Matlab与信号处理

周治国

2018.9

第一章

绪论

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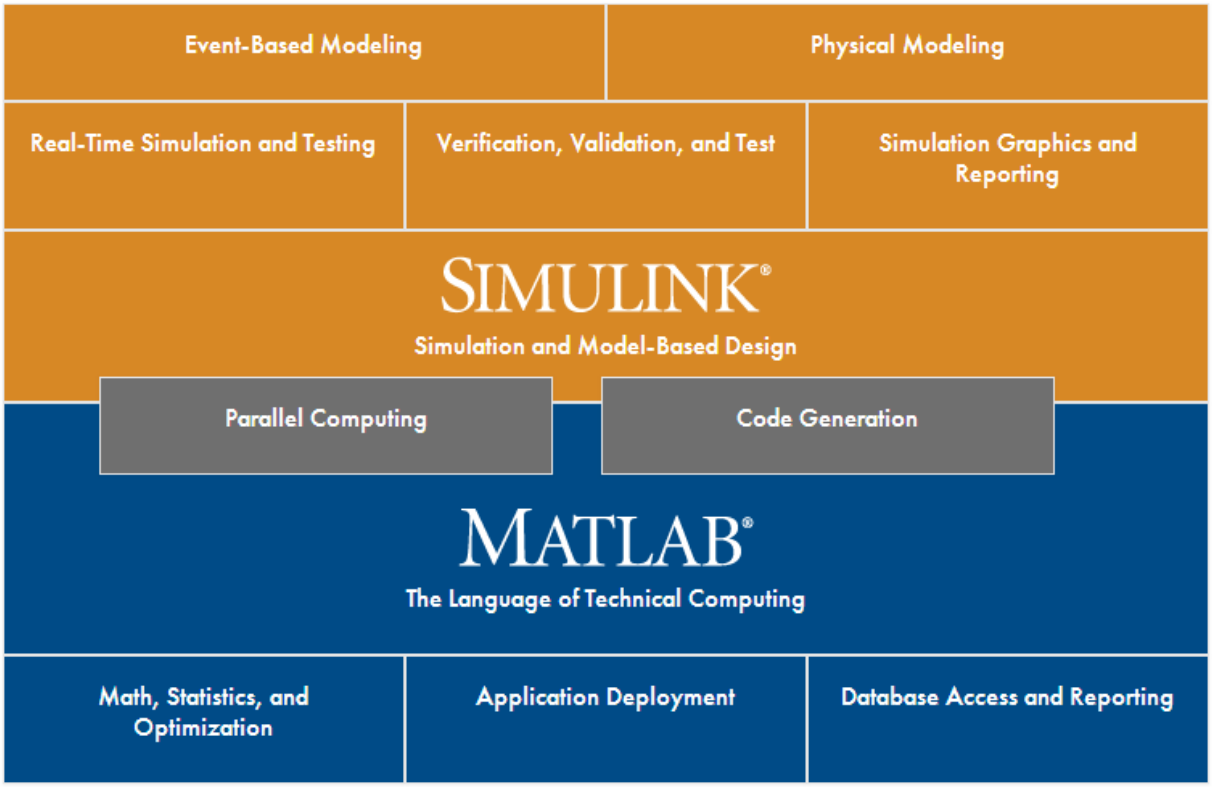

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- Control Systems
- Signal Processing and Communications
- Image Processing and Computer Vision
- Test and Measurement
- Computational Finance
- Computational Biology

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Perform signal processing, analysis, and algorithm development

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Design and simulate signal processing systems

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Design and test audio processing systems

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Design and simulate the physical layer of communication systems

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Analyze and synthesize signals and images using wavelet techniques

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Design, model, and analyze networks of RF components

Antenna Toolbox
Design, analyze, and visualize antenna elements and antenna arrays

Phased Array System Toolbox
Design and simulate phased array signal processing systems

RF Blockset
Design and simulate RF systems

Computer Vision System Toolbox
Design and simulate computer vision and video processing systems

LTE System Toolbox
Simulate, analyze, and test the physical layer of LTE and LTE-Advanced wireless communications systems

WLAN System Toolbox
Simulate, analyze, and test the physical layer of WLAN communications systems

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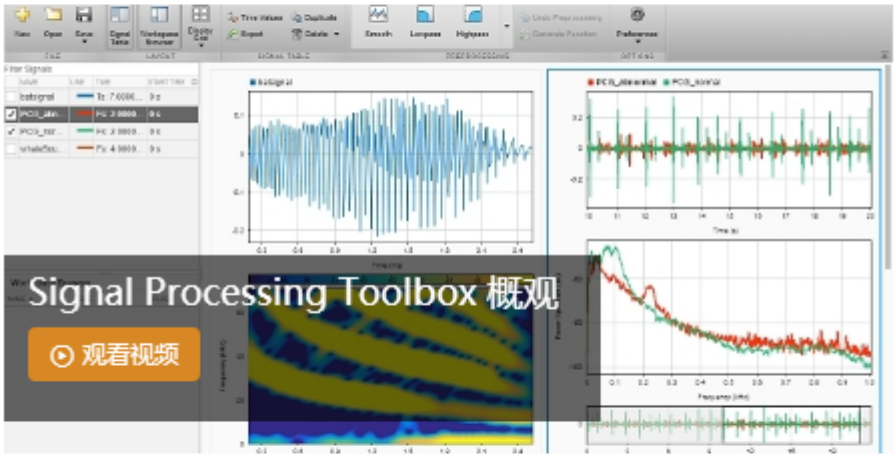
WLAN System Toolbox
Simulate, analyze, and test the physical layer of WLAN communications systems

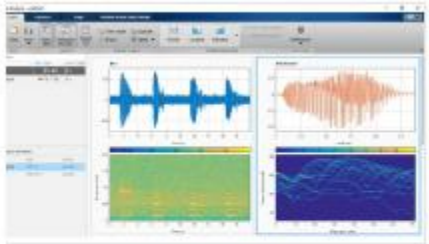
执行信号处理和分析

Signal Processing Toolbox™ 提供了用来分析、预处理均匀和非均匀采样的信号并从中提取特征的函数和应用程序。该工具箱包含用于滤波器设计和分析、重新采样、平滑处理、趋势消减和功率频谱估算的工具。该工具箱还提供了以下功能：提取变化点和包络之类的特征、查找峰值和信号模式、量化信号相似度，以及执行诸如 SNR 和失真等测量。您还可以执行振动信号的模态和阶次分析。

借助 Signal Analyzer 应用程序，您无需编写代码，就可以在时域、频域和时频域同时预处理和分析多个信号，探索长信号，并提取感兴趣区域。借助 Filter Designer 应用程序，您可以通过选择各种算法和响应来设计和分析数字滤波器。这两个应用程序都生成 MATLAB® 代码。



功能



信号探查

无需编写代码，便可探查时域、频域和时频域中的信号。

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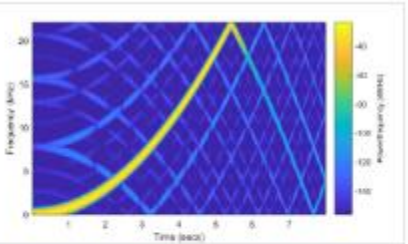

信号预处理

对信号进行去噪、平滑和重新采样，以做好进一步分析的准备。

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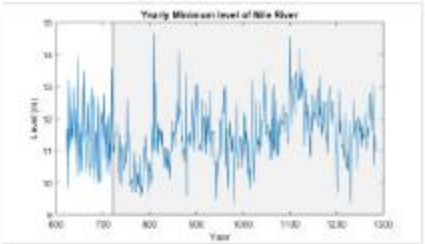

