Bayesian Particle Filter Tracking with CUDA

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Motivating Example

A submarine with a hydrophone (passive sonar) is following another ship using the direction of the sound from the ship's engine.

How can the series of bearing observations from the hydrophone be used to estimate the second ship's position and velocity?

Likelihood Function

$$L(y|x) = P(Y = y|X = x) \quad \text{for} \quad x \in S \tag{1}$$

- X Random variable on S
- Y Random variable on measurment space H
- $P(\cdot|x)$ Probability density function on H
- $P(y|\cdot)$ Likelihood function relating X and Y

Bayesian Inference

$$P(x|y) = \frac{L(y|x)P(x)}{P(y)} = \frac{L(y|x)P(x)}{\int L(y|x)P(x)\,dx} \tag{2}$$

- Observation y is fixed, x represents possible target states
- $P(x)$ Prior probability density function on true target state
- $P(x|y)$ Posterior distribution given observation y

Prior Distribution

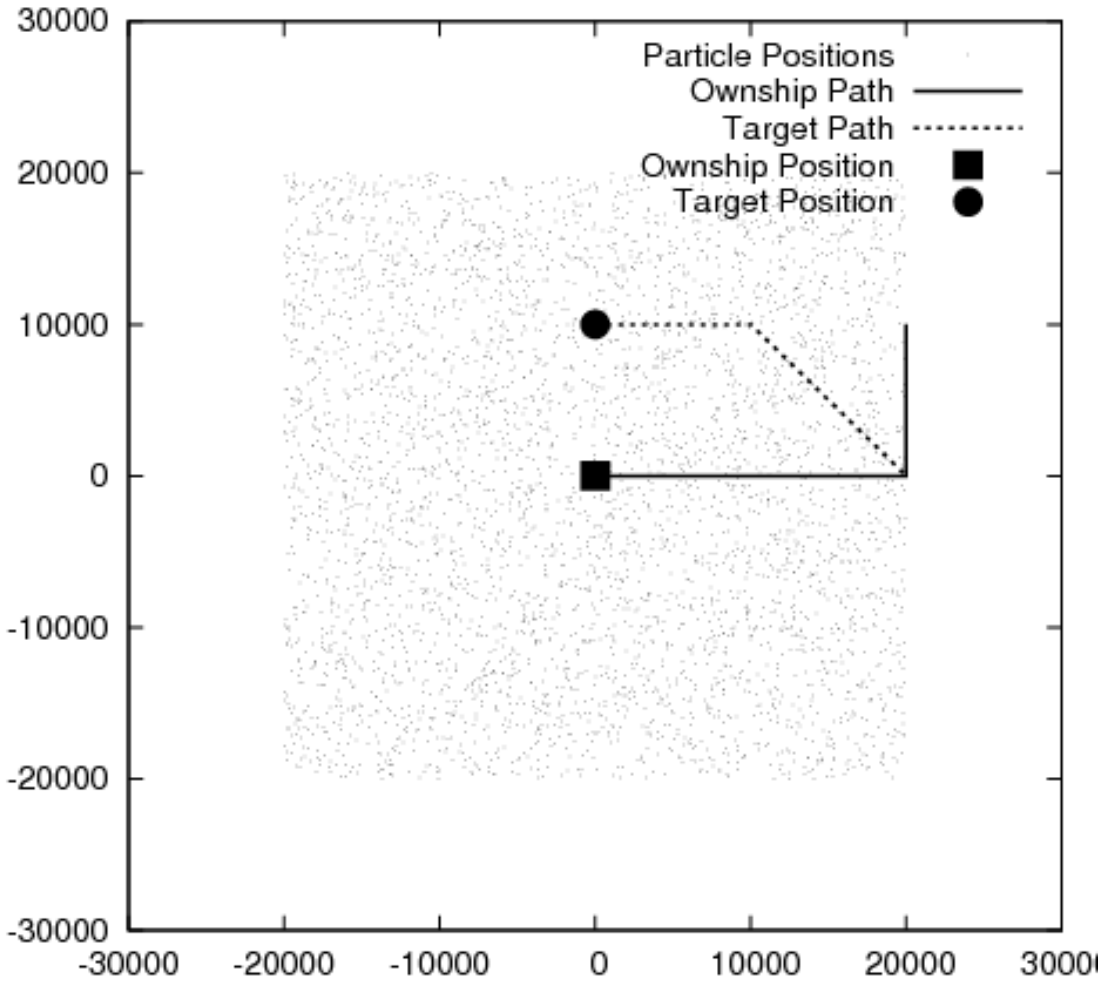


Figure: Prior Particle Position Distribution

