

# Embedded Computer Systems and Applications

## Lecture 2

Raspberry Pi, Linux and Python

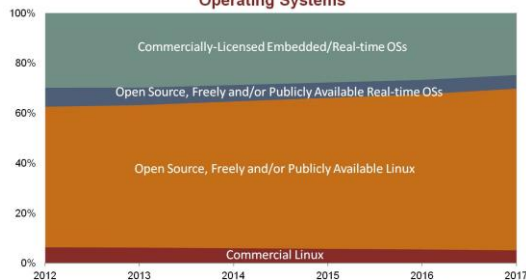
By Jien-Chung Lo

## Linux

- Distributions: operating system with Linux kernel, package management system, and a collection of software packages.
  - Debian, Ubuntu, Fedora, OpenSUSE, etc.
  - Android and Chrome OS (not sure?)
- Desktop environments: mainly to provide graphical user interface (GUI)
  - Based on X-Windows system for BSD Unix and Linux.
  - LXDE, KDE, Unity, etc.
- Window manager: control the placement and appearances of windows.
- Kernel: Linux

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## Worldwide Unit Shipments of Embedded/Real-time Operating Systems



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## Embedded Linux

- Linux is a freely available operating system created by Linus Torvalds as a public domain version of UNIX.
- Linux requires less system resources and computational power than, say Microsoft Windows. Linux can operate smoothly on the old Intel 486 PCs.
- An embedded Linux have the Linux Kernel at its core and with only the needed features for the application at hand.
  - Many modern applications require Desktop Environment to support GUI.
  - DE10-Standard has LXDE (Lightweight X-11 Desktop Environment) Linux.

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<https://developer.ibm.com/articles/1-linux-kernel/>

## Anatomy of the Linux kernel

History and architectural decomposition  
by M. Jones | Published June 6, 2007

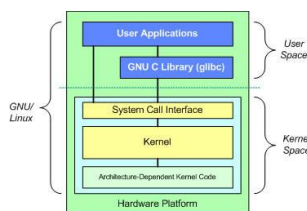
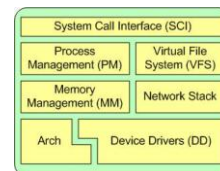


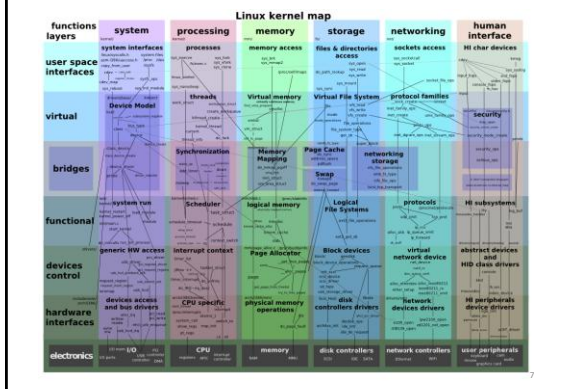
Figure 2. The fundamental architecture of the GNU/Linux operating system



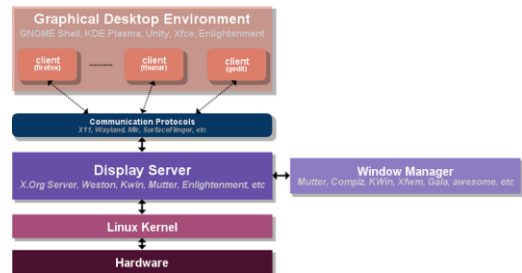
A more detailed view of the Linux Kernel. Device Drivers interface with the actual hardware platform. System Call Interface (SCI) provides entrances for user applications and Desktop Environment.

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Conan at English Wikipedia [CC BY 3.0 (<https://creativecommons.org/licenses/by/3.0/>)]



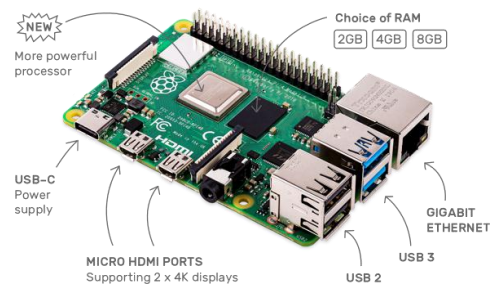
## Desktop Environment



## X11

- X windows system (X11 or simply X)
- X originated at the Project Athena at Massachusetts Institute of Technology (MIT) in 1984. The X protocol has been at version 11 (hence "X11") since September 1987.
- The X.Org Foundation leads the X project, with the current reference implementation, X.Org Server, available as free and open-source software under the MIT License and similar permissive licenses.
- X uses a client-server model: an X server communicates with various *client* programs. The server accepts requests for graphical output (windows) and sends back user input (from keyboard, mouse, or touchscreen).
- The server may function as:
  - an application displaying to a window of another display system
  - a system program controlling the video output of a PC
  - a dedicated piece of hardware

