Decentralised Task Allocation and Planning for Heterogeneous AUVs

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Innovation Ready

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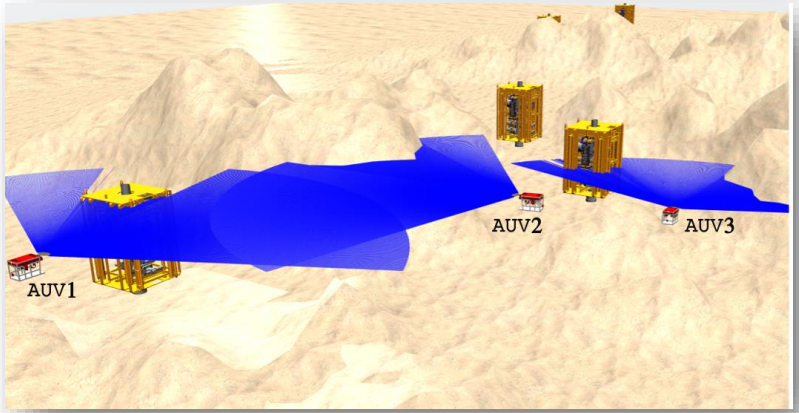
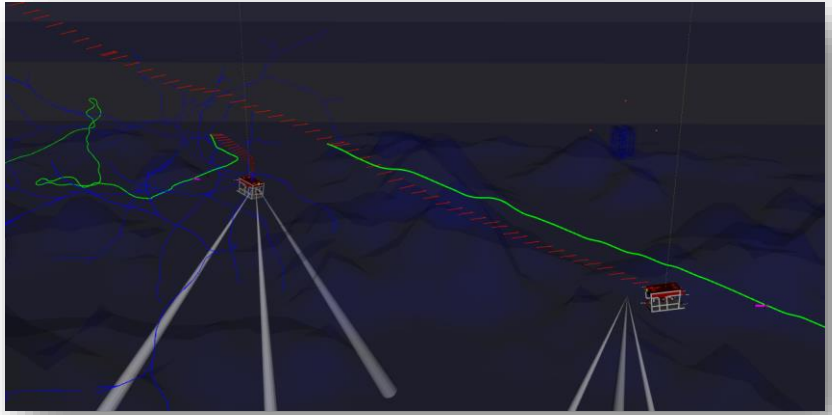
ICAPS 2020 System Demonstration and Exhibits, June 2020

Multi-Vehicle System

- Robot Models: Unmanned Underwater Vehicle Simulator Package (UUV Simulator).
- Robot Fleet Properties: Heterogeneous Robots.
- The system allows the robots to perform structure inspections, take images, take samples of rocks or soil, inspect the state of a valve, and turn a valve on/off.



Simulated hardware (Gazebo Environment)


Simulated hardware (RVIZ : topics information visualiser)

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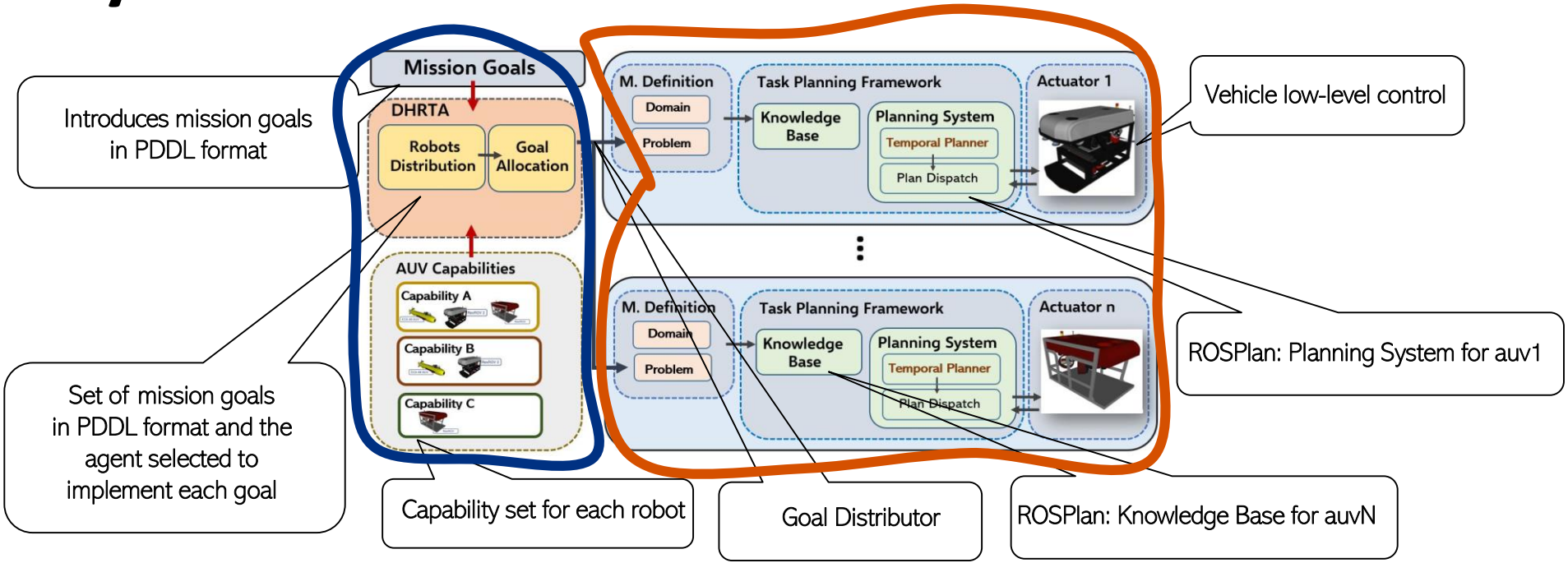
System Framework



