Integrating Cameras with the Robot Operating System (ROS)

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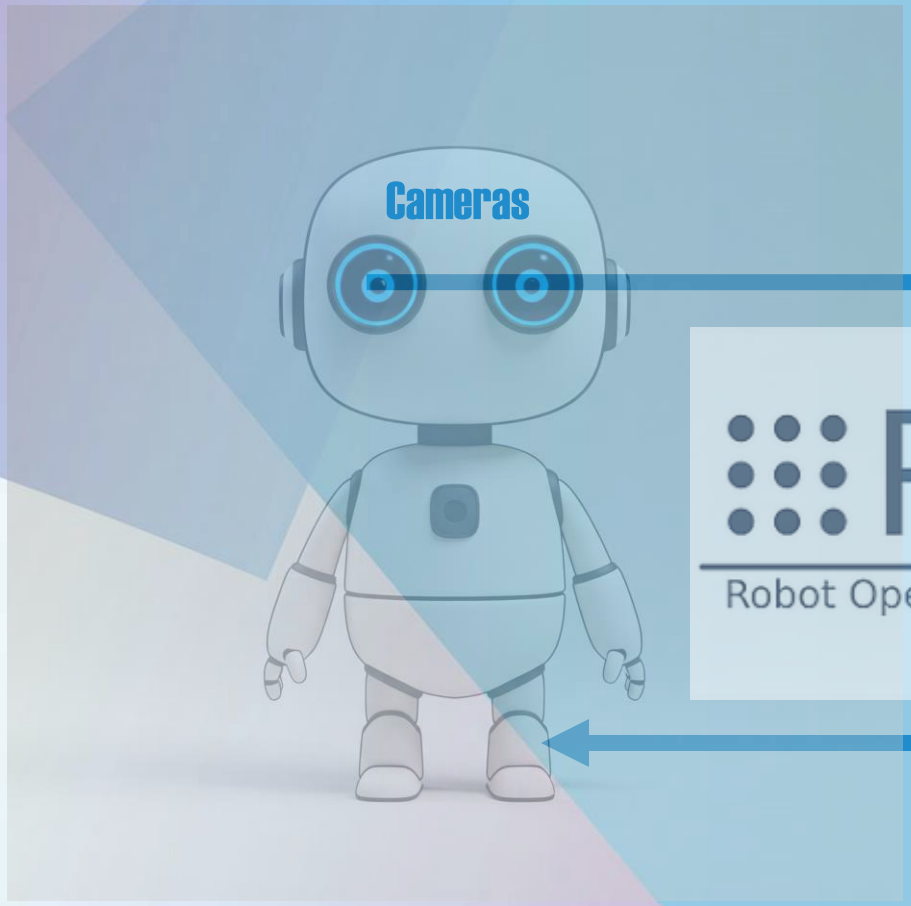


ROS

Robot Operating System

Algorithms

SLAM

Path Planning

Perception

What is ROS ?

