

# Navigation Toolbox™ Release Notes



# MATLAB® & SIMULINK®



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### *Navigation Toolbox™ Release Notes*

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# R2021a

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**Version: 2.0**

**New Features**

**Bug Fixes**

**Compatibility Considerations**

## Multigraph and Landmark Support For poseGraph and poseGraph3D

The poseGraph and poseGraph3D objects have been updated to support adding multiple edges between nodes and adding landmark points to a pose graph. The addRelativePose function now appends a new edge between specific nodes instead of overwriting the existing edge, which allows one to incorporate multiple sensor readings for node pose estimation. To add point landmarks, use the addPointLandmark function.

## poseGraph and poseGraph3D Object Functions Renamed

These poseGraph and poseGraph3D object functions have been renamed to better reflect their definitions:

Function Name in R2020b and Earlier	Function Name in R2021a
edges	edgeNodePairs
nodes	nodeEstimates

## Multilayer Grid Maps: Sync multiple map layers and store additional dynamic information

The multiLayerMap object groups and stores multiple map layers as binaryOccupancyMap, occupancyMap, or mapLayer objects. Once added, the map layers can be modified together using the multiLayerMap object functions. Individual actions applied to each map are synced with the multilayer map.

Assign and retrieve data from one or more cells in the map using the setMapData and getMapData object functions. Additionally, mapLayer objects can store numeric  $N$ -dimensional arrays, enabling you to store more than just occupancy values in each cell. This feature enables dynamic tracking of obstacles and other more advanced applications for mapping.

Sync data across maps using the syncWith function. Move the map in the world frame using the move function. Convert between grid, local, and world coordinates with other object functions.

## Global Navigation Satellite System Simulation Calculations: Access GNSS constellations, satellite look angles, pseudoranges, and receiver positions

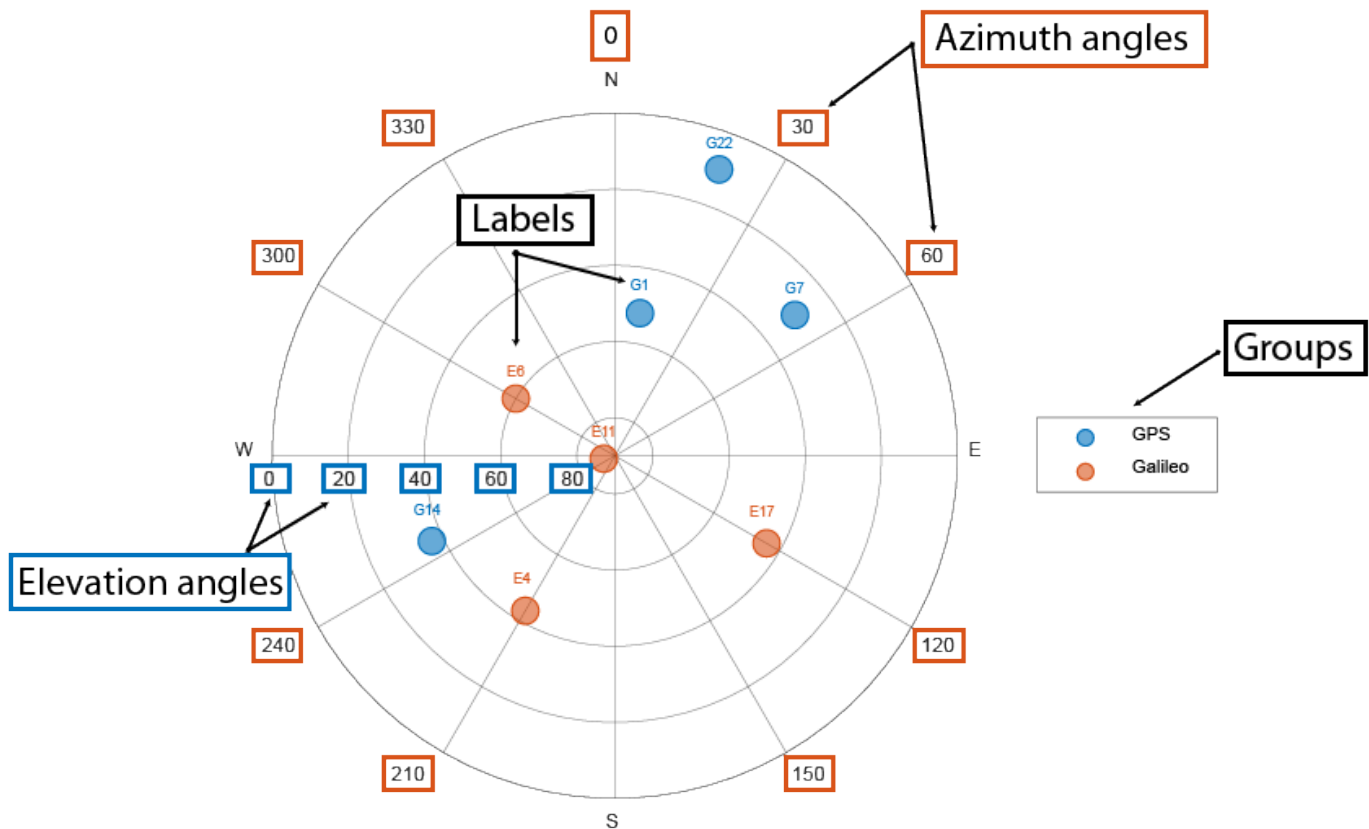
Four new functions related to GNSS simulation have been added:

- `gnssconstellation` — Satellite locations at the specified time.
- `lookangles` — Satellite look angles from receiver and satellite positions.
- `pseudoranges` — Pseudoranges between the GNSS receiver and satellites.
- `receiverposition` — Estimate GNSS receiver position and velocity.

