

## QUICK START GUIDE

# Getting Started with Sensor Fusion and Tracking Toolbox™

## Definitions of Localization-Related Terms

**Accelerometer:** a sensor that measures the object acceleration.

**Gyroscope:** a sensor that measures the object angular velocity.

**Magnetometer:** a sensor that measures the magnetic field around the object.

**IMU:** inertial measurement unit. A device that consists of accelerometers and gyroscopes.

**MARG:** magnetic, angular rate, and gravity (aka magnetometer, gyroscope, and accelerometer).


**AHRS:** attitude and heading reference system. A system that fuses accelerometers, gyroscopes, and magnetometers and provides object attitude information (MARG plus fusion algorithm).

**GPS:** global positioning system. A satellite-based system that provides accurate positioning.

**INS:** inertial navigation system. A system that fuses data from accelerometers, gyroscopes, magnetometers, and sometimes altimeters to continuously calculate the position, orientation, and velocity of moving objects without an external source.

**GPS/INS:** A system that fuses GPS information with INS information.

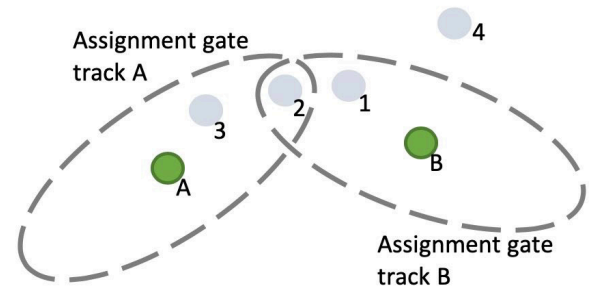
## Types of Tracking Filters and How to Choose the Right One

Filter Name	Supports Non-Linear Models	Gaussian Noise	Computational Complexity	Comments
Alpha-Beta				Sub-optimal.
Kalman		✓		Optimal for linear systems.
Extended Kalman	✓	✓		Uses linearized models to propagate uncertainty covariance.
Unscented Kalman	✓	✓		Samples the uncertainty covariance to propagate it. May become numerically unstable in single-precision.
Cubature Kalman	✓	✓		Samples the uncertainty covariance to propagate it. Numerically stable.
Gaussian-Sum	✓	✓ Assumes a weighted sum		Good for partially observable cases (e.g., angle-only tracking).
Interacting Multiple Models (IMM)	Multiple Models	Assumes a weighted sum of distributions		Maneuvering objects (e.g., acceleration, turns).
Particle	✓	Can be any distribution		Samples the uncertainty distribution using weighted particles.

## Assignment Algorithms and Trackers

A key stage in multi-object tracking is assigning new sensor detections to existing tracks. The diagram shows two tracks (A and B) and four detections (1–4).

The assignment algorithms below are used to solve this problem, also known as the 2D (or bipartite) assignment problem.



Assignment Name	Description	Example Result	Algorithms
Global nearest neighbor (GNN)	Single-hypothesis assignment, optimal.	Det 3 to Track A Det 1 to Track B Dets 2 and 4 unassigned	<code>trackerGNN</code> <code>assignmunkres</code> <code>assignjv</code> <code>assignauction</code>
Joint probabilistic data association (JPDA)	The likelihood of each detection to be assigned to a track is calculated, considering all tracks.	Det 3 very likely to A Det 1 very likely to B Det 2 somewhat likely to A and B Det 4 unassigned	<code>trackerJPDA</code> <code>jpdaEvents</code>
Track-oriented multiple-hypothesis tracking (TOMHT)	Each track creates branches (hypotheses) for every possible assignment and no assignment.	Det 3 creates branch A3 Det 2 creates branch A2 Det 2 creates branch B2 Det 1 creates branch B1 Branch A0 (A is not assigned) Branch B0 (B is not assigned) New track from each detection	<code>trackerTOMHT</code> <code>assignTOMHT</code>
Hypothesis-oriented multiple-hypothesis tracking (HOMHT)	We consider k-best assignments. Each assignment updates the tracks accordingly.	Best hypothesis = GNN result Another hypothesis: Det 2 to Track A Det 1 to Track B Det 3 and 4 are unassigned	<code>assignkbest</code>
Probability hypothesis density (PHD)	Does not perform assignment. Instead, models the multi-object tracking problem as a set of unknown and random number of objects and estimates the probability in each location based on the detections.		<code>trackerPHD</code> <code>ggiwphd</code> <code>gmphd</code> <code>partitionDetections</code>

### Point Objects

Sensor resolution is lower than object size.

Each object gives rise to at most one detection per sensor scan.

Conventional trackers may be used without preprocessing.

Learn more: [mathworks.com/products/sensor-fusion-and-tracking](https://www.mathworks.com/products/sensor-fusion-and-tracking)

### Extended Objects

Sensor resolution is higher than object size.

Each object gives rise to one or more detection per sensor scan.

Conventional trackers require clustering before assignment.

PHD tracker can be used without clustering.