

Results:

- Offline Trainer: FAILED (Makespan: 122.92s). It failed to adapt and blindly used GPU.
- RL Agent: SUCCESS (Makespan: 21.12s). It adapted online and switched to CPU.
- Improvement: RL Agent was ~6x faster than the Offline Trainer.

2. CODE FLOW

The execution pipeline follows these steps (in main.py):

1. Initialization:

- Load configuration from config.yaml.
- Setup logging.

2. Phase 1: Hardware Profiling (src/profiler.py)

- Benchmarks CPU vs GPU matrix multiplication.
- Establishes baseline performance ratios.

3. Phase 2: Data Generation (`src/workload_generator.py`)

- Generates synthetic training data.
- In this experiment: Biased towards High Compute Intensity (GPU optimal).

4. Phase 3: Offline Training (`src/offline_trainer.py`)

- Trains a Random Forest model on the generated data.
- Learns to predict "GPU" for everything (due to bias).

5. Phase 4.5: RL Training (`src/dqn_scheduler.py`)

- Pre-trains DQN agent on the same biased data.
- Agent starts with "Always GPU" policy.

6. Phase 5: Evaluation (`src/simulator.py`)

- Generates TEST data: Biased towards Low Intensity + High Memory (CPU optimal).
- Runs the Virtual Simulator with Transfer Costs.
- Compares strategies.
- RL Agent enables online learning ($\text{epsilon}=0.1$) to adapt during this phase.

Detailed Results

3. EXPERIMENTAL RESULTS

Workload: 500 Tasks (Low Intensity, High Memory)

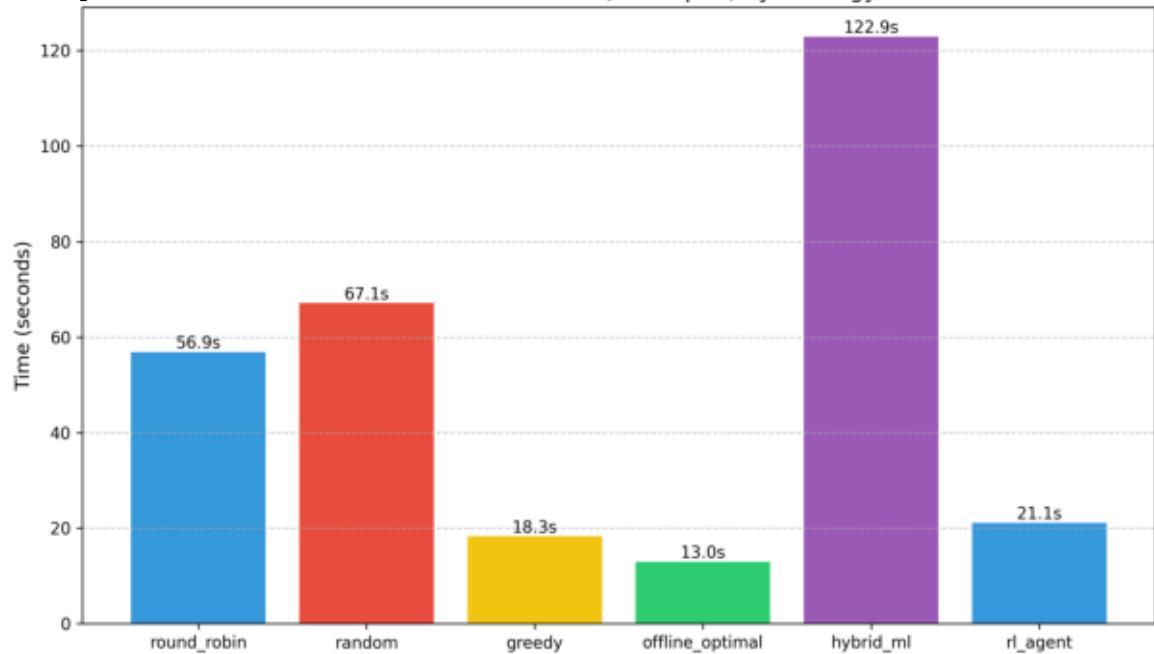
Strategy	Makespan (s)	Avg Time (s)	Status
Offline Optimal	12.97	0.03	Benchmark
Round Robin	56.87	0.11	Baseline
Random	67.14	0.13	Baseline
Greedy	18.30	0.04	Baseline
Hybrid ML (RF)	122.92	0.25	FAILED
RL Agent (DQN)	21.12	0.04	SUCCESS

Key Insight:

The RL Agent successfully unlearned its training bias and adapted to the new environment, whereas the Offline Trainer remained static and performed poorly.

