ICKEPS 2016: Star Trek - Rescue of Levaq

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In this ICKEPS challenge, your task is to model a Star Trek-themed scenario from the description that follows. There are many ways to model this problem. You should strive to be as efficient and clear as you can with your models.

Scenario to Model

Figure 1. Map for this rescue mission. All travel times are in hours. Note the ominous subspace dampening field around Levaq due to the Borg ship, slowing down any ships traveling there.

Planet Levaq needs your help! It is under attack by a very dangerous enemy: the Borg. You must act quickly, as the entire planet will be assimilated after a deadline. Your task is to command a fleet of ships to ferry

supplies and personnel, upgrade your technology, build a weapon system to attack the Borg cube (their ship), and save the day to promote an optimistic outlook on humanity by the end of the episode.

As a Starfleet Admiral in charge of the federation's fleet, you know exactly what to do: model the scenario in PDDL (or a language of your choice)! A planner should be able to find a solution and save Levaq (its citizens' lives are in the planner's hands).

In a Nutshell

To save Levaq, generated plans should do something roughly similar to the following.

Your fleet of starships must fly around the galaxy, beaming up supplies and then beaming them down to other planets. Ships may upgrade their warp drives to fly faster. Photon torpedo launchers should be built on some planets using delivered resources, and can be loaded with antimatter pack ammunition (also delivered). Then, Captain Picard must beam over to the Borg cube from Levaq, lower its shields from the inside, and allow the planets to fire their photon torpedos approximately simultaneously to damage the Borg cube. This disabling the shields and firing sequence may need to happen several times, until the Borg cube sustains enough damage to be destroyed.

Details

There are three ships at your disposal: the `enterprise`, the `klingon-bird-of-prey`, and the `romulan-warbird`. Unfortunately, all three of these ships were damaged during a preliminary confrontation with the Borg. They are still functional and can fly at (relatively slow) impulse speed, and *beam up / beam down* supplies from / to planets and ships (all beaming can happen in parallel). Each ship has two cargo bays and can store up to **2** beamed up resource items simultaneously (crew members do not count).

Additionally, it is possible to repair the warp drives on these three ships. Once warp capability is enabled, it is possible to travel 4X faster than those times listed on the map (for instance, traveling between `risa` and `levaq` would take 125 hours, not 500, with a warp drive). The `klingon-bird-of-prey` and the `romulan-warbird` have taken significant

damage, so it will take 150 hours to repair their warp drives. The `enterprise` has thankfully sustained less damage, and it will only take 3 hours to repair its warp drive. All warp drive repairs must occur on `earth`, where the necessary infrastructure is available. (Traveling quickly will be important, as the Borg have extended a subspace dampening field around `levaq`, making space travel significantly slower in that region of space - see the map).

The `borg-cube` is heavily defended. The only way to destroy it is with **5 direct hits** with high-power photon torpedoes launched from nearby planets (the stations require so much power that they cannot be built onto a starship). Each hit is **only effective if the Borg's shields are low, and if at least two photon torpedoes are fired simultaneously (one hit alone is not strong enough to penetrate even the lowered Borg's shields)**. For example, if Picard lower Borg's shield and only one torpedo is launched and hit the enemy ship, then the hit does not count. On the other hand, if two or more torpedoes are launched and hit Borg's ship then each hit counts (e.g., three torpedos = three hits). Thus, photon torpedos must be fired from at least two planets in parallel to have any effect.

Photon torpedos can only be launched from planets with a line-of-sight to the Borg cube. However, no planet currently has such powerful weapons. As such, photon torpedo launchers must be built (out of `tritanium`) on any planet before it may begin firing. Only the planet Vulcan has natural resources of `tritanium`; supplies must be ferried to other planets should photon torpedo launchers be built there. Once supplies are dropped off by the starships, engineers on the planet can assemble the launchers in 6 hours. Only one launcher can be build per planet.

Once built, the photon torpedo launchers need ammunition in the form of antimatter. Each antimatter pack is enough for a single photon torpedo to be fired. Antimatter is only available at `sb128`, a star base close to Earth, where it is manufactured in highly-controlled labs. Antimatter packs can be stockpiled on a planet for multiple successive shots, and are consumed by firing.