Information Update

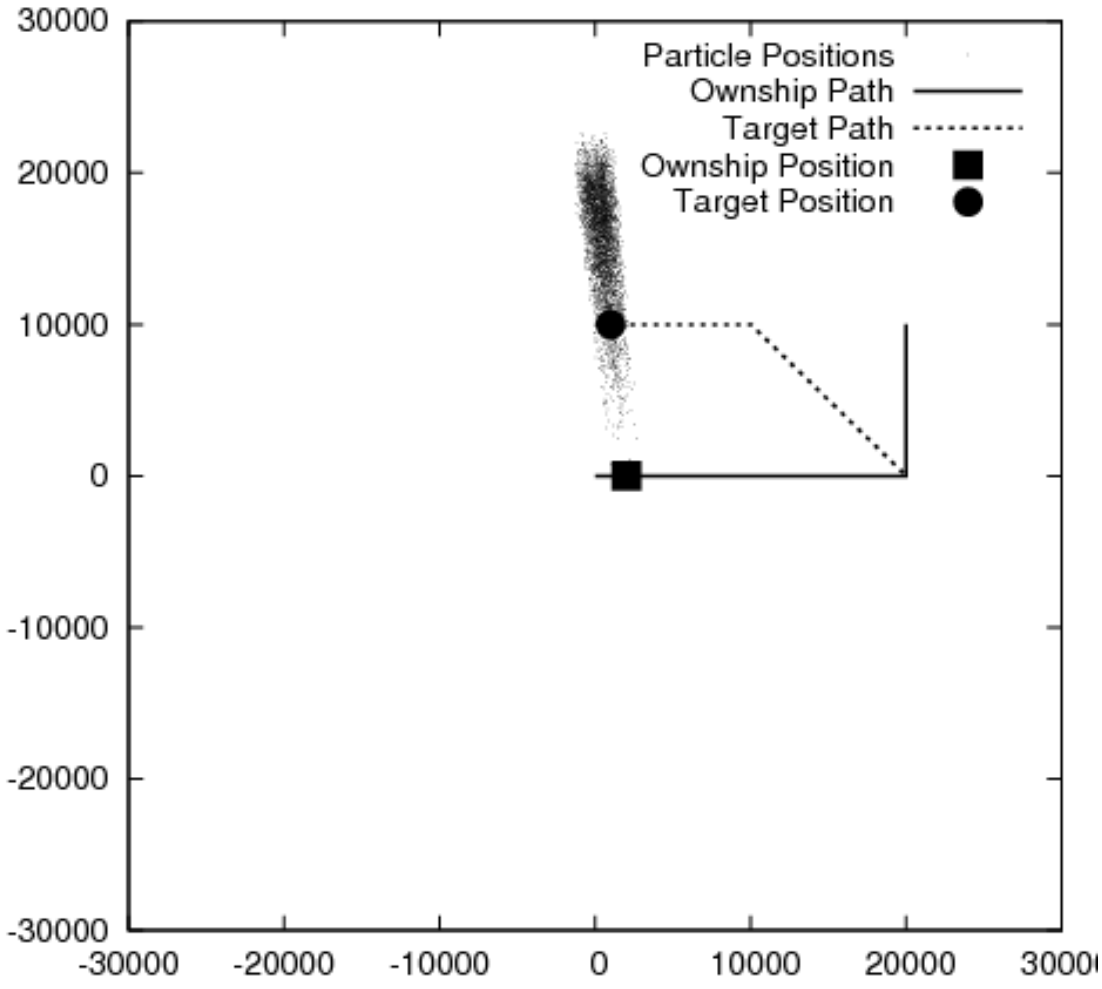


Figure: Posterior Particle Position Distribution after Azimuth Observation

Motion Model

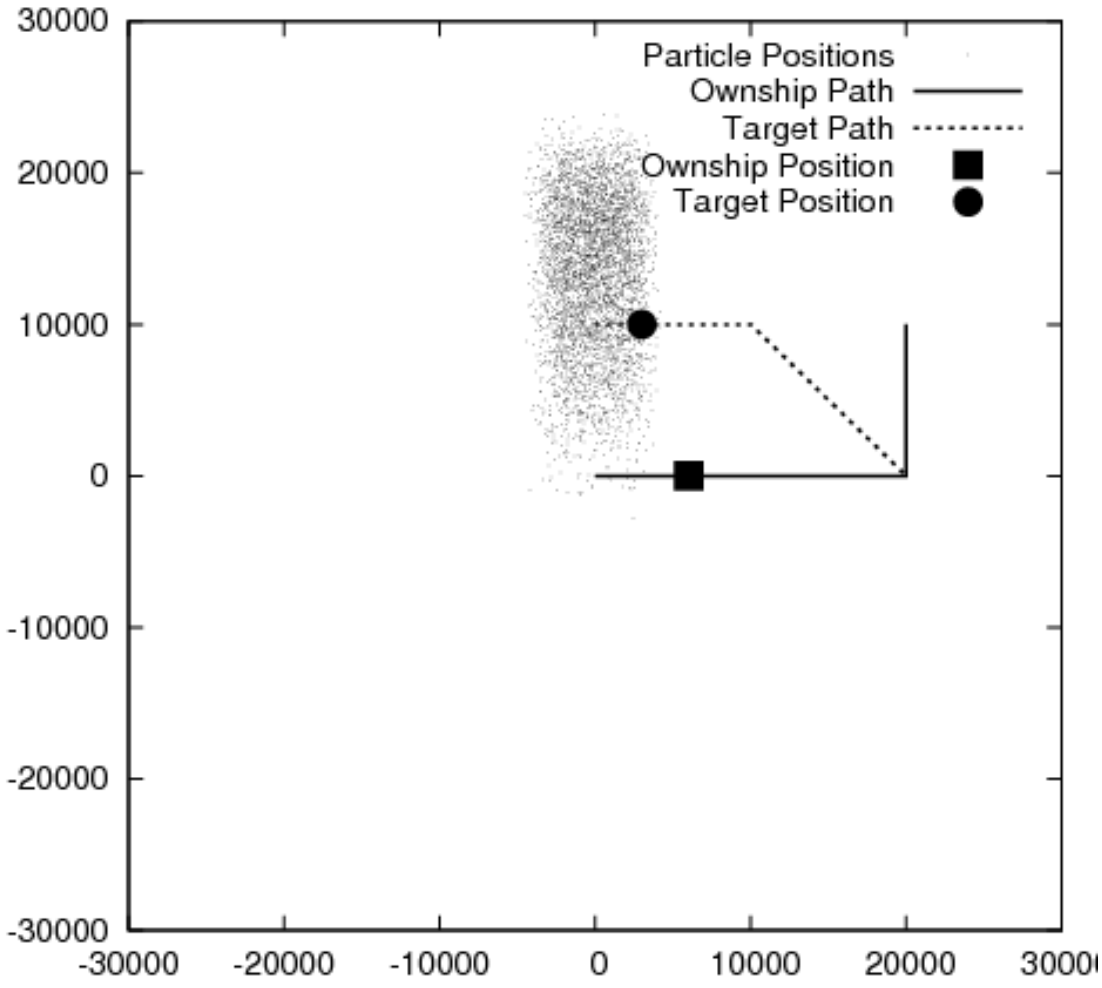


Figure: Posterior Particle Position Distribution after Motion Update

Resampling

$$C = \frac{n}{\sum_{i=0}^{n} w_i} \tag{3}$$

