

Lecture 10: Supercomputing for Robotics

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Challenges of supercomputing

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- Cloud computing for robotics
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Supercomputing for Robotics

My Mac Laptop

The screenshot shows the 'Hardware' section of the System Information application on a MacBook Pro. The left sidebar has three items: 'Hardware' (selected), 'Network', and 'Software'. The main pane is titled 'MacBook Pro' and contains a 'Hardware Overview' table.

| | MacBook Pro |
|--------------------------|--------------------------------------|
| Model Name: | MacBook Pro |
| Model Identifier: | MacBookPro17,1 |
| Model Number: | Z11C000C1X/A |
| Chip: | Apple M1 |
| Total Number of Cores: | 8 (4 performance and 4 efficiency) |
| Memory: | 16 GB |
| System Firmware Version: | 10151.61.4 |
| OS Loader Version: | 10151.61.4 |
| Serial Number (system): | C02GQ3EMQ05P |
| Hardware UUID: | 05246B10-4FD6-55A9-AB98-8407CE4FC0B2 |
| Provisioning UDID: | 00008103-000C54C914EB001E |
| Activation Lock Status: | Disabled |

Supercomputing for Robotics

My Mac Laptop

| Process Name | % CPU | CPU Time | Threads | Idle Wake Ups | Kind | % GPU | GPU Time | PID |
|----------------------------|-------|-------------|---------|---------------|-------|-------|------------|-------|
| WindowServer | 11.4 | 12:11:12.36 | 23 | 108 | Apple | 7.6 | 1:31:05.49 | 197 |
| kernel_task | 10.1 | 10:02:31.33 | 489 | 1031 | Apple | 0.0 | 0.00 | 0 |
| wdavdaemon_unprivileged | 4.8 | 9.16 | 14 | 1 | Apple | 0.0 | 0.00 | 33077 |
| sysmond | 4.1 | 3:19:43.56 | 3 | 0 | Apple | 0.0 | 0.00 | 387 |
| JamfDaemon | 3.5 | 1:14:34.35 | 7 | 2 | Apple | 0.0 | 0.00 | 7577 |
| launchd | 3.2 | 3:21:32.65 | 4 | 0 | Apple | 0.0 | 0.00 | 1 |
| Activity Monitor | 2.9 | 2:11:15.53 | 5 | 4 | Apple | 0.0 | 0.00 | 1303 |
| Microsoft SharePoint | 2.6 | 2:23:21.03 | 18 | 7 | Apple | 0.0 | 0.00 | 1633 |
| Google Chrome | 1.9 | 5:13:47.33 | 48 | 2 | Apple | 0.0 | 1.31 | 1269 |
| Acrobat | 1.7 | 44:41.27 | 56 | 200 | Apple | 0.0 | 3:13.89 | 92011 |
| distnoted | 1.4 | 1:20:09.55 | 2 | 0 | Apple | 0.0 | 0.00 | 1118 |
| wdavdaemon | 1.4 | 16:38:15 | 30 | 1 | Apple | 0.0 | 0.00 | 23984 |
| epsext | 1.2 | 14:45.41 | 4 | 12 | Apple | 0.0 | 0.00 | 24529 |
| coreaudiod | 1.1 | 51:41.42 | 16 | 0 | Apple | 0.0 | 0.00 | 269 |
| runningboardd | 1.1 | 32:06.33 | 7 | 1 | Apple | 0.0 | 0.00 | 203 |
| wdavdaemon_enterprise | 1.1 | 22:18.62 | 14 | 0 | Apple | 0.0 | 0.00 | 24289 |
| logd | 1.0 | 50:40.52 | 4 | 0 | Apple | 0.0 | 0.00 | 125 |
| Google Chrome Helper (GPU) | 1.0 | 3:01:59.19 | 19 | 43 | Apple | 1.7 | 35:20.07 | 1501 |