A Little Bit about ROS

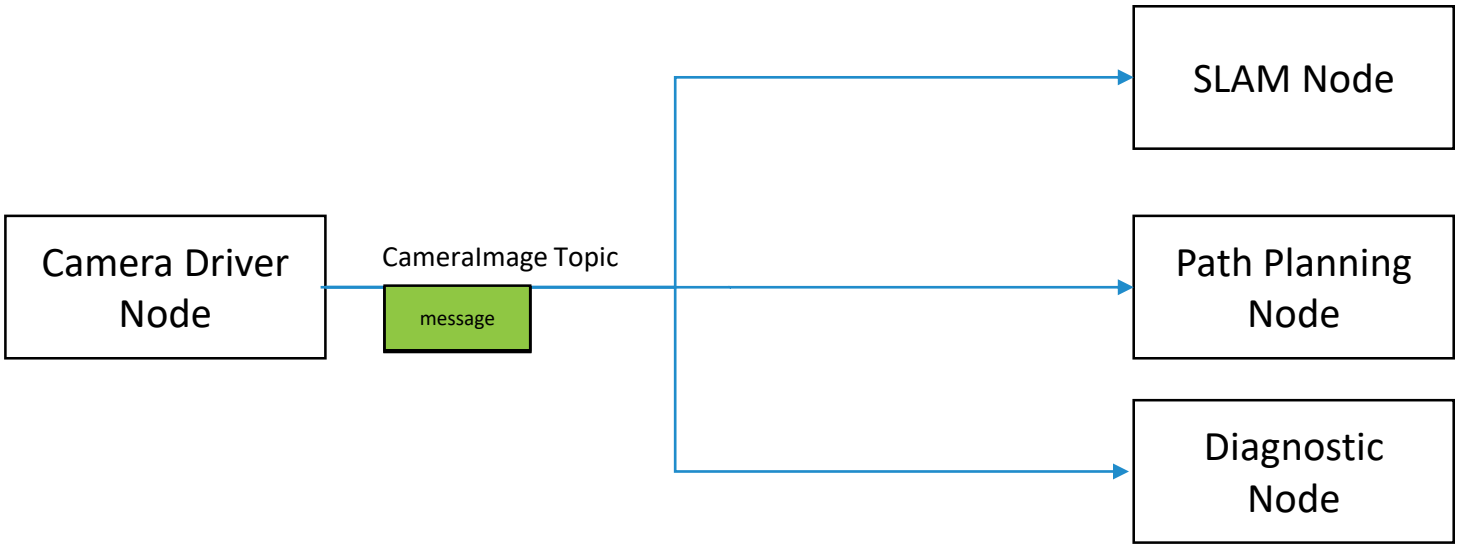
- ROS2 is the newer version of ROS since 2017
- Robotics middleware
- Provides abstractions and tools for:
  - Hardware driver management
  - Algorithm implementation
  - Visualizing and debugging robot data
- Core concepts
  - Nodes, Topics, Messages and Services

ROS Core Concepts

Nodes, Topics and Messages

- Node
  - An entity that either publishes messages on topics or subscribes or does both
- Message
  - A data structure (with a known format) that can be published or subscribed
- Topic
  - An instance of a message with a unique topic name set by the publisher Node
  - It’s a from of one-to-many communication
  - Once message published on a topic, framework delivers message to subscribers
  - ROS uses transport for pub/sub (Data Distribution Services or DDS)

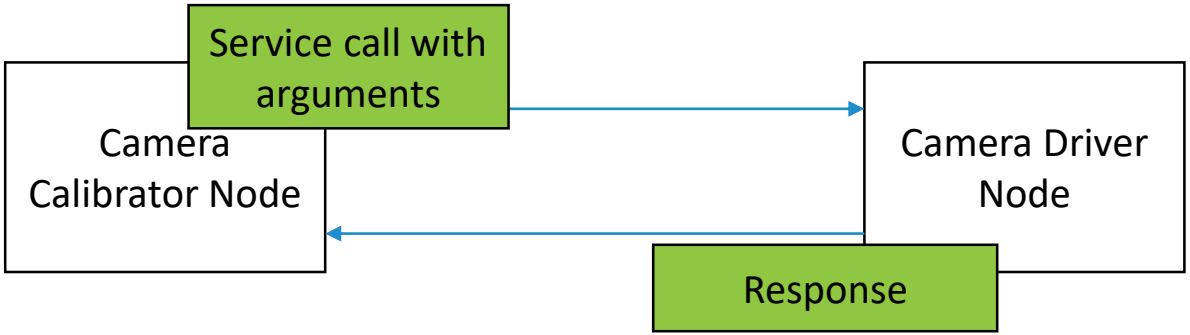
Nodes, Topics and Messages



Services

- Not every form of communication is one-to-many
- Sometimes one-to-one communication is needed
- Services offer one-to-one communication mechanisms in ROS
- Service calls are always accompanied with a response

