

Robotics System Toolbox™ Release Notes



MATLAB® & SIMULINK®



## How to Contact MathWorks



Latest news: [www.mathworks.com](http://www.mathworks.com)  
Sales and services: [www.mathworks.com/sales\\_and\\_services](http://www.mathworks.com/sales_and_services)  
User community: [www.mathworks.com/matlabcentral](http://www.mathworks.com/matlabcentral)  
Technical support: [www.mathworks.com/support/contact\\_us](http://www.mathworks.com/support/contact_us)



Phone: 508-647-7000



The MathWorks, Inc.  
1 Apple Hill Drive  
Natick, MA 01760-2098

### *Robotics System Toolbox™ Release Notes*

© COPYRIGHT 2015–2020 by The MathWorks, Inc.

The software described in this document is furnished under a license agreement. The software may be used or copied only under the terms of the license agreement. No part of this manual may be photocopied or reproduced in any form without prior written consent from The MathWorks, Inc.

FEDERAL ACQUISITION: This provision applies to all acquisitions of the Program and Documentation by, for, or through the federal government of the United States. By accepting delivery of the Program or Documentation, the government hereby agrees that this software or documentation qualifies as commercial computer software or commercial computer software documentation as such terms are used or defined in FAR 12.212, DFARS Part 227.72, and DFARS 252.227-7014. Accordingly, the terms and conditions of this Agreement and only those rights specified in this Agreement, shall pertain to and govern the use, modification, reproduction, release, performance, display, and disclosure of the Program and Documentation by the federal government (or other entity acquiring for or through the federal government) and shall supersede any conflicting contractual terms or conditions. If this License fails to meet the government's needs or is inconsistent in any respect with federal procurement law, the government agrees to return the Program and Documentation, unused, to The MathWorks, Inc.

### **Trademarks**

MATLAB and Simulink are registered trademarks of The MathWorks, Inc. See [www.mathworks.com/trademarks](http://www.mathworks.com/trademarks) for a list of additional trademarks. Other product or brand names may be trademarks or registered trademarks of their respective holders.

### **Patents**

MathWorks products are protected by one or more U.S. patents. Please see [www.mathworks.com/patents](http://www.mathworks.com/patents) for more information.

## R2020b

<b>RRT Planner for Manipulators: Plan collision-free motion for rigid body tree robot models</b> .....	1-2
<b>Collision Checking for Robot Meshes: Add collision meshes to rigid body tree models and check collisions for robot configurations</b> .....	1-2
<b>Custom Messages with Gazebo: Publish and subscribe to custom message types in a Gazebo simulation</b> .....	1-2
<b>Joint and Link States in Gazebo: Send and receive messages for robot joint and link states in a Gazebo Simulation</b> .....	1-2
<b>Analytical Inverse Kinematics: Generate functions for inverse kinematics solutions using closed-form solutions</b> .....	1-2
<b>Educational and Commercial Robot Models: Additional rigid body tree robot models for manipulators and mobile robots introduced to the library of robot models</b> .....	1-3
<b>Robotics System Toolbox UAV Library add-on is now the UAV Toolbox</b> ...	1-3
<b>Robotics System Toolbox Support Package for Manipulators Add-on</b> ....	1-3

## R2020a

<b>Interactive Robot Visualization: Manipulate rigid body tree models with visual meshes and perform inverse kinematics for target bodies</b> .....	2-2
<b>Commercial Robot Models: Load additional rigidBodyTree robot models for manipulators and mobile robots added to our library of existing models</b> .....	2-2
<b>Code Generation for Collision Checking: Generate C/C++ code using the checkCollision function and collision geometries</b> .....	2-2
<b>Simscape Multibody Model Parameters: Import models with initial position and joint limits</b> .....	2-2

<b>Gazebo Co-simulation: Perform time-synchronized simulation of Gazebo with Simulink</b> .....	3-2
<b>Robot Motion Modeling and Simulation: Simulate mobile robot kinematics and closed-loop manipulator dynamics</b> .....	3-2
<b>Collision Checking: Define collision shapes and detect collisions between mesh geometries</b> .....	3-2
<b>Commercial Robot Models: Use a provided library of rigid body robot models to quickly model your robot applications</b> .....	3-3
<b>Robot Application Examples: Get started with reference examples for pick-and-place robots and warehouse mobile robots</b> .....	3-3
<b>Robotics System Toolbox Support Package for Turtlebot-Based Robots functionality has moved</b> .....	3-3
<b>Robotics System Toolbox has transitioned into Robotics System Toolbox, Navigation Toolbox, and ROS Toolbox</b> .....	3-3

<b>SLAM Map Builder Sessions: Save and load app sessions</b> .....	4-2
<b>MAVLink Protocol Support: Communicate with UAVs using MAVLink messages and load log files</b> .....	4-2
<b>Trajectory Generation: Create piecewise polynomials, trapezoidal velocity profiles, B-splines, and task-space interpolation</b> .....	4-2
<b>Model Reference Support for ROS: Use model reference in models with ROS Blocks</b> .....	4-2
<b>Orbit Follower for UAVs: Follow a circular path around a point of interest</b> .....	4-2
<b>Code Generation for SLAM: Generate code using LidarSLAM, PoseGraph, and PoseGraph3D objects</b> .....	4-2