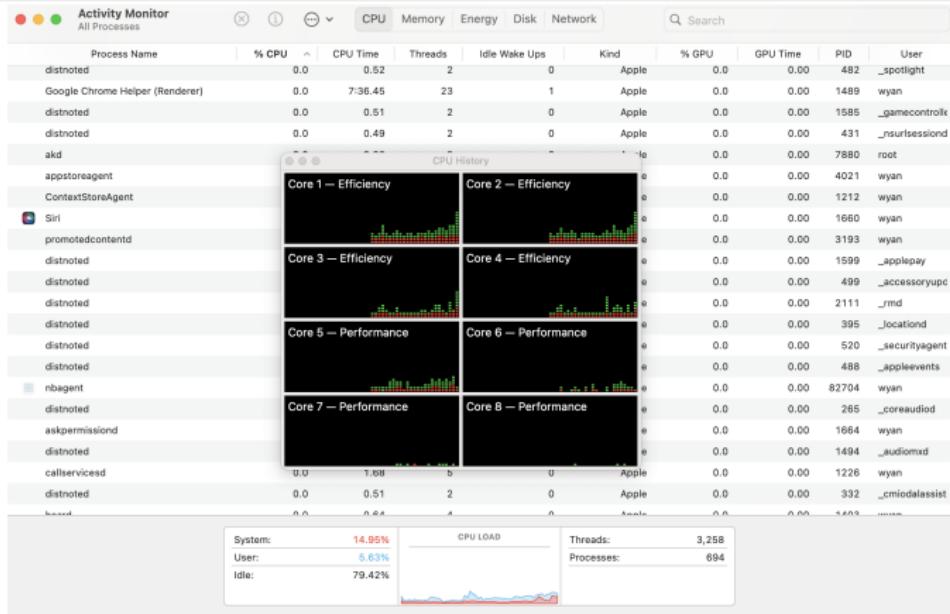
System: 5.10%
User: 5.70%
Idle: 89.20%

CPU LOAD

Threads: 3,637
Processes: 637

Supercomputing for Robotics

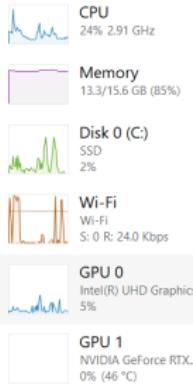
My Mac Laptop



Supercomputing for Robotics

My GPU Laptop

Performance



GPU



Intel(R) UHD Graphics



Shared GPU memory usage



Utilization
5%

Shared GPU memory
1.1/7.8 GB

Driver version: 31.0.1014.502
Driver date: 15/06/2023
DirectX version: 12 (FL 12.1)
Physical location: PCI bus 0, device 2, function 0

GPU Memory

1.1/7.8 GB

Challenges of Supercomputing

- *Parallel computing*: Simultaneous use of multiple processors
- *Multi-core processors*: Multiple processors (cores) on a single chip
- *Cluster computing*: Hierarchical combination of commodity units to build parallel system
- *Supercomputing*: Historically vector computers, now parallel vector
- *High performance computing*: Solving problems via supercomputers + fast networks + visualization

Multithreading

- In sequential computing, the components of a program are executed step-by-step to produce correct results.
- Parallelism is a condition wherein multiple tasks or distributed parts of a task run independently and simultaneously on multiple processors.
- A process is a program in execution with its own address space, memory, data stack, etc. under one operating system.
- The multiple threads execute within the same process and share the same context.

