A Decentralised Strategy for Heterogeneous AUV Missions via Goal Distribution and Temporal Planning

EDINBURGH CENTRE FOR ROBOTICS
Innovation Ready

HERIOT WATT UNIVERSITY

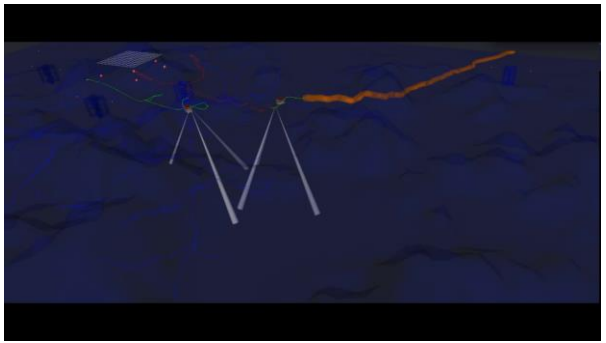
THE UNIVERSITY of EDINBURGH

Yaniel Carreno, Èric Pairet, Yvan Petillot, and Ron Petrick

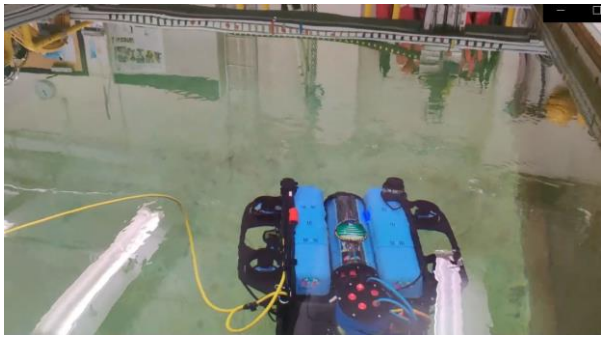
Edinburgh Centre for Robotics
Heriot-Watt University & University of Edinburgh
Edinburgh, Scotland, United Kingdom
{y.carreno, eric.pairet, y.r.petillot, r.petrick}@hw.ac.uk

edinburgh-robotics.org | orcahub.org

Robotics in the Underwater Domain



Simulation Environment



Lab Environment

- Long-term deployments in the underwater domain usually require the introduction of multi-robot systems as service-oriented agents.
- Multi-robot systems can support complex missions that overcome many of the limitations of single-robot solutions, providing robustness to the overall system.

ORCA HUB
Offshore Robotics for Certification of Assets

EDINBURGH CENTRE FOR ROBOTICS

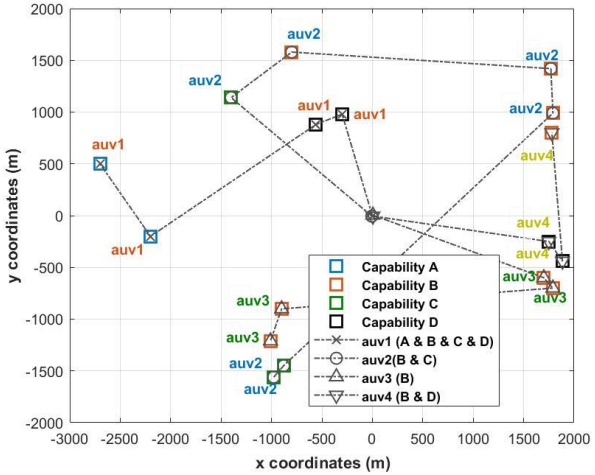
edinburgh-robotics.org | orcahub.org

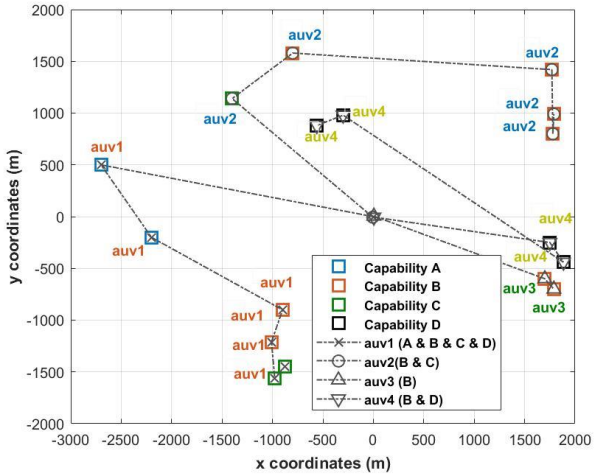
Temporal Planning for Heterogeneous Robots

