Voyant

THE EDGE OF DECISION

A VOYANT SERIES OF DEFENCE TECHNOLOGY INSIGHTS

Issue 01

Making sense of uncertainty

How unlocking advanced particle filtering helps defence see more, understand more and navigate in complex environments.

Tomorrow's military advantage will come from extracting more intelligence from the data already available.

Advanced sensing . Multi -sensor data fusion . Trusted autonomy

Why the future of defence tracking lies beyond the Kalman filter

The modern battlespace is changing. Threats are harder to detect, missions are conducted in increasingly complex environments, and radar, sonar and electronic warfare systems are generating more data than ever before.

Yet generating more data does not automatically deliver better decisions. Much of the huge volume of raw data produced by sensors never becomes operationally useful. The reason lies in the tracking filter at the heart of every sensing system.

Conventional tracking filters fundamentally limit how uncertainty is represented, inevitably discarding valuable information in the process. The choice of tracking filter therefore has a direct impact on what an operator sees, how confidently threats can be identified and tracked, and ultimately, how quickly critical decisions can be made.

Key insight

The quality of decisions is limited by the quality of information extracted from sensor data.

Better tracking unlocks better decisions.

The Kalman filter: a well-proven starting point

For decades, the Kalman filter and its derivatives have been the foundation of target tracking. Their speed, efficiency and mathematical elegance have made them the industry standard for radar, sonar and electronic warfare systems.

However, today's operational environments are becoming increasingly difficult to model using the assumptions on which conventional tracking relies.

This may result in reduced tracking confidence, temporary track loss, track swaps between closely spaced targets and an increased risk of genuine threats being masked by false contacts or decoys.

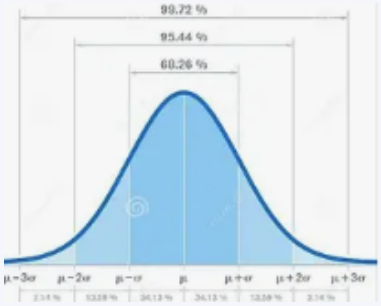
Operational impact

- Track swaps between closely spaced targets
- Temporary track loss
- Threats masked by clutter, deception or decoy
- Slower, less confident decision-making

About the Kalman filter

A Kalman filter estimates the position and movement of a target by combining previous track information with new sensor observations. Rather than retaining every possible interpretation of the data, it represents uncertainty using one or more Gaussian (bell-shaped) probability distributions.

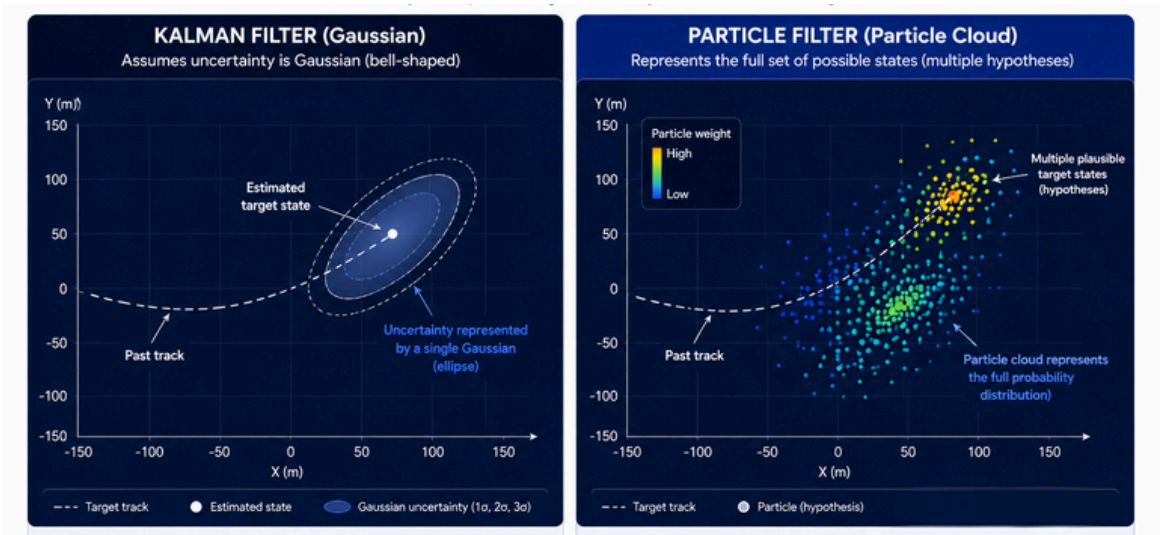
This makes the process computationally efficient and highly effective when targets behave predictably and sensor observations remain relatively clean. As operational environments become more complex and uncertainty becomes multi-modal, these assumptions become increasingly difficult to maintain.