Services

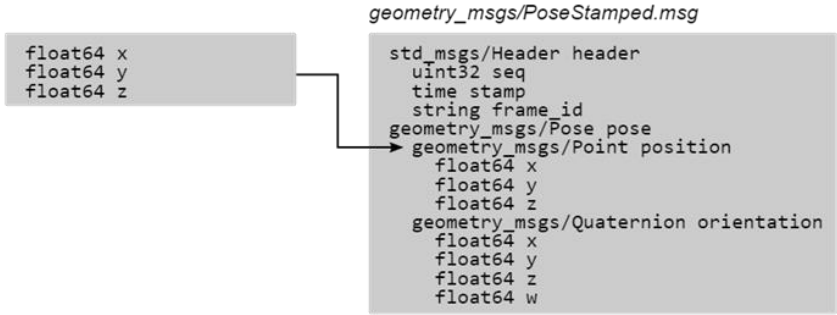


https://automaticaddison.com/topics-vs-services-vs-actions-in-ros2-based-projects/

ROS Messages

Messages

- Standard messages is a predefined collection of messages from ROS2
  - Try to find and use standard messages as much as possible
  - If really needed add custom message
- Standard message header contains
  - Seq, time stamp, frame_id
- Sensor_msgs standard sensor messages
  - Temperature
  - IMU
  - Image



sensor_msgs/Image

- Includes the standard messages header
- Has fields for height/width, data is the image data
- Encoding is the image format
  - MONO8/MONO16 (Grayscale)
  - BAYER_RGGB888 (Bayer Formats)
  - BGR888 (RGB Formats)
  - 8UC1 (OpenCV Formats)
  - NV12, YYVY (YUV Formats)

sensor_msgs/Image.msg

```
std_msgs/Header header
  uint32 seq
  time   stamp
  string frame_id
uint32  height
uint32  width
string  encoding
uint8   is_bigendian
uint32  step
uint8[] data
```

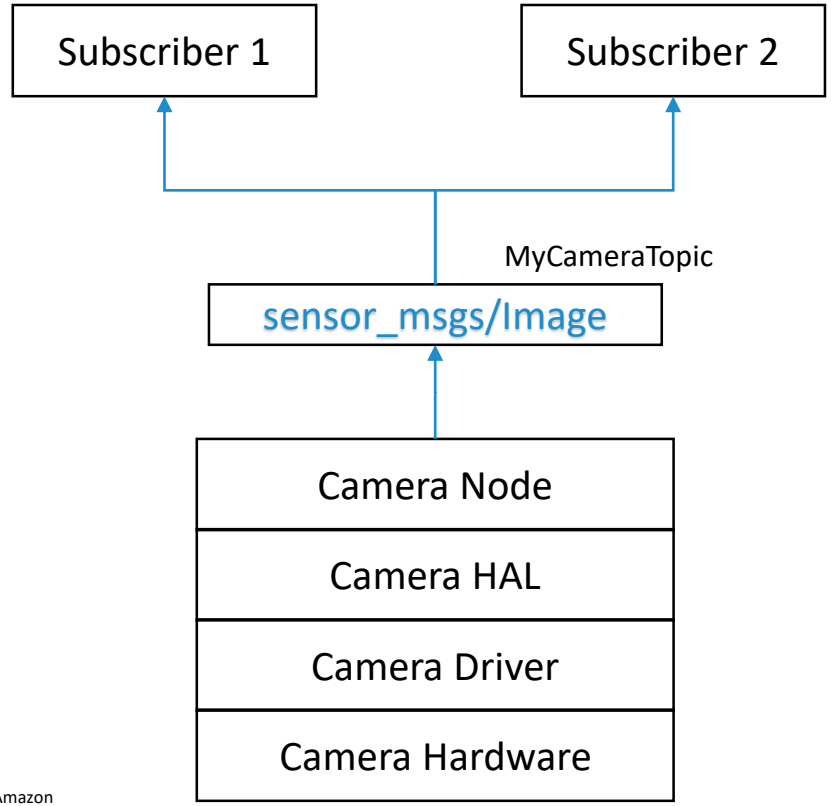
ROS Drivers

ROS Drivers

- These are ROS nodes that communicate with hardware and provide messages generated by hardware
- They may do so using a Hardware Abstraction Layer (HAL) API
- They will most likely publish a ROS message
  - Any number of interested subscribers can subscribe
- Driver nodes are typically optimized to publish only when there are subscribers
- Camera Driver nodes publish image messages typically using standard message type sensor_msgs/Image and a unique topic name