- In real-world applications of robotics, planning provides solutions in enabling autonomous and intelligent behaviours for heterogeneous robotic platforms to complete its tasks.

- Robotic platforms: mission deployments with fleets of Autonomous Underwater Vehicles (AUVs).
- Approach: model as temporal planning problems.
  - Concurrent action execution with different time slots.
  - Make use of numeric constraints.
  - Use temporal references to solve multi-vehicle problems.
  - Allow the implementation of coordinated actions.
- Build on previous approaches that use temporal planning (e.g., PANDORA project & EUROPtus).
  - Single robot approach.
  - Require fast planning techniques (small planning times) and (near) optimal goal distribution.
  - Often poor task allocation in complex missions with large numbers of goals.

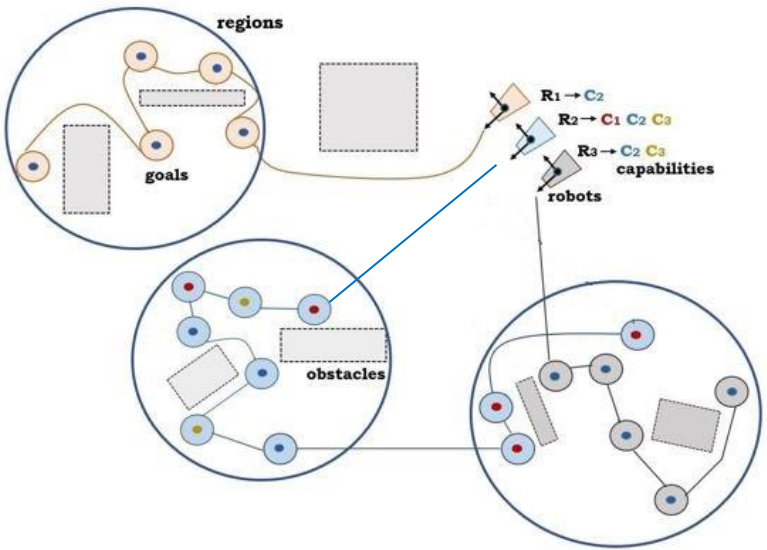
Experimental Results – task allocation(1)





- Benchmark planners generate non-optimal goal distributions (left – POPF, right – OPTIC) in the underwater scenario.
- Poor goal distribution affects mission costs: energy consumption and total distance travelled.