As noted earlier, photon torpedos are only effective if the Borg's shields are down. The only person in Starfleet who knows how to do this is, of course, Captain Picard aboard the `enterprise` (Locutus's knowledge is

advantageous here). The catch: Captain Picard must teleport to the `borg-cube` from the `enterprise` when it is at `levaq` and disable the shields from the inside. The shields will only stay down for 5 hours before the Borg adapt and raise them, so photon torpedos must be fired from the planets within this time window. Additionally, Captain Picard must teleport back off the Borg cube immediately after the shields going down, else he may be detected and assimilated. Picard is capable of teleporting and disabling the shields multiple times.

You'll need to get to Levaq and destroy the Borg cube quickly within **180 hours**, otherwise the Borg will succeed in assimilating the population. Hurry, Captain Picard!

Summary

Here is a summary of some of the suggested types and places for this domain:

Federation ships under your control:	Time required to repair warp drive (hrs)
enterprise	3
klingon-bird-of-prey	150
romulan-warbird	150

Each ship can store 2 items simultaneously.

Enemy ships not under your control:
borg-cube

Object type	Use	Where to get
tritanium	Strong material used to build photon torpedo launchers	vulcan
antimatter-pack	Ammunition (single fire) for photon torpedo launchers	sb128

Locations
earth
sb128 (Star Base 128)
vulcan
betazed*
cardassia*
qonos*
risa*
levaq*
romulus*
ferenginar*

* planets that have a clear line-of-fire to the Borg cube, and where photon torpedo launchers could be useful.

Engine type	Travel time (hours)
impulse drive (all ships)	See times in map.
Warp drive (once built)	Times in map / 4

Suggested actions:

Action Name	Description	Time (hr)
fly-impulse-speed	Fly at normal speed from planet to planet	(See map)
fly-warp-speed	Fly at 4X speed from planet to planet, once warp drive repaired.	(See map, divided by 4)
beam-up	Beam supplies into a ship's cargo bay from a planet	0.1
beam-down	Beam supplies in a ship's cargo bay town to planet	0.1
beam-over	Beam supplies from one ship to another, if both are at the same planet	0.1
teleport	Teleport crew members from one ship to	0

	another, if both are at the same planet	
lower-shields	Lower / weaken the shields. Requires an agent (i.e., Picard) to be in the borg ship. While the shields are lowered, photon torpedoes can be fired.	0
repair-warp-drive	Repairs the enterprise's warp drive; can travel at warp speed afterwards. Must be on earth, and at time t >= 20.	3
build-photon-torpedo-launcher	Build a photon torpedo launcher on a given planet, requiring tritanium (1 per planet).	6
load-photon-torpedo	Load a photon torpedo with an antimatter pack on that planet	0.5
fire-photon-torpedo	Fire a single photon torpedo from a loaded planet's launcher. Requires the launcher to be build, to be loaded, to have a line-of-sight to borg cube, and shields down on borg cube.	3
destroy-borg-ship	Once the Borg have sustained 5 hits, they can be easily destroyed	0.1

Other time constants not described in action times above:

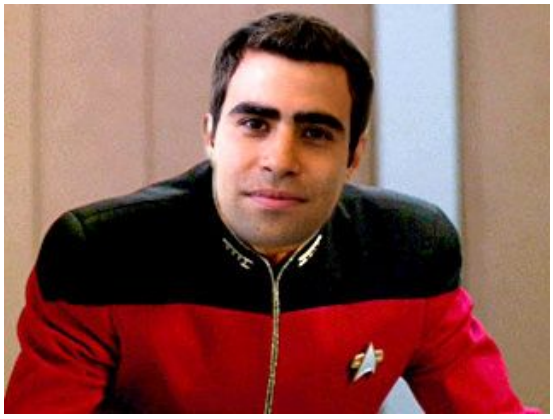
Property	Timing (hours)
Time after which Borg shields are fixed after being turned offline by Picard	5
Maximum time Capt. Picard can stay onboard Borg ship after shields are disabled before teleporting back to Enterprise	Immediately!
Time after which levaq will be assimilated (goals must be achieved by this time!)	180

We are not restricting the set of predicates you use in your modeling, so add any predicates, functions, or other model features as appropriate.