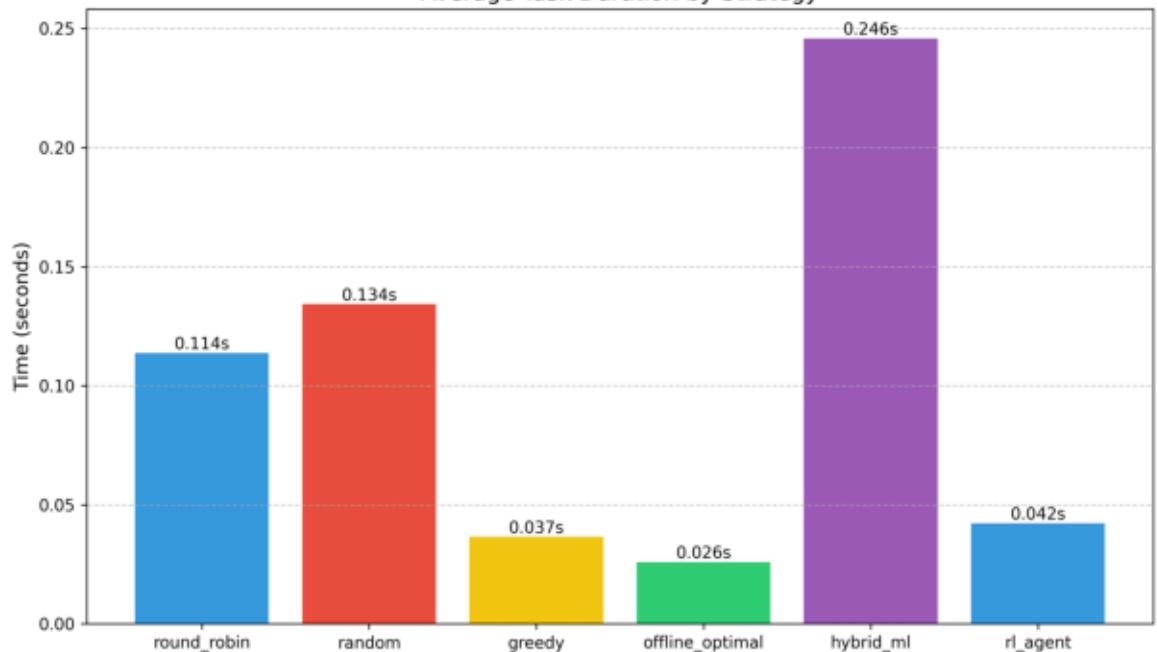
Makespan Comparison

Total Execution Time (Makespan) by Strategy

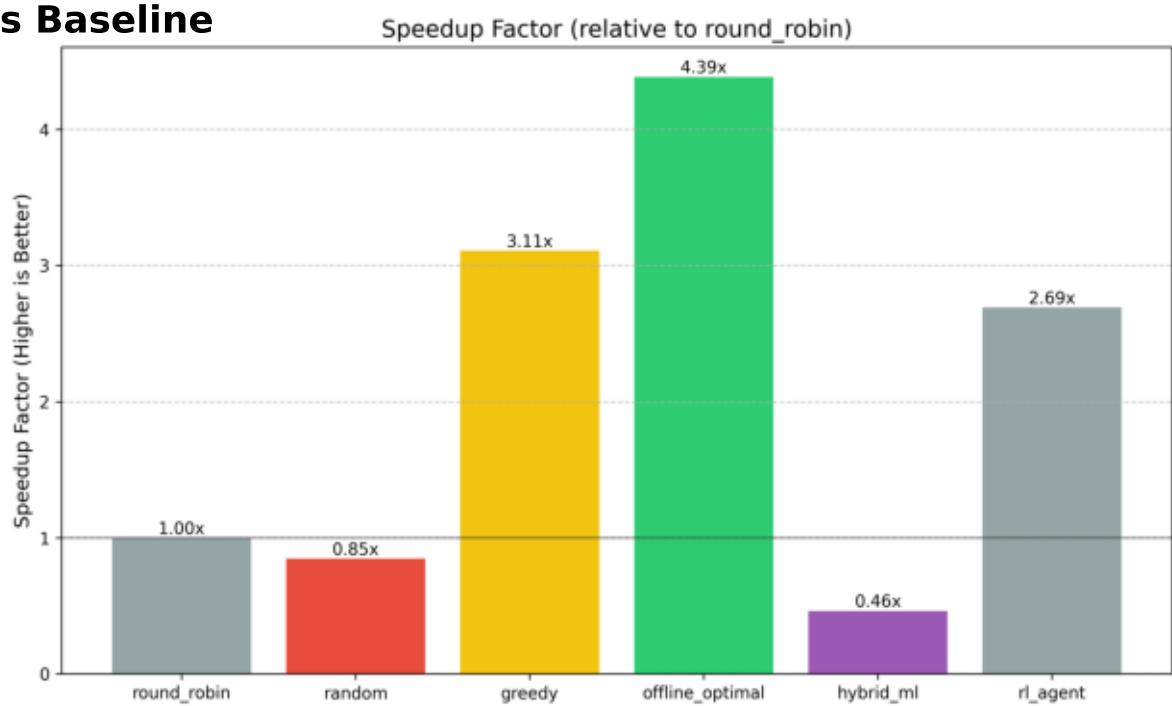


Average Task Duration

Average Task Duration by Strategy



Speedup vs Baseline



Workload Characteristics