Task Allocation Strategy



PLANNER AGNOSTIC APPROACH

capALLOCATION(g, r): *allocate(G, R, R_cap, G_cap)*

$\{GA_{INIT}, RA_{INIT}, C_{sol}, R_{sol}\} \leftarrow \emptyset$

$[C_{sol}, R_{sol}] = cluster\_cal\ (G, R, R_c, G_c)$

$RA_{INIT} = max\{weight\_cal(RG, C_{sol}, R_{sol})\}$

distROBOT(r,c): $regions\_dist(RA_{INIT}, R\_c, C\_sol, C\_c)$

firstGOAL(r,g): $allocate\_firstGoal(GA_{INIT} \leftarrow G)$

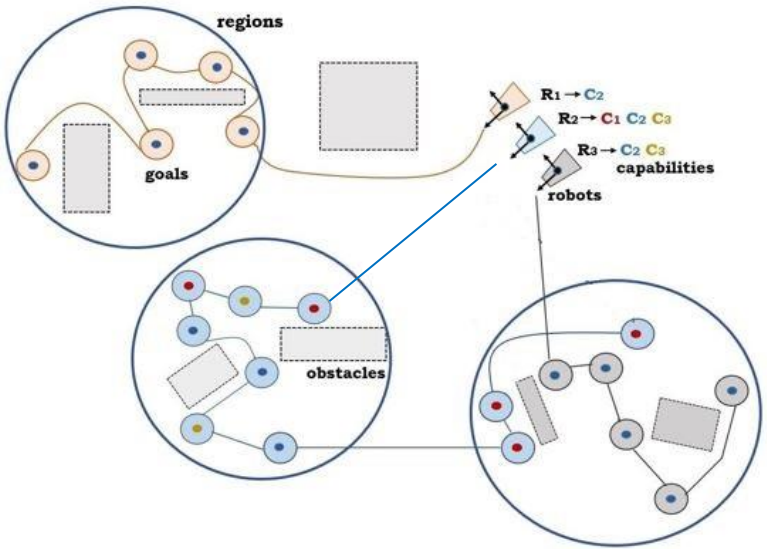
$GA_{FINAL}\ (G) \leftarrow GA_{INIT}$

allocGOAL(r,g): $allocateGoal(R, G, M^r_{max}, dist)$

OUTPUT

return $transformPDDL(GA_{FINAL})$

Task Allocation Strategy



PLANNER AGNOSTIC APPROACH

capALLOCATION(g, r): *allocate(G, R, R_cap, G_cap)*

$\{GA_{INIT}, RA_{INIT}, C_{sol}, R_{sol}\} \leftarrow \emptyset$

$[C_{sol}, R_{sol}] = cluster\_cal\ (G, R, R_c, G_c)$

$RA_{INIT} = max\{weight\_cal(RG, C_{sol}, R_{sol})\}$

distROBOT(r,c): $regions\_dist(RA_{INIT}, R\_c, C\_sol, C\_c)$

firstGOAL(r,g): $allocate\_firstGoal(GA_{INIT} \leftarrow G)$

$GA_{FINAL}\ (G) \leftarrow GA_{INIT}$

allocGOAL(r,g): $allocateGoal(R, G, M^r_{max}, dist)$

CAPABILITY ALLOCATION

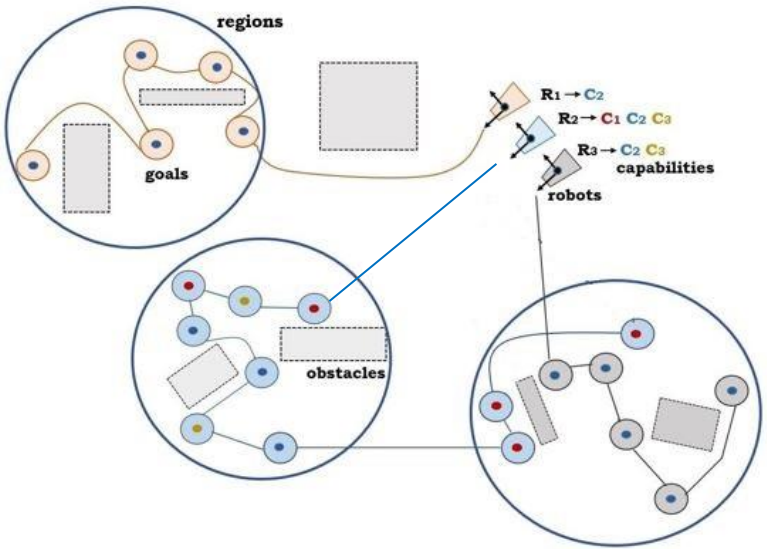
OUTPUT

return $transformPDDL(GA_{FINAL})$

ORCA HUB Offshore Robotics for Certification of Assets

EDINBURGH CENTRE FOR ROBOTICS

Task Allocation Strategy



PLANNER AGNOSTIC APPROACH

capALLOCATION(g, r): *allocate(G, R, R_cap, G_cap)*

$\{GA_{INIT}, RA_{INIT}, C_{sol}, R_{sol}\} \leftarrow \emptyset$

$[C_{sol}, R_{sol}] = cluster\_cal\ (G, R, R_c, G_c)$

$RA_{INIT} = max\{weight\_cal(RG, C_{sol}, R_{sol})\}$

distROBOT(r,c): *regions_dist*(RA_{INIT}, *R_c, C_sol, C_c*)

firstGOAL(r,g): *allocate_firstGoal*($GA_{INIT} \leftarrow G$)