## Sky Plot Visualization: Plot and label satellite positions in a polar plot

The skyplot function plots the azimuth and elevation angles for satellite positions. The function generates the plot as a SkyPlotChart Properties object.





These are the main elements of the figure:

- Azimuth axes — Specified by the `azdata` input argument, azimuth angle positions are measured clockwise from the North direction.
- Elevation axes — Specified by the `eldata` input argument, elevation angle positions are measured as the angle above the horizon line.
- Labels — Specified by the `labeldata` input argument as a string array in which each point in the `azdata` and `eldata` vectors represented by an element.
- Groups — Specified by the `GroupData` property, groups are a `categorical` array in which each satellite position represented by an element.

## Comprehensive support for tuning inertial sensor filters

You can tune the parameters of these inertial sensor filter objects using their `tune` object function:

- `insfilterNonholonomic`
- `ahrs10filter`
- `insfilterMARG`
- `insfilterErrorState`

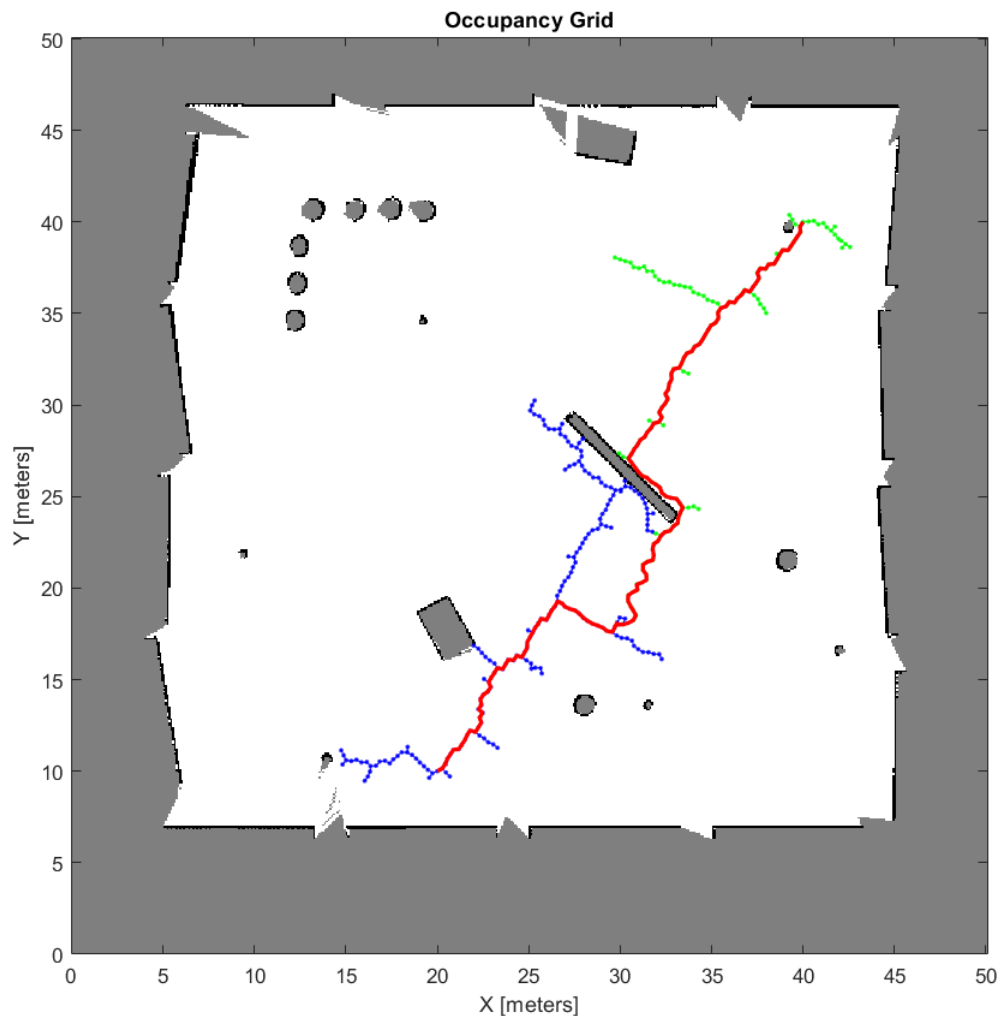
In the previous release, the other three inertial sensor filters (`imufilter`, `ahrsfilter`, and `insfilterAsync`) already supported the `tune` function.

The `tunerconfig` object, which is used to configure the tuning process, has three new properties:

- `Filter` — Class name of the fusion filter
- `FunctionTolerance` — Minimum change in cost to continue tuning
- `OutputFcn` — Output function to show tuning results. For example, you can use the `tunerPlotPose` function to visualize the truth data and state estimates after tuning.