The alternative: Particle filter tracking

A particle filter takes a fundamentally different approach. Rather than simplifying uncertainty using one or more Gaussian distributions, it represents the full range of possible target states using hundreds of individual "particles", each representing a different hypothesis about a target's position, movement or behaviour. As new sensor data become available, hypotheses that better explain the evidence gain confidence, while less likely alternatives are progressively discarded.

By preserving multiple plausible explanations until sufficient evidence emerges, particle filters retain far more of the information contained within uncertain or ambiguous observations. This makes them particularly well suited to the complex, non-linear and non-Gaussian conditions encountered in modern defence operations. In practice, they can provide greater tracking confidence, improved discrimination between genuine targets and clutter or decoys, and more robust track continuity when observations are intermittent, degraded or deliberately contested.



Key takeaway: Kalman filters commit to one answer. Particle filters keep many possibilities alive until the evidence resolves the ambiguity.

Why aren't particle filters used more widely in defence?

The barrier has been compute.

Despite their advantages, particle filters have historically seen limited operational use because of one fundamental challenge: computational demand.

Unlike conventional tracking algorithms, particle filters may require hundreds of hypotheses to be evaluated every time new sensor data is received. As the complexity of the environment increases, so too does the processing power needed to maintain accurate tracking.

For defence platforms, this creates a significant constraint. Every additional watt devoted to onboard processing is unavailable for propulsion, sensing, communications or mission payloads. On autonomous and edge platforms, where size, weight and power (SWaP) are tightly constrained, computational efficiency becomes an operational requirement rather than simply a technical consideration.

The challenge has therefore never been whether particle filters offer superior tracking performance. It has been how to deliver that performance within the computing resources available on operational platforms. A more computationally efficient tracking architecture delivers benefits far beyond tracking accuracy.

By reducing processing demand, it can extend platform endurance, reduce SWaP requirements, and ultimately increase mission effectiveness.

Onboard compute resources are always in demand

Voyant's breakthrough

A more intelligent approach to advanced particle filtering

Standard host computing

Runs on existing processing hardware. No dedicated accelerators required

Software-defined

Integrates as a software enhancement with existing radar, sensor and EW systems

Platform agnostic

Applicable across maritime, air, land, and other domains.

More than 20 years of specialist research has developed Voyant's deep, highly specialised technical know-how in particle filtering.

This expertise enables Voyant to identify the most intelligent approach for the problem and assemble the best 'team' for the job: using fewer, smarter particles to track down the most promising possibilities, or a larger number to explore many possibilities at once.

Think of it like a team of detectives — sometimes you want a few sharp investigators chasing the strongest leads; sometimes you want a larger team casting a wider net.

The result is a scalable, platform-agnostic capability that delivers greater detection range, improved target discrimination and enhanced tracking confidence in the congested and contested environments where these advantages matter most - within the power, size and hardware constraints of operational platforms.

Voyant is unlocking a fundamentally more intelligent approach to particle filtering — **overcoming the traditional computational barrier to make its advanced capabilities accessible to operational defence systems.**

Why this matters

As the battlespace grows more congested, contested and autonomous, defence organisations must extract greater value from existing sensors while operating within increasingly constrained SWaP requirements.

While Kalman filters remain well suited to many operating environments, the complexity and uncertainty of modern operations increasingly demand more advanced approaches capable of maintaining and interrogating multiple possibilities as conditions evolve.

Voyant's advanced particle-filter expertise makes this capability practical on existing host computing – delivering earlier threat detection, greater tracking confidence and enhanced situational awareness within the hardware, power and processing constraints of operational platforms.

Detect earlier

Track with greater confidence

Decision advantage

Tomorrow's military advantage will come from extracting more intelligence from the data already available.

Key Takeaways

- Defence has more sensor data than it can effectively exploit.
- Conventional approaches can lose valuable information by narrowing uncertainty too early.
- Particle filters preserve multiple possibilities, providing greater robustness in complex environments, but computational demand has historically constrained their operational adoption.
- Voyant's 20+ years of specialist know-how enables particle filtering to be applied far more intelligently.
- The result: advanced tracking, insight and navigation within real-world platform constraints.