TASK ALLOCATION PLANNING AND EXECUTION

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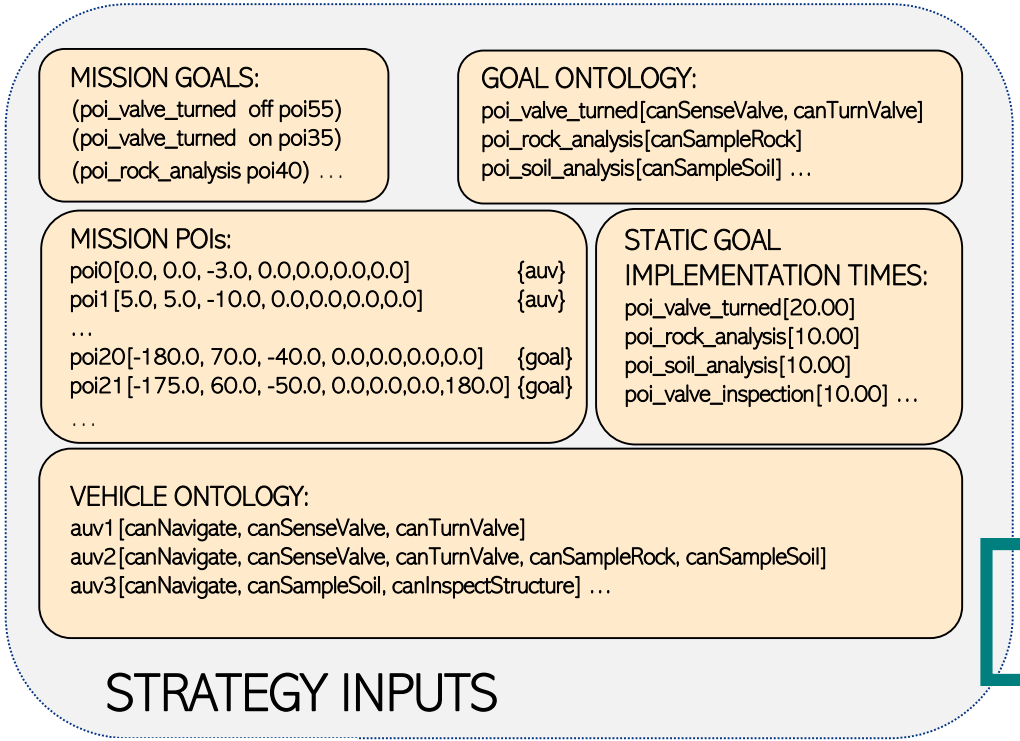
DHRTA Strategy



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

DHRTA

(poi_valve_turned off poi55) [auv1]
(poi_valve_turned on poi35) [auv2]
(poi_rock_analysis poi40) [auv2]
(poi_soil_analysis poi34) [auv2]
…
STRATEGY OUTPUT