- w_i Particle weights
- n Number of particles
- C Normalizing constant

Example w_i Array

0.8	0.4	6.6	0.6	1.6

$$C = \frac{5}{10} = 0.5$$

Resampling

$$\overline{w}_i = C w_i \tag{4}$$

Example $\overline{w}_i$ Array

0.4	0.2	3.3	0.3	0.8

Resampling

$$\hat{w}_i = \text{floor}(\sum_{j=0}^{i} \overline{w}_j) \tag{5}$$

Example $\hat{w}_i$ Array

0.4	0.6	3.9	4.2	5.0

0	0	3	4	5

Resampling Results

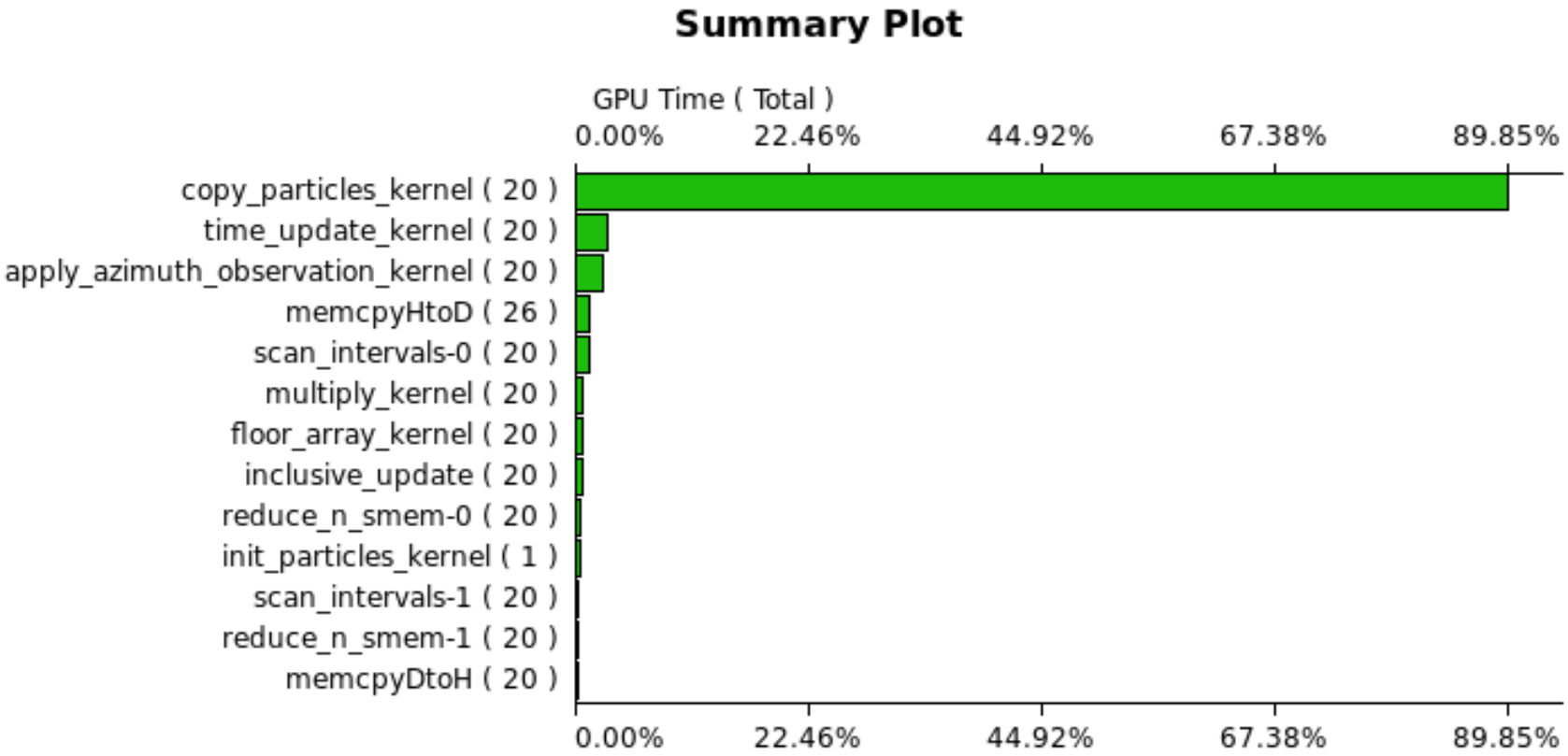


Figure: CUDA Visual Profiler Version 1 Results

Improved Resampling Results

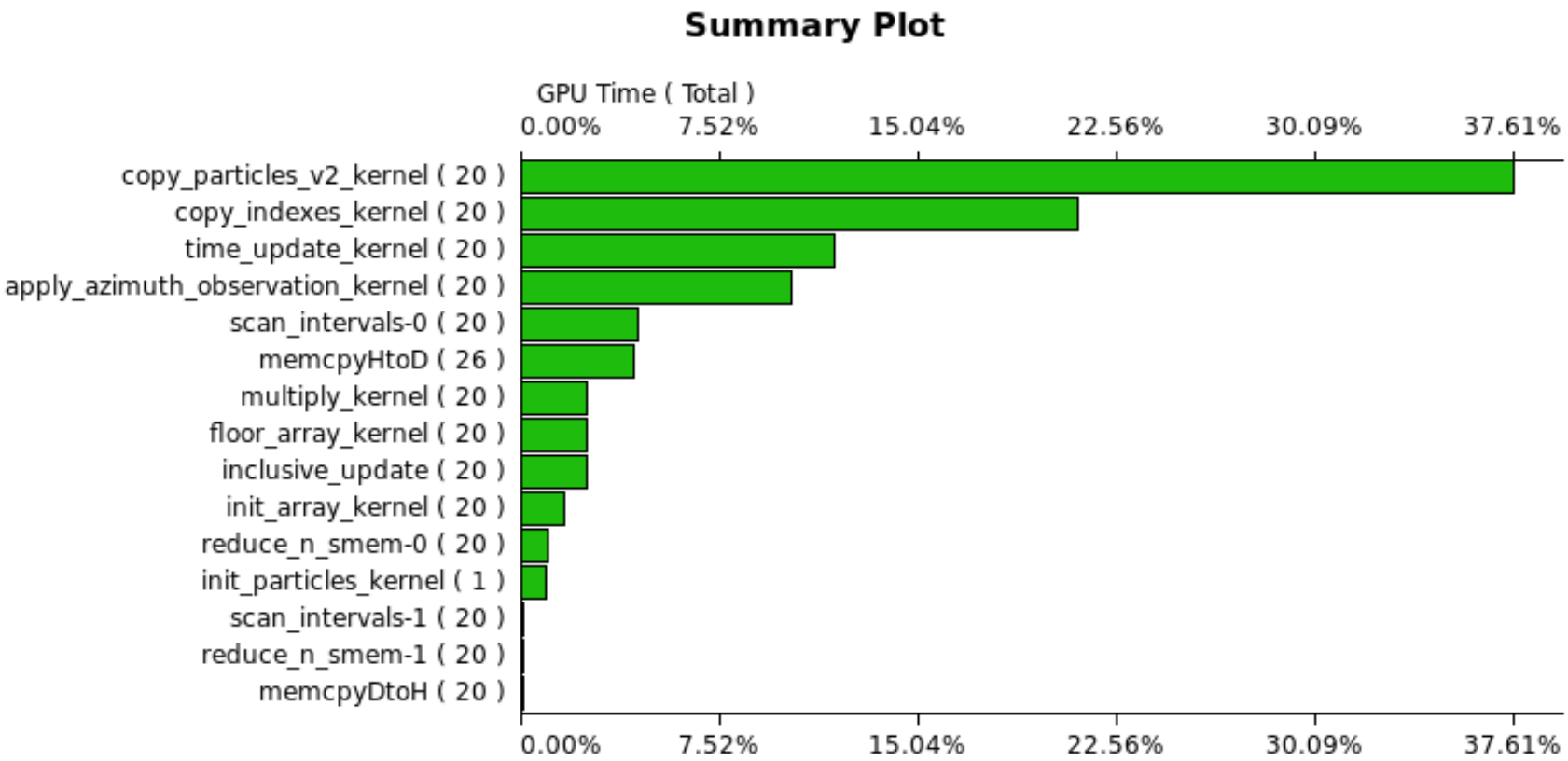
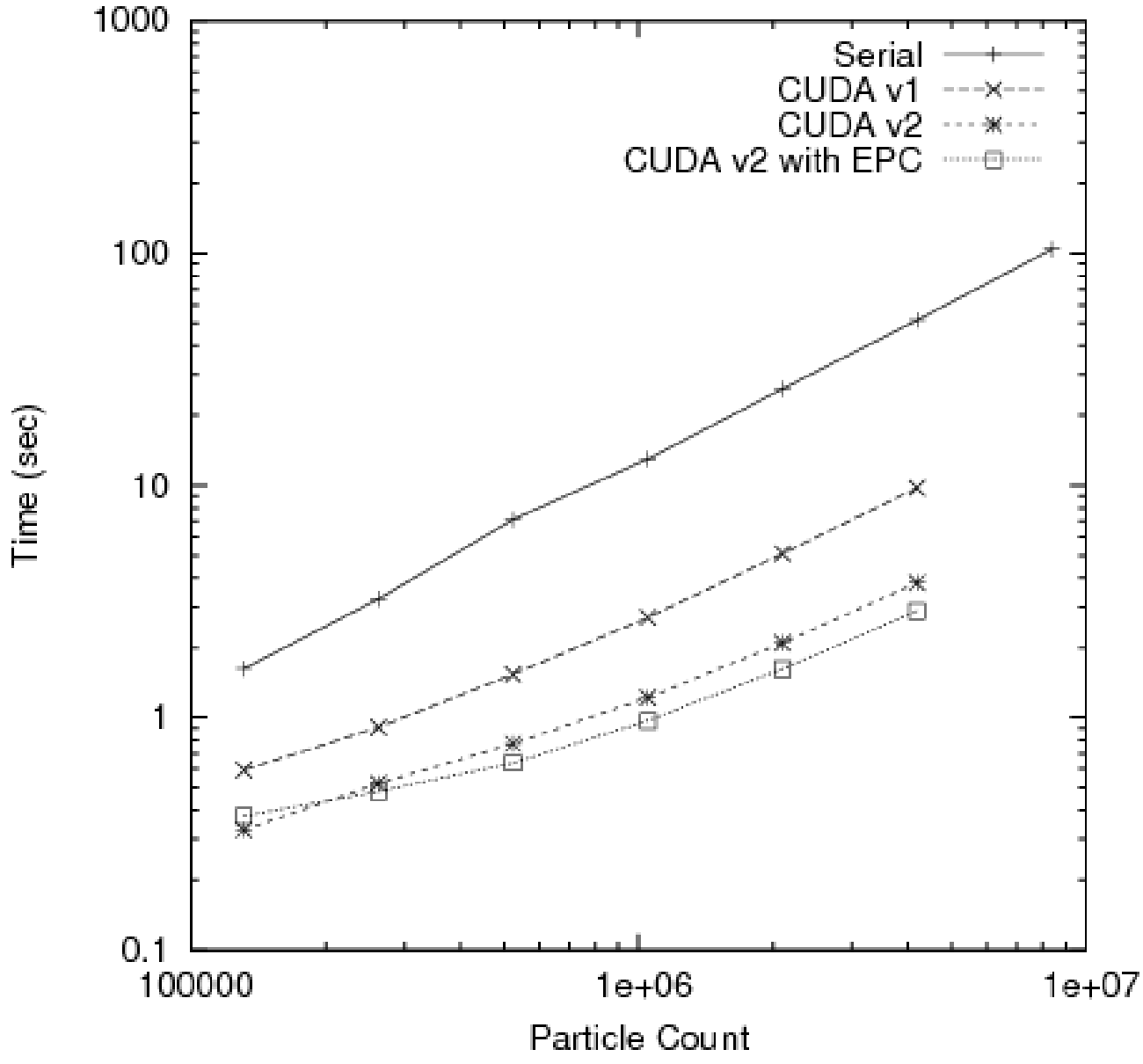


Figure: CUDA Visual Profiler Version 2 Results

Performance



Performance