特征提取和信号测量

提取信号的独特特征并进行测量。

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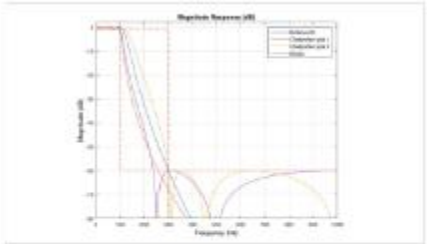

数字和模拟滤波器

设计、分析和实现各种数字 FIR 和 IIR 滤波器。

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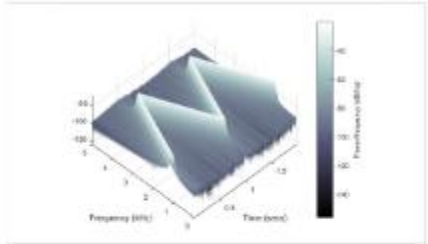

时频和频谱分析

描绘稳态和非稳态信号的频率内容。

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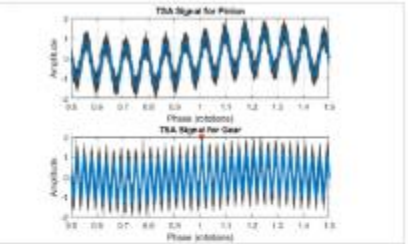


振动分析

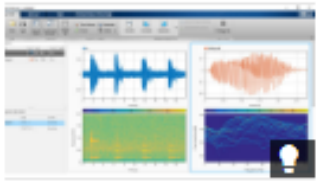
执行旋转机械的振动分析和结构的模态分析。

» 了解更多

信号探查

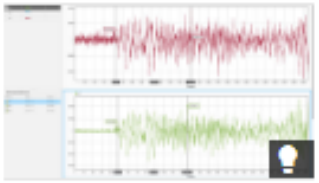
Signal Processing Toolbox™ 提供一些应用程序和函数，可用来分析、可视化和比较多个信号，检测和提取特征或有趣的事件。例如，借助 Signal Analyzer 应用程序，您可以：

- 分析时域、频域和时频域中的信号
- 预处理信号，以提高信号质量
- 从信号中提取感兴趣区域



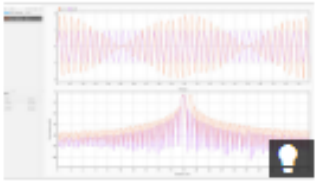
Signal Analyzer 应用程序简介

可视化和比较多个信号和频谱。



执行信号对齐

测量相关信号之间的时间延迟。



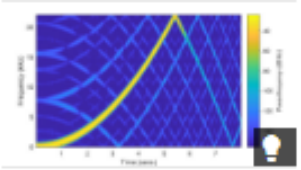
分解超短间距频谱分量

通过使用 Signal Analyzer 应用程序调节窗口泄露参数来识别音调。

信号预处理

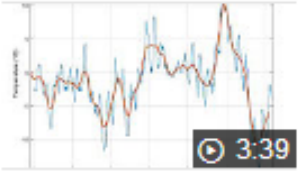
Signal Processing Toolbox 提供的函数允许您检测异常值，对常规采样信号进行平滑处理，并做好进行更深入分析的准备。例如，您可以：

- 从数据中消除噪声、异常值和虚假内容
- 增强信号、可视化信号和发现规律
- 更改信号的采样率，或者使采样不规律的信号或有数据丢失的信号具有恒定的采样率



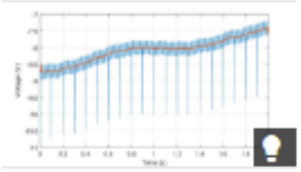
重新采样信号

更改信号的采样率而不引入人工产物。



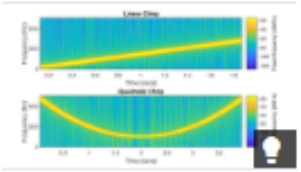
信号平滑处理

使用加权移动平均滤波器和 Savitzky-Golay 滤波器去除信号噪声。



异常值移除

使用中值滤波器消除尖峰



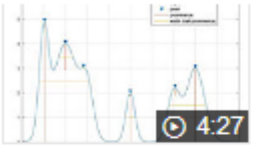
信号生成

生成脉冲和扫频信号（线性调频、VCO）。

特征提取和信号测量

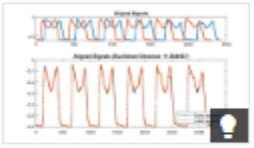
Signal Processing Toolbox 提供了可用来探查和提取信号中的模式的函数。具体来说，您可以：

- 找出信号峰值并确定它们的高度、宽度和相邻峰值的距离。
- 查找信号中的变化点并使用动态时间规整来校准信号。



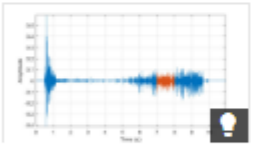
峰值分析

查找峰值位置并测量峰值高度、峰度和宽度。



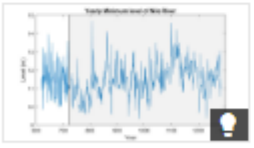
动态时间规整

提取用于步态信号分类的特征。



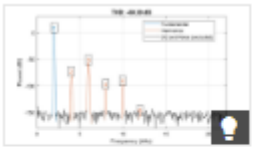
在数据中查找信号

在信号中查找完全或近似匹配。



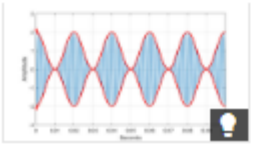
变化点检测

在时序数据中检测突变或有趣的事件。



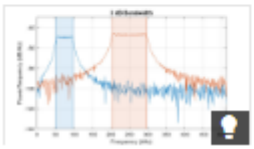
谐波失真

测量信噪比 (SNR)、总谐波失真 (THD) 以及信号对噪声和失真比 (SINAD)。



包络提取

使用希尔伯特变换和解析信号提取信号的包络



功率、带宽和频率

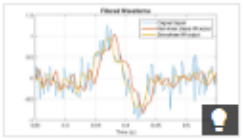
测量波段功率、带宽、均值和中值频率。

数字和模拟滤波器

数字滤波器

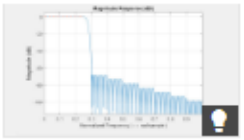
使用 Signal Processing Toolbox 中的函数和应用程序，设计、分析和实现各种数字 FIR 和 IIR 滤波器，如低通、高通和带阻。使用这些函数和应用程序，您可以：

- 对幅值、相位、群延迟、冲激和阶跃响应进行可视化
- 检查滤波器极点和零点
- 通过测试稳定性和相位线性来评估滤波器性能
- 使用零相位滤波对数据应用滤波器，并消除延迟和相位失真



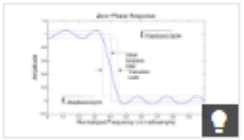
数字滤波

补偿由滤波器引入的延迟和失真。



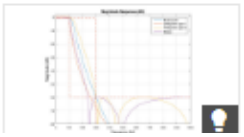
滤波器设计展示

探查低通、高通、带通、带阻、微分器和任意幅度频率响应。



FIR 滤波器设计

指定不同的滤波器设计约束条件，比较 FIR 设计算法，如 Parks-McClellan（等波纹）、最小二乘和 Kaiser 窗。



IIR 滤波器设计

比较 Butterworth、Chebyshev 和 elliptic IIR 滤波器的幅值和群延迟响应。

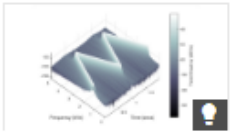
模拟滤波器

Signal Processing Toolbox 提供用于模拟滤波器设计和分析的函数。支持的模拟滤波器类型包括 Butterworth、Chebyshev、Bessel 和椭圆法。该工具箱还包含离散化函数，比如用于模拟滤波器到数字滤波器转换的脉冲响应不变法和双线性转换法。