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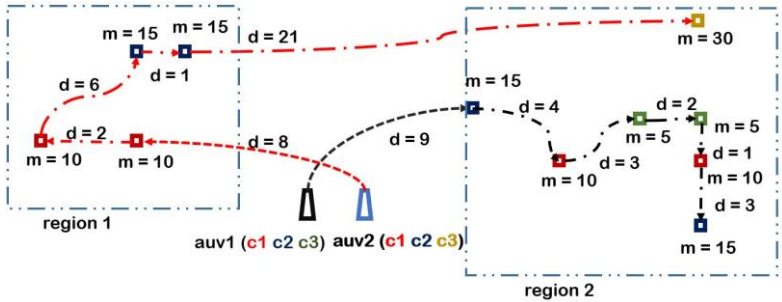
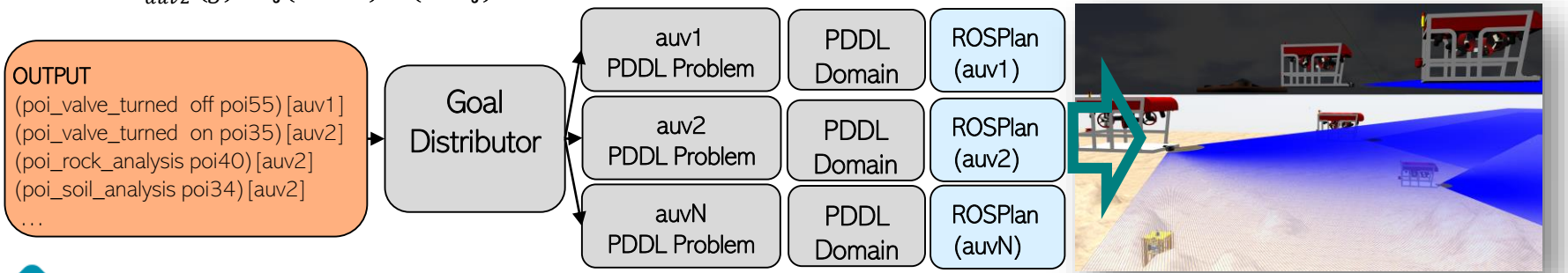
DHRTA Strategy



$$cost_{auv1}(g) = \gamma(9 + 15) + (1 - \gamma) * 4$$

$$cost_{auv2}(g) = \gamma(8 + 10) + (1 - \gamma) * 2$$

- Each robot presents its own PDDL domain and problem description.
- The DHRTA approach distributes the allocated goals to the robot problem files.
- The system presents multiple instances of ROSPlan that work concurrently to generate a plan for each robot.



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DHRTA & Temporal Planning

Mission Definition (auv1):

PDDL Domain:

```
(define (domain auvs_inspection)
(:requirements …)
(:types …)
(:predicates …)
(:functions …)
(:durative-action navigation …)
(:durative-action broadcast_data …)
(:durative-action rock_inspection …)
(:durative-action valve_inspection …)
(:durative-action valve_turning …)
…
```

PDDL Problem:

```
(define (problem task)
(:domain auvs_inspection)
(:objects …)
(:init …)
(:goal (and
        (poi_valve_turned  off poi55)))

(:metric minimize (total-time))
)
```

OUTPUT

(poi_valve_turned off poi55) [auv1]
(poi_valve_turned on poi35) [auv2]
(poi_rock_analysis poi40) [auv2]
(poi_soil_analysis poi34) [auv2] …

Goal Distributor

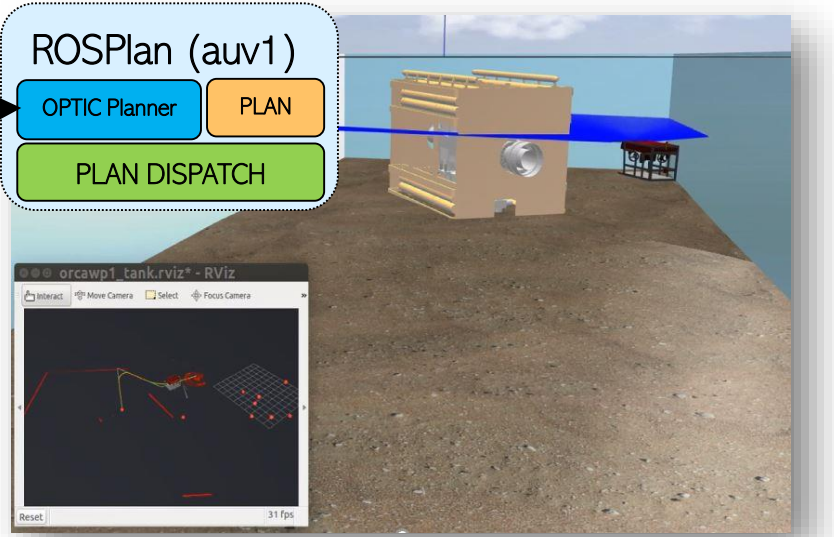
Mission Definition (auvN)