ROS Camera Drivers

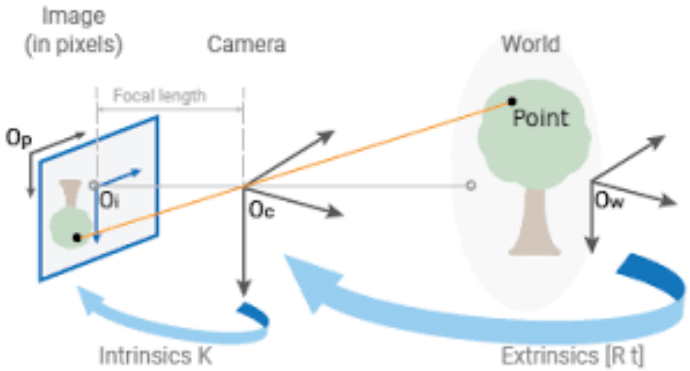
- These nodes interact with the underlying camera HAL's, such as:
  - Android HAL3
  - Libcamera
  - libUVC
  - Proprietary camera systems
- Driver typically:
  - Starts camera on first subscriber
  - Stops camera after last subscriber



Camera Calibration in ROS

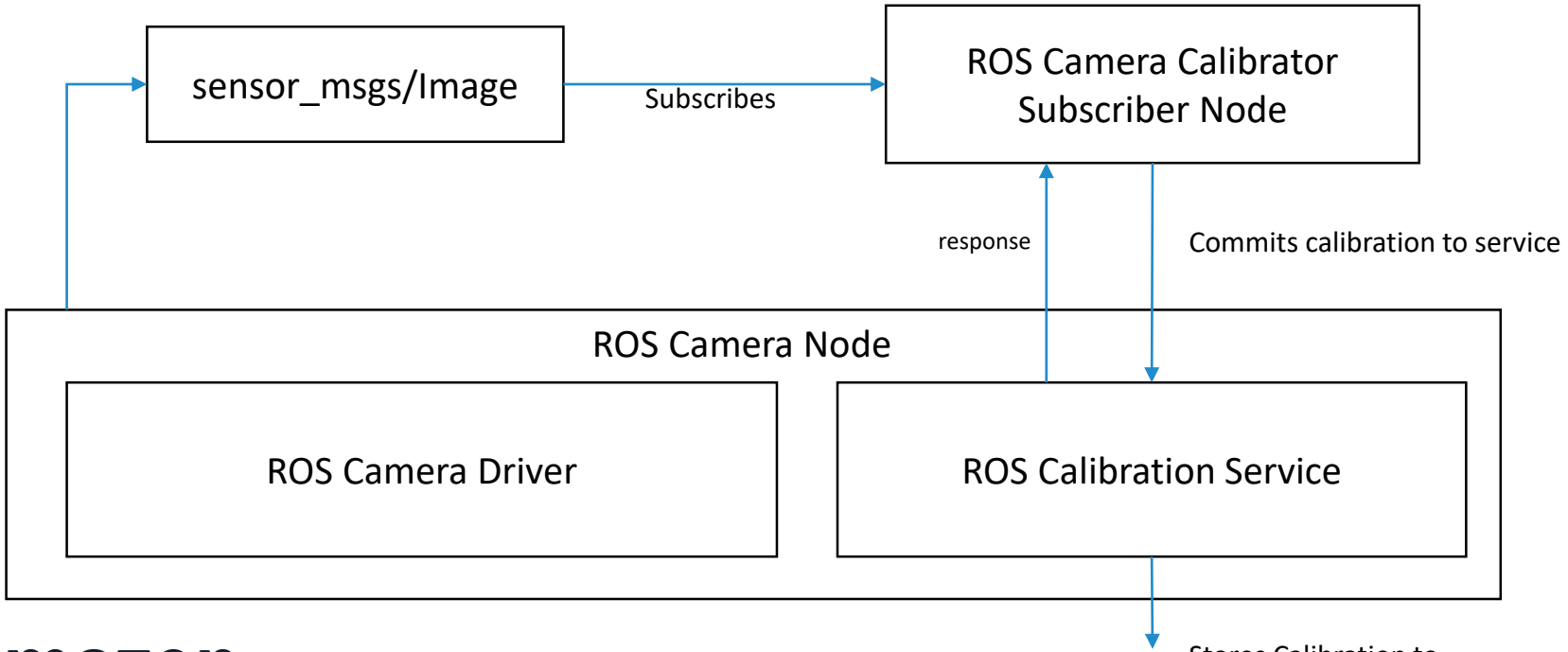
Camera Calibration

- Robotics systems are very sensitive to camera calibration
- Intrinsics
  - Properties local to camera independent of the world
    - Focal length
    - Distortion coefficients
  - Extrinsics
    - Mechanical mounting characteristics like:
      - Rotation
      - Translation