## Raspberry Pi 4B

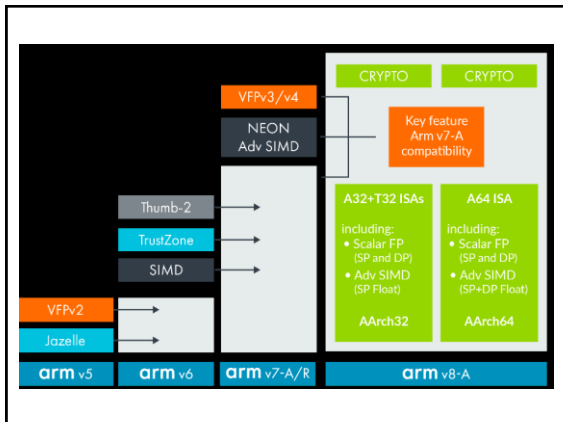


## Raspberry Pi 4B

- **Processor:** Broadcom BCM2711, quad-core Cortex-A72 (ARM v8) 64-bit SoC @ 1.5GHz
- **Memory:** 2GB, 4GB or 8GB LPDDR4 (depending on model)
- **Connectivity:** 2.4 GHz and 5.0 GHz IEEE 802.11b/g/n/ac wireless LAN, Bluetooth 5.0, BLE
  - Gigabit Ethernet
  - 2 x USB 3.0 ports
  - 2 x USB 2.0 ports.
- **GPIO:** Standard 40-pin GPIO header
- **Video & sound:**
  - 2 x micro HDMI ports (up to 4Kp60 supported)
  - 2-lane MIPI DSI display port
  - 2-lane MIPI CSI camera port
  - 4-pole stereo audio and composite video port
- **SD card support:** Micro SD card slot for loading operating system and data storage

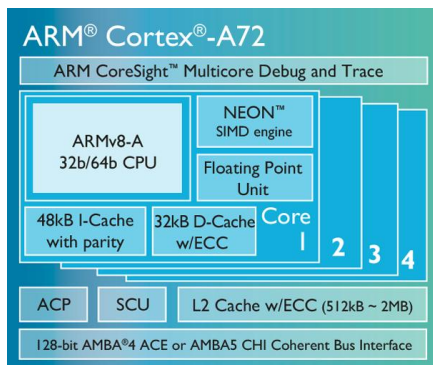
## Broadcom BCM2711

- Documentation available at <https://www.raspberrypi.org/documentation/hardware/raspberrypi/bcm2711/README.md>
- Datasheet at [https://www.raspberrypi.org/documentation/hardware/raspberrypi/bcm2711/rpi\\_DATA\\_2711\\_1p0.pdf](https://www.raspberrypi.org/documentation/hardware/raspberrypi/bcm2711/rpi_DATA_2711_1p0.pdf)

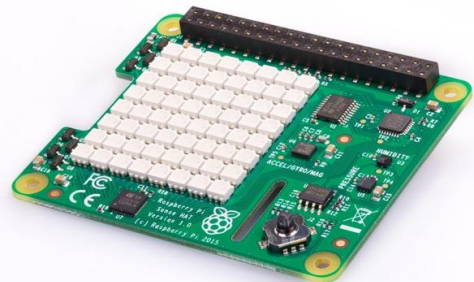


## ARM Architecture Profiles

- **A-profile (Applications)**
  - High performance
  - Designed to run a complex operating system, such as Linux or Windows.
- **R-profile (real-time)**
  - Targeted at systems with real-time requirements.
  - Commonly found in networking equipment, and embedded control systems.
- **M-profile (microcontroller)**
  - Smallest/lowest power. Small, highly power-efficient devices.
  - Found at the heart of many IoT devices.



## Raspberry Pi Sense Hat



## Raspberry Pi Sense Hat

- The Sense HAT is an add-on board for Raspberry Pi, made especially for the [Astro Pi](#) mission – it launched to the International Space Station in December 2015 – and is now available to buy.
- The Sense HAT has an 8x8 RGB LED matrix, a five-button joystick and includes the following sensors:
  - Gyroscope
  - Accelerometer
  - Magnetometer
  - Temperature
  - Barometric pressure
  - Humidity
- A [Python library](#) providing easy access to everything on the board.