<b>SLAM Map Builder App: Build and tune a 2-D grid map with lidar-based SLAM</b> .....	5-2
<b>UAV Algorithms: Create UAV guidance models and 3-D path following for fixed-wing and multirotor UAVs</b> .....	5-2
<b>Read Data Block: Play back data from a rosbag logfile in Simulink</b> .....	5-2
<b>Inverse Kinematics Block: Calculate joint configurations for a desired end-effector pose in Simulink</b> .....	5-2
<b>ROS Service and Current Time Blocks: Call ROS services and get the current ROS time in Simulink</b> .....	5-2
<b>Simscape Multibody Data Exchange: Use importrobot to import Simscape Multibody models to a RigidBodyTree object.</b> .....	5-3
<b>Ground Vehicle Motion Primitives: Generate paths using Dubins, Reeds-Shepp, and straight-line connections</b> .....	5-3

<b>Manipulator Algorithm Blocks: Compute rigid body tree kinematics and dynamics in Simulink</b> .....	6-2
<b>Lidar-Based SLAM: Localize robots and build map environments using lidar sensors</b> .....	6-2
<b>Pose Graph Data Structure and Optimization: Represent and optimize 2-D and 3-D pose graphs</b> .....	6-2
<b>3-D Occupancy Maps: Map 3-D environments using efficient octree data structure</b> .....	6-2
<b>Enhanced Performance for rosbag Logfiles: Load rosbags faster and extract message data as structures</b> .....	6-3

<b>RigidBodyTree Visualization Improvements: Attach mesh files and inspect individual bodies in a MATLAB figure</b> .....	7-2
---	-----

<b>Coordinate Transformation Conversion Block: Convert between coordinate system representations in Simulink</b> .....	7-2
<b>ROS Image and Point Cloud Blocks: Convert ROS messages to nonbus signals in Simulink</b> .....	7-2
<b>Lidar Sensor Object: Store and use lidar scan data</b> .....	7-2
<b>Scan Matching: New trust-region solver and code generation support</b> .....	7-3

## R2017a

<b>External Mode Support: Tune parameters and view signal values of deployed ROS nodes over TCP/IP (with Simulink Coder)</b> .....	8-2
<b>Dynamics for Robot Manipulators: Solve inverse and forward dynamics for RigidBodyTree objects</b> .....	8-2
<b>Generalized Inverse Kinematics: Solve multiconstrained inverse kinematics for robot manipulators</b> .....	8-2
<b>URDF File Importer: Import URDF robot descriptions as a RigidBodyTree object</b> .....	8-3
<b>Scan Matching: Calculate pose difference between laser scans</b> .....	8-3
<b>Code Generation for RigidBodyTree objects: Generate code with robot manipulator data structures</b> .....	8-3
<b>rosparam Simplified Commands: Modify ROS parameters using a simplified interface without creating a ParameterTree object</b> .....	8-3

## R2016b

<b>Robotic Manipulator Algorithms: Represent robot manipulators using a rigid body tree and calculate forward and inverse kinematics</b> .....	9-2
<b>Automated Deployment of ROS Nodes: Automatically deploy ROS nodes to target hardware using Simulink Coder</b> .....	9-2
<b>Occupancy Grid Class: Build a robot environment using a 2-D occupancy map with probabilistic values</b> .....	9-2
<b>Mobile Robot Algorithm Blocks: Perform obstacle avoidance and path following in Simulink</b> .....	9-2

<b>ROS Action Client: Send action goals via a ROS network and get feedback on their execution</b> .....	9-2
<b>Buffered ROS tf2 Transformations: Access time-buffered transformations from the ROS transformation tree</b> .....	9-2
<b>Odometry Motion Model Class: Predict poses for a differential drive robot</b> .....	9-3
<b>ROS Time and Duration: Use mathematical operations on ROS time and duration objects</b> .....	9-3
<b>Code Generation for Robotics Algorithms: Generate code for select algorithms</b> .....	9-4

## R2016a

<b>Monte Carlo Localization Algorithm: Estimate robot location in a known map</b> .....	10-2
<b>Particle Filter Algorithm: Estimate state for nonlinear systems</b> .....	10-2
<b>Fixed-Rate Execution: Run MATLAB code at a constant rate</b> .....	10-2
<b>Robotics System Toolbox Support Package for TurtleBot based Robots: Connect to TurtleBot hardware</b> .....	10-2
<b>String support for ROS parameters in Simulink</b> .....	10-2
<b>String array support for ROS messages in Simulink</b> .....	10-2
<b>Code generation from Simulink using Simulink Coder</b> .....	10-3
<b>roboticsSupportPackages function replaced with roboticsAddons</b> .....	10-3

## R2015aSP1

**Bug Fixes**

## R2015b

<b>Vector Field Histogram Plus (VFH+) obstacle avoidance algorithm</b> .....	12-2
--	------

<b>Access to ROS parameters from Simulink</b> .....	<b>12-2</b>
<b>Code generation for coordinate transforms and select robotics algorithms</b> .....	<b>12-2</b>

**R2015a**

<b>Path planning, path following, and map representation algorithms</b> ...	<b>13-2</b>
<b>Functions for converting between different rotation and translation representations</b> .....	<b>13-2</b>
<b>Bidirectional communication with live ROS-enabled robots</b> .....	<b>13-2</b>
<b>Interface to Gazebo and other ROS-enabled simulators</b> .....	<b>13-2</b>
<b>Data import from rosbag log files</b> .....	<b>13-2</b>
<b>ROS node generation from Simulink models (with Embedded Coder)</b> .....	<b>13-2</b>



# R2020b

---

**Version: 3.2**

**New Features**

**Bug Fixes**

## **RRT Planner for Manipulators: Plan collision-free motion for rigid body tree robot models**

The `manipulatorRRT` object enables you to plan paths for a `rigidBodyTree` robot model using the bidirectional rapidly-exploring random tree (RRT) algorithm. Specify the collision geometries for the `rigidBodyTree` object, a start and goal configuration, and any obstacles in the environment using collision meshes. Use the `plan` function to generate a collision-free path from start to goal.