$GA_{FINAL}\ (G) \leftarrow GA_{INIT}$

allocGOAL(r,g): *allocateGoal*($R, G, M^r_{max}, dist$)

ROBOTS DISTRIBUTION

OUTPUT

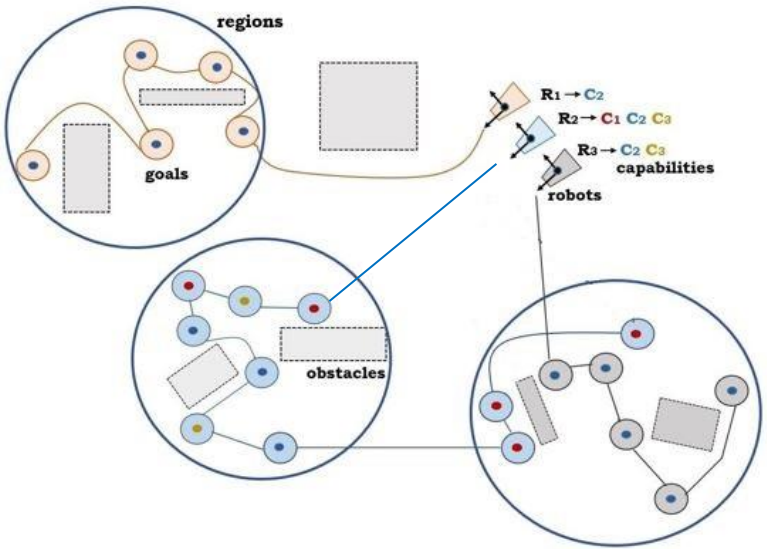
return *transformPDDL*(GA_{FINAL})

ORCA HUB Offshore Robotics for Certification of Assets

EDINBURGH CENTRE FOR ROBOTICS

edinburgh-robotics.org | orcahub.org

Task Allocation Strategy



PLANNER AGNOSTIC APPROACH

capALLOCATION(g, r): *allocate(G, R, R_cap, G_cap)*

$\{GA_{INIT}, RA_{INIT}, C_{sol}, R_{sol}\} \leftarrow \emptyset$

$[C_{sol}, R_{sol}] = cluster\_cal\ (G, R, R_c, G_c)$

$RA_{INIT} = max\{weight\_cal(RG, C_{sol}, R_{sol})\}$

distROBOT(r,c): *regions_dist*(RA_{INIT}, *R_c, C_sol, C_c*)

firstGOAL(r,g): *allocate_firstGoal*($GA_{INIT} \leftarrow G$)