## Sense Hat Installation

- In order to work correctly, the Sense HAT requires an up-to-date kernel, I2C to be enabled, and a few libraries to get started.
- Ensure your APT package list is up-to-date:
  - `sudo apt update`
- Next, install the sense-hat package which will ensure the kernel is up-to-date, enable I2C, and install the necessary libraries and programs:
  - `sudo apt install sense-hat`
- Finally, a reboot may be required if I2C was disabled or the kernel was not up-to-date prior to the install:
  - `sudo reboot`

## Sense Hat Software overview

- After installation, example code can be found under `/usr/src/sense-hat/examples`.
- These can be copied to the user's home directory by running `cp /usr/src/sense-hat/examples ~/ -a`.
- The C/C++ examples can be compiled by running `make` in the appropriate directory.
- The `RTIMULibDrive11` example comes pre-compiled to help ensure everything works as intended. It can be launched by running `RTIMULibDrive11` and closed by pressing `Ctrl+c`.

## Raspberry Pi OS

Formerly known as Raspbian



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## Raspberry Pi OS

- **Raspberry Pi OS** (formerly **Raspbian**) is a **Debian**-based operating system for Raspberry Pi. Since 2015 it has been officially provided by the **Raspberry Pi Foundation** as the primary operating system for the family of Raspberry Pi single-board computers.
  - The original Raspbian OS was created by Mike Thompson and Peter Green as an independent project.
  - The initial build was completed in June 2012.
- Raspberry Pi OS is highly optimized for the Raspberry Pi lines of compact Single Board Computers with **ARM** CPUs.
  - Modified **LXDE** as its desktop environment
  - The **Openbox** stacking window manager
  - The distribution is shipped with:
    - algebra program **Wolfram Mathematica**
    - a version of Minecraft called **Minecraft Pi**
    - a lightweight version of **Chromium**
    - **Python**

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## LXDE

- LXDE is written in the C programming language, using the GTK+ 2 toolkit, and runs on Unix and other POSIX-compliant platforms, such as Linux and BSDs. The LXDE project aims to provide a **fast** and **energy-efficient** desktop environment.
- GTK+2: Widget toolkit for creating GUI.
- POSIX (Portable Operating System Interface): IEEE 1003.1-1988, provides application programming interface (API), command line shells and utility interfaces.
- LXDE is the default desktop environment of Knoppix, Lubuntu, LXLE Linux and Peppermint Linux OS.
- PIXELdesktop of Raspberry Pi OS is a modified LXDE.

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## Openbox

- **Openbox** is a free, stacking window manager for the X Window System, licensed under the GNU General Public License.
- Originally derived from Blackbox 0.65.0 (a C++ project), Openbox has now been completely re-written in the C programming language and since version 3.0 is no longer based upon any code from Blackbox.
- Openbox is designed to be small, fast, and fully compliant with the Inter-Client Communication Conventions Manual (ICCCM) and Extended Window Manager Hints (EWMH). It supports many features such as menus by which the user can control applications or which display various dynamic information.
- Openbox is the standard window manager in LXDE and LXQt, and is used in many Linux distributions.

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## NOOBS

- **NOOBS** (new out-of-box software) is an easy operating system installation manager.
  - May be downloaded from Raspberry Pi website.
- May choose from “Raspberry Pi OS” and “LibreELEC”. Install “Raspberry Pi OS”.
- Once install the SD card will only have Raspberry Pi OS and you will not see NOOBS again.

## Installing operating system images

- Using Raspberry Pi Imager
  - Raspberry Pi have developed a graphical SD card writing tool that works on MacOS, Ubuntu 18.04 and Windows, and is the easiest option for most users as it will download the image and install it automatically to the SD card.
  - Download the latest version of [Raspberry Pi Imager](#) and install it.
    - If you want to use Raspberry Pi Imager on the Raspberry Pi itself, you can install it from a terminal using "sudo apt install rpi-imager".
  - Connect an SD card reader with the SD card inside.
  - Open Raspberry Pi Imager and choose the required OS from the list presented.
  - Choose the SD card you wish to write your image to.
  - Review your selections and click 'WRITE' to begin writing data to the SD card.
- Boot your new OS
  - You can now insert the SD card into the Raspberry Pi and power it up.
  - For the official Raspberry Pi OS, if you need to manually log in, the default user name is **pi**, with password **raspberrypi**. Remember the default keyboard layout is set to UK. You should change the default password straight away to ensure your Raspberry Pi is secure.