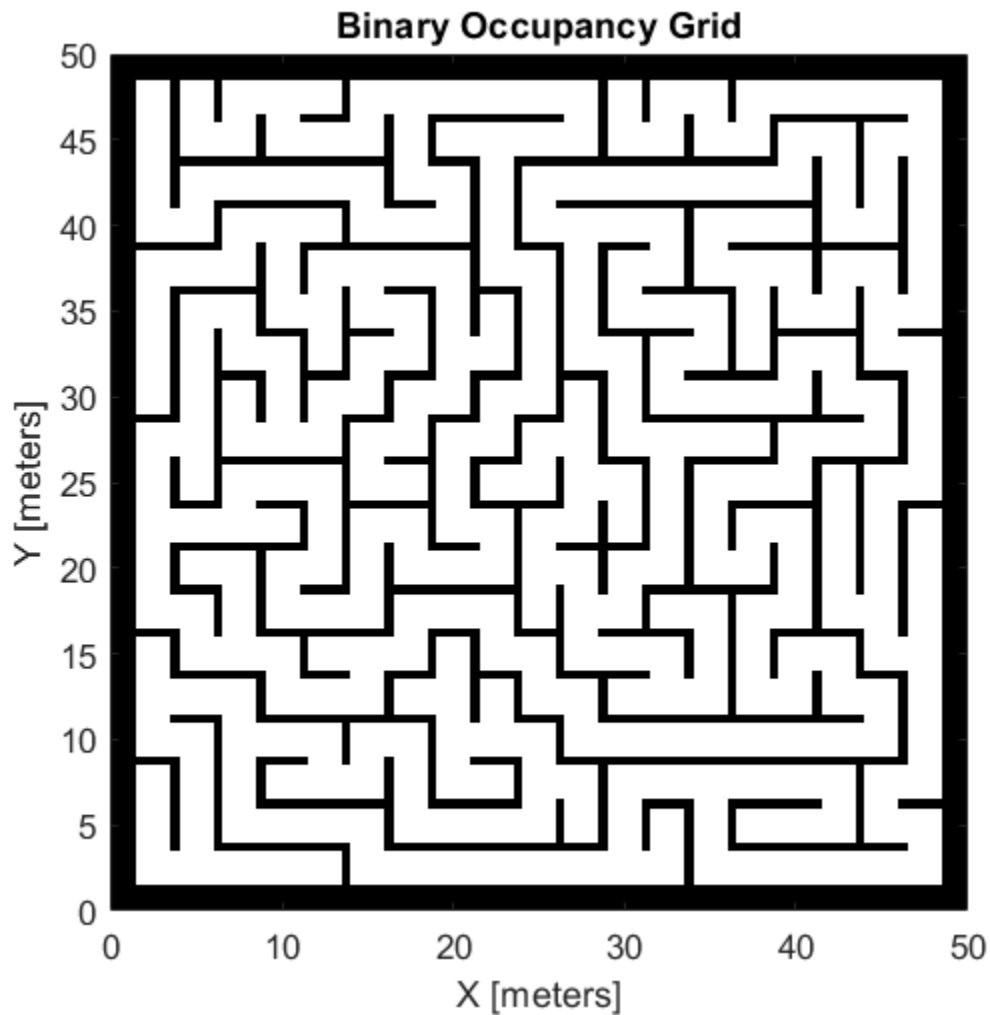
## Bidirectional RRT Path Planner: Plan path using the bidirectional rapidly exploring random tree algorithm

The `plannerBiRRT` object plans an obstacle-free path from a start state to a goal state using the bidirectional RRT algorithm.



## Generate Random Maze Maps for Planner Benchmarking

The `mapMaze` function generates a random maze map.



### **Transform Between Geodetic Coordinates and Local Cartesian Coordinates**

Use these functions to transform between geodetic coordinates and local North-East-Down (NED) or East-North-Up (ENU) coordinates.

- `enu2lla` – Transform local ENU coordinates to geodetic coordinates.
- `ned2lla` – Transform local NED coordinates to geodetic coordinates.
- `lla2enu` – Transform geodetic coordinates to local ENU coordinates.
- `lla2ned` – Transform geodetic coordinates to local NED coordinates.

## **RRT\* Path Planner Improvements: Returns PathCosts field in the solution information structure**

The `plan` function of the `plannerRRTStar` object now returns the `PathCosts` field in the solution information structure.

## **Lidar SLAM Object Update: Specify scan registration method to use while adding scan**

You can now specify which scan registration method to use when adding a scan to a `lidarSLAM` object by using the `ScanRegistrationMethod` property.

The `lidarSLAM` object now supports the `branchAndBound` (default) and `phaseCorrelation` scan registration algorithms. Using the `phaseCorrelation` algorithm requires an Image Processing Toolbox™ license.

## **optimizePoseGraph Function Update**

The `optimizePoseGraph` function now accepts a pose graph representation specified as a `digraph` object whose edges are described by `affine3d` or `rigid3d` objects.

## **NMEA Parser System Object Update: Support for GSV sentences**

You can now use the `nmeaParser` System object to extract National Marine Electronics Association (NMEA) data from GNSS Satellites in View (GSV) sentences that are compliant with the NMEA 0183® specification.

