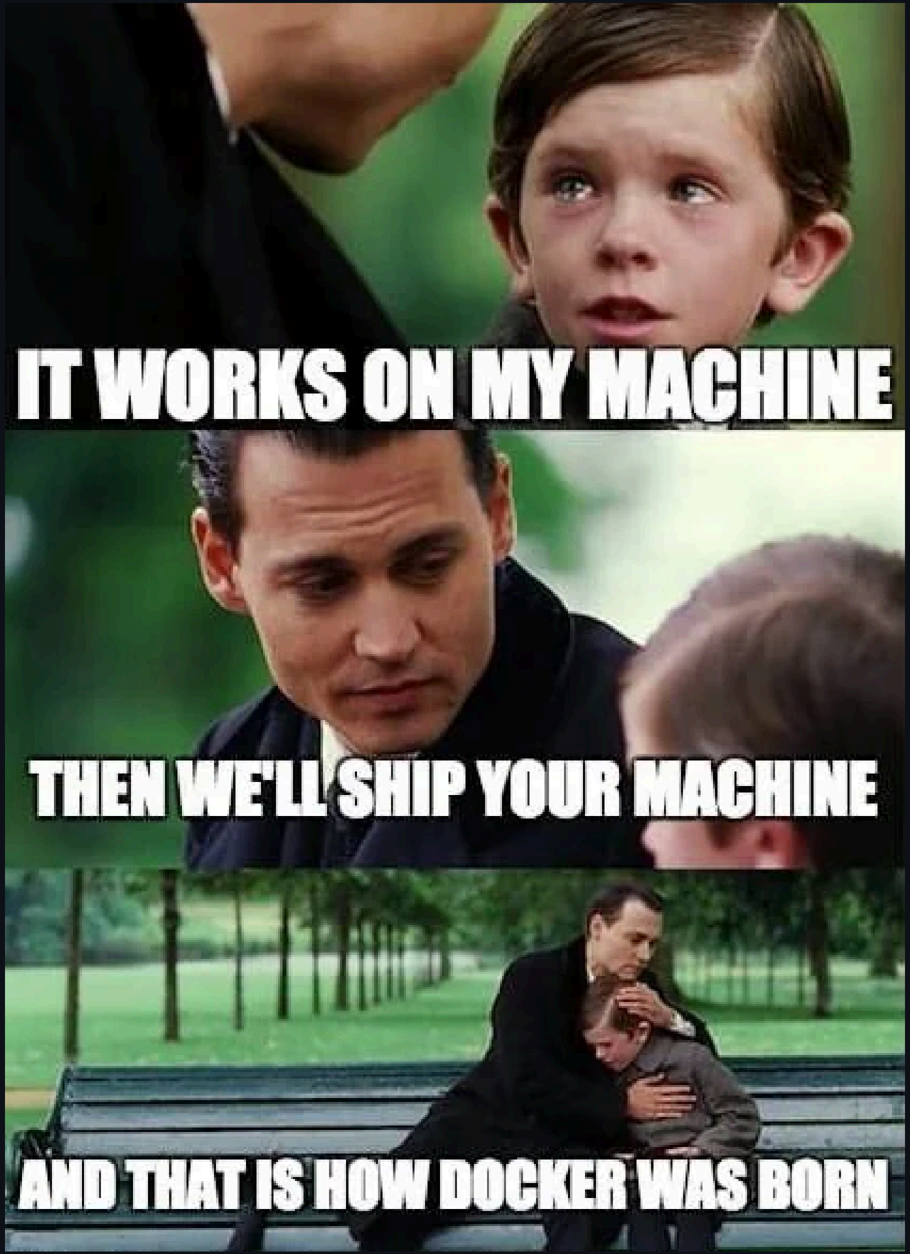
ROS Workshop

Prequisites

- Text editor - VScode (not sponsored)
- Terminal emulator - Depends on your OS
- Docker installation

What is docker?

