Using Robots to Maintain the Next Generation of Nuclear Fusion Reactors*

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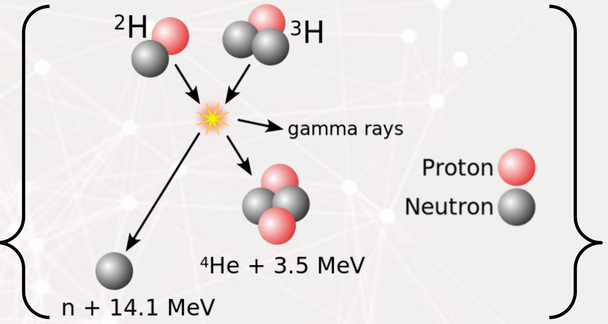
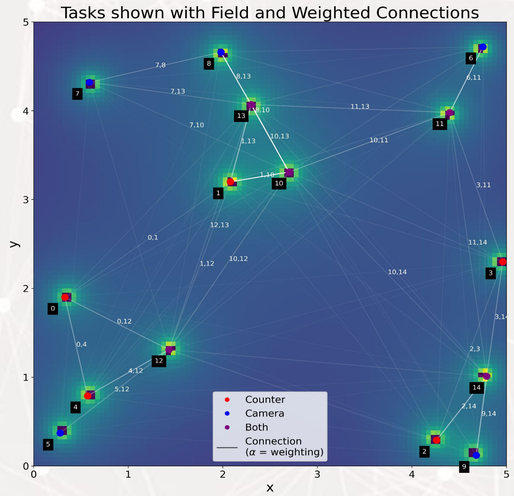
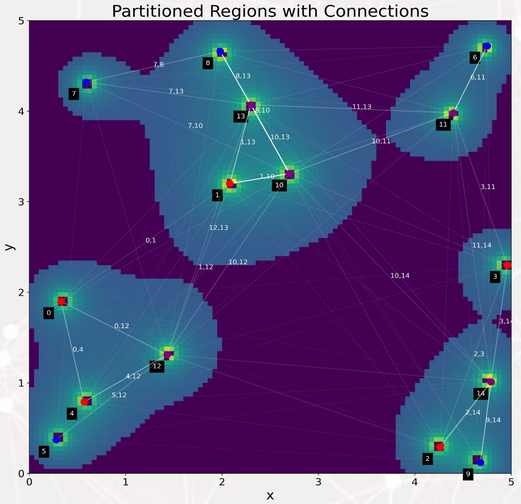
1. What is Fusion Energy?

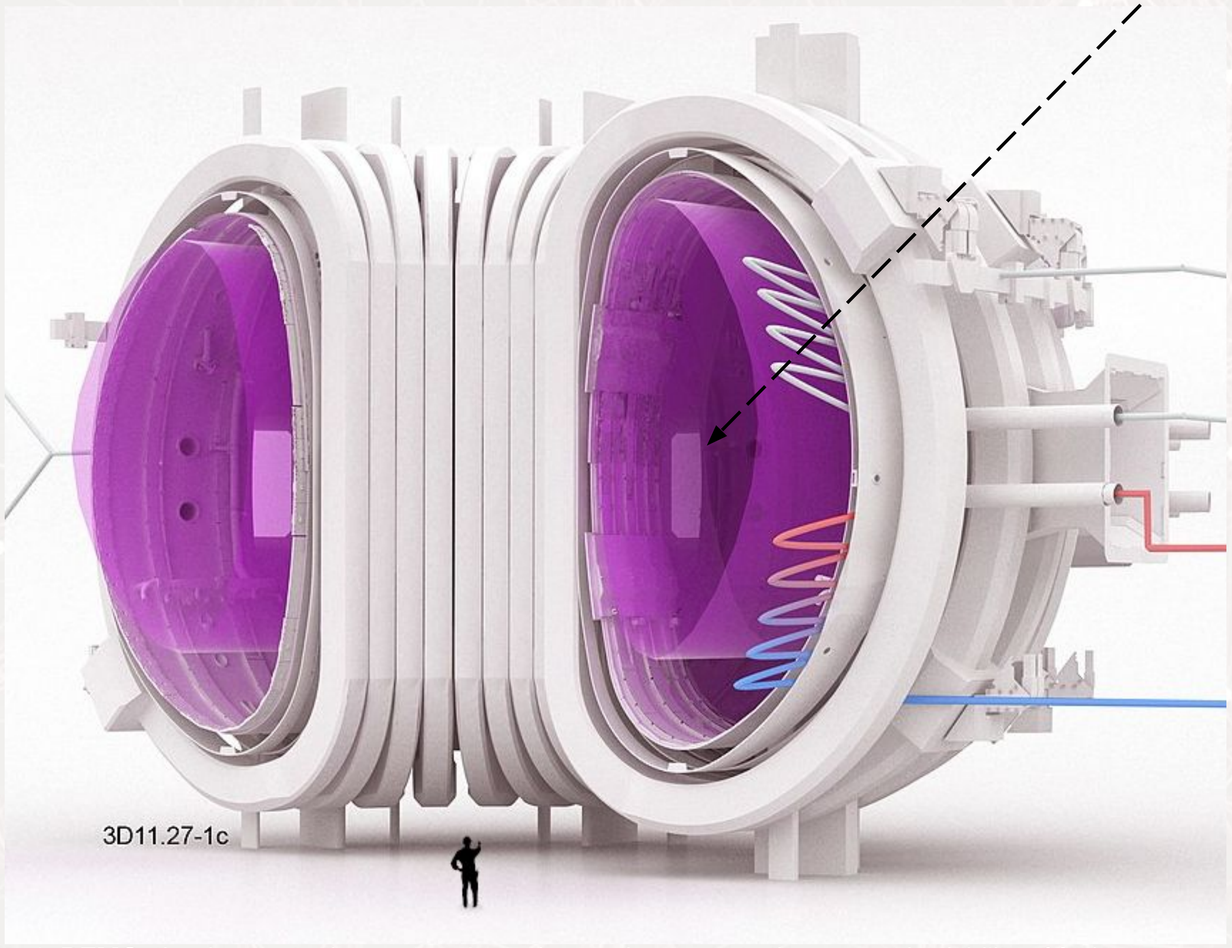
- **Light atomic nuclei join together** to form heavier ones, releasing energy & radiation.
- Requires a superheated gas (10 million Celsius). This is called a **plasma**.
- The plasma is confined in a '**tokamak**' (middle image), spinning at 100 km/s.
- **Efficient and environmentally friendly**...
  - No greenhouse gas emissions
  - 1000x shorter-lived waste than fission
- ...but difficult to achieve on Earth.