## **updateOccupancy Object Function Update**

The `updateOccupancy` object function now accepts occupancy values as a matrix. The size of the matrix must be equal to the `GridSize` property of the `occupancyMap` object.

## **Use geodetic coordinates as inputs to gpsSensor**

You can use geodetic coordinates as inputs to a `gpsSensor` System object™. To enable this option, specify the `PositionInputFormat` property of the `gpsSensor` object as `'Geodetic'`.

## **insSensor provides more properties to specify its characteristics**

The `insSensor` System object provides six new properties to model an inertial navigation system sensor:

- `MountingLocation` — Location of sensor on platform
- `AccelerationAccuracy` — Standard deviation of acceleration noise
- `AngularVelocityAccuracy` — Standard deviation of angular velocity noise
- `TimeInput` — Enable or disable input of simulation time
- `HasGNSSFix` — Enable or disable GNSS fix

- 
- `PositionErrorFactor` — Drift rate of position without GNSS fix

## **Variable-sized input support for timescope object**

The `timescope` object allows you to visualize scalar or variable-sized input signals. If the signal is variable sized, the number of channels (columns) cannot change.



# R2020b

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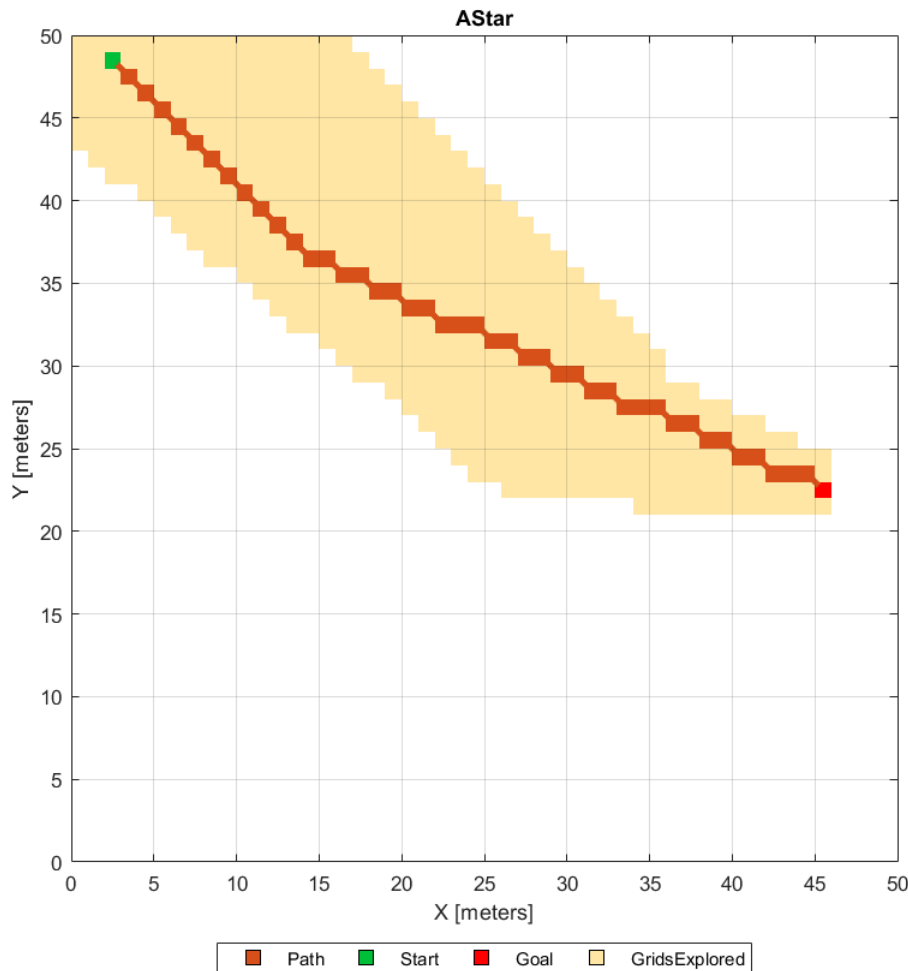
**Version: 1.2**

**New Features**

**Bug Fixes**

## Grid-Based A\* Path Planning: Plan path from start to goal location using the A\* algorithm

Plan a path on a 2-D grid map using the `plannerAStarGrid` object.



## Trajectory Optimal Frenet Utilities: More control in generating optimal trajectory in Frenet space

The `referencePathFrenet` object fits a smooth, piecewise continuous curve to the provided waypoints. Use the object functions to convert trajectories between global and Frenet coordinate systems, interpolate states along the path based on arc length, and query the closest point on the path from a global state.

The `trajectoryGeneratorFrenet` object generates trajectories between the initial and terminal states using fourth or fifth order polynomials. The trajectories are relative to a `referencePathFrenet` object. The `connect` function connects initial states to terminal states over a span of time.



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For more details, see the Highway Trajectory Planning Using Frenet Reference Path example.