时频和频谱分析

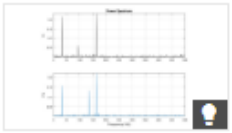
使用 Signal Processing Toolbox 中的一系列频谱分析函数和应用程序描述信号的频谱特征。基于 FFT 的非参数化方法（如 Welch 法或周期图法）对输入数据不作任何假设，可用于任何信号种类。参数化法和子空间法（如 Burg、Yule-Walker 和 MUSIC 方法）包含了信号的先验知识，可产生更准确的频谱估算。使用这些函数和应用程序，您可以：

- 使用 Lomb-Scargle 方法计算非均匀采样信号或丢失样本的信号的功率谱
- 使用时频技术（如频谱图）分析信号，通过估计频谱相关性来测量频域中的信号相似性



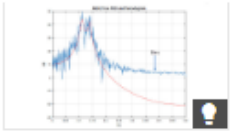
时频分析

使用频谱图确定信号中何时存在频率分量，探究时频分辨率权衡。



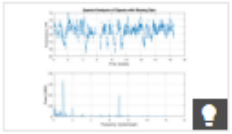
比较两个信号的频率

评估信号之间的频谱相关性，测量相关频率分量之间的相对相位。



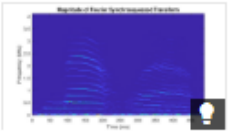
周期图中的偏差和变异性

使用 Welch 和多窗口方法的加窗操作和求平均值降低 PSD 偏差和变异性。



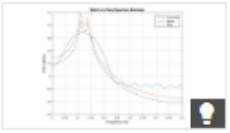
Lomb 周期图

估算非均匀采样信号或丢失样本的信号的频谱。



傅里叶同步压缩

获取锐化的时频估算并提取信号模式。



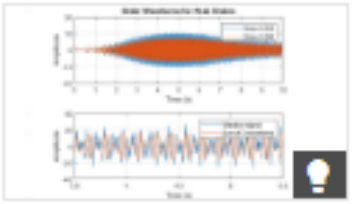
参数化方法

对短信号建模，作为自回归 (AR) 过程的输出，达到更高的频谱分辨率。

振动分析

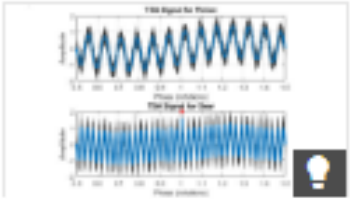
Signal Processing Toolbox 提供了可用来研究和描绘机械系统中的振动的函数。具体来说，您可以：

- 使用阶次分析，分析并可视化在旋转机械中出现的频谱成分
- 跟踪和提取阶次及其时域波形
- 以阶次的函数形式估算一个信号的平均频谱
- 通过估算频率响应函数、自然频率、阻尼比和模态形状进行实验性的模态分析



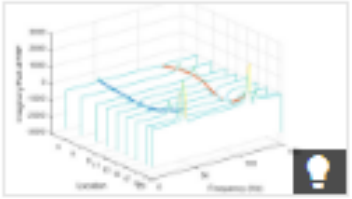
振动信号的阶次分析

使用阶次分析，识别多余振动的来源。



旋转机械的振动分析

使用时间同步的平均和包络频谱，分析变速箱的状况。



风力涡轮叶片的模态分析

通过估算频率响应函数评估的模式形状向量，分析风力涡轮叶片的动态行为。

产品资源

通过浏览这些资源，探索有关 Signal Processing Toolbox 的更多信息。

文档

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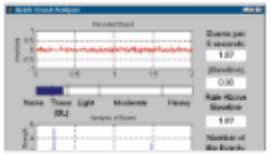
- 数据分析 
- 数据分析 
- 机器人 
- 测试和测量 
- 算法开发 
- 计算金融学 

新闻与事件

美国空军和海军提高测试数据分析速度

DEQX 使用 MATLAB 改善扬声器音质



福特汽车公司开发和部署声音质量衡量指标

Loren 带你品味 MATLAB 的艺术

用 MATLAB 书写创意

MATLAB 部署到 iPhone 和 Android 变得简单

观看在线研讨会 (47:01)

Signal Processing and Communications

Signal Processing Toolbox
Perform signal processing, analysis, and algorithm development

DSP System Toolbox
Design and simulate signal processing systems

Audio System Toolbox
Design and test audio processing systems

Communications System Toolbox
Design and simulate the physical layer of communication systems

Wavelet Toolbox
Analyze and synthesize signals and images using wavelet techniques

RF Toolbox
Design, model, and analyze networks of RF components

Antenna Toolbox
Design, analyze, and visualize antenna elements and antenna arrays

Phased Array System Toolbox
Design and simulate phased array signal processing systems

RF Blockset
Design and simulate RF systems

Computer Vision System Toolbox
Design and simulate computer vision and video processing systems

LTE System Toolbox
Simulate, analyze, and test the physical layer of LTE and LTE-Advanced wireless communications systems

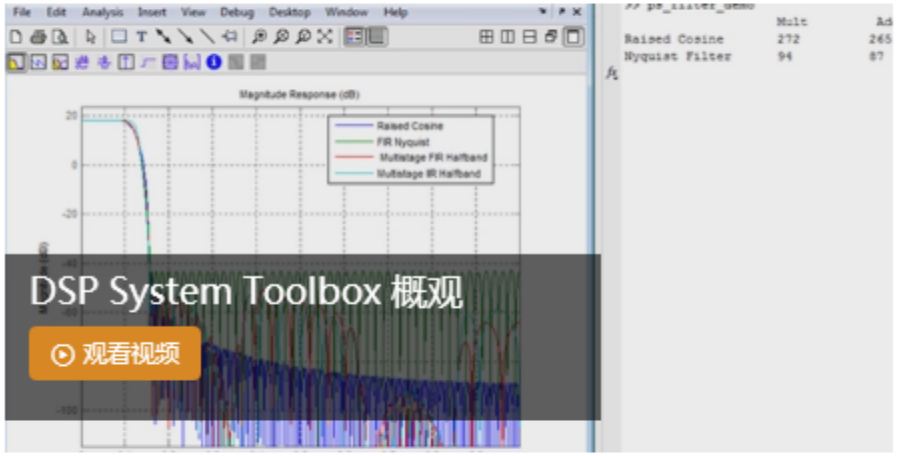
WLAN System Toolbox
Simulate, analyze, and test the physical layer of WLAN communications systems

对流信号处理系统进行设计和仿真

DSP System Toolbox™ 提供了各种算法、应用程序和示波器，用于在 MATLAB® 和 Simulink® 中设计、仿真和分析信号处理系统。您可以为通信、雷达、音频、医疗设备、IoT 和其它应用进行实时 DSP 系统建模。