To find direct connections between the bidirectional trees, enable the `ConnectHeuristic` property of the `manipulatorRRT` object, which ignores the maximum connection distance for extending the tree.

To shorten the path length, use the `shortenPath` function, which finds random edges to trim from the path.

## **Collision Checking for Robot Meshes: Add collision meshes to rigid body tree models and check collisions for robot configurations**

The `rigidBodyTree` object now supports adding collision meshes along with visual meshes by using the `addCollision` object function. The `checkCollision` object function checks for self collisions and collisions with the environment based on robot configurations and obstacle positions.

## **Custom Messages with Gazebo: Publish and subscribe to custom message types in a Gazebo simulation**

Use the Gazebo Publish and Gazebo Subscribe blocks to send and receive custom messages on specific topics in a Gazebo simulation. Specify messages as a bus with the appropriate elements based on your message type.

## **Joint and Link States in Gazebo: Send and receive messages for robot joint and link states in a Gazebo Simulation**

The Gazebo Blank Message block now generates commands for setting the position and velocity of different joint and link elements of a Gazebo simulation as a bus. Select the message type in the block mask, and assign the appropriate elements of the bus for your command. To send the commands, use the Gazebo Apply Command block. To read states, use a Gazebo Read block configured for the topic of the desired element.

## **Analytical Inverse Kinematics: Generate functions for inverse kinematics solutions using closed-form solutions**

The `analyticalInverseKinematics` object is an analytical inverse kinematics solver for a specific `rigidBodyTree` robot model. The object supports kinematic group types for six or seven degree-of-freedom (DoF) robots. Using the object, generate a function for your robot model and query solutions based on a desired end-effector pose.

---

## **Educational and Commercial Robot Models: Additional rigid body tree robot models for manipulators and mobile robots introduced to the library of robot models**

Load additional robot models using the `loadrobot` function, which returns a `rigidBodyTree` object. To access these robot models, specify the associated string name for the `robotname` argument of the `loadrobot` function

- "kukaIiwa14"
- "quanserQBot2e"
- "quanserQCar"
- "rethinkSawyer"

## **Robotics System Toolbox UAV Library add-on is now the UAV Toolbox**

The Robotics System Toolbox UAV Library add-on is now available as the UAV Toolbox.

## **Robotics System Toolbox Support Package for Manipulators Add-on**

The Robotics System Toolbox Support Package for Manipulators add-on is new in this release for connecting to KINOVA manipulator hardware.

To see available add-ons for Robotics System Toolbox, use the `roboticsAddons` function.



# R2020a

---

**Version: 3.1**

**New Features**

**Bug Fixes**

## **Interactive Robot Visualization: Manipulate rigid body tree models with visual meshes and perform inverse kinematics for target bodies**

Create an `interactiveRigidBodyTree` object to launch a window displaying a `rigidBodyTree` object and the attached visual meshes. You can directly modify the robot position and configuration using interactive markers and see the results in the figure. Also, you can specify additional constraints and inverse kinematics parameters in the object to further restrict the robot motion when solving for configurations.

## **Commercial Robot Models: Load additional rigidBodyTree robot models for manipulators and mobile robots added to our library of existing models**

Use commercially available robot models using the `loadrobot` function. Robot models are returned as a `rigidBodyTree` object. Starting this release, new robot model options available include:

- "abbIrb1600"
- "abbYuMi"
- "atlas"
- "fanucLRMate200ib"
- "fanucM16ib"
- "frankaEmikaPanda"
- "robotisOP2"
- "robotisOpenManipulator"
- "universalUR10"
- "universalUR3"
- "universalUR5"
- "valkyrie"
- "yaskawaMotomanMH5"

## **Code Generation for Collision Checking: Generate C/C++ code using the checkCollision function and collision geometries**

You can now generate code when using `checkCollision` and the collision geometry objects `collisionBox`, `collisionCylinder`, `collisionMesh`, and `collisionSphere`.

## **Simscape Multibody Model Parameters: Import models with initial position and joint limits**

When you import Simscape™ Multibody™ models using `importrobot`, the assembly initial position is set to the home configuration of your `rigidBodyTree` model. Also, the joint limits are set in the `PositionLimits` property of each `rigidBodyJoint` object.

# R2019b

---

**Version: 3.0**

**New Features**

**Bug Fixes**

**Compatibility Considerations**

## **Gazebo Co-simulation: Perform time-synchronized simulation of Gazebo with Simulink**

Gazebo is a physics-based simulator for testing and simulating robotics applications. Co-simulation means synchronized time-stepping of your Simulink® model with the Gazebo simulation. Use the Gazebo Pacer to control the pace of your model. To select entities, receive and send messages, or apply commands, use the other provided Gazebo blocks:

- Gazebo Apply Command
- Gazebo Blank Message
- Gazebo Read
- Gazebo Select Entity

For examples using Gazebo co-simulation, see

- Perform Co-Simulation between Simulink and Gazebo
- Control A Differential-Drive Robot in Gazebo With Simulink

## **Robot Motion Modeling and Simulation: Simulate mobile robot kinematics and closed-loop manipulator dynamics**

Use provided motion models to simulate mobile robots and manipulator robot motion. Mobile robot models include:

- `ackermannKinematics` object or Ackermann Kinematic Model block
- `bicycleKinematics` object or Bicycle Kinematic Model block
- `differentialDriveKinematics` object or Differential Drive Kinematic Model block
- `unicycleKinematics` object or Unicycle Kinematic Model block