<https://www.dataquest.io/blog/multithreading-in-python/>

Supercomputing for Robotics

Multithreading in Python

```
▶ import threading
import time

def calc_square(numbers):
    for n in numbers:
        print(f'\n{n} ^ 2 = {n*n}')
        time.sleep(0.1)

def calc_cube(numbers):
    for n in numbers:
        print(f'\n{n} ^ 3 = {n*n*n}')
        time.sleep(0.1)

numbers = [2, 3, 5, 8]

start = time.time()

square_thread = threading.Thread(target=calc_square, args=(numbers,))
cube_thread = threading.Thread(target=calc_cube, args=(numbers,))

square_thread.start()
cube_thread.start()

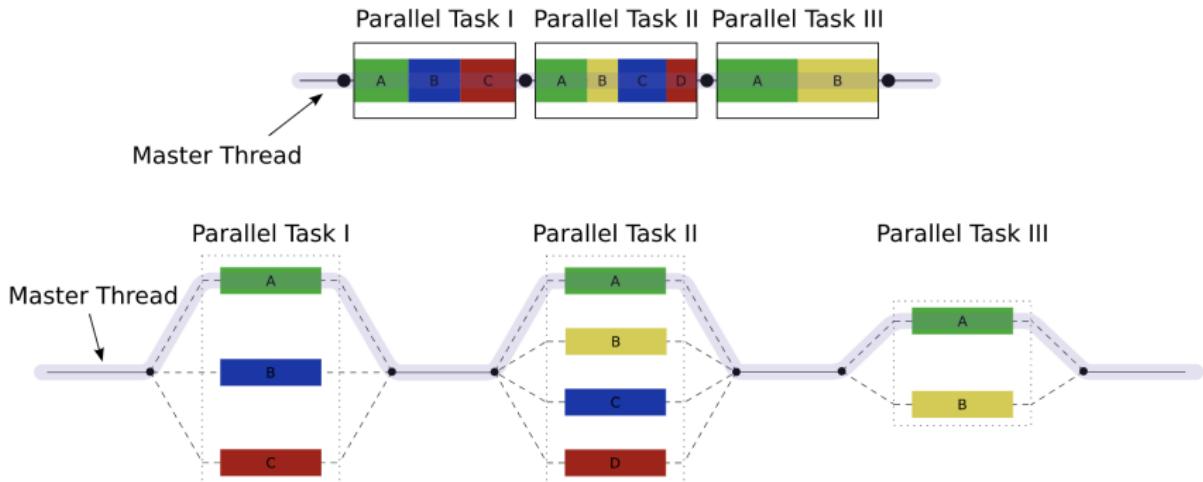
square_thread.join()
cube_thread.join()

end = time.time()

print('Execution Time: {}'.format(end-start))
```

<https://www.dataquest.io/blog/multithreading-in-python/>

Fork–Join Model



https://en.wikipedia.org/wiki/Fork%20join_model

Supercomputing for Robotics

Parallel Computing for Matrix Multiplication in Python

```
import numpy as np
from multiprocessing import Pool

# Define the matrix multiplication function
def matrix_multiply(args):
    A, B = args
    return np.dot(A, B)

# Create two random matrices of size 1000x1000
A = np.random.rand(1000, 1000)
B = np.random.rand(1000, 1000)

# Split the matrices into 4 parts
A_parts = np.array_split(A, 4, axis=1)
B_parts = np.array_split(B, 4)

# Create a multiprocessing pool with 4 workers
pool = Pool(4)

# Map the matrix multiplication function to the 4 parts of the matrices
C_parts = pool.map(matrix_multiply,
                    [(A_part, B_part) for A_part, B_part in zip(A_parts, B_parts)])

# Concatenate the parts of the result matrix
C = np.concatenate(C_parts, axis=1)

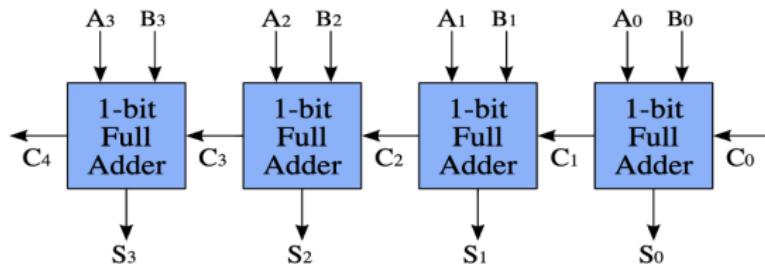
print(C)
```

<https://www.geeksforgeeks.org/parallel-programming-with-numpy-and-scipy/>

Adder and Matrix Multiplication

P-MATRIX-MULTIPLY(A, B, C, n)

```
1  parallel for  $i = 1$  to  $n$            // compute entries in each of  $n$  rows
2      parallel for  $j = 1$  to  $n$        // compute  $n$  entries in row  $i$ 
3          for  $k = 1$  to  $n$ 
4               $c_{ij} = c_{ij} + a_{ik} \cdot b_{kj}$ 
```



<https://www.geeksforgeeks.org/parallel-programming-with-numpy-and-scipy/>

GPU: Graphics Processing Unit

- A GPU is a specialized electronic circuit to accelerate the creation of images in a frame buffer for output to a display device.
- Modern GPUs are very efficient at manipulating computer graphics and image processing.
- In a personal computer, a GPU can be presented on a video card or embedded on the motherboard.



