Integrated task and motion planning for keel block optimisation at Captain Cook Graving Dock

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Abstract: Re-locating 25-tonne keel blocks inside a dry dock is a time-critical but highly constrained operation, critical to efficient turnaround between dockings. Space is tight, block moves are interdependent, and the process relies heavily on the expertise of the seasoned dockmasters. We recast the Captain Cook Graving Docks (CCGD) challenge as an integrated task-and-motion-planning (TAMP) problem. The workflow first solves a linear assignment that matches blocks to their required positions, it then combines a quadtree representation that delivers rapid, collision-aware forklift paths with a heuristic search algorithm to place individual moves into an executable sequence. Trials on realistic dock layouts show the planner can balance solution quality against computation time and readily expose trade-offs between the two. Continuous dialogue with dock personnel has kept modelling assumptions aligned with practice. Work now underway targets faster heuristics, adaptive re-planning, and pilot testing in the dock.

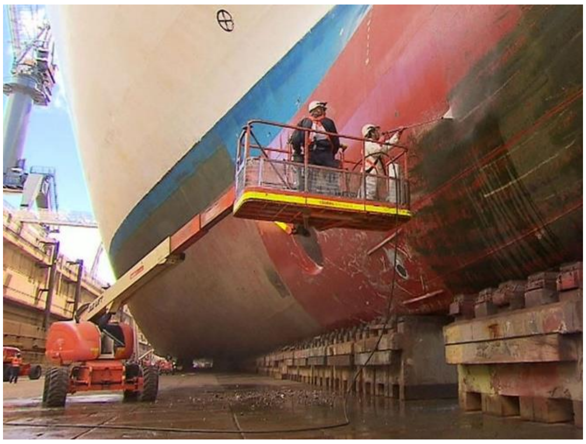

Figure 1: Keel blocks supporting a ship in the CCGD (9News 2023)

Keywords: *task-and-motion planning; maritime logistics; object re-arrangement; dry-dock*

1. INTRODUCTION

The CCGD on Garden Island, Sydney, is the largest repair dock in the Southern Hemisphere. It underpins both Royal Australian Navy readiness and commercial ship-repair schedules, making its limited berthing capacity a strategic chokepoint. Vessels cycle through according to a planned schedule; any delay in preparing the dock floor directly reduces national defence availability and commercial revenue, so streamlining turn-round operations is a high priority.

A chief bottleneck is laying out the reusable, 25-tonne concrete keel blocks that cradle each vessel. Often hundreds of blocks of several types must be manoeuvred into position, set to within ±10 mm, sometimes in stacked layers, while contending with the constrained space and obstruction of the dock (e.g., drains, and inner caisson - Fig. 2 (a)). The order of moves is constrained, blocks are often required to be set in positions that will then obstruct forklift access to other areas of the dock and so the order in which they are set is key. Rearranging them efficiently is a task dependent on experienced operators. We therefore cast keel-block repositioning as an integrated TAMP problem. We build on robotics research in TAMP (Garrett et al., 2021) and movable-obstacle planning (LaValle, 2006) to deliver the first computational framework that jointly decides which block moves where and how it gets there inside a dry dock so as to minimise setup time.

2. METHODOLOGY AND RESULTS

2.1 Block-to-target assignment

Given the known current positions and required target positions for blocks (200+ stay permanently in the dry dock and are uniquely configured for each docking), we solve a binary linear programme that minimises an

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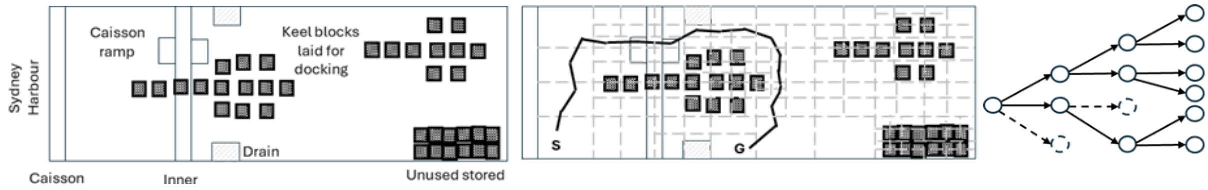

(a) (b) (c)

Figure 2: (a) Simplified dock layout with sample block positions, caisson ramp, and drains; all blocks must avoid fixed obstructions. (b) Quadtree motion planning: recursive subdivision gives fine cells near obstacles and coarse cells elsewhere; the resulting graph enables fast A* search (path S→G). (c) TAMP search tree: each node is a block configuration; solid branches are feasible moves, dashed branches are pruned when collisions or access limits arise. The search continues until the target configuration is reached. Realistic scenarios involve substantially greater complexity and branching.

approximation of forklift travel distance while enforcing packing preservation and penalising crossings of the internal caisson ramp. This defines the blocks' move tasks to be completed. The model extends naturally to multiple docking cycles to exploit opportunities for long-term savings.

2.2 Quadtree-based motion planner

Moving any block is dependent on a forklift. A quadtree partitions free space on the dock floor adaptively and obstacles (other blocks and fixed obstructions) are encoded as polygons. The process yields a compact adjacency graph. If a path for the forklift is available, A* search over the graph produces this efficiently; when a block moves, only affected quadrants are updated. The forklift footprint is modelled by inflating the carried block polygon, so loaded and unloaded transits are checked with the same routine. Some moves will not be feasible without moving other blocks first. Fig. 2 (b) shows an example computed path.

2.3 Integrated search

To define a feasible sequence of moves, the high-level planner expands a configuration tree (Fig. 2 (c)). Each candidate block move (branch of the tree) to a new set of unique positions (node of the tree) is accepted only if (1) the unloaded forklift can reach the block, and (2) a loaded path exists to the destination (target or temporary position). Infeasible branches are pruned immediately. We can find a feasible sequence by exploring this tree, experimenting with depth-first search (DFS) for speed and A* for optimality.

2.4 Case study

Table 1: Results

Metric	DFS	A*
Forklift pick–place actions	651	**360**
Total forklift travel (m)	8 800	**8 144**
Planner CPU time (min)	**3**	60

A scenario typical of CCGD operations, rearranging for three docked ships outgoing to two incoming, with 93 blocks to relocate was simulated. Results are summarised in Table 1. Although A* required longer compute, its 45 % reduction in loaded moves and shorter path translates directly to shorter block setup time (potentially reducing 5 days to 4 for this scale setup).

3. CONCLUSIONS

We have demonstrated that an integrated TAMP approach can generate executable, efficiency-focused block-movement plans for a major naval dry dock. Collaboration with dockmasters ensured operational realism and has led to a first software prototype. Beyond CCGD, the methodology is applicable to yard management, heavy-component staging and other industrial logistics domains where large movable obstacles constrain motion.

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