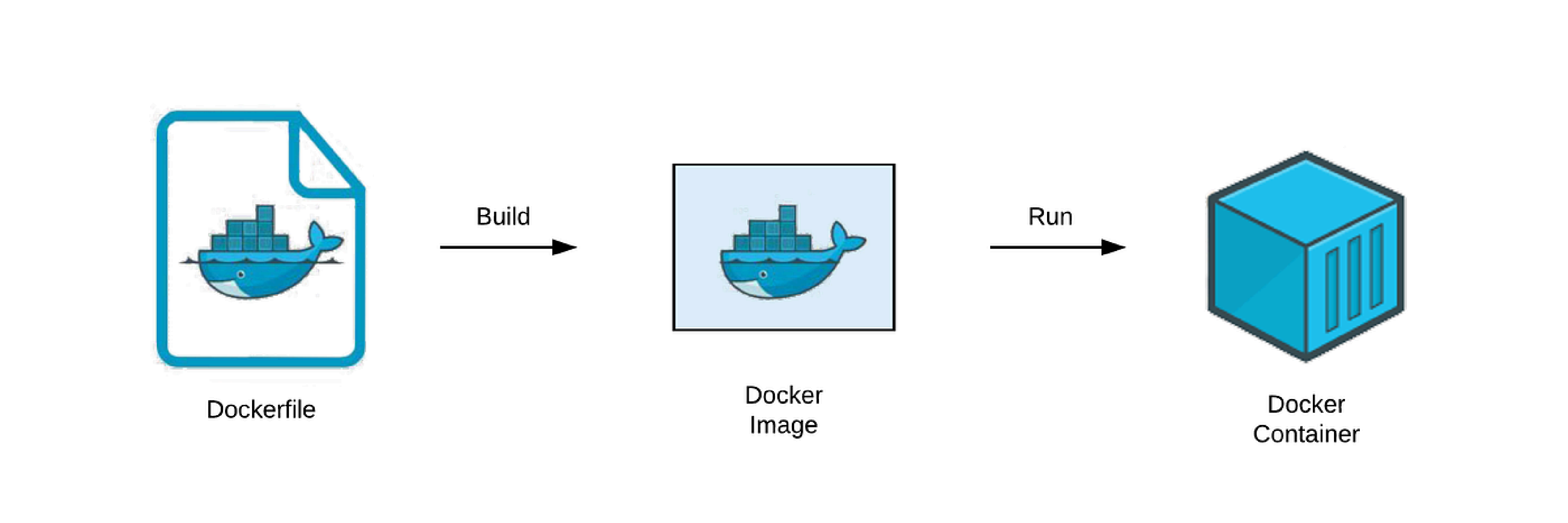
- **Containerisation**
    - Think of a container as a lightweight, portable box that contains everything an application needs to run.
    - It includes the application code, runtime, system tools, libraries, and settings.


IT WORKS ON MY MACHINE
THEN WE'LL SHIP YOUR MACHINE
AND THAT IS HOW DOCKER WAS BORN

Why docker?

- gives you the ability to run a program on any given machine with docker without dependency issues and conflicts
  `* additional usecase - scale apps over multiple servers`

How does it work?



- **Dockerfile**
  - A text file with instructions on how to build a Docker image.
  - It's like a recipe for creating your container environment.
- **Docker Image**
  - A snapshot of a container's file system.
  - Built from a Dockerfile.
  - Immutable and can be shared.
- **Docker Container**
  - A running instance of a Docker image.
  - Isolated and has its own filesystem, network, and process space.

Basic Docker Commands

Container Management and interaction

- `docker run`: Create and start a container.
  - Example: `docker run -it --rm f1tenth_gym_ros`
- `docker ps`: List running containers.
- `docker exec`: Run commands in a running container.
  - Example: `docker exec -it [container_id/name] bash`

Why *TERMINAL?*

* this is basically the `Avada Kedavra` of TERMINAL world, dont ever use this

Basic Terminal Navigation

File Navigation

- `ls`: List directory contents.
- `cd`: Change directory.
  `cd /home` - takes you to the home folder
  `cd /` - takes you to the root folder
- `pwd`: Print working directory path.

File Management

- `mkdir`: Create new folder.

  ```
  mkdir folder1
  ```

- `touch`: Create new empty files.

  ```
  touch file1.txt
  ```

  ```
  touch file2.txt
  ```

- `cp`: Copy files or directories.

  ```
  cp file1.txt [to_path]
  ```

  ```
  cp -r folder1 [to_path]
  ```

File Management

- `mv`: Move or rename files or directories.

  ```
  mv file2.txt file3.txt
  mv file1.txt [to_path]
  mv folder1 [to_path]
  ```

- `rm`: Remove files or directories (use with caution). (rm -rf)

  ```
  rm file3.txt
  rm -r folder1
  rm -rf [path_to_folder]
  ```

Viewing and Editing Files

- `cat`: Display file contents.