Manipulator models support any `rigidBodyTree` model for both joint- and task-space kinematics:

- `taskSpaceMotionModel` object or Task Space Motion Model block
- `jointSpaceMotionModel` object or Joint Space Motion Model block

## **Collision Checking: Define collision shapes and detect collisions between mesh geometries**

Create collision meshes using either primitive shapes or custom mesh definitions with:

- `collisionBox`
- `collisionCylinder`
- `collisionSphere`
- `collisionMesh`

Check for collisions and calculate distances between meshes using the `checkCollision` function. For examples using collision detection, see:

- Check for Manipulator Self Collisions using Collision Meshes



- 
- Check for Environmental Collisions with Manipulators

## **Commercial Robot Models: Use a provided library of rigid body robot models to quickly model your robot applications**

Use commercially available robot models using the `loadrobot` function. Robot models are returned as a `rigidBodyTree` object. Robot models available include:

- KINOVA® Gen3
- KINOVA JACO®
- KINOVA MICO®
- ABB IRB 120
- Rethink Robotics Baxter
- Willow Garage PR2

For an example using the Gen3 robot, see [Plan and Execute Collision-Free Trajectories using KINOVA Gen3 Manipulator](#).

## **Robot Application Examples: Get started with reference examples for pick-and-place robots and warehouse mobile robots**

Reference examples for complete mobile robot and manipulator workflows are provided:

### **Pick-and-Place Manipulator Robots**

- [Plan and Execute Task- and Joint-space Trajectories using KINOVA Gen3 Manipulator](#)
- [Plan and Execute Collision-Free Trajectories using KINOVA Gen3 Manipulator](#)
- [Pick-and-Place Workflow using Stateflow for MATLAB](#)

### **Warehouse Mobile Robots**

- [Plan Path for a Differential Drive Robot in Simulink](#)
- [Execute Tasks for a Warehouse Robot](#)
- [Control A Differential-Drive Robot in Gazebo With Simulink](#)
- [Simulate Different Kinematic Models for Mobile Robots](#)

## **Robotics System Toolbox Support Package for Turtlebot-Based Robots functionality has moved**

Starting in R2019b, the Robotics System Toolbox Support Package for Turtlebot-Based Robots will no longer be available for download. This functionality has been moved to ROS Toolbox Support Package for TurtleBot -Based Robots.

## **Robotics System Toolbox has transitioned into Robotics System Toolbox, Navigation Toolbox, and ROS Toolbox**

Starting in R2019b, the Robotics System Toolbox has been transitioned to 3 products:

- Robotics System Toolbox
- Navigation Toolbox
- ROS Toolbox

Explore product capabilities for designing robotics applications, planning and navigation algorithms, and ROS-based applications.

# R2019a

---

**Version: 2.2**

**New Features**

**Bug Fixes**

## **SLAM Map Builder Sessions: Save and load app sessions**

The **SLAM Map Builder** app now allows you to save and load app sessions. While building a map and tuning SLAM parameters, your progress can be saved to a file. Load the session to return to the same point in your map-building process.

## **MAVLink Protocol Support: Communicate with UAVs using MAVLink messages and load log files**

Use the MAVLink communication protocols in MATLAB® and load specific MAVLink dialects. To load a dialect, use `mavlinkdialect`. Connect to MAVLink clients and send and receive messages using `mavlinkio`. You can also load telemetry logs (`.tlogs`) and use the data in MATLAB.

## **Trajectory Generation: Create piecewise polynomials, trapezoidal velocity profiles, B-splines, and task-space interpolation**

You can now generate multi-axis trajectories using new functions or blocks. Specify waypoints and time-scaling vectors to get a series of accelerations, velocities, and positions using third-order (cubic) polynomials, fifth-order (quintic) polynomials, B-splines, or trapezoidal velocity profiles. You can also interpolate between rotations or transformations with a specified time-scaling vector.

## **Model Reference Support for ROS: Use model reference in models with ROS Blocks**

All ROS (Robot Operating System) blocks can now be used with model reference in Simulink. Simulink models are still limited to one ROS node, so referenced models all contribute to a single node at the top-level model. Execution modes that require host code generation (Accelerator and Rapid Accelerator modes) do not support model reference.

## **Orbit Follower for UAVs: Follow a circular path around a point of interest**

The Orbit Follower block and `uavOrbitFollower` object allow you to follow a circular path around a central point. Specify the center location and radius of the circular path to follow. The block uses the current pose and look ahead distance and generates the desired heading ad yaw to achieve the circular path.

## **Code Generation for SLAM: Generate code using LidarSLAM, PoseGraph, and PoseGraph3D objects**

You can now generate code when using `robotics.LidarSLAM`, `robotics.PoseGraph`, and `robotics.PoseGraph3D` objects. The `optimizePoseGraph` function also supports code generation.

# R2018b

---

**Version: 2.1**

**New Features**

**Bug Fixes**

## **SLAM Map Builder App: Build and tune a 2-D grid map with lidar-based SLAM**

Use the **SLAM Map Builder** app to import lidar scan and odometry data from a rosbag logfile or the MATLAB workspace to build an occupancy grid map. The app utilizes the lidar-based SLAM (simultaneous localization and mapping) algorithm to map the environment and localize the robot. To improve map quality, the app also provides an easy user interface to tune the SLAM algorithm parameters and manually modify individual incremental scans and loop-closure matches.

