GPU accelerated SLAM and Particle Filter

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1 Introduction

Mapping of the environment using sensor data is an important problem in robotics and even more in autonomous cars. Fusion of this data helps us to build a spacial model of the physical environment around the vehicle and also to know its position in the world if the spacial model is already available. This information is very crucial for making decisions while planning trajectories to the destination. In case of autonomous cars which typically travel at 60mph(88ft/s), it is crucial to update its position and map the surroundings at a very high rate. This project aims at speeding up one such mapping algorithm called Simultaneous Localization and Mapping(SLAM)[1] using Monte Carlo Localization utilizing the parallelism of the GPU.

The project will be split into two parts.

- Particle Filter[2]: The first part involves building a particle filter. This algorithm helps to localize the car in the given map of the environment. To achieve this, the algorithm starts with a uniform random distribution of particles. Then it uses the sensor information to determine which particle represents the best estimate of the attitude of the car. As the car moves, the estimate of how well each particle performs is tracked.
- SLAM: Particle filter algorithm can be further extended to simultaneously localize & build the map as the car moves through an unknown environment using an occupancy grid.

2 Implementation

The following stages are involved,

a) Initialize a uniform distribution of particles
b) Perform kinematics update of vehicle
c) Calculate correlation score of particles
d) Update Particle weights
e) Choose best particle and update map
f) Recalibrate weights if needed.

A Matlab implementation of a robot moving around moore 2nd floor and performing SLAM can be seen in this video. The red dots is the point cloud from the 2D LiDAR scanner. Black pixels are the walls and the green trace is the path followed by the robot.
https://www.youtube.com/watch?v=ykQvQrcE3Xk

3 Platform

The hardware to be used for the project is Nvidia Jetson TK1 or TX1 mounted on a 1/10th scale autonomous race car(www.f1tenth.org). A Lidar sensor and a camera would be used for sensing the environment. The project would be implemented on Robot Operating System(ROS)[3] framework. It provides us abstraction to variation of data formats of different sensors and also allows easy flow of data between other modules of the vehicle(planning and control). C/C++ would be used as the primary language and CUDA for GPU implementation.

4 Goals

The project will be divided into the four stages

1. **Milestone 1:** Setting up of environment(hardware & software) and sensor configuration
2. **Milestone 2:** CPU and GPU implementation of Particle Filter.
3. **Milestone 3:** GPU implementation of SLAM.
4. **Milestone 4:** GPU vs CPU performance analysis of various stages and testing car in the corridor for performance.