## **Dynamic Capsule-Based Obstacle: Model and simulate ego bodies and obstacles using collision primitive objects in environment**

The `dynamicCapsuleList` and `dynamicCapsuleList3D` objects manage two lists of collision primitive objects: ego bodies and obstacles. Use the object functions to dynamically add, remove, and update the geometry and future poses of ego bodies and obstacles in the environment. To validate stored trajectories, use the `checkCollision` function, which checks the collisions between ego bodies and obstacles at each time step.

For more details, see the Highway Trajectory Planning Using Frenet Reference Path example.

## **SLAM Map Builder Update on Data Import: Import lidar scans and odometry data from MATLAB workspace**

The **SLAM Map Builder** app now allows you to import lidar scans and odometry data from the MATLAB® workspace. To import data from the workspace, select **Import > Import from workspace**. Workspace import does not require a ROS Toolbox license.

## **Pose Graph Optimization Updates: Additional optimization functionality for pose graphs**

The `poseGraph` and `poseGraph3D` objects now support the `edgeResidualErrors` function. This function computes edge residual errors for each edge in the pose graph given the current pose node estimates.

The `trimLoopClosures` function optimizes pose graphs by removing bad loop closure edges that would otherwise cause edge residual errors.

The `poseGraphSolverOptions` function creates solver options for pose graph optimization.

## **Wheel Encoder Sensor Models: Simulate wheel encoder sensor readings**

Use provided sensor models to simulate wheel encoder sensor readings for various types of vehicles. Wheel encoder sensor models include:

- `wheelEncoderAckermann` object
- `wheelEncoderBicycle` object
- `wheelEncoderDifferentialDrive` object
- `wheelEncoderUnicycle` object

## **Wheel Encoder Odometry: Compute vehicle odometry using wheel encoder sensor readings**

Use provided odometry models to compute vehicle odometry of various types of vehicles using wheel encoder sensor readings. Wheel encoder odometry models include:

- `wheelEncoderOdometryAckermann` object
- `wheelEncoderOdometryBicycle` object
- `wheelEncoderOdometryDifferentialDrive` object
- `wheelEncoderOdometryUnicycle` object

### **INS Sensor Model: Simulate inertial navigation and GPS readings**

Use the `insSensor` object or INS block to simulate inertial navigation and GPS readings.

### **GNSS Sensor Model: Simulate GNSS receiver readings**

Use the `gnssSensor` object to simulate Global Navigation Satellite System (GNSS) receiver readings.

### **Code Generation for 3-D Occupancy Map: Generate C/C++ code using `occupancyMap3D` object**

You can now generate code when using the `occupancyMap3D` object.

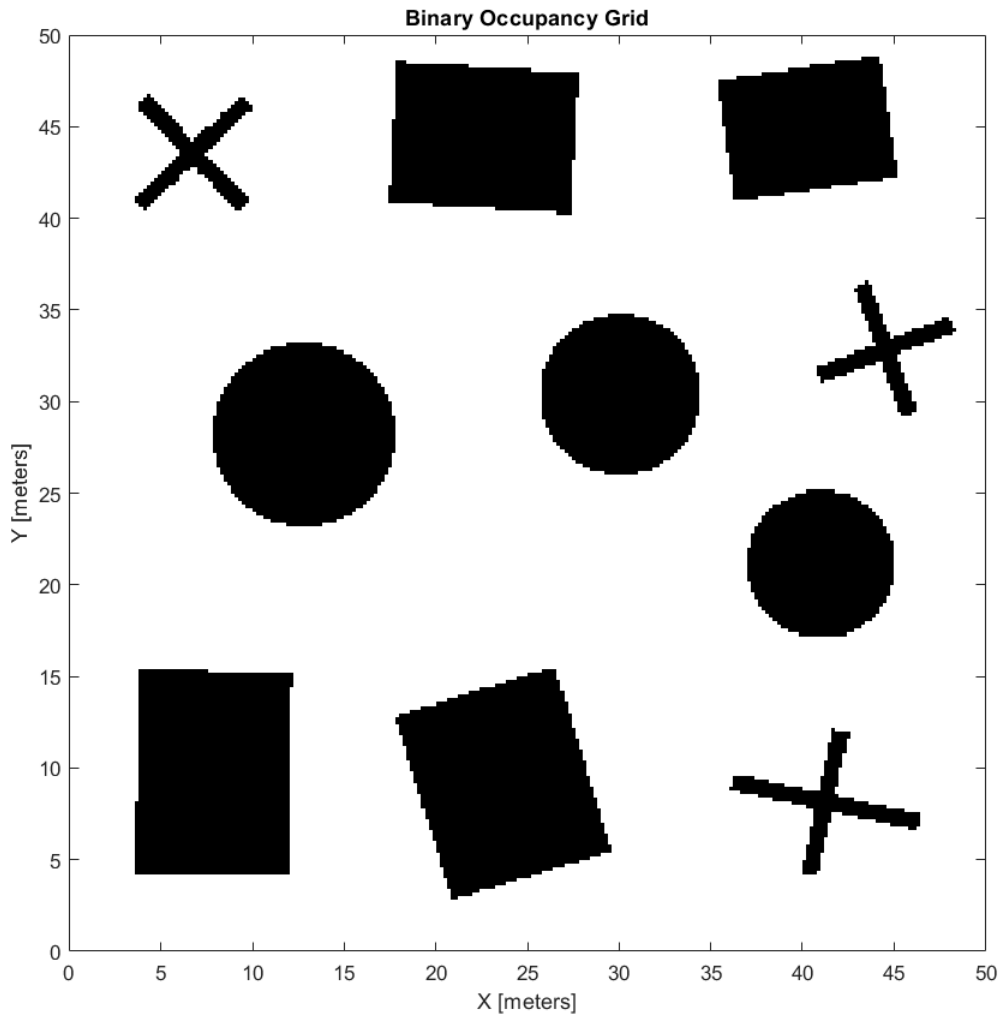
### **State Space and State Validator for 3-D Occupancy Map**

Use the `stateSpaceSE3` object to store parameters and states in the 3-D state-space representation.