ROSPlan (auvN)

ROSPlan (auv1)

OPTIC Planner | PLAN

PLAN DISPATCH



DHRTA+TP combines the DHRTA approach with a temporal planner to generate a mission plan.

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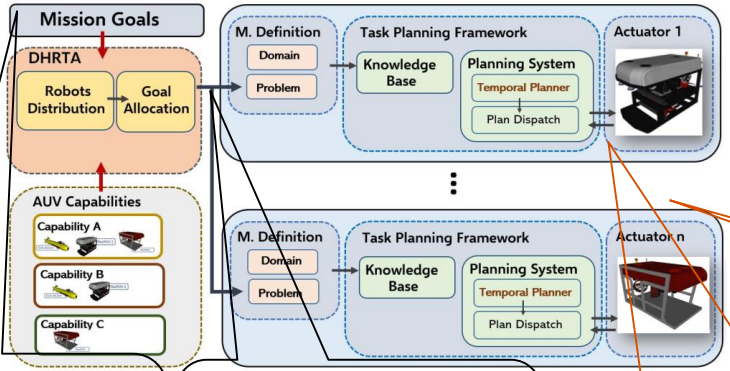
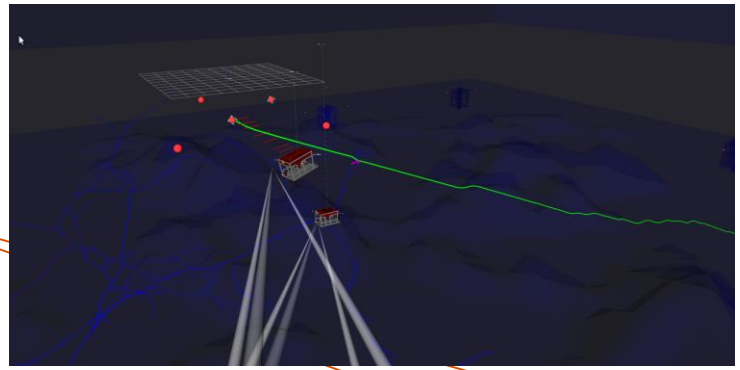
System Framework: General Example





(poi_valve_turned off poi55)
(poi_valve_turned on poi35)
(poi_rock_analysis poi40)
(poi_soil_analysis poi34)
(poi_image_taken poi40)
(poi_structure_id poi74)

(poi_valve_turned off poi55) [auv1]
(poi_valve_turned on poi35) [auv2]
(poi_rock_analysis poi40) [auv2]
(poi_soil_analysis poi34) [auv2] . . .

0.00: navigate auv1 poi0 poi55	[457.90]
457.90: valve_inspection auv1 s1_1 poi55	[10.00]
467.90: correct_valve_pos auv1 poi55	[10.00]
477.90: valve_turning auv1 poi55	[20.00]

0.00: navigate auv2 poi1 poi34	[134.45]
134.45: soil_analysis auv2 s2_2 poi34	[10.00]
135.45: correct_valve_pos auv2 poi34	[10.00]
145.45: navigate auv2 poi34 poi35	[14.15]
159.60: valve_inspection auv2 s2_1 poi35	[10.00]
169.60: correct_valve_pos auv2 poi35	[10.00]
179.60 : valve_turning auv2 poi35	[20.00]

- Robots execute their plans concurrently using ROSPlan.
- Mission execution is based on a decentralised architecture.