Supercomputing for Robotics

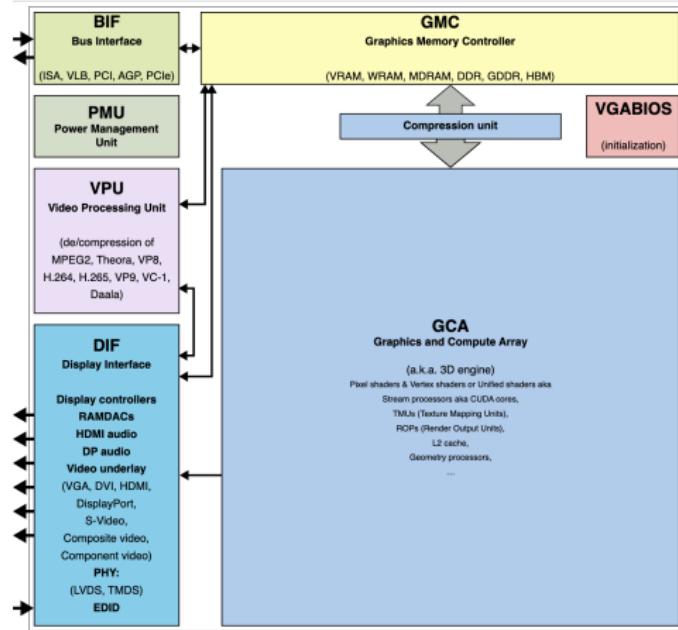
GPU: Graphics Processing Unit



https://youtu.be/-P28LKWTzrI?si=-FFv9_0Vv1MWxgP_-

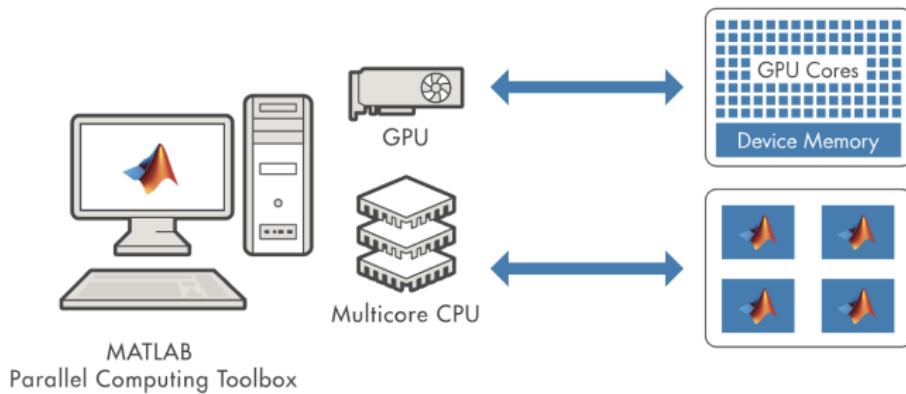
Supercomputing for Robotics

GPU: Graphics Processing Unit



Supercomputing for Robotics

MATLAB Parallel Computing



MATLAB Parallel Computing

- *Worker*: An independent MATLAB session that runs code distributed by the client.
- *Client*: MATLAB session as an interface that distributes jobs to workers.
- *Parfor*: A parallel computing function that distributes independent code segments to workers.
- *Random stream*: A pseudorandom number generator and the sequence of values it generates.
- *Reproducible computation*: A computation that can be exactly replicated even in the presence of random numbers.

MATLAB Paralell Computing

- Parallel for-loop (parfor) for running task-parallel algorithms on multiple processors
- Support for CUDA-enabled NVIDIA GPUs
- Ability to run workers locally on a multicore desktop
- Computer cluster and grid support (with MATLAB Distributed Computing Server)
- Interactive and batch execution of parallel applications
- Distributed arrays and single program multiple data (SPMD) constructed for large dataset handling and data-parallel algorithms

Google Colab

Google Colaboratory, or “Colab” allows us to write and execute Python codes in a browser with:

- Zero configuration required;
- Free access to GPUs;
- Easy sharing;
- With Google Colab, we harness the full power of popular Python libraries to analyze and visualize data.
- Colab notebooks execute code on Google’s cloud servers, including GPUs, TPUs, and NPUs.
- All we need is a browser.