3. Maintenance tasks (dots) are partitioned into manageable 'remits'. This decomposes the larger planning problem into a series of smaller, easier ones.



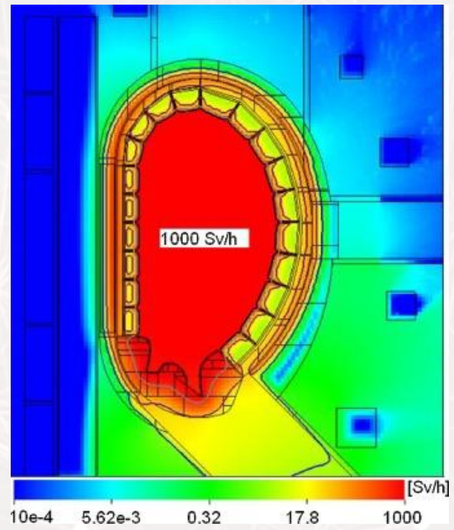
1. **DEMO**, the demonstration power plant, aims to demonstrate the economic viability of fusion power for widespread use in the 2050s. Maintenance is amongst its primary concerns.

2. Why is Fusion Maintenance so Difficult?

Fusion is the intersection between **delicate scientific apparatus** and **heavy duty engineering**.

A robotic solution for DEMO must:

- handle a **heterogeneous** set of **100-200 robots,** an intimidating number for modern robotic solutions,
- be '**always-on**' - unlike many robotic systems, the uptime of the system will be long enough for the robots and environment to **evolve** during runtime,
- reason about **hazard** and provide **safety evidence** - robots must be able to minimise the hazard to which they expose themselves, while providing assurances that they are maximising the safety of the system.



2. The radiation distribution inside the DEMO tokamak, 2 months after shutdown[1]. A lethal dose to humans is about 5 - 10 Sv.

3. My Research

- I want to tackle the scalability issue using a system of **partitioning**.
- The set of maintenance tasks is partitioned into **remits** which each contain a sub-set of tasks and an operational area, inspired by psychology literature on **human teamwork**.
- Sufficiently **independent** remits will not interfere with each other's planning → Can be **planned for independently**, which is much easier from a computational perspective.
- Tasks are described using a **potential field** representing the probability that a point in space will be occupied by a robot attempting the task. The cumulative field from every task is divided along its minima to form the remits (see figure 3).
- Tasks also require specific **capabilities** for their completion - for example a visual inspection task requires a visual-spectrum camera. This informs the partitioning to create manageable remits.

[1]: Bachmann et al., Overview over DEMO design integration challenges and their impact on component design concepts, 2018