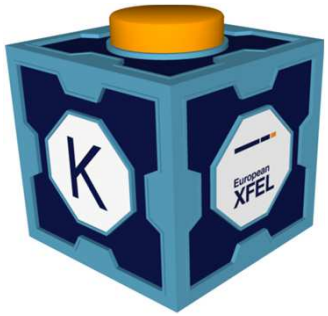

Handling Fast Data through Pipelines

Karabo Developer Workshop 2024

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(based on slides from Raul Costa)
Controls Group @ European XFEL

Satellite Workshop:

An introduction to developing in the Karabo SCADA Framework

Outline

- Introduction: Pipelines and their uses
- Hands-On Exercises

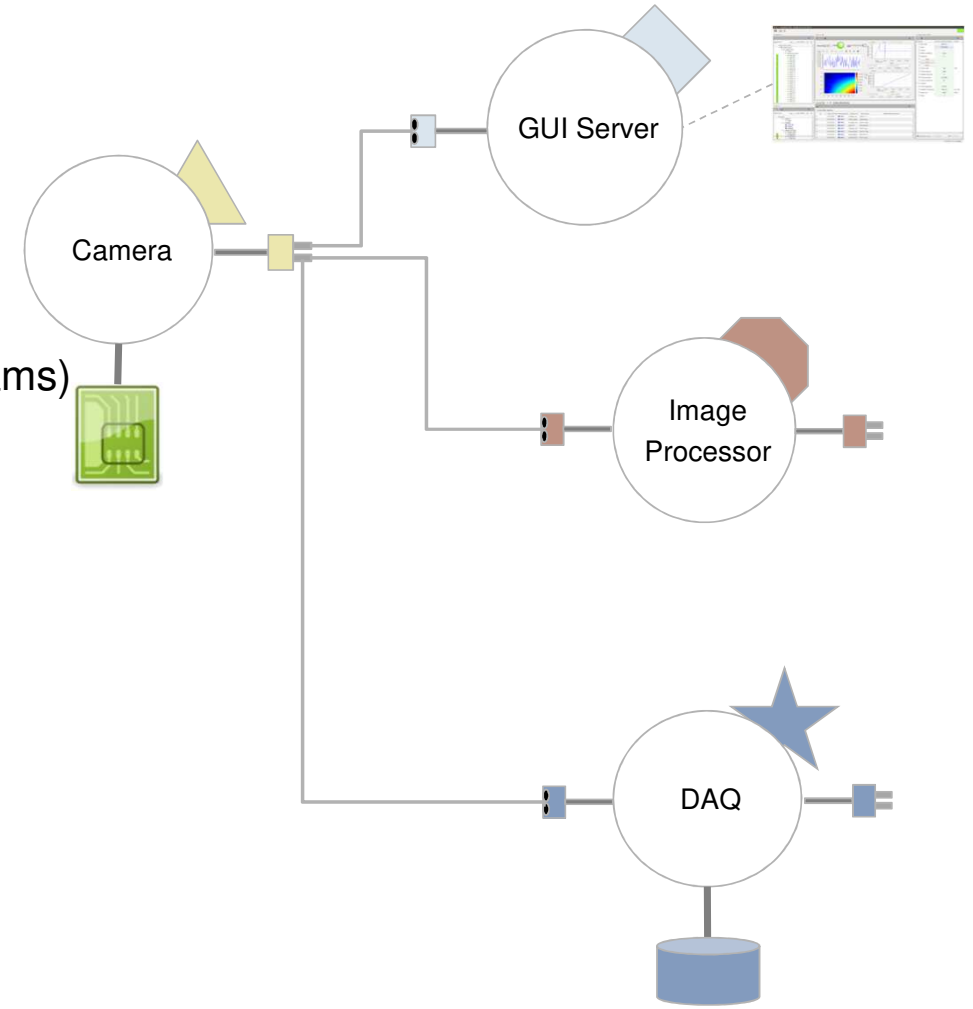
Karabo: Device Based Communication via a Message Broker