Use the `validatorOccupancyMap3D` object to validate SE3 states in a 3-D occupancy map.

### **Generate Random Grid Maps for Planner Benchmarking**

Use the `mapClutter` function to generate a map with randomly scattered obstacles.



## Adjust Inertial Sensor Fusion Performance Using Filter Tuner

Use the `tune` function and the `tunerconfig` object to adjust the properties of the `imufilter`, `ahrsfilter`, and `insfilterAsync` objects. Adjusting these properties can impact performance.

For more details, see the Automatic Tuning of the `insfilterAsync` Filter example.

## GPS Device Object: Connect to GPS receiver from host computer

Use the `gpsdev` object to create connection to a GPS receiver connected to the host computer running Navigation Toolbox™. You can create the object either by specifying the serial port as an input argument or by using the `serialport` object from MATLAB.

After you create the `gpsdev` object, use these functions to perform further actions:

- `read` — Obtain GPS data like latitude, longitude and altitude (LLA), ground speed, course, dilution of precisions, and GPS receiver time, along with timestamp and overrun information.
- `flush` — Clear the software buffers and serial port buffers.
- `writeBytes` — Write raw data to configure the GPS receiver.

### **NMEA Parser Object: Parse data from standard NMEA sentences sent from GNSS receivers**

Use the `nmeaParser` object to parse data from some of the standard NMEA (National Marine Electronics Association) sentences that are compliant with the NMEA 0183® specification.

The `nmeaParser` object parses data sent from GNSS receivers and identified by these NMEA message types: RMC, GGA, GSA, VTG, GLL, GST, ZDA, and HDT. The object outputs an array of structures corresponding to the data extracted from the requested NMEA message types.

### **Time Scope object: Bilevel measurements, triggers, and compiler support**

The `timescope` object now includes support for:

- Bilevel measurements - Measure transitions, overshoots, undershoots, and cycles.
- Triggers - Set triggers to sync repeating signals and pause the display when events occur.
- MATLAB Compiler™ support - Use the `mcc` function to compile code for deployment.

### **New examples**

This release contains several new examples:

- Wheel Encoder Error Sources
- Highway Trajectory Planning Using Frenet Reference Path
- GNSS Simulation Overview
- Automatic Tuning of the `insfilterAsync` Filter

# R2020a

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**Version: 1.1**

**New Features**

**Bug Fixes**

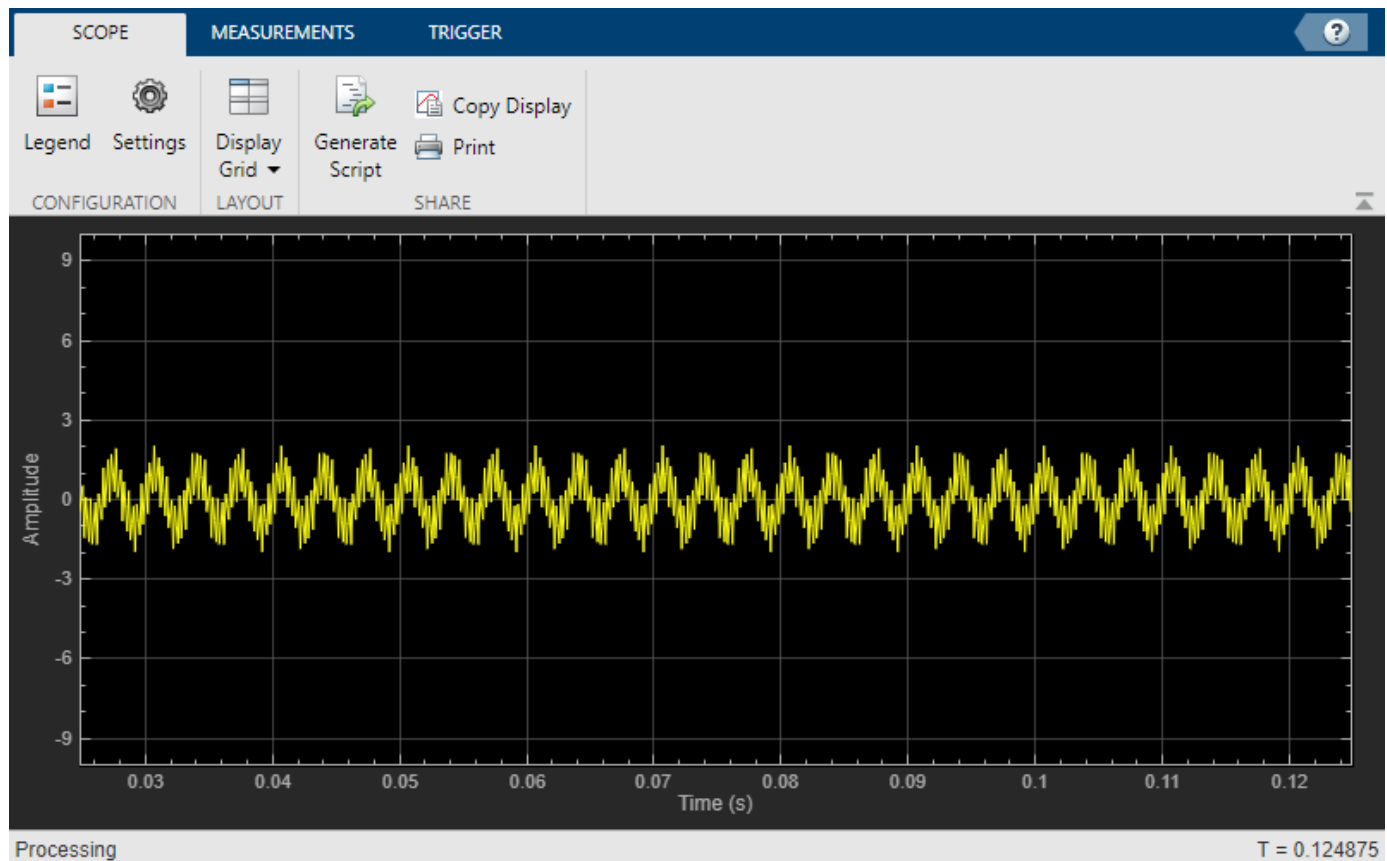
## New Time Scope object: Visualize signals in the time domain