About the Authors

Captain **Steven J. Levine** is a Ph.D student in the MERS group at MIT. His work focuses on task execution and monitoring, specifically in the context of human-robot collaboration where humans and robots recognize each other's intentions and adapt accordingly. After completing his Ph.D, Steve plans to join Starfleet academy and subsequently captain his own Galaxy-class starship. His other interests include running, the design of positronic nets for androids, and spending time with a goose.

Admiral **Tiago Vaquero** is a postdoctoral fellow in the MERS group at MIT. He's additionally associated with Caltech, a division of Starfleet's warp propulsion center. Prior to coming to MIT, Tiago was a postdoctoral fellow at University of Toronto, where he rose to the rank of admiral following his Ph.D work at the University of São Paulo, where he successfully passed the Kobayashi Maru.



ICKEPS 2016: Roundabout Scenario

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This domain represents a micro-simulation model of traffic scenario. The overall aim is for ICKEPS teams to create a model so that a planner can be used to navigate a number of vehicles through the network, from some entry points to their specified exit point. In this way the planner acts like a centralised control for all the traffic.

The road network can be represented by a directed graph, where edges stand for road sections and vertices stand for either junctions, entry or exit points. Vehicles enter the network in entry points, and leave the network from exit points. Each road section has a given length and capacity (i.e. a maximum number of vehicles that can be travelling along it at the same time).

In the modelled road networks, all the junctions are roundabouts. Here we consider only 3 and 4-road roundabouts. Roundabouts are divided into sectors, where each sector is delimited by a start and end road sections. From the start road section, vehicles can enter a sector on the roundabout; from the end road section, vehicles can exit a sector on the roundabout. See Figure 1 for an example with 6 road sections (R1--6) and 3 sectors.

We say that a sector is **before** (**after**) a road section, if the road section is at the **end** (**start**) of the sector. Both road sections and roundabout sectors are one-way.

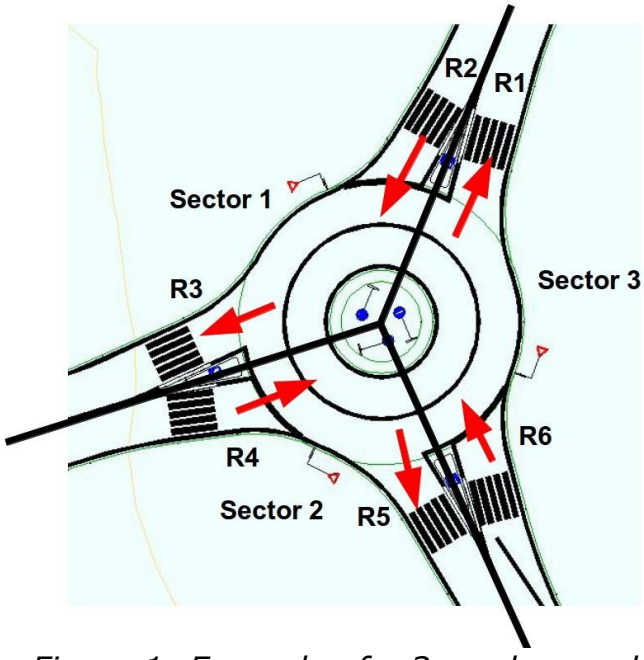

Figure 1: Example of a 3-roads roundabout

A vehicle can drive on road sections. Driving from start to end of a road section requires a certain amount of time, depending on the length of the road section, and to the speed of the vehicle. For moving between different road sections, vehicles can use roundabouts. In order to avoid collisions, a vehicle cannot enter a roundabout if the sector before the road it is entering the roundabout from, and the sector after the road, are not free. Here, for the sake of simplicity, we assume that every movement of a vehicle into *and* along a roundabout takes 2 time units: entering the roundabout takes 2 times units, moving from one sector into another takes 2 times units, and leaving the roundabout takes 2 time units to be performed.