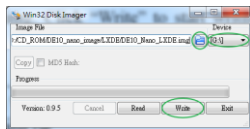
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## Micro SD Card with Windows (I)

- Format MicroSD card as type FAT32.
  - Run **command prompt** as administrator.
  - Type "diskpart".
  - Type "list volume".
  - Type "select volume #" where # corresponds to your volume (FAT and Removable).
  - Type "list disk".
  - Type "select disk #" where # corresponds to your disk (verify the disk size).
  - Type "clean" to clean the disk of partitions
  - Type "create partition primary" to create the primary partition.
  - Type "list partition" to make sure you successfully created the partition.
  - Type "format fs=FAT32 label=NAME" to format the partition with NAME as the name. This will take some time.

## Micro SD Card with Windows (II)

- Run **Win32 Disk Imager**. This is a freeware program. You may run it without installation!



- Make sure device is set to your SD card.
- Select the appropriate .img file. You may find Raspberry Pi OS disk image online.
- Click on Write and wait for the program to complete.

## Set Date and Time

- Raspberry Pi does not have a real-time clock.
- Make link between files:
  - `ln -sf /usr/share/zoneinfo/US/Eastern/etc/localtime`
  - /usr/share/zoneinfo is the directory for system wide time zone information.
  - /etc/localtime is the system wide time zone information for the local system. This is accessed by the applications for the local date and time.
- Set the local date and time by polling the network time protocol (NTP) server:
  - `ntpdate ntp1.ele.uri.edu`
  - You may use any NTP.

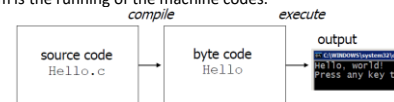
## Python

- Python was created by Guido van Rossum in 1991.
- Python is an **interpreted language**; i.e. program is executed by the interpreter, instead of being compiled into executable codes first.
- Python is highly extensible: small core language with large standard libraries.
  - "import" only the necessary library for the program.
- Python already has a large number of libraries including GUI, Web framework, networking, databases, scientific computing, etc.

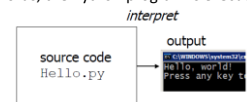
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## Compiling vs. Interpreting

- Programming language like C or C++ need a compiler to translate the program to the low-level machine codes. The execution of the program is the running of the machine codes.



- Python uses an interpreter not compiler. The Python program is run by the interpreter. In other words, the Python program is executed indirectly on the computer.



## Python Packages

- Scientific computing:
  - Numpy: a language extension that adds support for large and fast multi-dimensional arrays and matrices.
  - SciPy: library of scientific and numerical routines
  - Matplotlib: provide MATLAB-like plotting and math functions
- Artificial Intelligent:
  - TensorFlow: a symbolic math library, also used for machine learning. Developed by Google.
  - Keras: for experimentation of deep neural networks
  - Scikit-learn: a library for machine learning
- Graphics
  - Pygame: Python binding for SDL (Simple DirectMedia Layer)
  - Panda3D: a 3D game engine

## Thonny→Python (Raspberry Pi)

- Thonny
  - Integrated development environment (IDE) for Python.
  - Already installed on Raspberry Pi OS.
  - Also available on Windows and MacOS.

## Anaconda→Spyder→Python

- Anaconda individual edition
  - Available on Windows, MacOS and Linux
  - Free; no need to sign up
  - For Python and R programming platform
  - Data science and machine learning
  - Package manager
- Spyder (as part of the Anaconda distribution)
  - Integrated development environment (IDE) Python programs
  - Spyder 4 supporting Python 3 (Python 2 is no longer supported)
- Python (the interpreted language)
  - Currently Python 3.7
  - Use Anaconda "Powershell prompt" or "Prompt" to install Python library packages.

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## Package Manager

- PIP: Python package manager
  - Issue this command at "Terminal" or "Command Prompt".
  - PIP install package
  - PIP uninstall package
- APT: Advanced package tool for Linux
  - Apt, Apt-get, and Apt-cache
  - Sudo to gain temporary super-user privileges.

## Sense Hat Python Library

- Document on <https://pythonhosted.org/sense-hat/>
- The API reference on <https://pythonhosted.org/sense-hat/api/>