## **UAV Algorithms: Create UAV guidance models and 3-D path following for fixed-wing and multirotor UAVs**

Use a `fixedwing` or `multirotor` object to generate a reduced-order guidance model for fixed-wing and multirotor UAVs (unmanned aerial vehicles). Use these functions with the guidance model:

- `control` — Control commands for UAVs
- `derivative` — Time derivative of UAV states
- `environment` — Environment inputs for UAVs
- `state` — UAV states for position, velocity, attitude, and thrust

The UAV Guidance Model block also contains these same guidance models for both UAV types. Specify the UAV initial state, control commands, and the environmental conditions to get the simulated UAV states from the block.

Use the Waypoint Follower block or the `uavWaypointFollower` System object™ to navigate a set of waypoints using a lookahead point. You can specify your UAV type, a fixed or variable transition radius, and control yaw at the waypoints.

## **Read Data Block: Play back data from a rosbag logfile in Simulink**

The Read Data block loads rosbag logfile data into Simulink for playback in simulation. Messages are played back at the simulation time corresponding to the recorded rosbag time. Specify the logfile, time settings, and the desired topic to output.

## **Inverse Kinematics Block: Calculate joint configurations for a desired end-effector pose in Simulink**

Use the Inverse Kinematics block to calculate the joint configuration for a desired end-effector pose in Simulink. Specify a `robotics.RigidBodyTree` object for your manipulator robot in MATLAB. The block uses this model to generate valid joint positions and angles to achieve the desired end-effector pose.

## **ROS Service and Current Time Blocks: Call ROS services and get the current ROS time in Simulink**

Use the Call Service block to call a ROS service in Simulink. Specify a service request message and get a response from the service server. A valid ROS service server must be running on your ROS network. You can also now generate blank service request and response messages using the Blank Message block.

---

Use the Current Time block to get the current ROS or system time based on your ROS network connection.

You can now run a deployed model based on the ROS time. Select the **Enable ROS time model stepping** in the **Model Configuration Parameters**. Under **Hardware Implementation**, set **Hardware board** to Robot Operating System (ROS), and select **Enable ROS time model stepping** under **Target Hardware resources > ROS time**.

## **Simscape Multibody Data Exchange: Use importrobot to import Simscape Multibody models to a RigidBodyTree object.**

Use importrobot to import a Simscape Multibody model to MATLAB as a robotics.RigidBodyTree object. The RigidBodyTree object supports rigid bodies with revolute, prismatic, and fixed joints. Supported blocks are mapped to these components.

## **Ground Vehicle Motion Primitives: Generate paths using Dubins, Reeds-Shepp, and straight-line connections**

Use motion models for Dubins, Reeds-Shepp, and straight-line connections to generate path segments. Specify the properties for the different motion models in the connection objects:

- robotics.DubinsConnection
- robotics.ReedsSheppConnection

Use the connectconnect function to create valid path segments between poses:

- robotics.DubinsPathSegment
- robotics.ReedsSheppPathSegment

You can then interpolate poses along the path segment or visualize it using showshow.





# R2018a

---

**Version: 2.0**

**New Features**

**Bug Fixes**

## Manipulator Algorithm Blocks: Compute rigid body tree kinematics and dynamics in Simulink

Simulink now supports dynamics and kinematics functions for rigid body trees. The following blocks use an associated rigid body tree model, specified as a `RigidBodyTree` object, to compute the kinematic or dynamic values for the robot:

- Inverse Dynamics: Required joint torques for given motion
- Forward Dynamics: Joint accelerations given joint torques and states
- Get Transform: Get transform between body frames
- Get Jacobian: Geometric Jacobian for robot configuration
- Gravity Torque: Joint torques that compensate for gravity
- Joint Space Mass Matrix: Joint-space mass matrix
- Velocity Product Torque: Joint torques that cancel velocity-induced forces

## Lidar-Based SLAM: Localize robots and build map environments using lidar sensors

The `LidarSLAM` class uses lidar sensor data and robot poses to simultaneously localize the robot and build a map. The class uses an underlying `PoseGraph` class that contains pose estimates for lidar scan readings. Lidar scans are incrementally added to the `LidarScan` object. The object detects loop closures and optimizes pose graphs as scans are added to the map. A grid-based, scan-matching algorithm determines placement in the map and detects loop closures.

## Pose Graph Data Structure and Optimization: Represent and optimize 2-D and 3-D pose graphs

The `PoseGraph` and `PoseGraph3D` classes store pose graph data with pose estimates and information matrices to specify the uncertainty. The data is represented as nodes and edges connecting the different poses to draw out a robot trajectory. Nodes represent the pose estimates, and edges contain the relative pose differences between nodes and information matrices as edge constraints. Loop closure edges link existing nodes together as a relative pose difference.

The `optimizePoseGraph` function optimizes the entire graph using the edge constraints. The function attempts to balance the relative poses and their edge constraints across the whole graph. The option to ignore specific loop closures is also available.

The `LidarSLAM` class uses the 2-D `PoseGraph` class for simultaneous localization and mapping based on lidar scan data.

## 3-D Occupancy Maps: Map 3-D environments using efficient octree data structure

The `OccupancyMap3D` class supports the mapping of 3-D environments using probabilities to represent occupancy of locations. The class stores the occupancy map using an efficient octree structure to minimize data storage and dynamically prunes the tree appropriately. Sensor observations are added as point clouds using `insertPointCloud` to incrementally build a map that you can show in a figure. Also, you can `inflate` the map for obstacle avoidance and navigation.

---

## Enhanced Performance for rosbag Logfiles: Load rosbags faster and extract message data as structures

Performance improvements for reading rosbags enable faster load times using the `rosbag` function. ROS messages can now be returned as a cell array of structures instead of ROS message objects using `readMessages`, which allows for easier access of fields in the message and direct access to custom message data:

```
bag = rosbag('ros_turtlesim.bag');  
msgStructs = readMessages(bSel, 'DataFormat', 'struct');
```

The `getTransform` and `canTransform` functions now support accessing transformations from rosbags. You can also query statistics about the rosbag using `rosbag info fileName`.