Each vehicle is described by speed, initial position (initial entry point) and goal destination (exit point).

Problem 1

Here we are considering the network shown in Figure 1. Roads have the following length:

- R1, R2, R5: 6 length units
- R3, R4: 8 length units
- R6: 10 length units

The capacity of all the roads is 3 vehicles, i.e. 3 vehicles can be in the road at the same time.

We are modelling four vehicles:

- Vehicle 1; speed 2 length/units per time unit; going from entry point of R2 to exit point of R5.
- Vehicle 2; speed 1 length/units per time unit; going from entry point of R6 to exit point of R3.
- Vehicle 3; speed 1 length/units per time unit; going from entry point of R4 to exit point of R1.
- Vehicle 4; speed 3 length/units per time unit; going from entry point of R2 to exit point of R1.

Problem 2

Here we consider the network described in Figure 2. There are 6 roads, 3 entry points and 1 exit point.

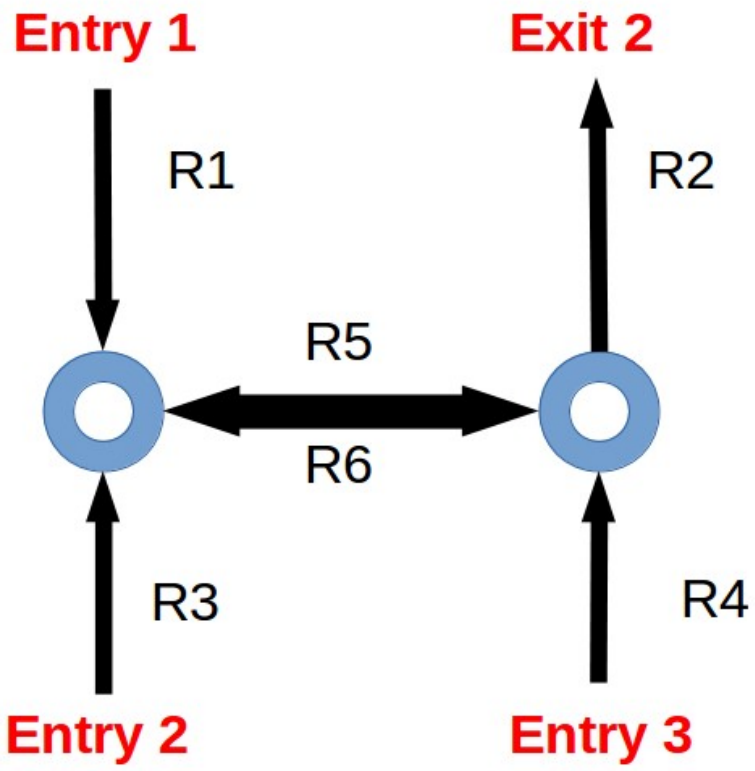

Figure 2: Network to be encoded for problem 2

Roads have the following length and capacity:

- R1, R2, R3, R4: 10 length units; capacity of 5 vehicles.
- R5, R6: 5 length units; capacity of 2 vehicles.

We are modelling 20 vehicles:

- Vehicles 1 – 10: speed 3 length/units per time unit; going from Entry 1 to Exit 1
- Vehicles 11 – 15: speed 2 length/units per time unit; going from Entry 2 to Exit 1
- Vehicles 16 – 20: speed 2 length/units per time unit; going from Entry 3 to Exit 1

In both considered problems, the goal is to navigate vehicles from entry to exit points, while minimising the overall time.

ICKEPS 2016: RPG Scenario

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Help a hero to get out of dungeon! The hero woke up in a dungeon full of monsters and traps (perhaps the party last night went wrong...) and needs your help to get out. Here are basic facts about the dungeon:

- The dungeon contains rooms that are connected by corridors (dungeon can thus be represented by undirected graph)
- each room can be empty, or can have a monster in it, or can have a trap in it, or can have a sword in it
- one of the empty rooms is the "goal": it has an exit, so the hero can escape

The hero is lucky since he has full knowledge about the dungeon. But not that lucky – just after the hero leaves room s/he just visited, the room is destroyed and cannot be visited again.