Use the `timescope` object to visualize real- and complex-valued floating-point and fixed-point signals in the time domain.

The Time Scope window has two toolstrip tabs:

### Scope Tab

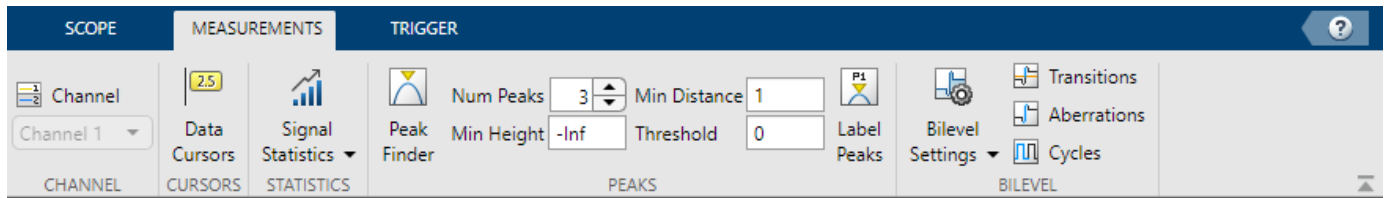
In the **Scope** tab, you can control the layout and configuration settings, and set the display settings of the Time Scope. You can also generate script to recreate your Time Scope with the same settings. When doing so, an editor window opens with the code required to recreate your `timescope` object.



### Measurements Tab

In the **Measurements** tab, all measurements are made for a specified channel.





- **Data Cursors** -- Display the screen cursors.
- **Signal Statistics** -- Display the various statistics of the selected signal, such as maximum/minimum values, peak-to-peak values, mean, median, RMS.
- **Peak Finder** -- Display peak values for the selected signal.



## Scale Axes

You can use the mouse to pan around the axes, and use the scroll button on your mouse to zoom in and out of the plot.

You can also use the buttons that appear when you hover over the plot window.

-  — Maximize the axes, hiding all labels and inseting the axes values.
-  — Zoom in on the plot.
-  — Pan around the axes.
-  — Autoscale the axes to fit the shown data.

For more details, see [Configure Time Scope MATLAB Object](#).

## Scan Matching Using Line Features: Estimate pose and covariance based on line features in lidar scans

The `matchScansLine` function calculates a relative pose and estimated covariance between lidar scan readings based on estimated linear features.

## Trajectory Optimization Improvements: Specify longitudinal segments, deviation offsets, and additional waypoint parameters

The `trajectoryOptimalFrenet` contains two new properties: `NumSegments` and `DeviationOffset`. Increasing `NumSegments` divides the longitudinal terminal states into multiple segments to calculate more dynamic trajectories, but increases computational complexity. `DeviationOffset` specifies an offset on the cost calculation for trajectories to bias the optimal trajectory in a specific direction that deviated from the reference path.

You can also calculate trajectories based on a velocity-keeping behavior by specifying `NaN` for the `Longitudinal` field of the `TerminalStates` property.

The `plan` function no longer errors when a feasible trajectory is not found. The function now returns an empty trajectory vector and an exit flag is included in the output arguments.

## **Path Metrics Improvements: Specify `validatorVehicleCostmap` as a state validator**

The `pathmetrics` function now supports the `validatorVehicleCostmap` as the state validator input to the function.

## **Ray Intersections for 3-D Maps: Calculate ray intersections, import, and export with a 3-D occupancy map**

The `occupancyMap3D` object now supports the `rayIntersection` function for calculating the intersection of rays with obstacles in the environment. You can also import and export occupancy maps as a `.bt` or `.ot` octomap file.

