Particle Filter Speed Up Using a GPU

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By

John Sacha & Andrew Shaffer

Applied Research Laboratory
The Pennsylvania State University
P. O. Box 30
State College, PA 16804

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• Things people want to track
  – Physical objects, using radar and sonar (airplanes, ships, fish schools, …)
  – Time series (financial information, weather statistics, …)
  – Classification features (spectral lines, …)
• Tracking is commonly formulated as a probabilistic state-space problem
  – Chapman-Kolmogorov/Fokker-Planck equations for density evolution
  – Bayesian approach to density updating
• There are few closed-form solutions
  – Gaussianity and linearity assumptions lead to the Kalman Filter
• Simple special-case extensions can be made (e.g., Extended Kalman Filter, mixture models)
• General solutions require use of numeric methods
  – Mesh representations
  – Monte Carlo integration (particle filters)
Particle Filters for Tracking in Complex Environments

• Particle Filters are a sequential Monte Carlo methodology for state estimation in which collections of weighted point particles are used to model state probability density functions.
• Able to handle complicated non-Gaussian and non-linear problems not easily solvable by Kalman Filters.
• Approximate solution to the exact problem, rather than an exact solution to an approximate problem.
• Other names:
  – Condensation Trackers
  – Bootstrap Filters
  – Survival of the Fittest
• Appropriate for:
  – Applying non-linear constraints
    • Boundaries
    • Kinematic limitations
  – Handling sensor blind spots (exploiting absence of measurements)
  – Tracking “features”
  – Groups of objects
Particle Filters and GPUs: A Marriage Made in Heaven?

- Particle Filters are flexible and powerful, but ...
  - Accuracy increases with the number of particles
  - So does the computation cost

- Graphic Processing Units
  - Commodity items specialized for gaming/imaging applications
  - Highly parallel co-processors
  - Lots of bang for the buck (and watt)

- Particle Filter paradigm appears well-suited to parallel processing
  - Particles can be propagated independently (mostly!)

Particle Filter Algorithm

State PDF Representation
Collection of particles \( \{(x, w)\} \)

Arbitrary Models
\[
\begin{align*}
x' &= F(x, u) \quad \text{(propagation)} \\
z &= G(x, v) \quad \text{(measurement)}
\end{align*}
\]

Prediction Step:
For each particle:
\[
x'' = F(x, u)
\]

Correction Step:
For each particle:
\[
w'' = P(x'|z)w
\]

Periodic resampling of population:
Cumulative sum of weights
Sorted RNG
Binary search

Possibly Complicated