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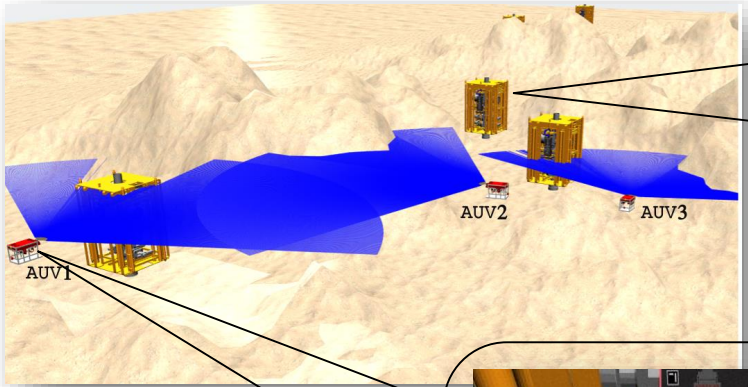
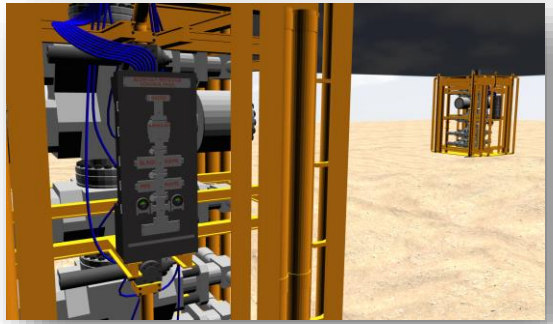
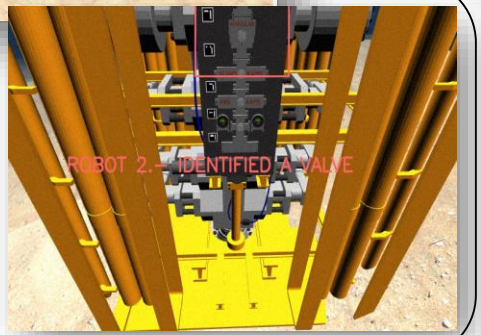
Simulation Environment







MISSION GOALS:

(poi_valve_turned off poi55)
(poi_valve_turned on poi35)
(poi_rock_analysis poi40)

- Maritime scenario where a fleet of AUVs must complete multiple tasks located at blowout preventers (BOPs).
- Robots must explore different points of interest (POI) and turn valves based on their capabilities.

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Valve Turning

Task poi_valve_turned requires a plan that considers the valve state analysis.

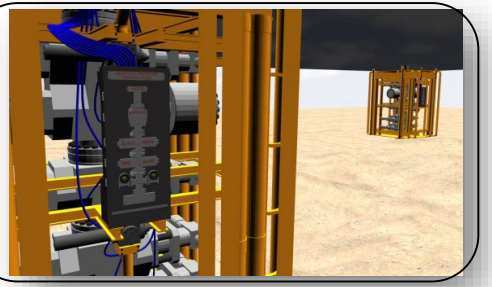
```
(:durative-action valve_turning
:parameters (?r - robot ?poi - waypoint ?a - robot_actuator ?v1 ?v2 - valve)
:duration (= ?duration 20)
:condition (and
            (over all (equipped_for_valve_turning ?r ?a))
            (over all (at ?r ?poi))
            (at start (at ?r ?poi))
            (at start (available ?r))
            (at start (poi_target_inquired ?poi))
            (at start (valve_state ?poi ?v1))
            (at start (>= (energy ?r) 3)))
:effect (and
        (at start (not (available ?r)))
        (at start (decrease (energy ?r) 5))
        (at start ( not (valve_state ?poi ?v1)))
        (at end (valve_state ?poi ?v2))
        (at end (poi_valve_turned ?v2 ?poi))
        (at end (available ?r))
        (at end (increase (data_adquired ?r) 1))))
```

PREVIOUS ACTION

```
(:durative-action valve_inspection
:parameters (?r - robot ?s - robot sensor ?poi - waypoint)
:duration ( = ?duration 10)
:condition (and
            (over all (at ?r ?poi))
            (over all (equipped_for_cad_classification ?r ?s))
            (at start (at ?r ?poi))
            (at start (available ?r))
            (at start (>= (energy ?r) 2))
            (at start (< (data_adquired ?r) (data_capacity ?r))))
:effect (and
        (at start (not (available ?r)))
        (at end (poi_target_inquired ?poi))
        (at end (decrease (energy ?r) 2))
        (at end (available ?r))
        (at end (increase (data_adquired ?r) 1))))
```

PLAN (auv1):

```
0.00: navigate auv1 poi0 poi55                [457.90]
457.90: valve_inspection auv1 s1_1 poi55      [10.00]
467.90: correct_valve_pos auv1 poi55          [10.00]
477.90: valve_turning auv1 poi55              [20.00]
```



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References and Acknowledgments

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