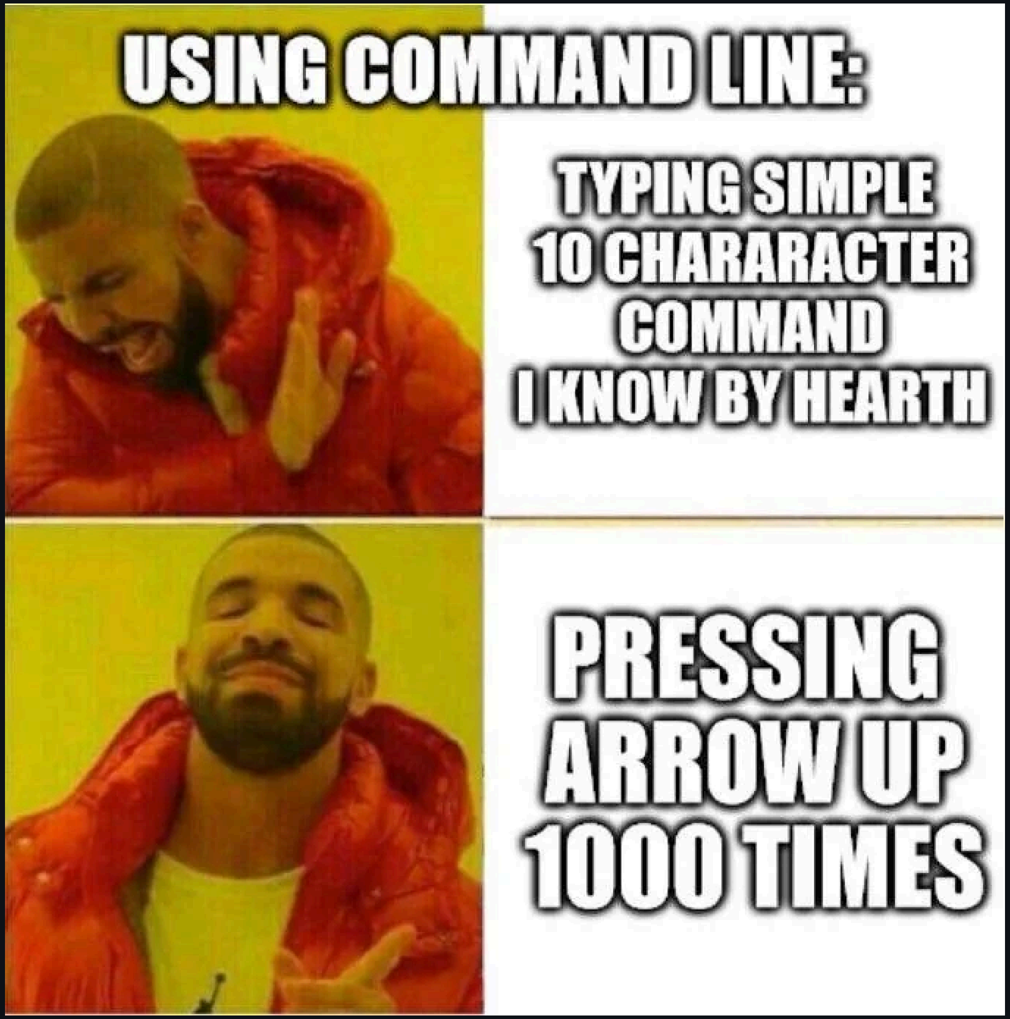
  ```
  cat file1.txt
  ```

- `nano` or `vim`: Basic text editors within the terminal.