# R2017b

---

**Version: 1.5**

**New Features**

**Bug Fixes**

## **RigidBodyTree Visualization Improvements: Attach mesh files and inspect individual bodies in a MATLAB figure**

The `robotics.RigidBodyTree` class's `show` method can now display visual meshes in a figure window. `addVisual` can assign an individual mesh file (`.stl`) to a rigid body a mesh file, or you can use `importrobot` with a Unified Robotics Description Format (URDF) file that has mesh files associated with bodies.

Other improvements to the visualization include inspection of individual body properties and toggling of individual visual elements of the rigid body tree using mouse interaction.

## **Coordinate Transformation Conversion Block: Convert between coordinate system representations in Simulink**

You can now convert between different coordinate system representations using the Coordinate Transformation Conversion block. The supported representations are:

- Axis-Angle (AxAng) - [x y z theta]
- Euler Angles (Eul) - [z y x], [z y z], or [x y z]
- Homogeneous Transformation (TForm) - 4-by-4 matrix
- Quaternion (Quat) - [w x y z]
- Rotation Matrix (RotM) - 3-by-3 matrix
- Translation Vector (TrVec) - [x y z]

For more information about the different coordinate transformation representations and the equivalent MATLAB functions, see [Coordinate System Transformations](#).

## **ROS Image and Point Cloud Blocks: Convert ROS messages to nonbus signals in Simulink**

You can now use Robotics System Toolbox to convert Robot Operating System (ROS) Image, CompressedImage, and PointCloud2 messages to nonbus signals in Simulink. The image or point cloud data are output as an array. Subscribe to a ROS message using Subscribe and feed the output bus to the Read Image or Read Point Cloud block to convert the message to an array signal. You can configure the block from a topic on a live ROS network or specify message parameters manually.

## **Lidar Sensor Object: Store and use lidar scan data**

The `lidarScan` object can store data from a lidar (light detection and ranging) scan. A lidar scan, also called a laser scan, contains ranges and angles from a sensor to measure and map your environment. This object contains sensor information and the data collected from an individual scan. You can use this object with other Robotics System Toolbox functionality that previously used ranges and angles as inputs:

- `matchScans`
- `transformScan`
- `robotics.MonteCarloLocalization`

- 
- `robotics.VectorFieldHistogram`
  - `robotics.OccupancyGrid.insertRay`

You can also convert LaserScan ROS messages to the `lidarScan` object.

## **Scan Matching: New trust-region solver and code generation support**

You can now use the `'trust-region'` solver for the `matchScans` function. This solver does not require an Optimization Toolbox™ license and replaces the `'fminunc'` solver as the default. Code generation for the `'trust-region'` solver with MATLAB Coder™ is now available as well.

To use a specific algorithm, specify the `'SolverAlgorithm'` name-value pair:

```
pose = matchScans( ___, 'SolverAlgorithm', 'trust-region' )
```





# R2017a

---

**Version: 1.4**

**New Features**

**Bug Fixes**

## External Mode Support: Tune parameters and view signal values of deployed ROS nodes over TCP/IP (with Simulink Coder)

You can now use external mode with your deployed ROS nodes. External mode enables you to tune parameters and log signals while code is running on the target hardware. You must have Simulink Coder installed.

To deploy a standalone ROS node, see [Generate a Standalone ROS Node from Simulink](#).

To use external mode, see [Enable External Mode for Robotics System Toolbox Models](#)

## Dynamics for Robot Manipulators: Solve inverse and forward dynamics for RigidBodyTree objects

The `RigidBodyTree` class provides dynamics information for robot manipulators. For each `RigidBody` object, you can specify the following properties:

- `Mass` — Total mass of rigid body
- `CenterOfMass` — Location of body's center of mass in the body frame
- `Inertia` — Independent elements of the inertia tensor in the body frame

You can also specify the `Gravity` property for the entire `RigidBodyTree` object.

New object functions are available for solving inverse and forward dynamics and for calculating other relevant values for the robot model:

- `forwardDynamics` — Compute the resulting joint accelerations for given joint torques, joint positions, and velocities. You can also specify external forces to the robot model by using `externalForce`.
- `inverseDynamics` — Compute the required joint torques for given joint positions, velocities, and accelerations (robot motion). You can also specify external forces on the robot model.
- `externalForce` — Create external forces to apply to a robot model. This function creates a matrix that `forwardDynamics` and `inverseDynamics` use as an input.
- `massMatrix` — Compute the joint-space mass matrix for a certain robot configuration.
- `velocityProduct` — Compute the joint torques that compensate for Coriolis and centrifugal terms for given joint positions and velocities.
- `gravityTorque` — Compute the joint torques required to compensate for gravity for a certain robot configuration.
- `centerOfMass` — Compute the center of mass position and center of mass Jacobian for a certain robot configuration in the base frame.

## Generalized Inverse Kinematics: Solve multiconstrained inverse kinematics for robot manipulators

Find a robot configuration on a `RigidBodyTree` model given one or more constraints. The `InverseKinematics` class previously supported a single end-effector pose constraint. The `GeneralizedInverseKinematics` class supports multiple constraints with different types.