使用 DSP System Toolbox 可以设计和分析 FIR、IIR、多速率、多级和自适应滤波器。您可以从变量、数据文件和网络设备传输信号流来进行系统开发和验证。示波器、频谱分析仪和逻辑分析仪可用于对流信号进行动态可视化和测量。对于桌面原型建立和部署至嵌入式处理器（包括 ARM® Cortex® 架构），该系统工具箱支持 C/C++ 代码生成。它支持从滤波器、FFT、IFFT 和其他算法进行位准确的定点建模和 HDL 代码生成。

算法形式可以是MATLAB 函数、System objects™ 和 Simulink 模块。



R2018a

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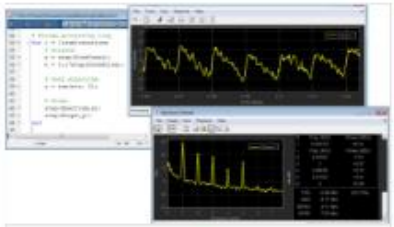
免费电子书：使用 MATLAB 进行无线设计

马上下载

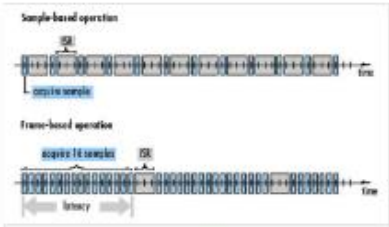
功能



MATLAB 中的流信号处理

在 MATLAB 中处理流信号。

» 了解更多



Simulink 中的信号处理和线性代数模块

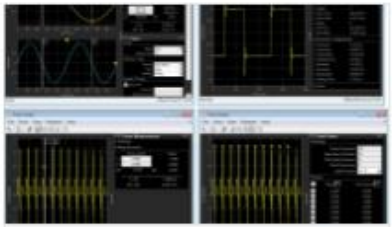
使用滤波器、信号变换和线性代数的信号处理算法模块库。

» 了解更多

单速率和多速率 FIR 和 IIR 滤波器设计和自适应滤波器

使用大量 FIR、IIR、多级、多速率和自适应滤波器的滤波器设计和实现算法。

» 了解更多



信号示波器、分析仪和测量

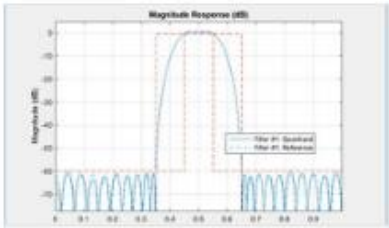
使用各种文件格式、声音设备 I/O 执行多声道实时音频捕获和处理，并且支持低延迟。

» 了解更多

定点建模和仿真

执行 MATLAB 和 Simulink 中流信号的时域或频域可视化、测量和分析。

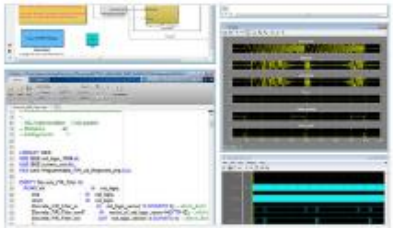
» 了解更多



用于桌面和嵌入式工作流程的 C 和 C++ 代码生成

通过信号处理算法和系统模型生成针对性能调优的 C 和 C++ 源代码或 MEX 函数

» 了解更多



为 FPGA 和 ASIC 开发生成 HDL 代码

设计数字滤波器并生成有效的、可合成且可移植的 VHDL 和 Verilog 代码用于 FPGA 或 ASIC 中的实现。

» 了解更多

产品资源

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System Objects

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Connect DSP System Toolbox to hardware platforms.

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相关解决方案

使用 Signal Processing Toolbox 来解决科技与工程上的挑战：

数字信号处理 

数据分析 

数据分析 

机器人 

测试和测量 

算法开发 

计算金融学 

MathWorks® 产品 解决方案 学术 支持 社区 活动

Digital Signal Processing (DSP)

Search Math

Signal processing is essential for a wide range of applications, from data science to real-time embedded systems. MATLAB® and Simulink® products make it easy to use signal processing techniques to explore and analyze time-series data, and they provide a unified workflow for the development of embedded systems and streaming applications.

With MATLAB and Simulink signal processing products, you can:

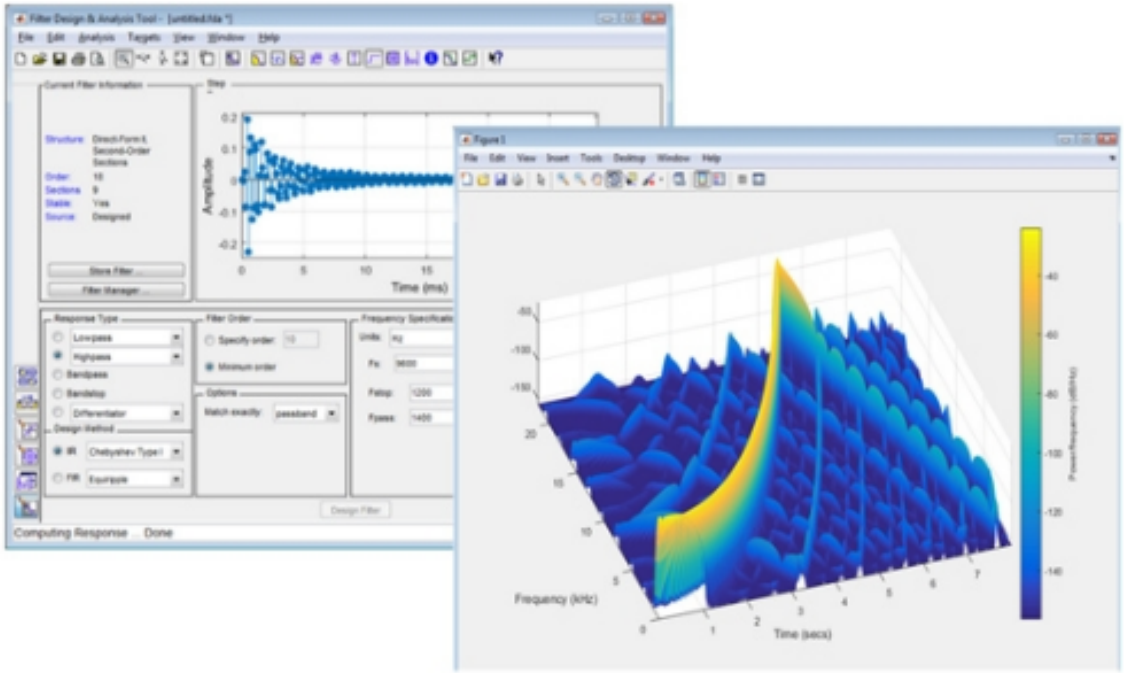
- Acquire, measure, and analyze signals from many sources.
- Design streaming algorithms for audio, smart sensor, instrumentation, and IoT devices.
- Prototype, test, and implement DSP algorithms on PCs, embedded processors, SoCs, and FPGAs.

https://ww2.mathworks.cn/solutions/dsp.html

Signal Analysis for Everyone

MATLAB and signal processing products help you analyze signals from a range of data sources. You can acquire, measure, transform, filter, and visualize signals without being an expert in signal processing theory. You can apply signal processing tools to:

- Preprocess and filter signals prior to analysis.
- Explore and extract features for data analytics and machine learning applications.
- Analyze trends and discover patterns in signals.
- Visualize and measure time and frequency characteristics of signals.