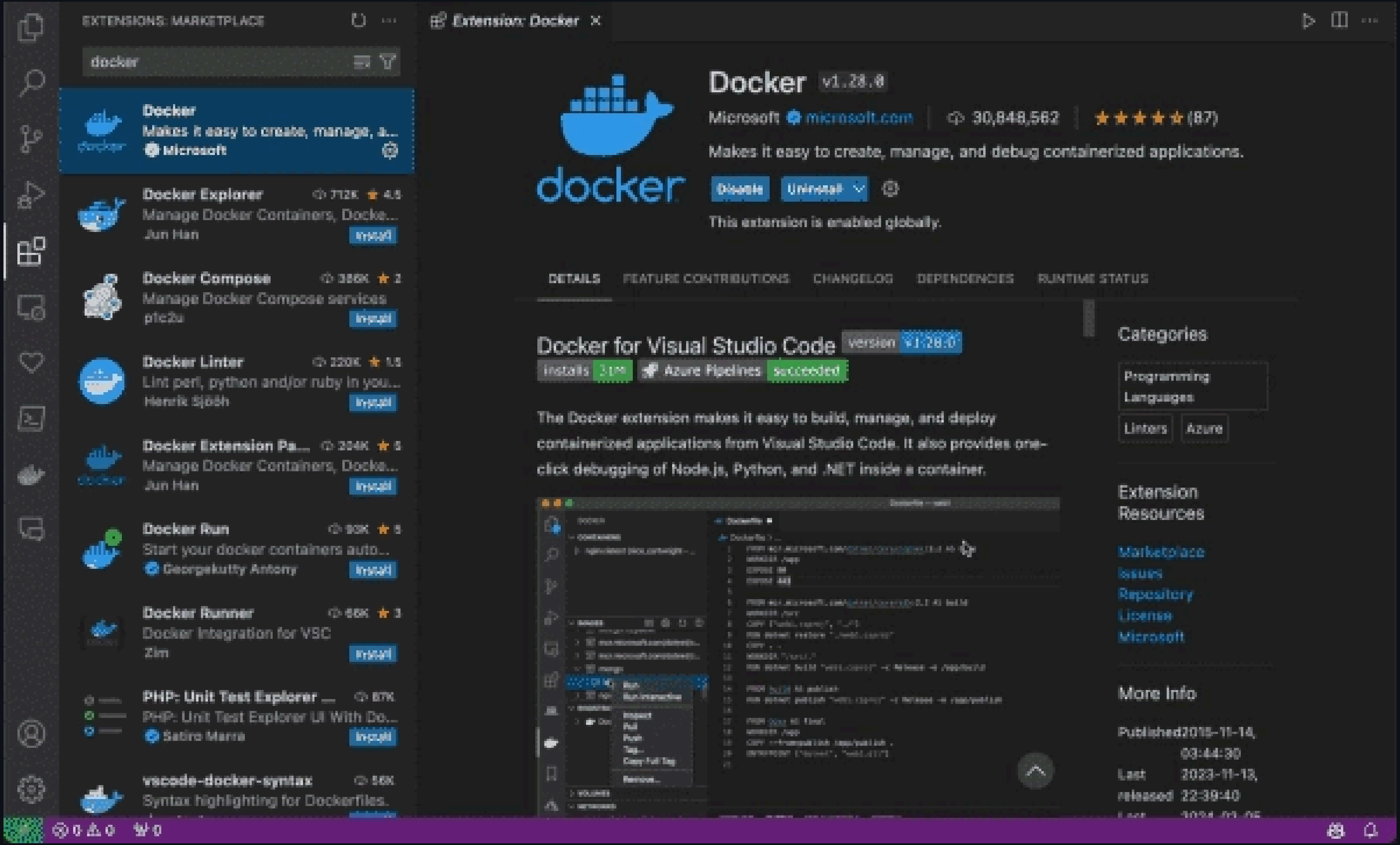
  ```
  nano file1.txt
  ```

Tips and Tricks

- **Tab Completion**: Quickly complete commands or file names.
- **Command History**: Use the up/down arrow keys to navigate through previous commands.
- **Wildcards**: Utilize `*` and `?` for pattern matching.
  `ls *.txt` Lists all files in the current directory that end with .txt
  `ls file?.txt` Lists files that match the pattern file?.txt, ie:file1.txt

USING COMMAND LINE:
TYPING SIMPLE 10 CHARARACTER COMMAND I KNOW BY HEARTH
PRESSING ARROW UP 1000 TIMES

Acessing your container through VS code



Makes it easy to create, manage, and debug containerized applications.

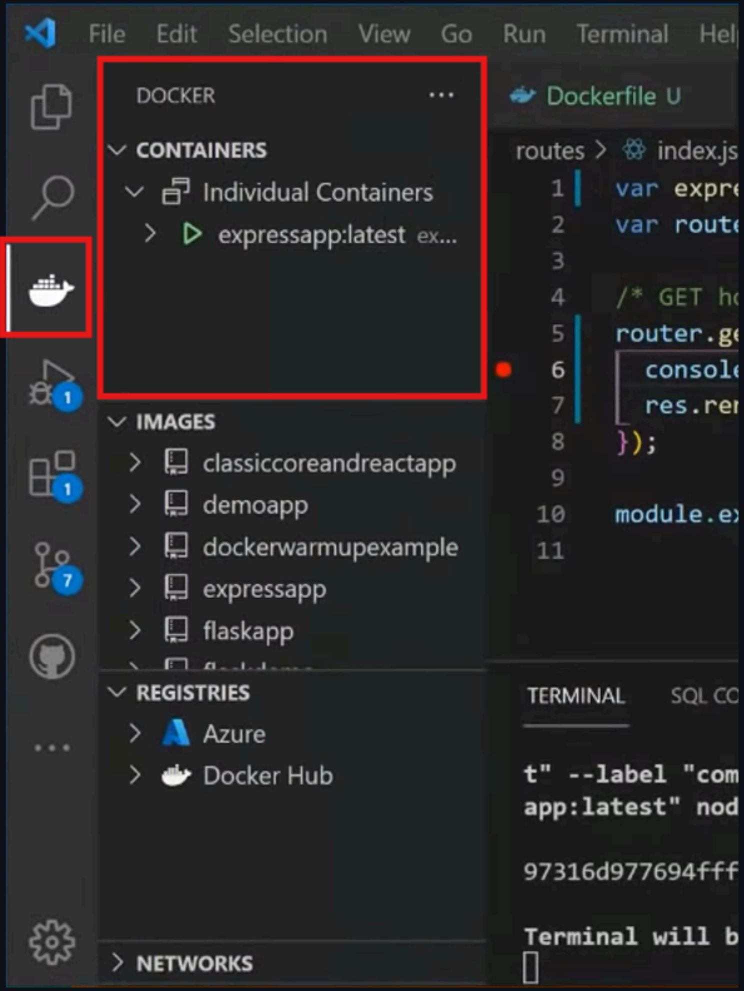
This extension is enabled globally.

Docker for Visual Studio Code

The Docker extension makes it easy to build, manage, and deploy containerized applications from Visual Studio Code. It also provides one-click debugging of Node.js, Python, and .NET inside a container.