The hero can perform the following actions – but only if s/he is alive!

- The hero can move to an adjacent room (connected by a corridor) that has not been destroyed (i.e., the hero has not already visited the room)
- Pickup the sword if present in the room the hero is currently in and the hero is empty handed
- Destroy the sword that the hero currently holds. However, this can have unpleasant effects if done in a room with a trap or a monster.
- Disarm a trap – if there is a trap in the room the hero is in and the hero is empty-handed (does not hold a sword), then the hero can disarm it

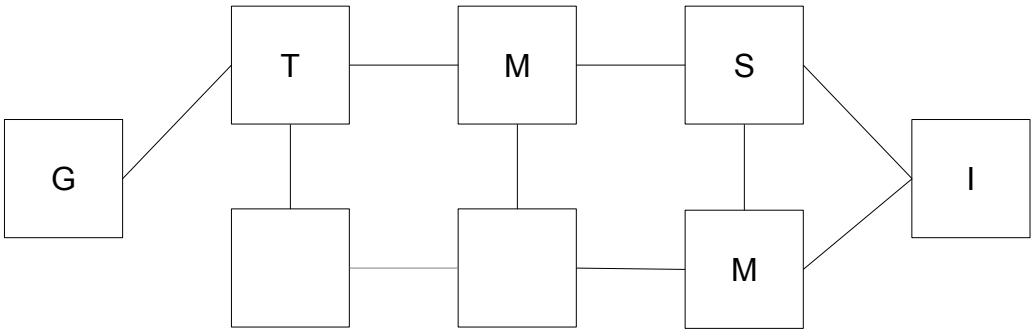
However, there are some (dangerous) constraints the hero has to consider:

- If the hero enters a room with a monster in it, s/he has to carry a sword (so the monster is afraid of him/her), otherwise the monster kills him/her. Notice that the hero is pacifist, so s/he cannot kill the monster.
- If the hero destroys the sword in a room with a monster in it, the monster kills him/her as well.
- The only action the hero can safely perform in a room with a trap in it is the "disarm a trap" action. Any other action (even moving away) triggers the trap which kills the hero.

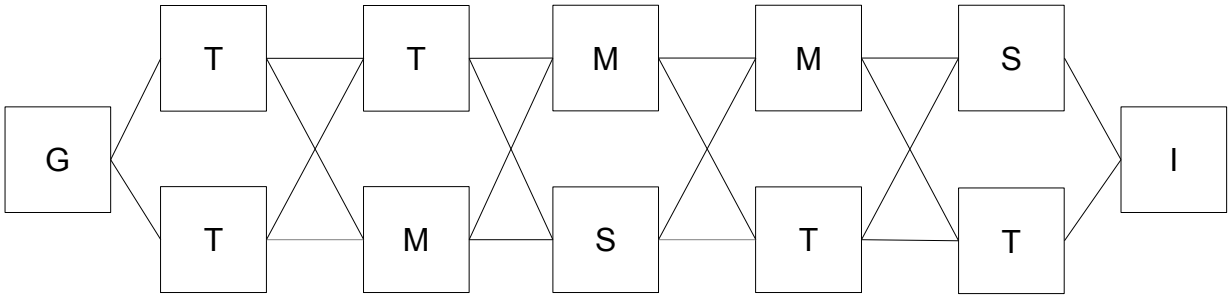
Problems are specified such that cells stand for rooms and edges between them represent corridors. "**I**" is an initial hero's position, "**G**" is hero's desired goal position, "**S**" indicates sword, "**M**" is a monster, and "**T**" stands for trap.

Good luck!