$GA_{FINAL}\ (G) \leftarrow GA_{INIT}$

allocGOAL(r,g): $allocateGoal(R, G, M^r_{max}, dist)$

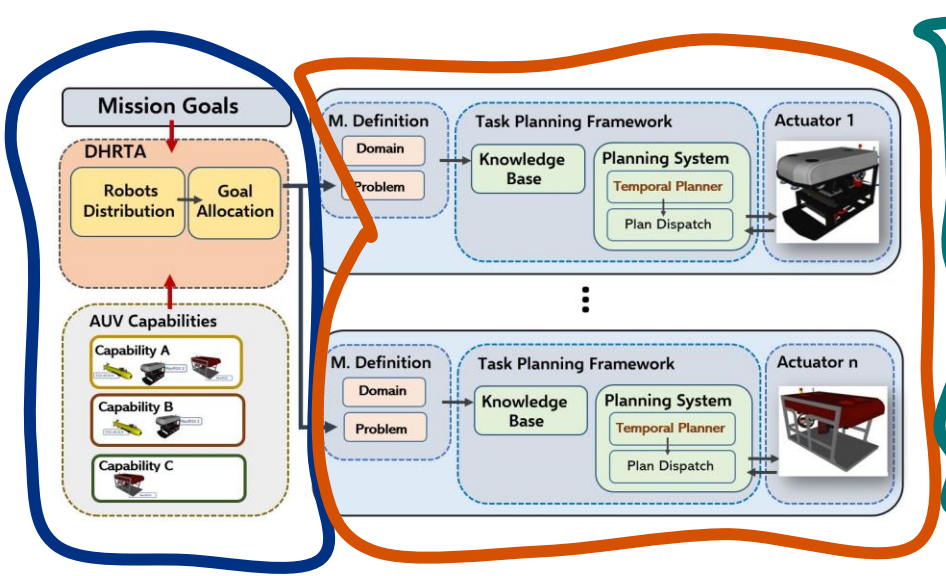
GOALS ALLOCATION

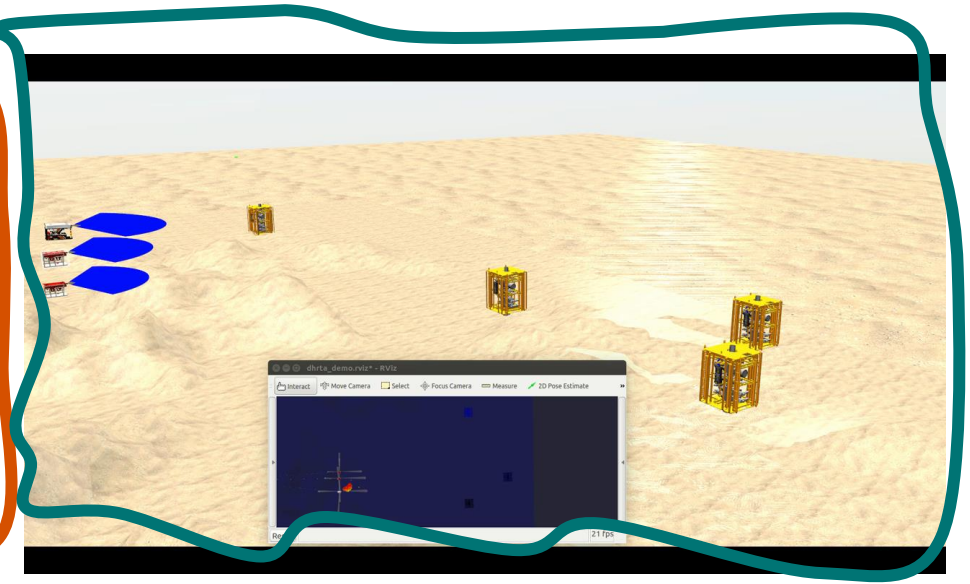
OUTPUT

return $transformPDDL(GA_{FINAL})$

System Framework

The DHRTA module output is a set of mission goals described in standard PDDL with the following structure: (goal_name parameters) [robot]





