Constrained Path Planning for Energy Efficiency in Mobile Robots

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Introduction

- Embedded processors and Systems-on-Chip (SoCs) have gained attention in mobile robotics
    - **Reduced size and weight**
    - **High performance-per-watt**

- Many state-of-the-art solutions require **significant computing power**

- As embedded processors become more powerful, **their energy requirements grow as well**

Introduction

- We propose the use of **constrained planning** to implement **energy-efficient path planning** in an embedded mobile ground robot
  - Turtlebot 2
  - Jetson TX2 embedded computer

- The goal is to find **the path which simultaneously minimizes travel distance and increases battery life**

Introduction

- The implemented method will be compared to a conventional path planning method for mobile robots (i.e., D* search), in terms of:
    - **Reliability** (how often the robot reaches its goal);
    - **Battery power consumption**;

- While energy efficiency is normally a bonus of optimal planning, **some works consider this as a key aspect of the path planning problem** [1-5]

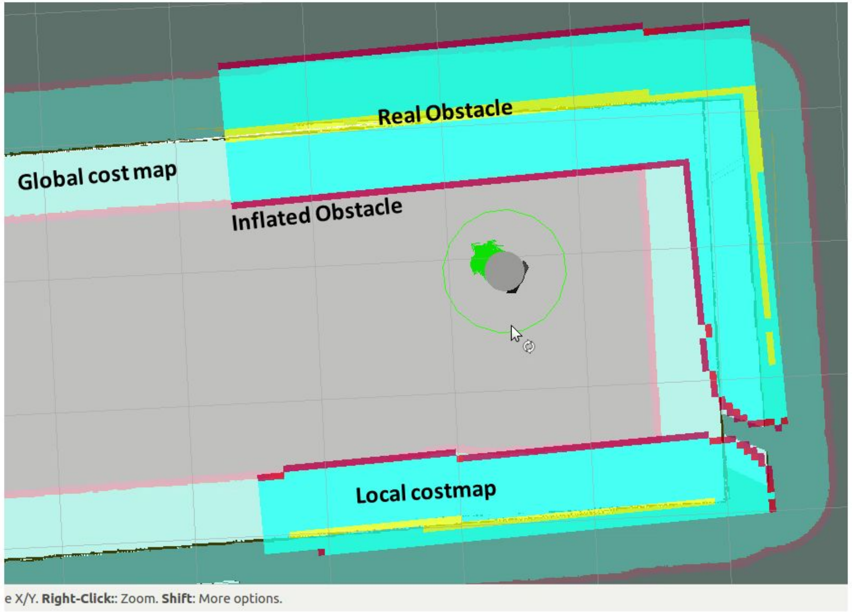
Technical Approach

- The method chosen to implement energy-efficient path planning is **constrained heuristic search**, applied to the domain of automated planning
    - Combines **constraint satisfaction** with **heuristic search**

- Considering **energy restrictions** in mobile robots on top of **distance-based heuristics** naturally fits the definition of constrained heuristic search

Technical Approach

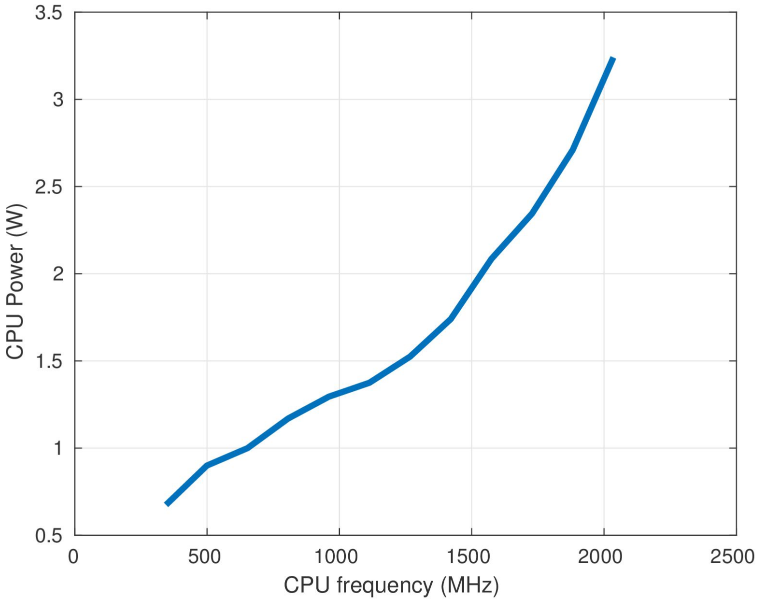
- The idea is to adapt a path planning method for mobile robots (e.g., D*, A*), to include an additional **energy constraint**



