COGROB HW2: THE DYSON SWARM ADVENTURE

Application of AI Planning Methods to a Hypothetical Engineering Problem

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Author: Yotam Granov
E-mail: yotam.g@campus.technion.ac.il

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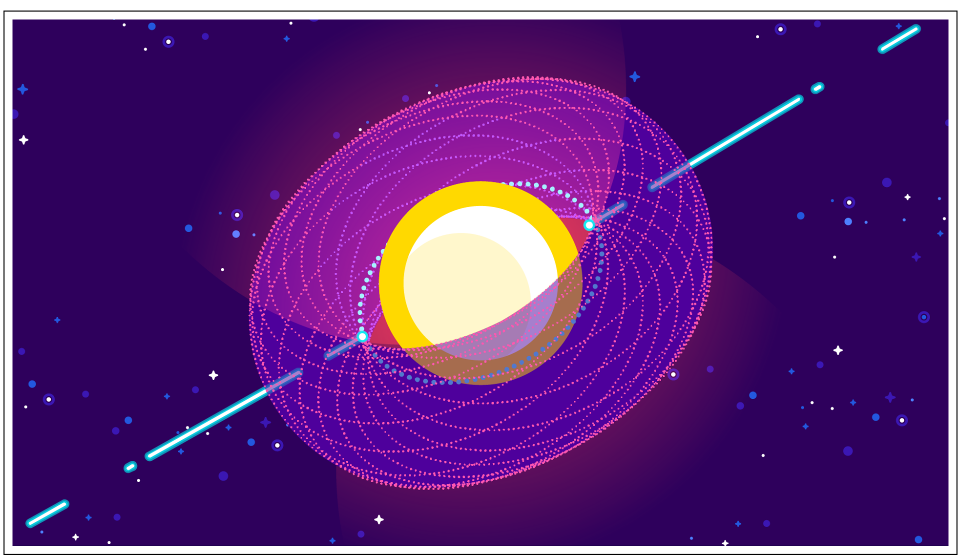
Guidelines

In this assignment, you will tackle a hypothetical engineering problem using AI planning methods. This is intended to be an open-ended assignment (i.e. it is not rigid in structure nor solution as the first assignment was), similar to a mini-research project. Given the nature of the assignment, you are welcome to approach the problem however you'd like (as long as you implement some of the methods we've learned in class), and there is no official solution - thus, any solution can be acceptable as long as you prove it sufficiently (you can also say that no solution is possible, which is fully acceptable as long as you show that this is indeed the case). You will receive as much guidance and assistance from the course staff (specifically, from Yotam) as needed!

You must submit a short report (`.pdf`) of a few pages explaining your solution and the steps you took to reach it, as well as a folder containing all of the relevant code (it doesn't have to be Python, though this is assuredly preferable). You can submit the assignment alone or in pairs, and you will submit everything on Moodle as a single **zip file**.

Assignment: The Dyson Swarm

This proposal is inspired by the following video (highly recommended / required viewing) from the German science education YouTube channel Kurzgesagt: How to Build a Dyson Sphere - The Ultimate Megastructure



Background

The Dyson Swarm (named for its inventor and scientific renegade Freeman Dyson) is a hypothetical megastructure that completely encompasses a star and captures a large percentage of its solar power output. It is composed of a very large fleet of autonomous solar power satellites which generate electrical power from solar radiation and can distribute it onward (i.e. back to Earth or other extraterrestrial colonies) using wireless energy transfer methods. Such a structure would allow a civilization to access and consume most (if not all) of the energy output of its nearest star(s), and thus ascend to Type II Civilization status on the Kardashev scale.

While this might seem like an outlandish concept, it is conceivable that humanity could construct a Dyson swarm in the near future. What might this look like?

Assuming that each satellite in our swarm has one square kilometer of solar panels, we would need around thirty quadrillion satellites in order to capture most of the Sun's power output. If they are built lightly, we would need about one hundred quintillion tons of material, roughly equivalent to the mass of a whole planet like Mercury. One proposed method for constructing a Dyson swarm in the near term is as follows:

- Construct the first set of solar power satellites on Earth and send them to solar orbit
- Using the energy provided by the preliminary fleet, construct a mining system on Mercury that can autonomously produce new satellites
- Construct an autonomous launching system (for example, a railgun) to launch the newly constructed satellites into solar orbit
- Using the power generated by the new satellites, mine more material from Mercury, construct more satellites, and launch them into orbit

The last step would continue autonomously and would allow the fleet to grow exponentially in size, allowing us to construct thirty quadrillion satellites in a matter of only decades.

Your Mission

In this assignment, you will use the AI planning methods we've covered in class in order to plan the most effective strategy for constructing a Dyson swarm around our Sun. You will begin by modelling the problem as realistically as you can:

- Given the photovoltaic technologies available today (consider their efficiencies), how much surface area would we really need in order to capture at least 90% of the Sun's power output? Propose a simple model for the satellites in the fleet (i.e. just specify the surface area of their solar panels and their total mass)
- Given the launch technologies available today, how much energy would a launch from Earth and from Mercury to the Sun require? How much mass could each launch carry?
- How much of Mercury's mass do we need to mine for our fleet? Does Mercury have actually enough usable mass for our purposes?

You do not have to use the Mercury deconstruction strategy outlined in the Background section, feel free to propose whatever (realistic-ish) strategy you'd like. You do not need to consider the dynamics or orbital mechanics of the satellites in the swarm (i.e. you can assume they won't ever crash into each other) nor the trajectories of the materials through space (i.e. you don't need to design any trajectories between Mercury and the Sun - just estimate the launch costs however you see fit).

Once you've modelled the problem, it will be up to you to build a strategy for fleet construction using AI planning methods. Choose your own algorithms and optimization metrics, and model whatever planning problems you'd like (i.e. temporal, numeric, etc.) with your own optimization schemes. You might want to consider:

- How many satellites should we build on Earth initially in order to optimize the future fleet construction? Consider the energy tradeoff of launching more satellites to solar orbit from Earth vs. the energy they'll provide for us to mine Mercury.
- What optimization metrics should we consider? Do we want to minimize the total time required to build the entire (or only part of the) swarm, or should we focus on minimizing the amount of materials we use up?
- Should we invest in better launch and photovoltaic technologies up front (i.e. in the present) in order to increase efficiency later on, or we should we start building the fleet immediately? (This is a very interesting tradeoff to model!)

You will have a lot of freedom to approach this assignment however you'd like (i.e. if you want to create more sophisticated models than I've described, if you'd like to add more constraints or considerations that I haven't outlined, etc.), but you must satisfy the following conditions:

- Your strategy must allow humanity to capture at least 90% of the Sun's power output by the year 2100. If this is not at all possible, you must provide a sound justification!
- You must choose your strategy with the help of planning methods and algorithms (such as, but not limited to, the ones we've discussed in class).
- You must justify (at least briefly) every decision, consideration, and parameter used in your models and strategies. Rudimentary calculations are acceptable.
- You must include some form of visualizations and graphics in your assignment that exemplify and help justify your models and decisions, and an exceptional project will include animations that actually visualize your strategy in action (this could make for some nice LinkedIn fodder)!

Good luck, and we hope you enjoy the assignment!