https://ww2.mathworks.cn/solutions/dsp.html

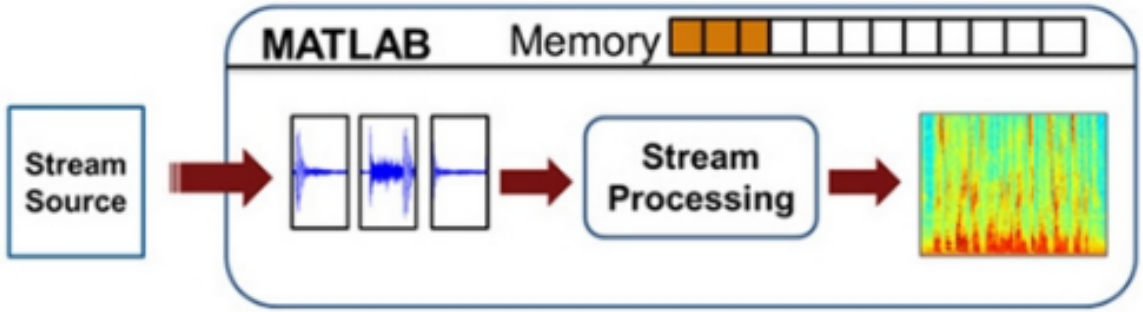
Streaming DSP Design

MathWorks provides design apps, DSP algorithm libraries, and I/O interfaces for real-time processing of streaming signals in MATLAB and Simulink. You can rapidly design and simulate streaming algorithms for audio, video, instrumentation, smart sensors, wearable devices, and other electronic systems.

DSP System Toolbox™ enables a workflow that helps you design and verify your streaming applications in one environment. You can rapidly optimize designs, find errors early, and deliver a working PC-based prototype.

This streaming design workflow provides:

- Implementation-ready DSP algorithms and extensive filter design tools
- System-level integration and simulation of algorithms and electronic components
- Professional-quality streaming signal scopes, analyzers, and measurements
- Low-latency multichannel I/O for real-time audio processing
- Code generation for accelerating simulation and real-time prototyping

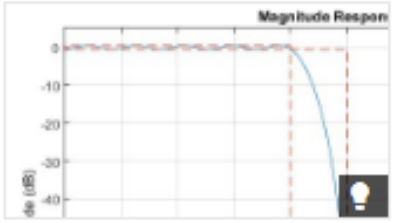


Embedded DSP Implementation

MATLAB and Simulink products streamline the development of embedded DSP software and hardware by providing a complete workflow for fixed-point design and code generation. Using your streaming algorithm and test bench in DSP System Toolbox, you can:

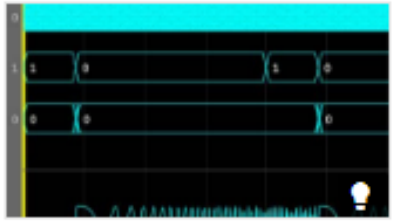
- Verify fixed-point designs in simulation before implementation.
- Automatically generate C/C++ or HDL code for production and integration into your application.
- Incorporate implementation-ready algorithms that generate optimized C code for ARM® processors and HDL code for FPGAs and ASICs

Learn more about capabilities for fixed-point design, embedded C code generation, HDL code generation, and HDL verification.



Floating-Point to Fixed-Point Filter Conversion

ARM Cortex-A, -R, -M Optimized Code Generation using MATLAB and Simulink



Generate HDL Code for Programmable FIR Filters

Signal Processing and Communications (MathWorks Consulting)

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数据分析 

机器人 

测试和测量 

算法开发 

计算金融学 

Engineering and IT teams are using MATLAB to build today's advanced Big Data Analytics systems ranging from predictive maintenance and telematics to advanced driver assistance systems and sensor analytics. Teams select MATLAB because it offers essential capabilities not found in business intelligence systems or open source languages:

Physical-world data: MATLAB has native support for sensor, image, video, telemetry, binary, and other real-time formats. Explore this data using MATLAB MapReduce functionality for Hadoop, and by connecting interfaces to ODBC/JDBC databases.

Machine learning, neural networks, statistics, and beyond: MATLAB offers a full set of statistics and machine learning functionality, plus advanced methods such as nonlinear optimization, system identification, and thousands of prebuilt algorithms for image and video processing, financial modeling, control system design.

High speed processing of large data sets. MATLAB's numeric routines scale directly to parallel **processing on clusters and cloud.**

Online and real-time deployment: MATLAB integrates into enterprise systems, clusters, and clouds, and can be targeted to real-time embedded hardware.

"No matter what industry our client is in, and no matter what data they ask us to analyze - text, audio, images, or video - MATLAB code enables us to provide clear results faster."

— *Dr. G. Subrahamanya VRK Rao, Cognizant*

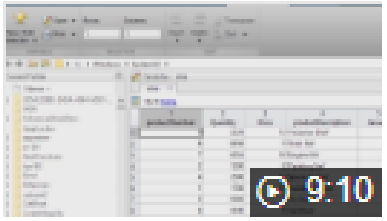
https://ww2.mathworks.cn/solutions/data-analytics.html

Accessing and Exploring Data

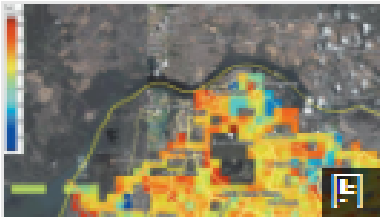
The first step in performing data analytics is to access the wealth of available data to explore patterns and develop deeper insights. From a single integrated environment, MATLAB helps you access data from a wide variety of sources and formats including:

- Databases (ODBC-compliant and JDBC-compliant), data warehouses, and distributed file systems (Hadoop)
- Financial data servers to access live and historical market data
- Internet of Things devices
- OPC servers to access live and historical industrial plant data
- File I/O including text, spreadsheet, XML, CDF/HDF, image, audio, video, geospatial, and web content

MATLAB for Data Analytics



Using the Database Explorer App



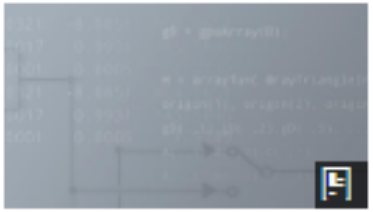
Analyzing Test Data from a Worldwide Fleet of Vehicles

Access and Organize Data with MATLAB

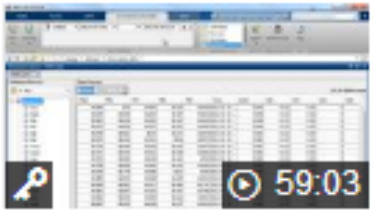
Preprocessing and Data Munging

When working with data from numerous sources and repositories, engineers and scientists need to preprocess and prepare data before developing predictive models. For example, data might have missing values or erroneous values, or it might use different timestamp formats. MATLAB helps you simplify what might otherwise be time-consuming tasks such as:

- Cleaning data that has errors, outliers, or duplicates
- Handling missing data with discarding, filtering, or imputation
- Removing noise from sensor data with advanced signal processing techniques
- Merging and time-aligning data with different sample rates
- Feature selection to reduce high-dimension data to improve model predictive power
- Feature extraction and transformation for dimensionality reduction
- Domain analysis such as signal, image, text, and video processing



Feature Selection



Working with Time-Series Data in MATLAB

Turning an Idea into a Data-Driven Production System: An Energy Load Forecasting Case Study

Preprocessing Time-Series Data with MATLAB

Developing Predictive Models

Prototype and build predictive models directly from data to forecast and predict the probabilities of future outcomes. You can compare machine learning approaches such as logistic regression, classification trees, support vector machines, and ensemble methods, and use model refinement and reduction tools to create an accurate model that best captures the predictive power of your data. Use flexible tools for processing financial, signal, image, video, and mapping data to create analytics for a variety of fields within the same development environment.