- In conventional methods, a “***costmap***” is computed offline for each position in a known map, based on the **distance to obstacles**

Technical Approach

- Let us assume that the robot can adopt different **levels of responsiveness** depending on its CPU frequency
  - Faster frequencies decrease the robot's response time
  - When near an obstacle, the response time must be low to avoid collisions
  - CPU frequency has a **direct influence on the processor's power draw**



Technical Approach

- Thus, we can compute an ***"energymap"*** offline, **mapping the CPU frequencies based on the distance to obstacles**

- **This energy map will be considered alongside the costmap** when performing heuristic search
    - The optimal path will simultaneously minimize energy draw and travel distance between initial and goal positions

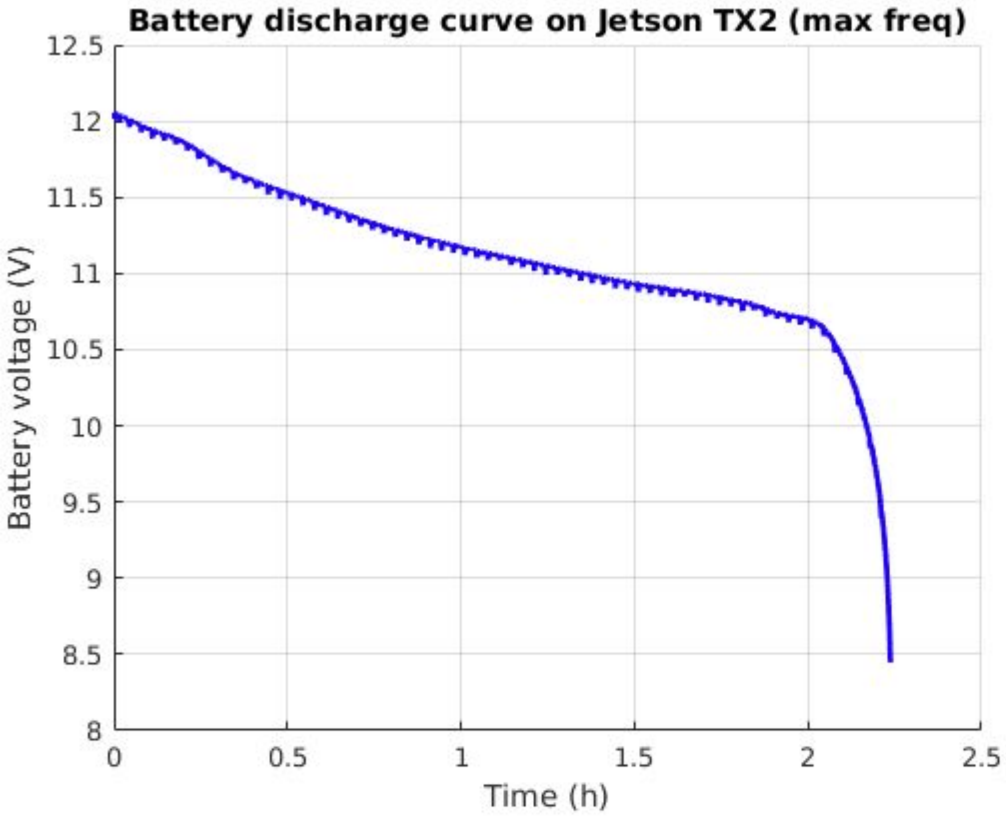
Technical Approach

- To evaluate the solution, it will be implemented in a **Jetson TX2** embedded system, to run on a Turtlebot 2 mobile base
  - The Jetson TX2 has **internal power sensors;**
  - Its power draw due to computation is **the most expressive** when compared with similar embedded systems;