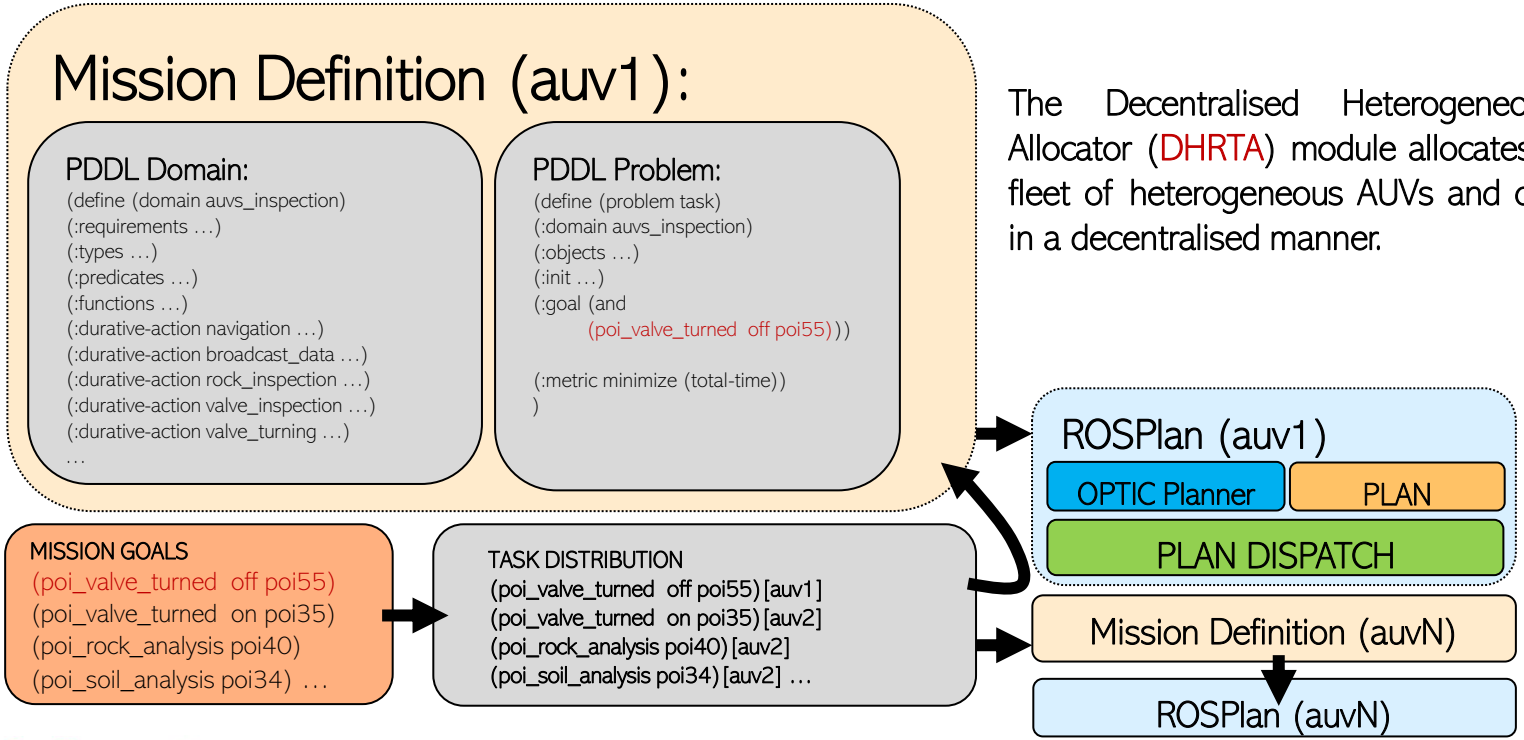
TASK ALLOCATION DECENTRALISED PLANNING MISSION EXECUTION

ORCA HUB Offshore Robotics for Certification of Assets

EDINBURGH CENTRE FOR ROBOTICS

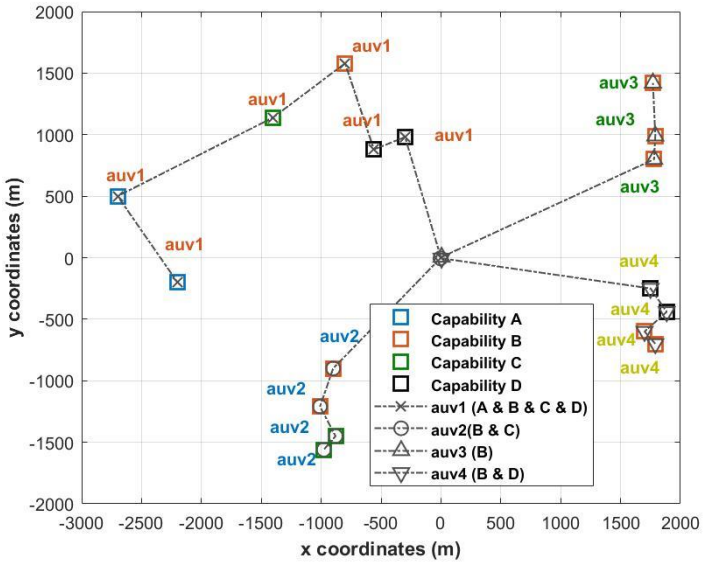
edinburgh-robotics.org | orcahub.org

DHRTA & Temporal Planning



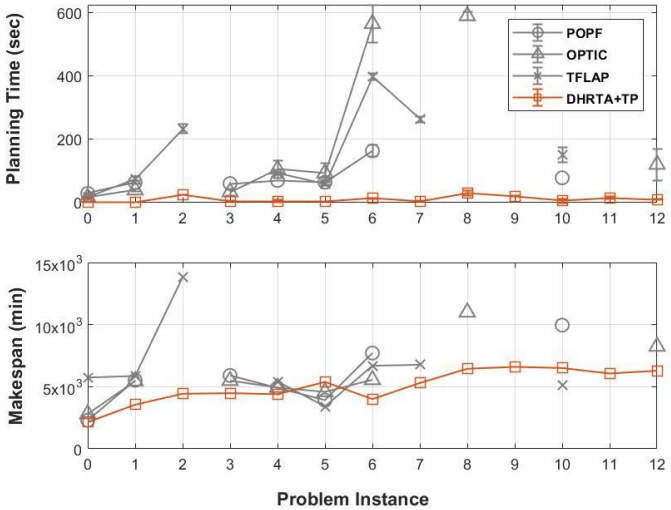
The Decentralised Heterogeneous Robots Task Allocator (DHRTA) module allocates mission goals to a fleet of heterogeneous AUVs and distributes the goals in a decentralised manner.

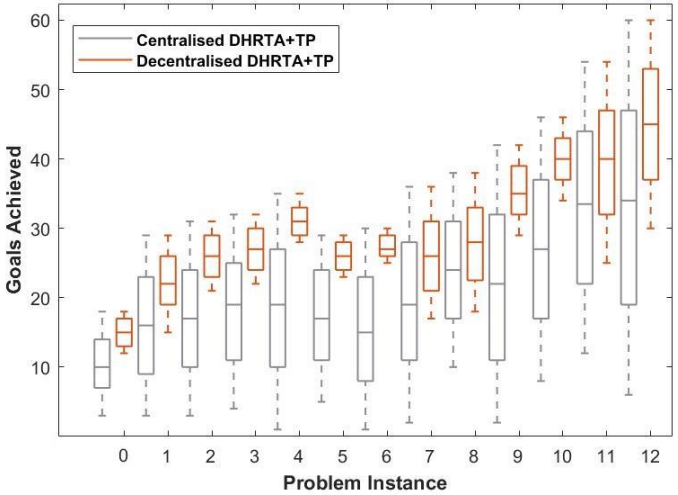
Experimental Results – task allocation(2)



- DHRTA+TP improves goal distribution and overall complexity of the global plan.
- Optimises the use of robots and resources.

DHRTA-TP: Experimental Results





- DHRTA-TP generates the first solvable plan in shorter time period than benchmark planners (left top).
- The makespan results (left bottom) are similar to the values obtained by the benchmark planners.
- DHRTA-TP strategy outperforms the centralised approach, achieving the highest number of goals during the mission for all goal sets.

Thanks!!

Yaniel Carreno

Èric Pairet

Yvan Petillot

Ron Petrick

ORCA HUB
Offshore Robotics for Certification of Assets

EDINBURGH CENTRE FOR ROBOTICS
Innovation Ready

HERIOT WATT UNIVERSITY

THE UNIVERSITY of EDINBURGH

icaps

edinburgh-robotics.org | orcahub.org