Machine Learning with MATLAB Overview

How Weather and Pricing Affect Sales: Using MATLAB to Improve Tesco's Supply Chain

BuildingIQ Develops Proactive Algorithms for HVAC Energy Optimization in Large-Scale Buildings

Deep Learning with MATLAB (5 Videos)

Predictive Analytics with MATLAB

(White Paper)

Integrating Analytics with Systems

Integrate analytics developed in MATLAB into production IT environments (23:19) without having to recode or create custom infrastructure. MATLAB analytics can be packaged as deployable components compatible with a wide range of development environments such as Java, Microsoft .NET, Excel, Python, and C/C++. You can share standalone MATLAB applications or run MATLAB analytics as a part of web, database, desktop, and enterprise applications. For low latency and scalable production applications, you can manage MATLAB analytics running as a centralized service that is callable from many diverse applications.

Big Data and Predictive Analytics at Shell

Horizon Wind Energy Develops Revenue Forecasting and Risk Analysis Tools for Wind Farms

Advanced Crash Detection at RAC: The Road from Deployment to Production

Data Analytics for Engine and Vehicle Design

MATLAB in Business Critical Applications (MathWorks Consulting)

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测试和测量 

算法开发 

计算金融学 

Data Analysis

With MATLAB® and related data analysis products you perform analyses and gain insight into your data in a fraction of the time required with spreadsheets or traditional programming languages such as C, C++, or Visual Basic.

These products combine a powerful numeric engine and programming environment with interactive tools for statistical analysis, image processing, signal processing, and other domains. You can:

- Access data from files, spreadsheets, databases, test equipment, data acquisition hardware, other software, or the Web
- Explore your data to identify trends, test hypotheses, and estimate uncertainty
- Create customized algorithms, visualizations, and models and publish customized reports
- Share your analysis tools as MATLAB code or as standalone desktop or Web applications

Learn More About Data Analysis Solutions

Analyzing Historical and Experimental Data

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Analyzing Data from Simulations or Physical Tests

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Building Custom Data Analysis Tools, Visualizations, or Applications

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使用 Signal Processing Toolbox 来解决科技与工程上的挑战：

数字信号处理 

数据分析 

数据分析 

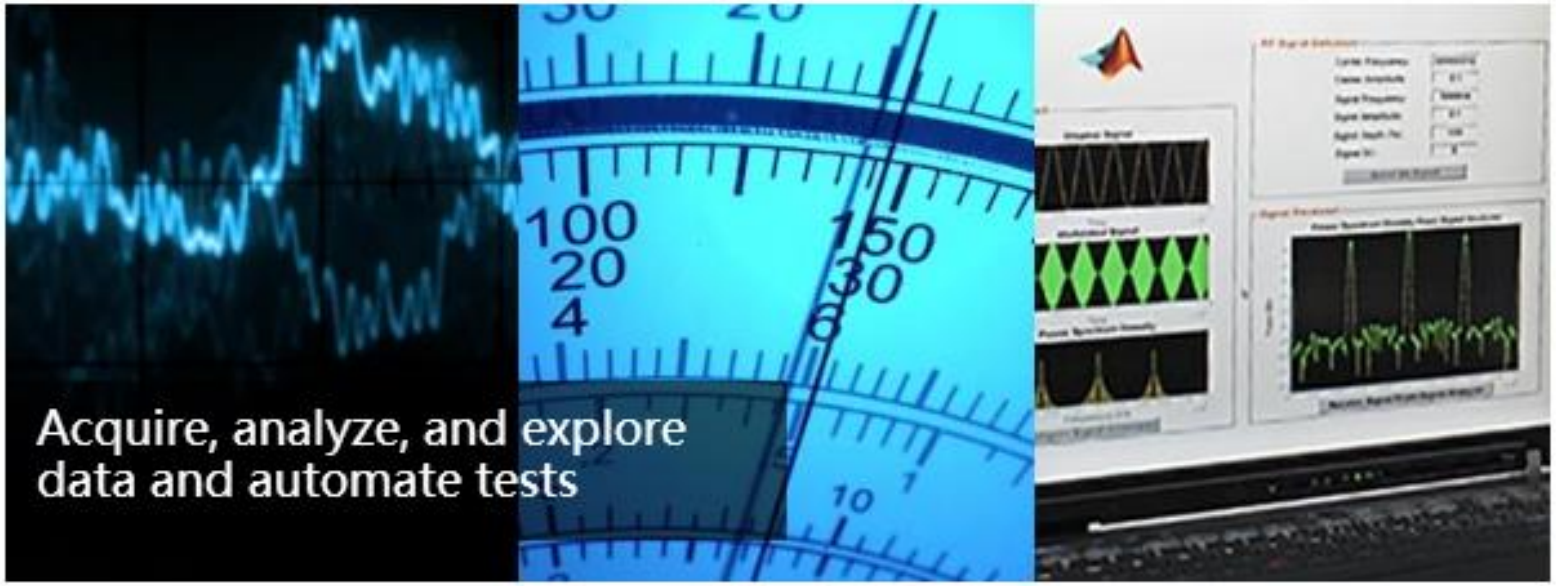
机器人 

测试和测量 

算法开发 

计算金融学 

Test and Measurement



The MATLAB® environment for analysis provides the tools you need to acquire data and automate tasks. Within MATLAB and Simulink® you can control and acquire data from plug-in data acquisition boards, test instruments, Web cameras and frame grabbers, as well as send and receive messages over CAN buses.

Once you acquire data, you can interactively explore it and perform live visualization and data analysis. You can then build test systems, verify designs and concepts, and automate repetitive tasks. You can also deploy test applications built in MATLAB onto other computers.

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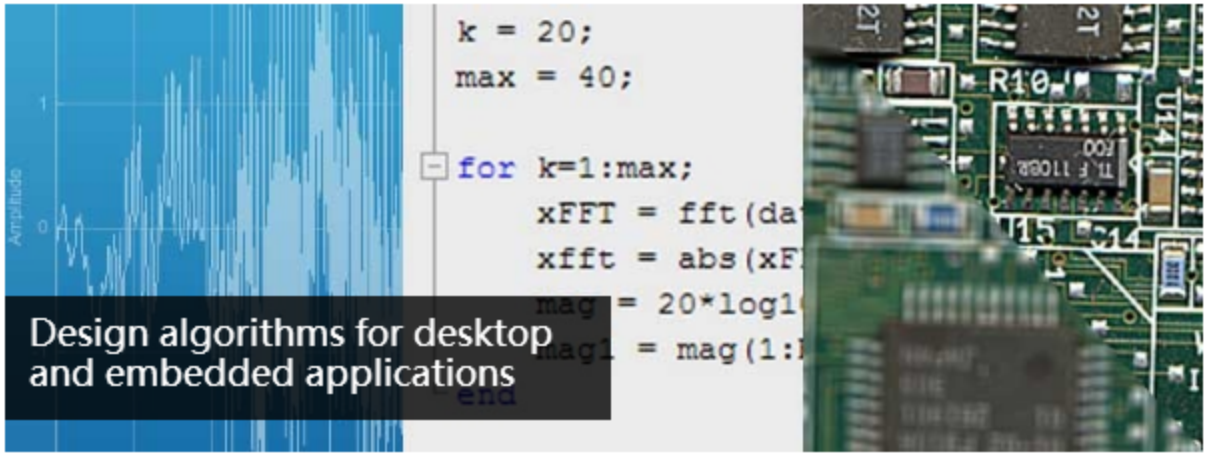
Algorithm Development



MATLAB® lets you develop algorithms much faster than in traditional languages such as C, C++, or Fortran. You can validate concepts, explore design alternatives, and distribute your algorithm in the form that best suits your application. MATLAB provides the tools you need to transform your ideas into algorithms, including:

- Thousands of core mathematical, engineering, and scientific functions
- Application-specific algorithms in domains such as signal and image processing, control design, computational finance, and computational biology
- Development tools for editing, debugging, and optimizing algorithms

These capabilities, combined with MATLAB programs created by the worldwide user community, let you explore approaches that otherwise would be too time-consuming to consider.