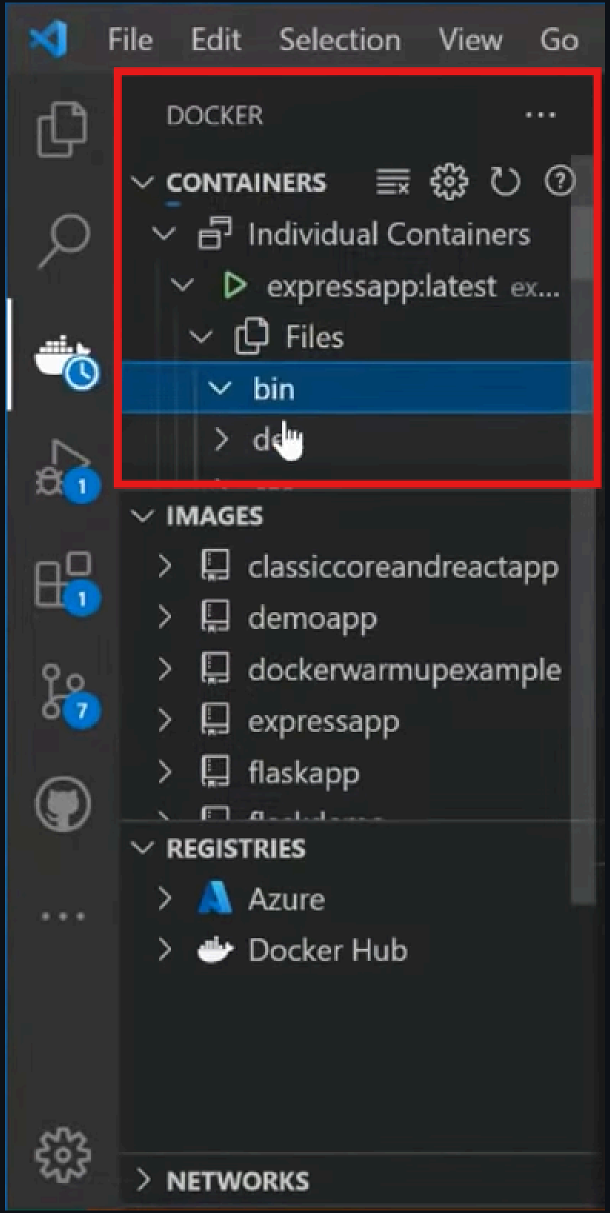
Published 2015-11-14, 03:44:30

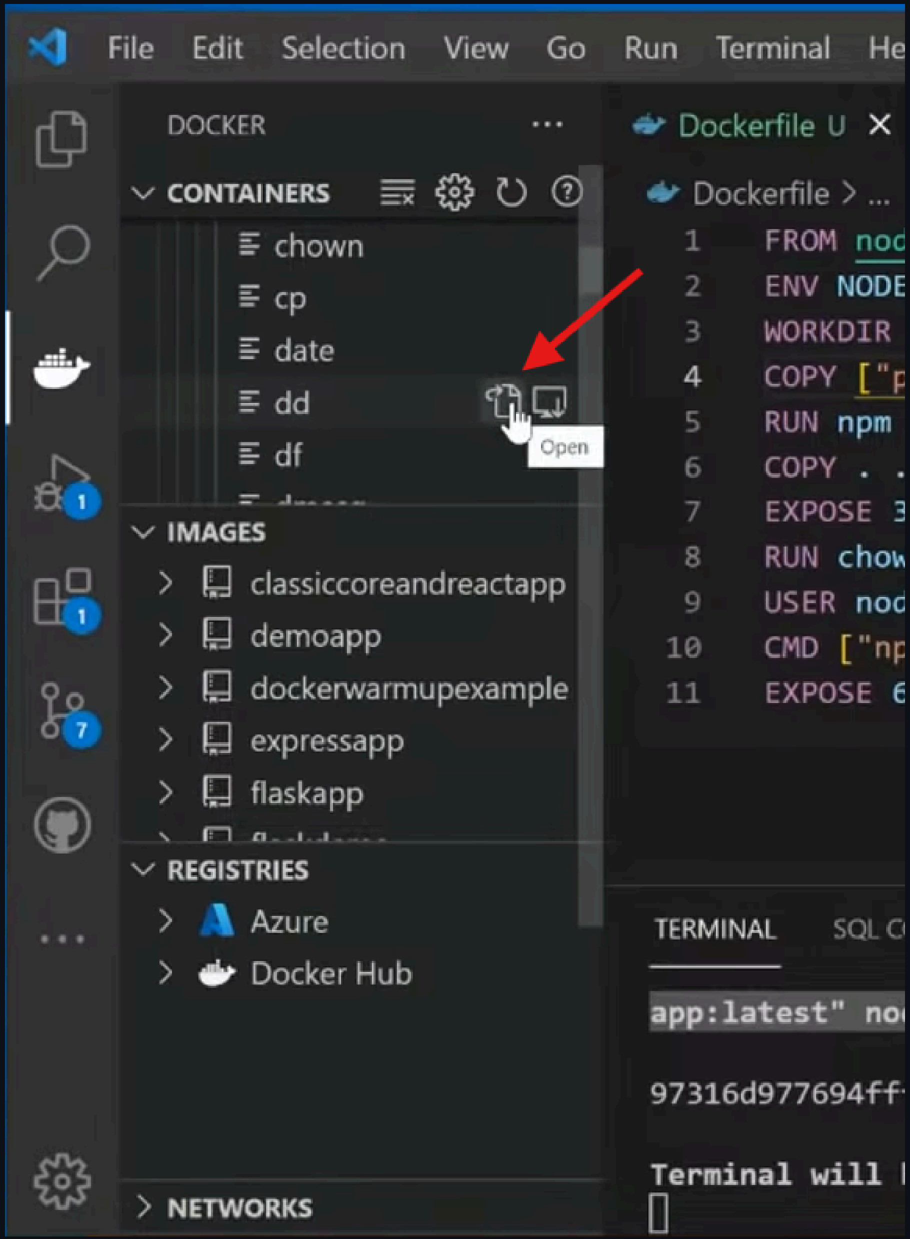
Last released 2023-11-13, 22:39:40



```
var expre
var route

/* GET ho
router.ge
  console
  res.ren
});

module.ex
```

```
t" --label "com
app:latest" nod

97316d977694fff

Terminal will b
```


File
Edit
Selection
View
Go
DOCKER
CONTAINERS
Individual Containers
expressapp:latest ex...
Files
bin
de
IMAGES
classiccoreandreactapp
demoapp
dockerwarmupexample
expressapp
flaskapp
REGISTRIES
Azure
Docker Hub
NETWORKS



```
FROM nod
ENV NODE
WORKDIR
COPY ["p
RUN npm
COPY . .
EXPOSE 3
RUN chow
USER nod
CMD ["np
EXPOSE 6
```

```
app:latest" no

97316d977694ff

Terminal will
```

- Explains key concepts (fast!)