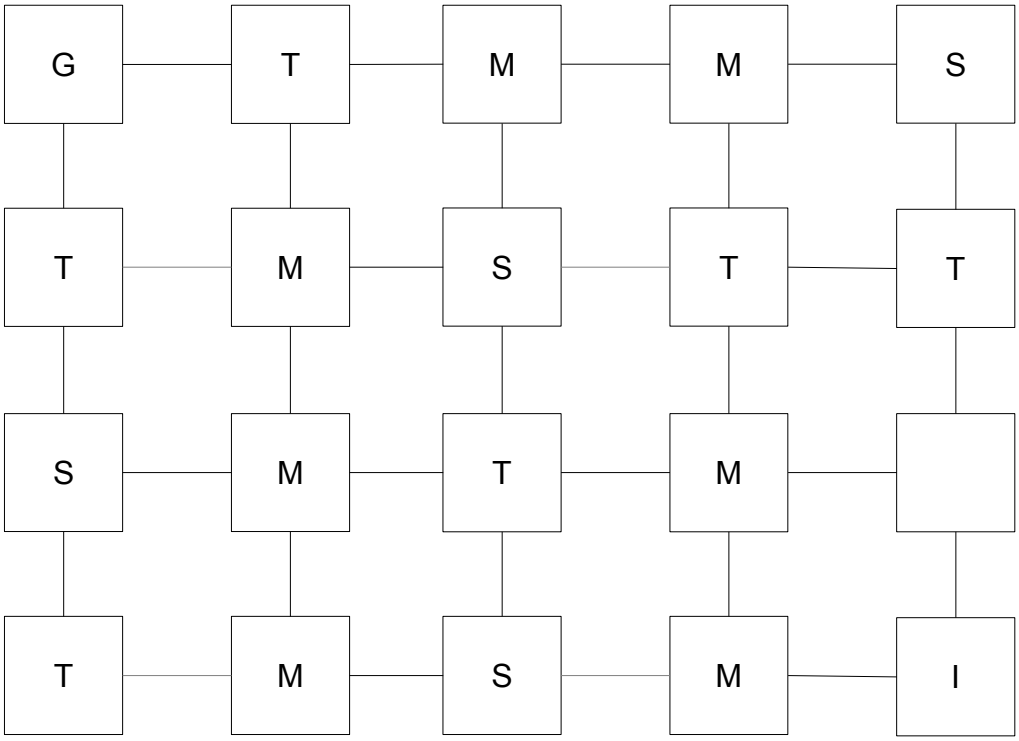
Problem 1



Problem 2



Problem 3



ICKEPS 2016: Match-three, Harry!

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In this domain we want to use planning engines for solving a match-three game.

This is a type of game where the player (in this case, the planner) can make tiles disappearing according to a matching criterion. Here, three tiles of the same type which are adjoined, either vertically or horizontally, can be removed from the board. Once tiles are removed, the corresponding cells are left empty.

Given an initial board setting, the goal is to obtain an empty board by removing all the tiles. In order to achieve the goal, the planner can swap two tiles –that must be of a different type– which are adjoined either vertically or horizontally. The only constraint on swapping tiles, is that it is not allowed to move a tile into an empty position. It is not required that a swap results into a three adjoined tile set to be formed. Three adjoined tiles of the same type are not *automatically* removed: the planner can also decide to keep them on the board for swapping purposes.

Four different type of tiles are considered in this version of the game: Gryffindor (**G**), Hufflepuff (**H**), Ravenclaw (**R**) and Slytherin (**S**). **It should be noted that, for some inexplicable reasons, when a Gryffindor tile is swapped with a Slytherin tile, the swap is correctly performed, but the Slytherin tile is destroyed, resulting in an empty cell.**

Quality of plans is measured in terms of number of swaps needed to achieve the goal.

Example

	1	2	3
a	G	H	G
b	H	H	R
c	R	R	G

In order to reach the goal, i.e. achieving an empty board, a valid solution plan

would be:

- Swap c3, b3 (row *c* can then be emptied)
- Match-three c1, c2, c3
- Swap a2, a3
- Swap a3, b3 (rows *a* and *b* can then be emptied)
- Match-three a1, a2, a3
- Match-three b1, b2, b3

Problem 1

	1	2	3
a	G	H	G
b	H	H	S
c	S	S	G
d	R	R	R

Goal: obtain an empty board –i.e., all the cells are empty.

Problem 2

	1	2	3	4
a		S	G	H
b	S	H	G	R
c	S	H	R	G
d	H	H	H	R

Black cell is empty.
Goal: obtain an empty board –i.e., all the cells are empty.