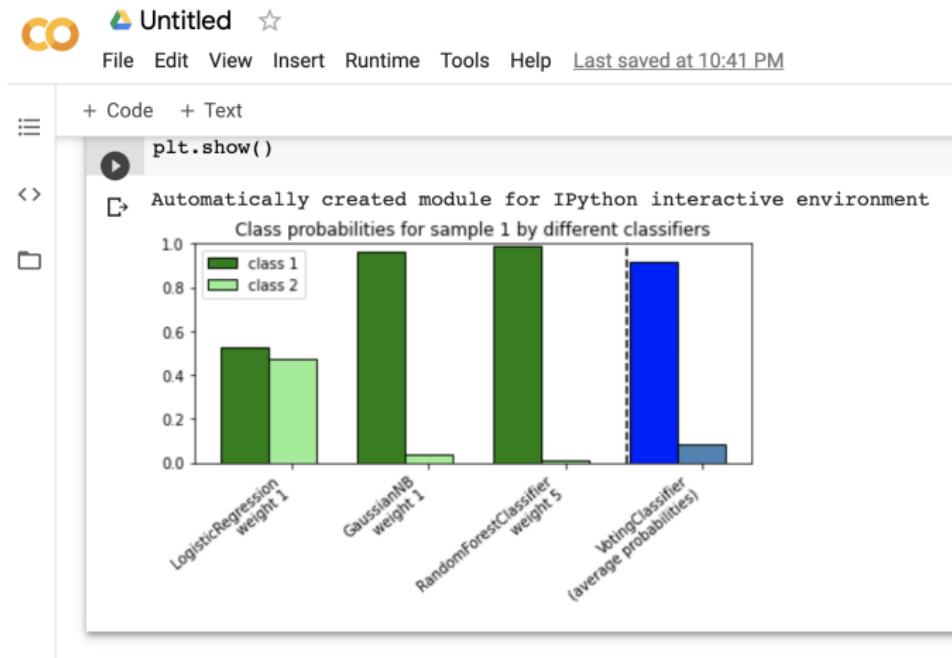
Google Colab

Google Colab is used extensively in the machine learning community with applications including:

- Getting started with TensorFlow
- Experimenting with GPUs & TPUs
- Disseminating AI research
- Creating tutorials
-

Supercomputing for Robotics

Google Colab



Supercomputing for Robotics

Questions?



Questions?

Parallelism is a condition wherein multiple tasks or distributed parts of a task run independently and simultaneously on

- ① multiple processors
- ② a single processor
- ③ a single core
- ④ none of the given options

The right answer is:___

Supercomputing for Robotics

Questions?



Mobile Computing for Robotics

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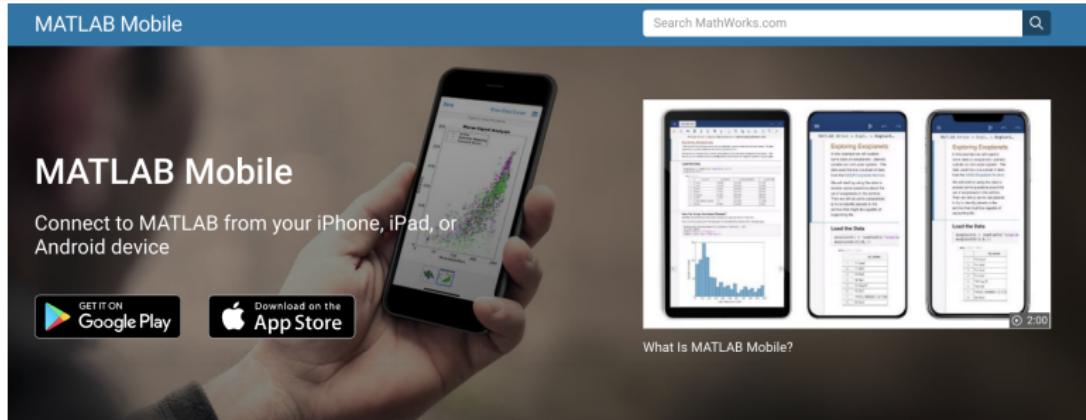
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Mobile Computing for Robotics

MATLAB Mobile



The screenshot shows the MATLAB Mobile landing page. At the top, there's a navigation bar with the text "MATLAB Mobile" on the left and a search bar with "Search MathWorks.com" and a magnifying glass icon on the right. Below the header, the main title "MATLAB Mobile" is displayed in large, bold, white font. A subtext below it reads "Connect to MATLAB from your iPhone, iPad, or Android device". To the left of the text, there's a hand holding an iPhone displaying a scatter plot. To the right, there are three smaller screenshots of the app interface showing data analysis and reporting features. At the bottom of the main content area, there are download links for "GET IT ON Google Play" and "Download on the App Store". A button labeled "What Is MATLAB Mobile?" is also present.