  100+ Docker Concepts you Need to Know (youtube.com)

- CLI Cheat Sheet

  docker_cheatsheet.pdf

Introduction to ROS

What is ROS?

Middleware framework for robot software development

Facilitates communication (Topics, Services, Actions) between different robot components (Nodes)

Why Use ROS?

- Modularity and reusability
- Large, active community
- A lot of libraries and tools provided

OPEN SOURCE FTW!!

What are ROS Nodes?

- Nodes are individual processes that handle specific tasks
- Example (For camera processing):
  - Camera node (to get images)
  - Processing node (to process images)
  - Output node (uploads the processed images)
- Can be combined to create a complete robot system

Node Communication

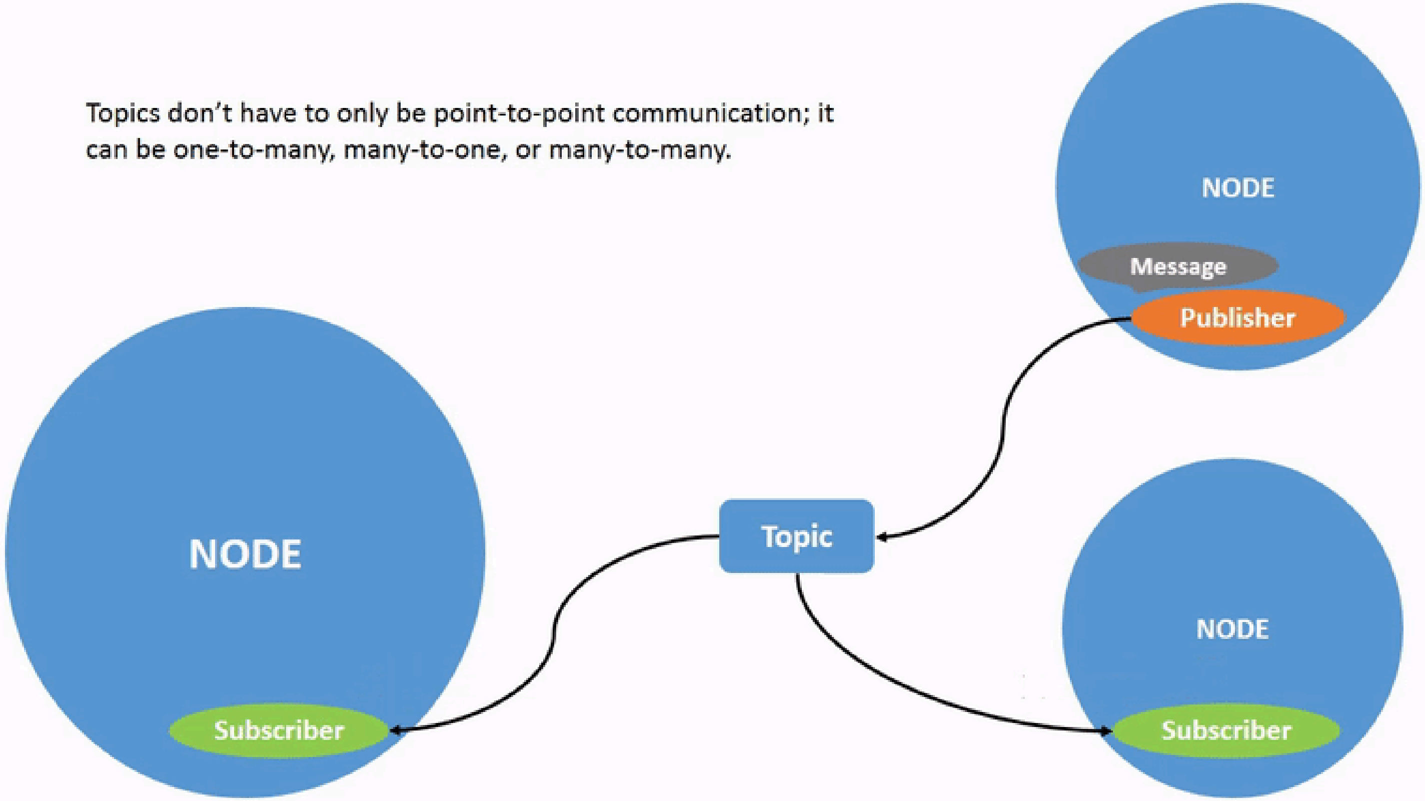
How do nodes communicate?