---

Specify constraint types when creating the object, and specify the constraint parameters when calling the object. You can create constraint inputs from these classes:

- `AimingConstraint`
- `CartesianBounds`
- `JointPositionBounds`
- `OrientationTarget`
- `PoseTarget`
- `PositionTarget`

## **URDF File Importer: Import URDF robot descriptions as a RigidBodyTree object**

You can now import rigid body tree models from the Unified Robot Description Format (URDF) robot description using `importrobot`. The function parses the URDF information and returns a `RigidBodytree` object.

## **Scan Matching: Calculate pose difference between laser scans**

Use the `matchScans` function to calculate the pose difference between two laser scans. This pose difference, given as `[x y theta]`, is used to correlate scans together and transform them into the same coordinate frame. To transform laser scans based on this pose difference, use the `transformScan` function.

## **Code Generation for RigidBodyTree objects: Generate code with robot manipulator data structures**

Code generation with MATLAB Coder is now available for `RigidBodyTree` objects. You can generate code for all inverse and forward dynamics algorithms, but not for the `show` and `showdetails` methods.

## **rosparam Simplified Commands: Modify ROS parameters using a simplified interface without creating a ParameterTree object**

You can now set, get, list, and delete ROS parameters directly using the `rosparam` function. Previously, you had to create a ROS `ParameterTree` object to modify parameter values. `rosparam` has simplified commands that mimic ROS behavior. For example, to set the `'/param_value'` ROS parameter to the value, `42.15`, use:

```
rosparam set /param_value 42.15
```



# R2016b

---

**Version: 1.3**

**New Features**

**Bug Fixes**

**Compatibility Considerations**

## **Robotic Manipulator Algorithms: Represent robot manipulators using a rigid body tree and calculate forward and inverse kinematics**

The `robotics.RigidBodyTree` class enables you to build kinematic chains or trees using rigid bodies to represent physical robots. You can add or modify bodies on a structure, specify joint limits, and replace bodies or joints. In addition, you can use forward kinematics to get transformations between two body frames and compute geometric Jacobians for specified end effectors for a given robot configuration.

Inverse kinematics is available in the `robotics.InverseKinematics` class. Use inverse kinematics to calculate corresponding joint angles for desired end-effector positions.

## **Automated Deployment of ROS Nodes: Automatically deploy ROS nodes to target hardware using Simulink Coder**

You can now automatically deploy and run ROS nodes using Simulink Coder. Create a Simulink model using Robotics System Toolbox blocks and deploy it to your target Linux device that has ROS installed. You can use the `rosdevice` object to connect to the target device and run or stop the deployed ROS nodes.

For more information, see [Generate a Standalone ROS Node from Simulink®](#).

## **Occupancy Grid Class: Build a robot environment using a 2-D occupancy map with probabilistic values**

The `robotics.OccupancyGrid` class enables you to create 2-D occupancy maps using probabilistic values. You can incorporate probabilistic sensor information using Bayes' rule. Also, you can use the occupancy grid with the `robotics.PRM` and `robotics.MonteCarloLocalization` classes for path planning and localization.

## **Mobile Robot Algorithm Blocks: Perform obstacle avoidance and path following in Simulink**

You can now use the Vector Field Histogram and Pure Pursuit algorithms with Simulink. The Pure Pursuit block outputs a target direction, which you can feed directly into the Vector Field Histogram block to perform obstacle avoidance with path following.

## **ROS Action Client: Send action goals via a ROS network and get feedback on their execution**

By setting up a simple action client using the `rosactionclient` function, you can now perform predefined actions that are available on the ROS network. Once an action is triggered, the client receives asynchronous feedback about a specified goal and can preempt the execution of goals on the server.

## **Buffered ROS tf2 Transformations: Access time-buffered transformations from the ROS transformation tree**

The ROS transformation tree now supports time-buffered transformation. By default, the `TransformationTree` object has a time buffer of 10 seconds. After creating a transformation tree

---

using `rostopic`, transformations are saved based on the buffer time. You can call `getTransform` or `transform` to access and apply the transformations at a specified source time. A new function, `canTransform`, enables you to check if the transformation is available.

## Compatibility Considerations

`waitForTransform` will be removed in a future release. Use `getTransform` with a specified `timeout` instead. To wait indefinitely, specify `timeout` as `inf`.

The behavior of `getTransform` will change in a future release. The function will no longer return an empty transform when the transform is unavailable and no `sourcetime` is specified. If `getTransform` waits for the specified timeout period and the transform is still not available, the function returns an error. The timeout period is 0 by default.

## Odometry Motion Model Class: Predict poses for a differential drive robot

The `robotics.OdometryMotionModel` class contains the equations of motion that govern a differential drive robot. The odometry motion model predicts the motion of a robot based on previous poses and noise parameters. You can tune the `Noise` property and see the effect on particle distributions using the `showNoiseDistribution` function. You can also use this motion model with `robotics.MonteCarloLocalization` to localize robots in a known environment.

## ROS Time and Duration: Use mathematical operations on ROS time and duration objects

In the `rostopic` function, you can now specify second and nanosecond scalar inputs when creating a ROS Time message object. You can also use the new `rostopic` function to create a ROS Duration message object. Both message types support mathematical operations and comparisons. For example:

Create a ROS Time and Duration object and add them together. Compare the two Time objects.

```
time = rostopic(5.54);
duration = rostopic(2);
time2 = time + duration
```

```
time2 =
```

```
  ROS Time with properties:
```

```
    Sec: 7
    Nsec: 540000000
```

```
time2 <= time
```

```
ans =
```

```
  0
```

## **Code Generation for Robotics Algorithms: Generate code for select algorithms**

Code generation with MATLAB Coder is now available for the following algorithms:

- `robotics.BinaryOccupancyGrid`
- `robotics.OccupancyGrid`
- `robotics.OdometryMotionModel`
- `robotics.PRM` — The map input must be specified on creation of the PRM object.
- `robotics.PurePursuit`

For a full list of code generation support for Robotics System Toolbox, see [Code Generation](#).