## **Code Generation for Monte Carlo Localization: Generate C/C++ code using the `monteCarloLocalization` object**

You can now generate code when using the `monteCarloLocalization` object.

## **Code Generation for Sampling-Based Planners: Generate C/C++ code using the `plannerRRT`, `plannerRRTStar`, and `plannerHybridAStar` objects**

You can now generate code when using the `plannerRRT`, `plannerRRTStar`, and `plannerHybridAStar` objects.

## **Code Generation for Trajectory Optimization: Generate C/C++ code using the `trajectoryOptimalFrenet` object**

You can now generate code when using the `trajectoryOptimalFrenet` object.

## **Access residuals and residual covariance of insfilters and `ahrs10filter`**

You can access the residuals and residual covariance information of insfilters (`insfilterMARG`, `insfilterAsync`, `insfilterErrorState`, and `insfilterNonholonomic`) and `ahrs10filter` through their object functions such as `fusegps`, `fusegyro`, `residual`, and `residualgps`.

## **Model inertial measurement unit using IMU Simulink block**

Use the IMU Simulink block to model an inertial measurement unit (IMU) composed of accelerometer, gyroscope, and magnetometer sensors.

## **Estimate device orientation using AHRS Simulink block**

Use the AHRS Simulink block to estimate the orientation of a device from its accelerometer, magnetometer, and gyroscope sensor readings.



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## **Calculate angular velocity from quaternions**

Use `angvel` to calculate angular velocity from an array of quaternions.

## **Transform position and velocity between two frames to motion quantities in a third frame**

Use `transformMotion` to transform position and velocity between two coordinate frames to motion quantities in a third coordinate frame.



# R2019b

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**Version: 1.0**

**New Features**

## **Simultaneous Localization and Mapping (SLAM): Create 2-D and 3-D occupancy maps using SLAM algorithm and lidar scan data**

Use the SLAM algorithm to tune parameters for scan matching and loop-closure detection. The `LidarSLAM` object takes lidar scan data and builds a map as your vehicle moves through it. The algorithm generates a `poseGraph` and continuously optimizes edge-constraints based on detected loop closures. As more loop closures are detected, you can continuously build a map of your environment and adjust for odometry drift.

For an example using 2-D lidar scans, see [Implement Online Simultaneous Localization And Mapping \(SLAM\) with Lidar Scans](#).

For an example using 3-D lidar point clouds, see [Perform SLAM Using 3-D Lidar Point Clouds](#).

For more information, see [SLAM](#).

## **SLAM Map Builder App: Interactively modify loop closures and adjust overall map using SLAM algorithm**

Use the **SLAM Map Builder** app to load and filter lidar scans and estimated poses from a log file or data in the workspace. Tune and run the SLAM algorithm to automatically build the map. Pause at any time to modify relative poses between scans. Modify or delete loop closures from the pose graph to improve the overall map. After you are done with the entire data set, output the map as an occupancy grid to use with path planning or other navigation algorithms.

## **Pose Estimation: Accurately estimate vehicle poses using IMU and GPS sensors and Monte Carlo Localization**

Use localization and pose estimation algorithms to orient your vehicle in your environment. Sensor pose estimation uses filters to improve and combine sensor readings for IMU, GPS, and other sensors. Localization algorithms, like Monte Carlo localization and scan matching, estimate your pose in a known map using range sensor or lidar readings. Pose graphs track your estimated poses and can be optimized based on edge constraints and loop closures.

For more information, see [Localization and Pose Estimation](#)

## **Customizable Sampling-Based Path Planners: Plan a path from start to goal locations using RRT and RRT\* algorithms**

Plan paths through a 2-D environment using provided path planning algorithms:

- `plannerRRT`
- `plannerRRTStar`
- `plannerHybridAStar`

Specify parameters for provided 2-D state-space representations:

- `stateSpaceSE2`
- `stateSpaceDubins`

- 
- `stateSpaceReedsShepp`

Validate your planned paths using occupancy maps or vehicle cost maps:

- `validatorOccupancyMap`
- `validatorVehicleCostmap`

Write your own custom state space or state validator using class interfaces:

- `nav.StateSpace`
- `nav.StateValidator`

## **Path-Planning Metrics: Use metrics to check and compare the output of path planners**

Calculate path metrics to evaluate planned paths using the `pathmetrics` object. Check the clearance and smoothness based on your path constraints.

## **Sensor Models: Use simulated models for IMU, GPS, and range sensors**

Perform sensor modeling and simulation for accelerometers, magnetometers, gyroscopes, altimeters, GPS, IMU, and range sensors. Analyze sensor readings, sensor noise, environmental conditions, and other configuration parameters. Generate trajectories to emulate these sensors traveling through a world, and calibrate the performance of your sensors.

Sensor models include:

- `gpsSensor`
- `imuSensor`
- `rangeSensor`

For other sensors and more information, see [Sensor Models](#).

## **Trajectory and Waypoint Following Algorithms: Use built-in algorithms to generate trajectories and control commands for robots**

Use the `waypointTrajectory` and `kinematicTrajectory` objects to generate trajectories for sensors or vehicles and control commands to send to your vehicle