- Topics
- Services
- Actions

ROS2 Communication: Topics

- Deploys a Publish-Subscribe Mechanism
- Used on continuous data streams
- The topic acts as a notice board for all to see messages.
- Nodes **publish** messages to topics and other nodes **subscribe** to those topics to receive the messages.

Topics don’t have to only be point-to-point communication; it can be one-to-many, many-to-one, or many-to-many.



ROS Messages

- ROS messages are the data that are communicated via topics.
- A message has a fixed structure that defines what kind of data it can carry (e.g. `sensor_msgs`, `geometry_msgs`)
- Data types (vectors, numbers, characters)
- Holds different types of data together

Example: LaserScan Message

- `sensor_msgs/LaserScan` is used to communicate data from a LIDAR sensor.
- It contains:
  - **Header**: Timestamp and frame ID
  - **Angle** and **range** arrays for LIDAR measurements

```
std_msgs/Header header
float32 angle_min
float32 angle_max
float32[] ranges
```

Example: Odom (Odometry) Message

- `nav_msgs/Odometry` is used for representing robot's movement in space.
- Contains:
    - **Pose**: Position and orientation.
    - **Twist**: Velocity information (linear and angular).

```
std_msgs/Header header
geometry_msgs/PoseWithCovariance pose
geometry_msgs/TwistWithCovariance twist
```

Example: Ackermann Steering Message

- `ackermann_msgs/AckermannDrive` is used for controlling vehicle steering.
- Contains:
  - **Steering angle**: Angle to turn the wheels.
  - **Speed**: Forward velocity of the vehicle.

```
float32 steering_angle
float32 speed
```

ROS Projects

Content

1. ROS Workspaces
2. ROS Packages
3. ROS Launch Files

ROS Workspaces

A workspace is a collection of ROS2 packages and nodes for a specific project.

- It contains important directories:
    - `src` : Source code for packages
    - `build` : Compiled binaries
    - `install` : Development environment setup
- **colcon build** builds your binaries. It happens when you're creating your workspace
- **Sourcing** allows access to those binaries `source ./install/local_setup.bash`

Python Workspace

```
ros_ws/
├── build/
│   └── ...
├── install/
│   └── ...
├── log/
│   └── ...
└── src/
    └── my_package/
        ├── package.xml
        ├── CMakeLists.txt
        ├── resource/my_package
        ├── setup.cfg
        ├── setup.py
        └── my_package/
            └── node.py
```

ROS Packages

A ROS package is the basic building block of ROS projects.

It contains:

- Nodes
- Message definitions
- Service and Action definitions
- Launch files
- Metadata files (list of dependencies)

Makes it easier to share code with others

ROS Launch Files

- A **launch file** is a script that automates the process of starting multiple nodes and setting configurations in ROS2.
- Instead of manually starting each node, a launch file can launch them all together.
- They are written in Python in ROS2 (unlike XML in ROS1).

Why Use Launch Files?

- Simplifies running multiple nodes, especially in complex systems.
- Allows for setting parameters, remapping topics, and configuring environments.
- Great for automating testing and deployment of robots.

Launch File Example

```python
# my_launch_file.py
from launch import LaunchDescription
from launch_ros.actions import Node

def generate_launch_description():
    return LaunchDescription([
        Node(
            package='my_package',
            executable='my_node',
            name='my_node_name',
            output='screen',
        ),
    ])
```

ROS2 Practical

Contents

1. ROS2 Debugging on Terminal
2. Creating ROS2 Workspaces
3. Creating ROS2 Packages
4. Publishing
5. Subscribing
6. Extra
7. References

Open the Container

- Windows/ Linux

```
cd ~/F1Tenth_Workshop/install_linux
sudo ./run_docker_container.sh
```

- Mac

```
cd ~/F1Tenth_Workshop/install_macos
sudo ./run_docker_containers_mac.sh
```

1. ROS2 Debugging on Terminal

- Useful for quick debugging and sanity checks
- Viewing Topics

  ```
  ros2 topic list
  ```

- Publishing Topics

  ```
  ros2 topic pub -r 1 /topic_name std_msgs/String "data: Hello World!"
  ```

- Viewing messages of a topic

  ```
  ros2 topic echo /topic_name
  ```

2. Creating ROS2 Workspaces

1. Make a directory for a ros2 workspace

```
mkdir -p /ros2_ws/src
```

2. Change directory to the ros2 workspace

```
cd /ros2_ws
```

3. Build your workspace

```
colcon build
```

3. Creating ROS Packages

1. Change directory to the source folder

```
cd /ros2_ws/src
```

2. Create a ROS package

```
ros2 pkg create my_package --build-type ament_python --node-name my_node --dependencies rclpy
```

3. Creating ROS Package (for workshop)

- To facilitate the workshop, all scripts and packages have already been made

1. Deleted the package created

```
rm -rf /ros2_ws/src/my_package
```

2. Copying the pre-made package

```
cp -r /f1tenth_workshop/ros2_ws/src/my_package /ros2_ws/src
```

4. Minimal Publisher

1. Writing your first publisher script

- minimal_publisher.py

4. Minimal Publisher cont.

2. Adding your script as an executable. Open `setup.py`

```
entry_points = {
    "console_scripts":[
        ...
        minimal_publisher = my_package.minimal_publisher:main
        ...
    ]
}
```