Your completed algorithms can be converted into self-contained applications and software components for desktop and Web deployment. Alternatively, you can incorporate the algorithm in a system simulation or an embedded system.

Learn More About Algorithm Development Solutions

Developing Algorithms in the MATLAB Environment

» Learn more

Designing Embedded Algorithms

» Learn more

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Robotics and Autonomous Systems

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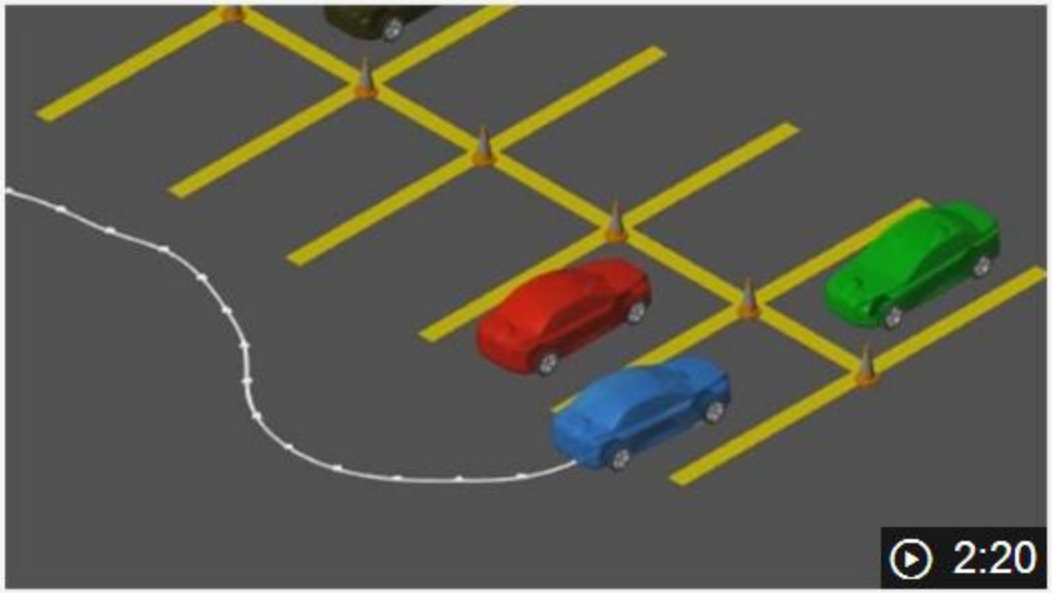
Robotics researchers and engineers use MATLAB and Simulink to design and tune algorithms, model real-world systems, and automatically generate code – all from one software environment.

With MATLAB and Simulink, you can:

- Connect to and control your robot **with the algorithms you develop**.
- Develop **hardware-agnostic algorithms** and connect to the **Robot Operating System (ROS)**.
- Connect to a **range of sensors and actuators** so you can send control signals or analyze many types of data.
- **Eliminate hand-coding** by automatically generating code for embedded targets like microcontrollers, FPGAs, PLCs, and GPUs in many languages such as C/C++, VHDL/Verilog, Structured Text, and CUDA.
- Connect to **low-cost hardware such as Arduino and Raspberry Pi** using pre-built hardware support packages.
- **Simplify design reviews** by creating shareable code and applications.
- Work with legacy code and **integrate with existing robotics systems**.

Watch a Robotics Example



Path Planning and Navigation for Autonomous Robots

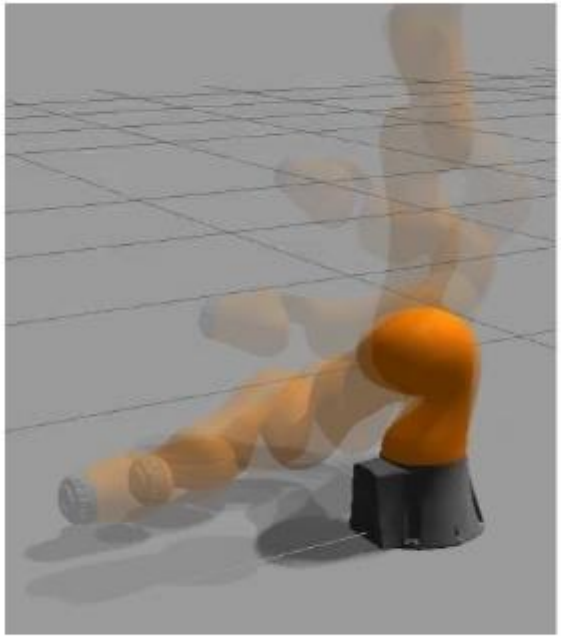
Simplify the complex tasks of robotic path planning and navigation using MATLAB and Simulink. This demonstration walks through how to simulate an autonomous robot using just three components: a path, a vehicle model, and a path following algorithm.

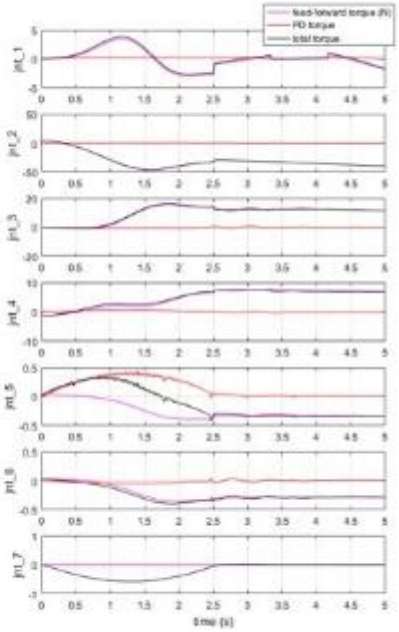
Follow along:

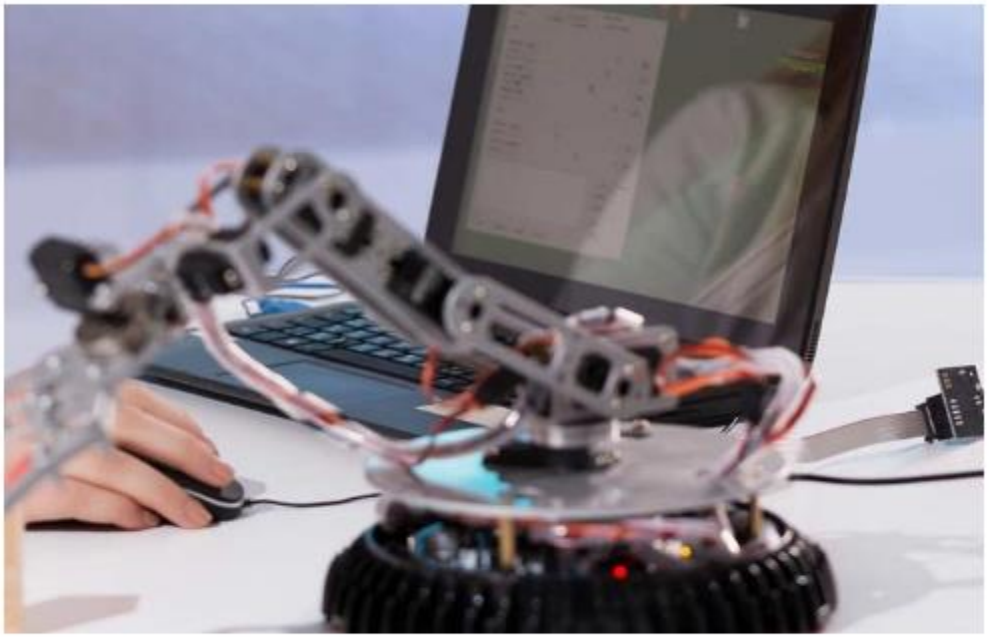
Get a trial of the products you' ll need and download the model.

