Inteligência Artificial
IARTI
Sprint B

Realizado por:

Inês Ressurreição - 1221197

Gonçalo Araújo - 1220671

Martim Monteiro - 1230722

Nuno Teixeira – 1231375

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Study of Commercial Software Tools for Scheduling Unload/Loading Operations

Introduction

The management of container terminals represents a complex logistical challenge, mathematically classified as an NP-Hard problem. While the IARTI project explores this domain through logic programming (Prolog) to minimize delays, the global industry relies on **Terminal Operating Systems (TOS).** These commercial solutions do not merely schedule tasks; they synchronize Quay Cranes (QC), Yard Cranes (RTG/RMG), and Prime Movers in real-time.

This study analyzes three market-leading solutions—**Navis N4**, **OPUS Terminal**, and **TBA CommTrac**—comparing their operational logic with the academic prototype developed during Sprint B.

Market Analysis and Functional Logic

Navis N4 (Konecranes)

Overview:

Navis N4 is the global standard for container terminal operations. It is designed to act as a "brain" for the terminal, centralizing decision-making across multiple facilities.

Implementation Logic (Scheduling):

- **Optimization Engine:** Unlike simple heuristic sorters, N4 uses a sophisticated optimization module often referred to as *PrimeRoute*. This module implements dynamic dispatching logic. Instead of creating a fixed schedule at the beginning of the day (static scheduling), it constantly re-evaluates the best assignment for every vehicle and crane based on their current GPS position and status.

- **Vessel Planning:** The software utilizes a module called *Autostow*. It considers the vessel's stability (hydrostatics) and the discharge sequence. The logic prioritizes moves that minimize the "gantry travel distance" of the crane (moving left/right along the rails) rather than just the lift time.

OPUS Terminal (CyberLogitec)

Overview:

Widely adopted in high-density Asian ports, OPUS Terminal is known for its capability to handle fully automated terminals.

Implementation Logic (Scheduling):

- **Constraint-Based Planning:** OPUS relies heavily on "Advanced Planning & Scheduling" (APS) methodology. The system models the port operations as a series of constraints (e.g., "Yard Block A is full", "Crane 3 is under maintenance").
- **Synchronization:** Its distinctive feature is the tight coupling between the Quay (where the ship is) and the Yard (where containers are stored). The scheduling algorithm creates a "handshake" protocol: a crane is only scheduled to lift a container if a truck is confirmed to be available to receive it. This prevents the bottlenecking often seen in simpler greedy algorithms.

CommTrac (TBA Group)

Overview:

While Navis focuses on containers, CommTrac is a leader in bulk and general cargo operations. TBA Group is also renowned for its simulation software (*CONTROLS*).

Implementation Logic (Scheduling):

- **Simulation-Based Decision Making:** TBA employs a "Digital Twin" approach. Before the actual operation begins, the software runs faster-than-real-time simulations of the schedule.
- **Look-ahead Logic:** The algorithm tests various "What-If" scenarios to predict congestion. If a specific unloading sequence is predicted to cause

a traffic jam on the quay in 2 hours, the system proactively alters the crane schedule to prevent it. This is a practical application of the "Generate and Test" search strategy, but applied to physics-based simulations rather than abstract permutations.

Comparative Analysis: Academic vs. Commercial Approaches

This section contrasts the logic implemented in the IARTI Prolog module with the logic observed in commercial tools.

Objectives and Cost Functions

- **IARTI Project:** The developed module focuses on a **Single-Objective Optimization**: minimizing the total delay of vessel departures. The cost function is linear and purely time-based.
- **Commercial Tools:** These systems perform **Multi-Objective Optimization**. They simultaneously try to minimize time, minimize fuel consumption (energy efficiency), maximize equipment lifespan (reduce wear), and ensure safety (avoid collisions).

Handling of Uncertainty

- **IARTI Project:** The system assumes a deterministic environment. The duration of unloading is a fixed fact in the knowledge base.
- **Commercial Tools:** These systems operate in a stochastic environment. The algorithms include buffer times and probability factors to account for weather disruptions, worker shifts, or mechanical breakdowns.

Resource Allocation (Multiple Cranes)

- **IARTI Project:** We implemented a logic where extra cranes are added to reduce the total duration mathematically (dividing time by the number of cranes).
- **Commercial Tools:** In reality, adding cranes has diminishing returns due to "Crane Clashing" (interference). Commercial software calculates the

safety distance between cranes. If two cranes are too close, the software locks one until the other moves, a complex constraint that simple mathematical division cannot model.

Conclusion

The study of commercial tools like Navis N4 and OPUS Terminal highlights the gap between academic prototyping and industrial application. While the Prolog-based module successfully implements the core logic of sequencing and resource allocation using state-space search and heuristics, commercial tools wrap this core logic in layers of real-time data processing, predictive simulation, and multi-variable constraints.

However, the fundamental algorithmic principle remains consistent: defining a search space of possible operations and traversing it to find the most efficient sequence, proving the relevance of the Artificial Intelligence concepts explored in this Sprint.