	Max. overall power (W)	Max. power due to computation (W)	Percent of power due to computation
Jetson TX2	9.50	6.96	**73.32 %**
ODroid xu4	**11.52**	**7.15**	62.07 %
Jetson TK1	4.19	2.04	48.69 %
Raspberry Pi 3	4.79	2.20	46.41 %

- The Jetson's battery level will be monitored as the robot performs autonomous navigation
  - The expected result is an increase in battery life, compared to conventional path planning methods

Technical Approach



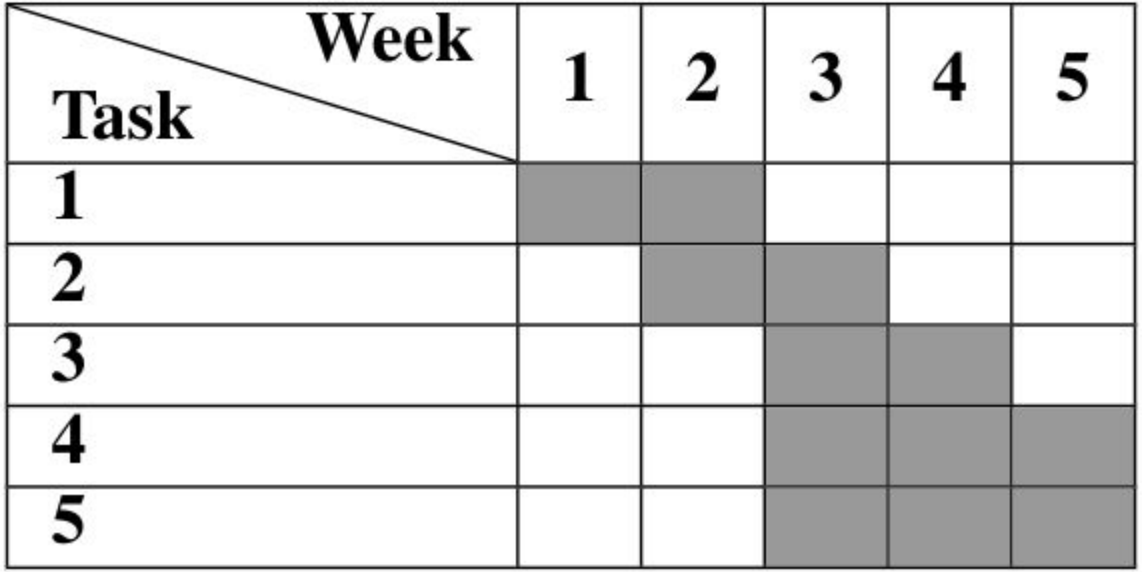
Project Management

- The main tasks in this project are:

1. **Define** the constrained planning problem for the domain of energy-efficient path planning;
2. **Implement** and validate the proposed solution;
3. **Integrate** the solution with the Turtlebot 2;
4. **Measure** the battery discharge curves for the proposed solution and for a conventional path planner;
5. **Compare** the results and write a report;

Project Management

Table 2: Tentative time schedule for completing the project's tasks



- Week 1 starts on October 11 and week 5 ends on November 15

Conclusion

- We have proposed the **implementation of an energy-efficient path planning solution** to mobile robots, based on constrained heuristic search
    - Considers the **relationship between power draw and CPU frequency** as a constraint in heuristic search
    - Optimal path **minimizes both travel distance and energy consumption**

- The expected result is an **increase in battery life** when using our energy-aware path planning method, compared to common heuristic search algorithms (e.g., D*)

References

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