Connect to MATLAB Mobile

Connect to a MATLAB® session running on MathWorks Cloud.

[» Connect to the cloud](#)



Acquire Sensor Data

Acquire data from device sensors – like the accelerometer and GPS – and analyze the data in MATLAB.



Capture Images, Video, and Audio

Take pictures and record video and audio for further processing and analysis.



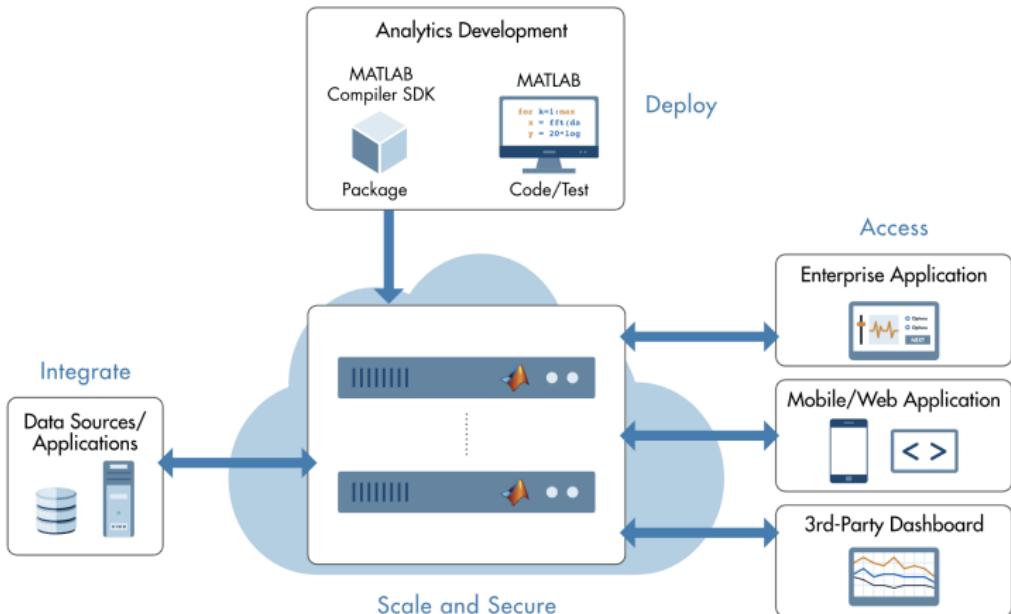
Learn and Teach

Learn and teach math, engineering, and other subjects right from your mobile device.