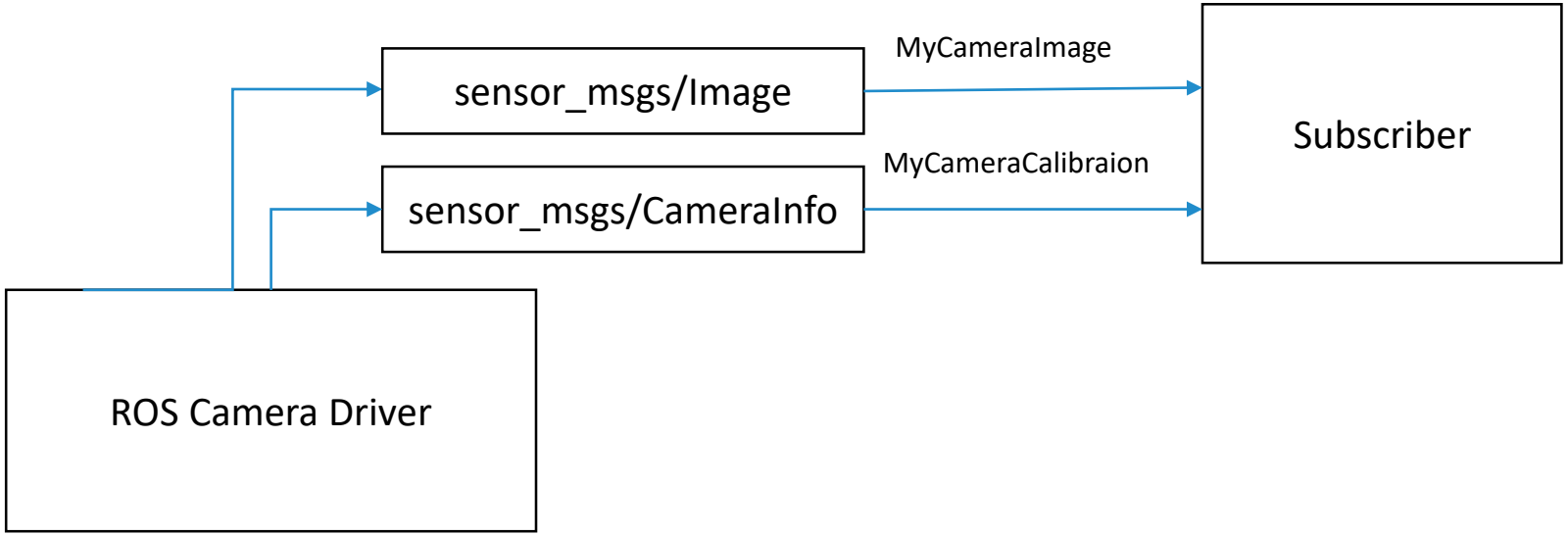


https://www.mathworks.com/help/vision/ug/camera-calibration.html

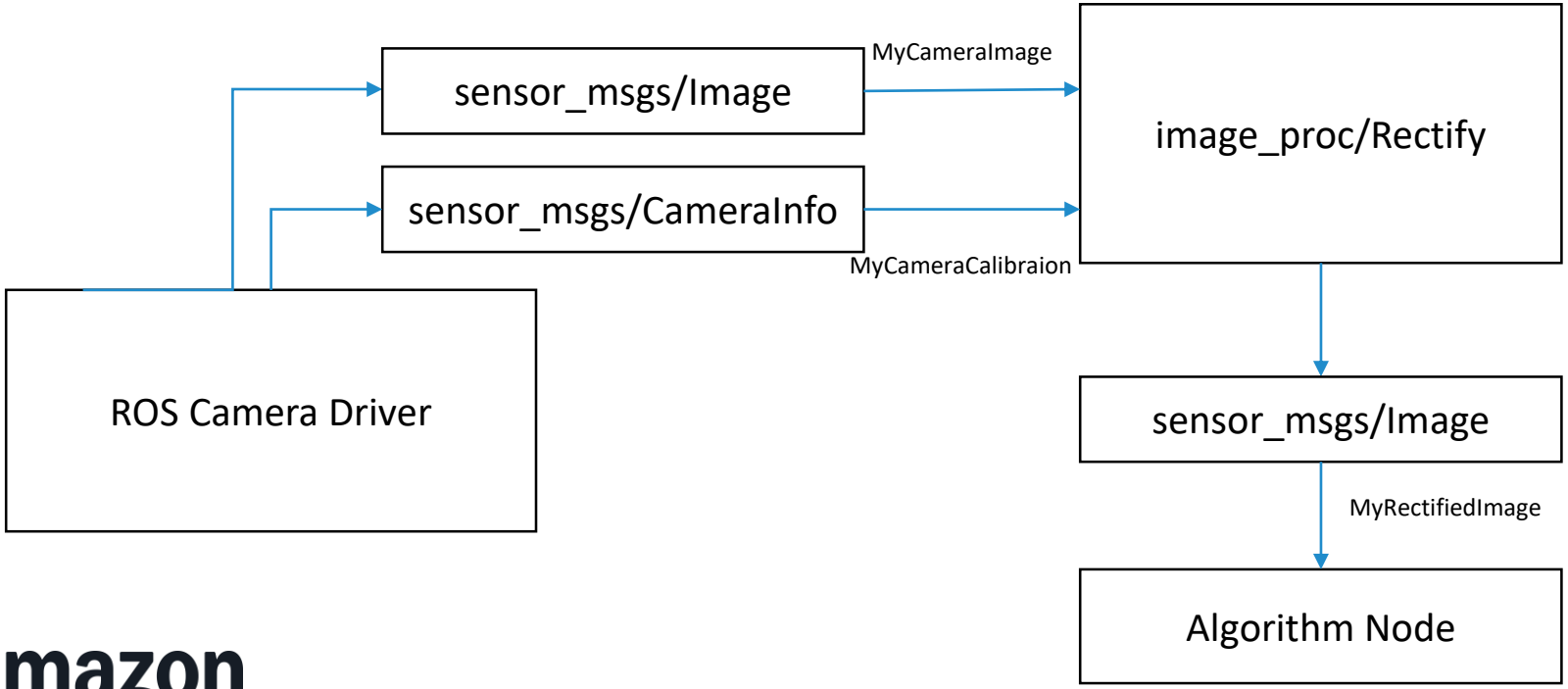
ROS Camera Calibration Process



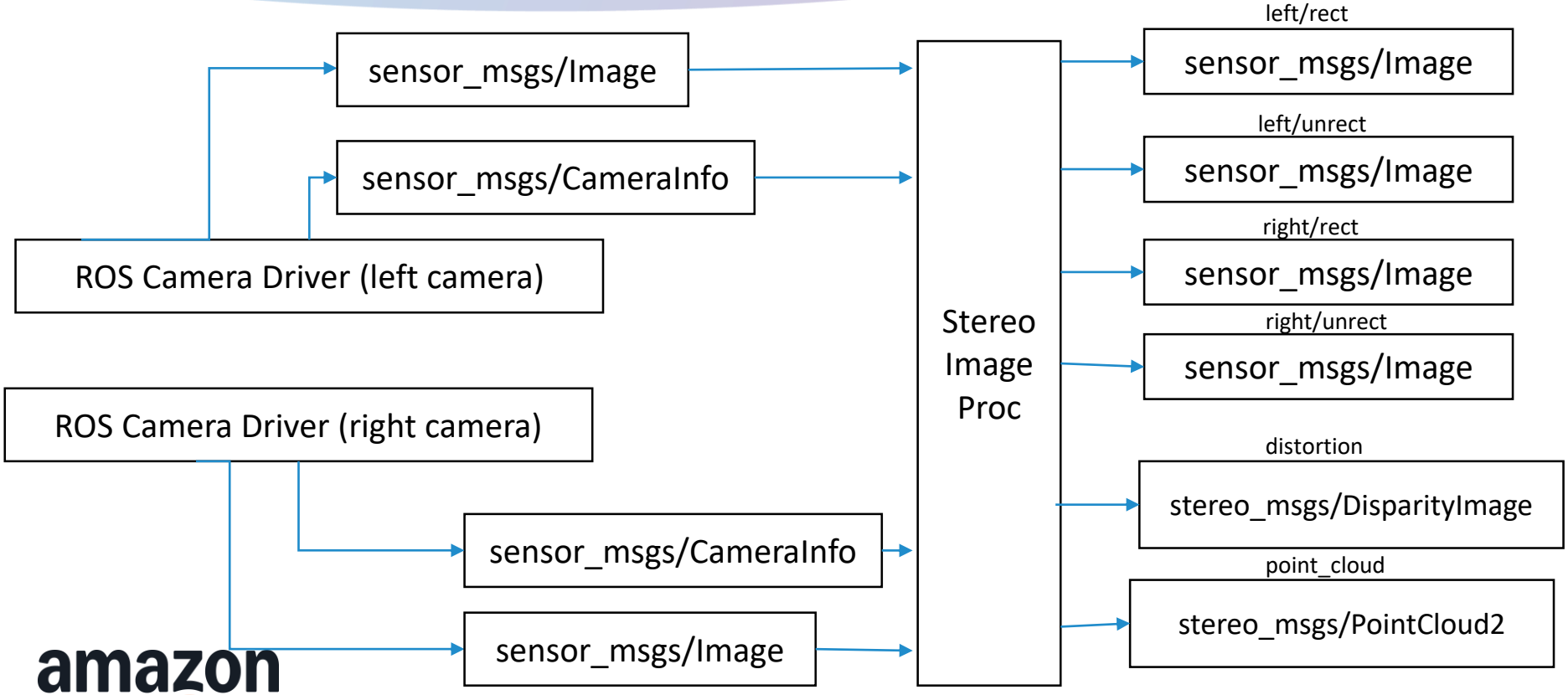
ROS Camera Driver with Calibration



ROS Camera Driver with ImageProc



Stereo Image Example



Conclusion

Conclusion

- ROS is a middleware framework for robotics
- Many of the robotics requirements have been solved by ROS with Publish/Subscribe and Services
- Camera being an important part of Robotics have been well defined for
  - Image message header containing frame_id, timestamp
  - Image message data containing raw data with encoding
  - Image Calibration continuously published with frame
- Building camera drivers using these framework definitions offers interop with other nodes

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References

ROS

https://docs.ros.org/

ROS Messages

https://docs.ros.org/en/noetic/api/sensor_msgs/html/msg/CameraInfo.html

https://docs.ros.org/en/noetic/api/sensor_msgs/html/msg/Image.html

Image Nodes

https://wiki.ros.org/stereo_image_proc

https://wiki.ros.org/image_proc