Designing the Hardware Platform

Design and analyze 3D rigid-body mechanics (such as vehicle platforms and manipulator arms) and actuator dynamics (such as mechatronic or fluid systems). You can work directly with existing CAD files by importing URDF files directly into Simulink or from CAD software like SolidWorks and Onshape. Add constraints, such as friction, and model multi-domain systems (2:15) with electrical, hydraulic, or pneumatic, and other components.







Collecting Sensor Data

You can connect to sensors through ROS. Specific sensors, such as cameras, LiDAR, and IMUs, have ROS messages that can be converted to MATLAB data types for analysis and visualization.

You can automate common sensor processing workflows such as importing and batch-processing large data sets, sensor calibration, noise reduction, geometric transformation, segmentation, and registration.

Perceiving the Environment

Built-in MATLAB apps let you interactively perform object detection and tracking, motion estimation, 3D point-cloud processing, and sensor fusion. Use deep learning for image classification, regression, and feature learning using convolutional neural networks (CNNs).

Automatically convert your algorithms into C/C++, fixed-point, HDL, or CUDA code.

Planning and Decision Making

Create a map of the environment using the LiDAR sensor data via Simultaneous Localization and Mapping (SLAM).
Navigate constrained environments by designing algorithms for path and motion planning. Use path planners to compute an obstacle-free path in any given map.

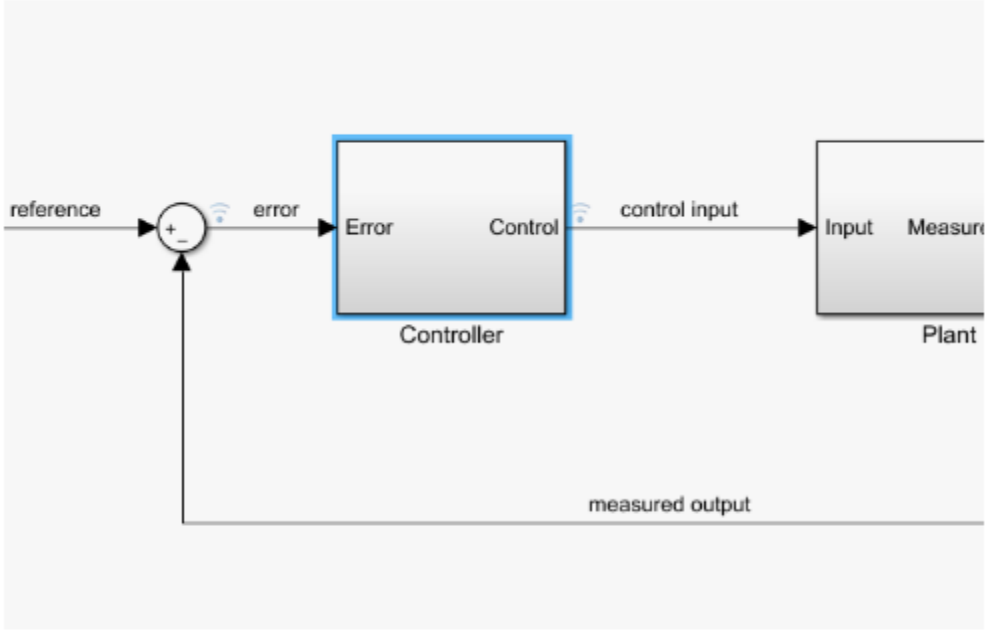
Design algorithms that allow your robot to make decisions when faced with uncertainty and perform safe operation in collaborative environment.
Implement state machines to define the conditions and actions needed for decision making.

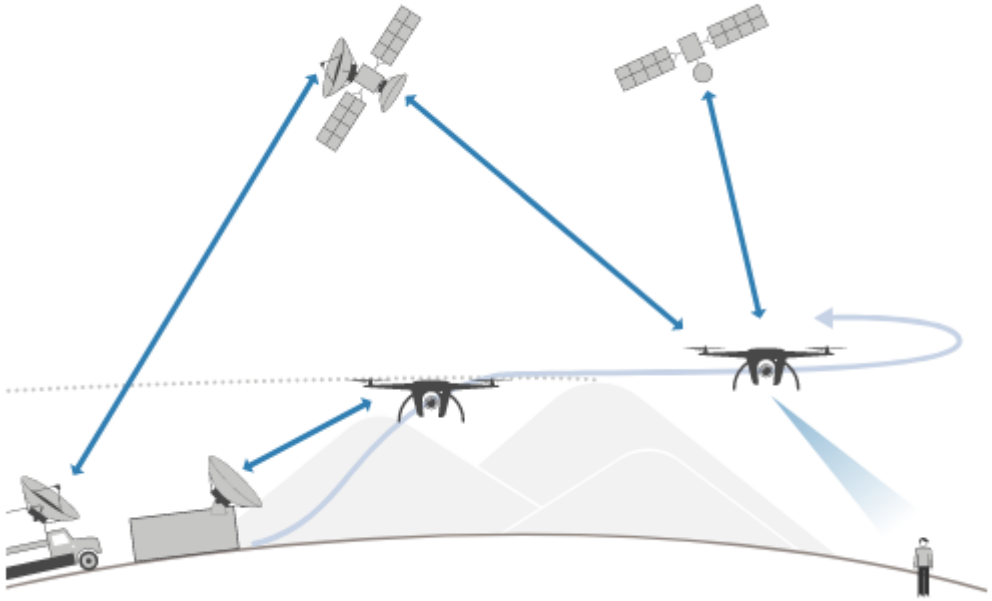
Designing Control Systems

You can use algorithms and apps to systematically analyze, design, and visualize the behavior of complex systems in time and frequency domains.

Automatically tune compensator parameters using interactive techniques such as bode loop shaping and the root locus method. You can tune gain-scheduled controllers and specify multiple tuning objectives, such as reference tracking, disturbance rejection, and stability margins.

Code generation and requirements traceability helps you validate your system and certify compliance.





Communicating with Other Platforms and Targets

Communicate with embedded targets using several protocols including CAN, EtherCAT, and 802.11. Use digital, RF, and other wireless technologies to connect to hardware that supports TCP/IP, UDP, I2C, SPI, MODBUS, and Bluetooth serial protocols.

> "With MATLAB and Simulink we can use a single environment for control algorithm development, debugging, data analysis, and more—instead of switching between multiple tools. That integration reduces overall project development time and the chances of introducing errors."
>
> — *Dr. John Wen, Rensselaer Polytechnic Institute*

Learn How You Can Use MATLAB with Robotics Hardware

Parrot Minidrone

Turtlebot 2

Kinova: JACO²

» Explore all supported hardware