# R2016a

---

**Version: 1.2**

**New Features**

**Compatibility Considerations**

## **Monte Carlo Localization Algorithm: Estimate robot location in a known map**

Monte Carlo Localization utilizes a particle filter to localize a robot in a known environment. You can supply a `BinaryOccupancyGrid` object of your map and range sensor data from the robot to the `robotics.MonteCarloLocalization` object to estimate the pose (location and orientation) of the robot. You have the option of using global localization or specifying an initial pose to improve performance. As sensor data is supplied to the algorithm, particles converge on the best estimate of the robot location.

## **Particle Filter Algorithm: Estimate state for nonlinear systems**

The `robotics.ParticleFilter` class enables you to create a particle filter for state estimation. The algorithm uses particles and sensor data to try to match the posterior distribution of the current state. It first predicts the current state based on a given system model and then corrects the estimate based on sensor data inputs. You can specify a fixed number of particles to use, number of state variables to estimate, and your method for final estimation based on the particle weights. You can customize your particle filter by giving a state transition function and measurement likelihood model to match your system.

## **Fixed-Rate Execution: Run MATLAB code at a constant rate**

Execute loops at a constant rate based off either your system time or ROS time. By creating a `robotics.Rate` object, you can call `waitfor` to pause a loop until the next time step. This feature ensures that loops are run at a fixed rate when accurate timing of commands is required.

You can also use `rosclock` to base timing off the current time published in a ROS network. Therefore, messages and control commands can be published at a fixed rate to a ROS-enabled system.

## **Robotics System Toolbox Support Package for TurtleBot based Robots: Connect to TurtleBot hardware**

ROS Toolbox Support Package for TurtleBot<sup>®</sup>-Based Robots allows robotics researchers to acquire sensor data from TurtleBot-based robots (either simulated or physical robots). You can use the data for visualization and analysis, and send commands to control the robots.

## **String support for ROS parameters in Simulink**

Support for using strings as ROS parameters is now available in Simulink. When using strings, they must be cast as a `uint8` array of ASCII values. See [ROS String Parameters](#) for more information.

## **String array support for ROS messages in Simulink**

You can now use an array of strings when using the Publish, Subscribe, and Blank Message blocks to create, send, and receive messages using a ROS network in Simulink.

---

## **Code generation from Simulink using Simulink Coder**

You can now generate standalone ROS nodes from Simulink models with just Simulink Coder. If you have Embedded Coder<sup>®</sup>, you can customize the generated code with additional optimization, readability, and code configuration options.

## **roboticsSupportPackages function replaced with roboticsAddons**

The `roboticsSupportPackages` function is no longer available. Instead, use `roboticsAddons` to access Add-ons for Robotics System Toolbox.



# R2015aSP1

---

**Version: 1.0.1**

**Bug Fixes**



# R2015b

---

**Version: 1.1**

**New Features**

## **Vector Field Histogram Plus (VFH+) obstacle avoidance algorithm**

The VFH+ obstacle avoidance algorithm is a reactive algorithm that calculates obstacle-free robot movements using range sensor information. You can use this algorithm to have your robot avoid unknown obstacles while driving through dynamic or partially known environments. See `robotics.VectorFieldHistogram` for more information.

## **Access to ROS parameters from Simulink**

Simulink workflows now support ROS parameters. You can get and set parameter values using the new Get Parameter and Set Parameter blocks.

## **Code generation for coordinate transforms and select robotics algorithms**

For select Robotics System Toolbox algorithms, you can now generate C/C++ code using MATLAB Coder. You can create MEX-files and shared libraries from your MATLAB application. These code generation workflows are supported for the coordinate transformation functions (Coordinate System Transformations), the VFH+ obstacle avoidance algorithm, and the Pure Pursuit controller algorithm (`robotics.PurePursuit`). See Code Generation for more information.



# R2015a

---

**Version: 1.0**

**New Features**

## **Path planning, path following, and map representation algorithms**

The Robotics System Toolbox provides algorithms for path planning, path following, and map representations. The support in this release includes classes for Binary Occupancy Grids, Probabilistic Roadmaps (PRM), and a Pure Pursuit controller.

## **Functions for converting between different rotation and translation representations**

Coordinate system transformations are provided as functions for converting between many different representations including quaternions, rotation matrices, homogeneous transformation matrices, and Euler angles. Other functions are available for converting between radians and degrees and for angle calculations. For more information, see [Coordinate System Transformations](#).

## **Bidirectional communication with live ROS-enabled robots**

Communication with ROS using publishers and subscribers is available in MATLAB and Simulink. Many message types are readily supported. Robotics System Toolbox can also access ROS services, the parameter server, and the tf transformation tree in MATLAB.

## **Interface to Gazebo and other ROS-enabled simulators**

ROS-enabled simulators allow prototyping of algorithms and testing systems developed in MATLAB. Connection to a Gazebo simulator is supported with an example interacting with the simulator shown here: [Reading Model and Simulation Properties from Gazebo](#).

## **Data import from rosbag log files**

This release of the Robotics System Toolbox includes the ability to access rosbags, which are logfiles from ROS. You can access whole log files or portions and manipulate the data as desired (see [Working with rosbag Logfiles](#)).

## **ROS node generation from Simulink models (with Embedded Coder)**

This release includes ROS node generation using Simulink. You can use Simulink to create models that exchange messages with a ROS network. Using Embedded Coder, you can generate C++ code for standalone ROS nodes from these models.