4. Minimal Publisher cont.

3. Build your package

```
colcon build --packages-select my_package
```

4. Run your node

```
# Sourcing the Overlay
source /ros2_ws/install/local_setup.bash
# Starting the Node
ros2 run my_package minimal_publisher
```

5. Minimal Subscriber

1. Writing your first subscriber script

- minimal_subscriber.py

5. Subscriber cont.

2. Adding your script as an executable. Open `setup.py`

```
entry_points = {
    "console_scripts":[
        ...
        minimal_subscriber = my_package.minimal_publisher:main
        ...
    ]
}
```

5. Minimal Subscriber cont.

3. Build your package

```
colcon build --packages-select my_package
```

4. Run your node

- Running ROS2 Executable

```
# Sourcing the Overlay
source /ros2_ws/install/local_setup.bash
# Starting the Node
ros2 run my_package minimal_subscriber
ros2 topic pub -r 10 my_topic std_msgs/String "data: Hello minimal_subscriber!"
```

6. Extra

- Additional Info
- ROS2 Launch
- ROS2 Messages

Additional Info

- Running as Python script as it is a quick way to tune parameters.

```
python3 minimal_pubsub.py
```

- Publishing and Subscribing in the same node. minimal_pubsub

```
ros2 run my_package minimal_pubsub
```

- Developing ROS2 packages in C++ `ros2 pkg create cpp_package --build-type ament_cmake`

ROS2 Launch

1. Initialise a ros2 package

```
ros2 pkg create my_bringup --dependencies ros2launch
```

2. Define your launch file my_bringup.py

3. Add launch file to `setup.py`

```
import os
from glob import glob
...
(os.path.join('share', package_name, 'launch'), glob(os.path.join('launch', '*launch.[pxy][yma]*')))
...
```

ROS2 Messages

- Rarely, altough sometimes, you'll need to create your own ROS messages.
- Steps:

1. Initialise a ros2 package `ros2 pkg create my_msgs --dependencies std_msgs geometry_msgs`
2. Edit the `CMakeList`:

```
find_package(rosidl_default_generators REQUIRED)

rosidl_generate_interfaces(${PROJECT_NAME}
        "msgs/MyMessage.msg"
)

ament_export_dependencies(rosidl_default_runtime)
```

ROS2 Messages cont.

3. Edit the `package.xml`

```
  <buildtool_depend>rosidl_default_generators</buildtool_depend>
  <exec_depend>rosidl_default_runtime</exec_depend>
  <member_of_group>rosidl_interface_packages</member_of_group>
```

ROS2 Messages cont.

4. Create your message file:

```
cd /ros2_ws/src/
mkdir msgs
cd msgs
touch my_msg.msg
```

ROS2 Messages cont.

5. Define your message file.

- This uses other ROS2 messages e.g. std_msgs, geometry_msgs
- my_msg.msg

ROS2 Messages cont.

6. Build, Source and Run

```
colcon build --packages-select my_msgs
source /ros2_ws/install/local_setup.bash
ros2 topic pub -r 1 some_topic my_msgs/my_msg "{name: "Lawrence", some_integer: 10, some_vector: [1, 2]}"
ros2 topic echo some_topic
```

7. References

- Creating a Workspace
- Creating a Package
- Simple Pusblisher/ Subscriber (Python)
- Create Custom Message
- Create a Launch File

F1Tenth Simulator

Launch The Simulator

Open a terminal in the docker container

```
source /opt/ros/foxy/setup.bash
source ./install/local_setup.bash
ros2 launch f1tenth_gym_ros gym_launch.py
```

F1Tenth Topics

Open a new terminal in the container

```
ros2 topic list
```

Topics related to the car

```
/drive              # Drive command via AckermannDriveStamped messages
/ego_racecar/odom   # Odometry of the car
/scan               # Lidar Scans
/cmd_vel
```

Publishing a Drive Command

```
ros2 topic pub -r <Hz> <topic_name> <msg_type> <msg_atributes?>
```

```
ros2 topic pub -r 1 /drive ackermann_msgs/msg/AckermannDriveStamped
"drive: {'speed': 1.0, 'steering_angle': 0.5}"
```

Echoing Odom

```
ros2 topic echo ego_racecar/odom --no-arr
```

> NOTE: The `--no-arr` argument is to prevent displaying large covariance arrays

Driving The Car Via Teleoperation

Keyboard Teleoperation

```
ros2 run teleop_twist_keyboard teleop_twist_keyboard
```

Changing The Map

- Stop the simulator from running using `CTRL+C`
- Navigate to `/sim_ws/src/f1tenth_gym_ros/config` and edit the `sim.yaml` file

```
    # map parameters
    map_path: '/sim_ws/src/f1tenth_gym_ros/maps/Spielberg_map'
    map_img_ext: '.png'
```

- Rebuild the workspace

```
colcon build
source install/local_setup.bash
```

Driving The Car Autonomously

Local Planner (Gap Finder)

```
cd /f1tenth_workshop/f1tenth_simulator
python3 gap_finder_base.py
```