<https://au.mathworks.com/products/matlab-mobile.html>

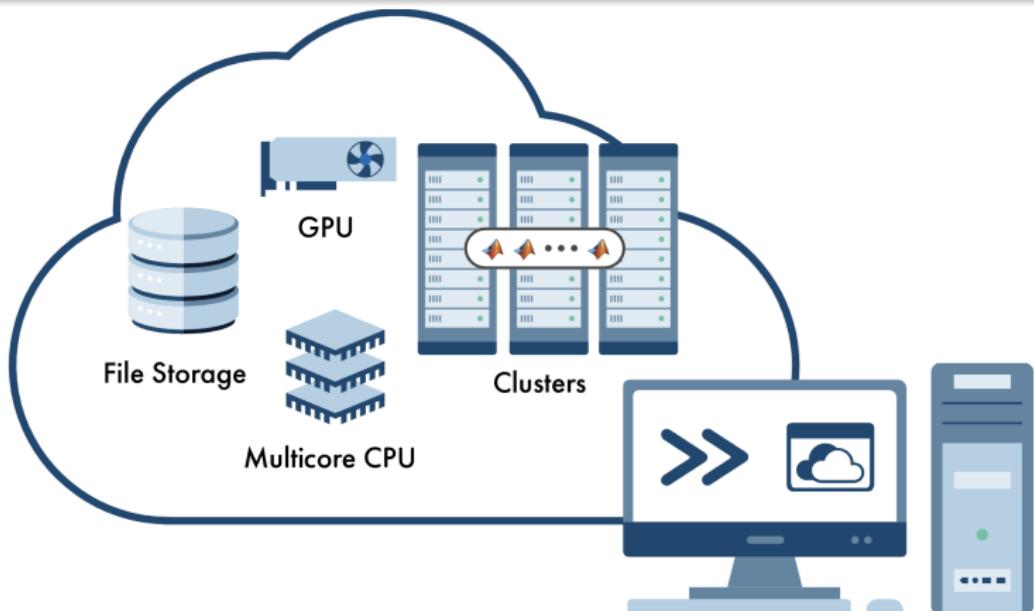
Mobile Computing for Robotics

MATLAB Mobile



<https://au.mathworks.com/solutions/cloud.html>

MATLAB Mobile



<https://au.mathworks.com/solutions/cloud.html>

MATLAB Mobile

- **Connection:** Connect to a MATLAB session running on MathWorks Cloud.
- **Acquisition:** Acquire data from device sensors – like the accelerometer and GPS – and analyze the data in MATLAB.
- **Capturing:** Take pictures and record video / audio for further processing and analysis.
- **Teaching and Learning:** Learn and teach maths, engineering, and other subjects right from mobile device.

<https://au.mathworks.com/products/matlab-mobile.html>

Acquire Data from Mobile Sensors

Acquire data from built-in sensors on mobile device and stream sensor data directly to the MathWorks Cloud. The data includes:

- Acceleration on 3 axes
- Angular velocity on 3 axes
- Magnetic field on 3 axes
- Orientation (azimuth, pitch, and roll)
- Position (latitude, longitude, altitude, horizontal accuracy, speed, and course)

<https://au.mathworks.com/products/matlab-mobile.html>

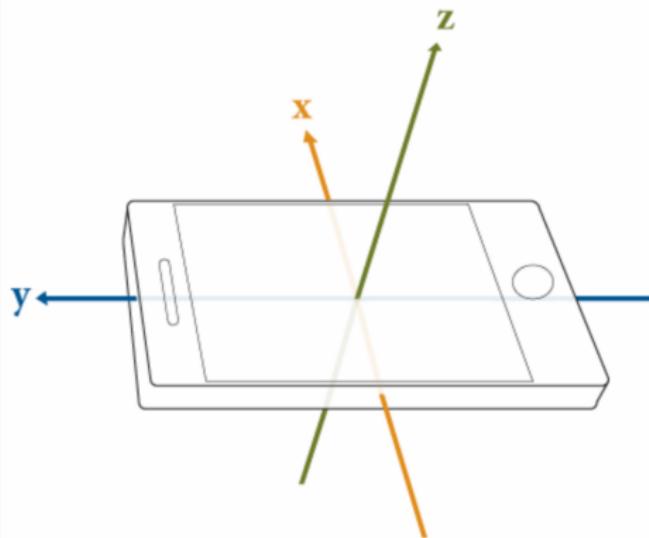
MATLAB Mobile

- MATLAB Mobile sends all commands that were entered on the device to the Cloud for evaluation.
- Autocomplete in MATLAB Mobile makes typing easier.
- MATLAB Mobile displays thumbnails and larger previews when figures are created or updated with MATLAB commands.
- MATLAB Mobile deletes unwanted commands to improve scrolling performance in history.

<https://au.mathworks.com/products/matlab-mobile.html>

MATLAB Mobile: Logging Accelerometer Data

This example shows how to manipulate and visualize data coming from a smartphone or tablet accelerometer.



<https://au.mathworks.com/help/matlabmobile/ug/logging-accelerometer-data.html>

Questions?



Concise Robot Vision

June 2025



Questions?



Learning Objectives

- Derive solutions for particular robotic vision and visual control tasks characterised by specifics of image data and deep learning algorithms.
- Examine opportunities of using robotic vision as a part of complex robotic systems and applications.