Self-describing
Karabo Devices

- Equipment control,
  e.g. motors, valves,…
- Detectors
  - e.g. cameras
- Online data analysis
- Data Logging
- Other system services
  - GUI entry point
  - DAQ for big/scientific data (not shown)

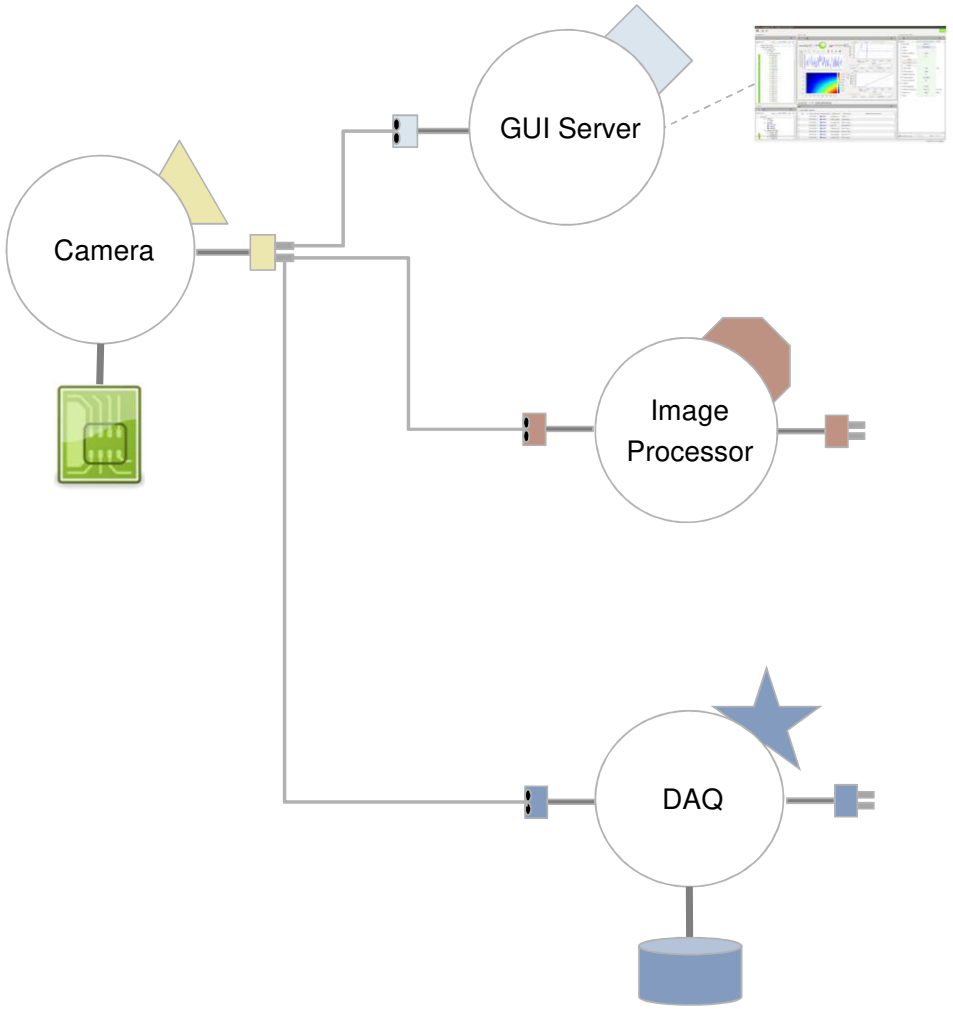
Introduction – Pipelines and their Uses

- Karabo data can be split in 2 categories:
  - **Slow Data** and **Fast Data.**
- **Slow Data**: exchanged via broker (AMQP)
  - Device properties (configurations and read-only params)
    - ►Logged by (InfluxDB) data loggers
  - Instantiations, shutdowns, state changes, …
- **Fast Data**
  - Sent directly from one device to another (no broker)
  - High throughputs must be supported
    - ►Camera images, digitizer data
    - ►Saved by the DAQ on request



Introduction – Pipelines and their Uses (ctd.)

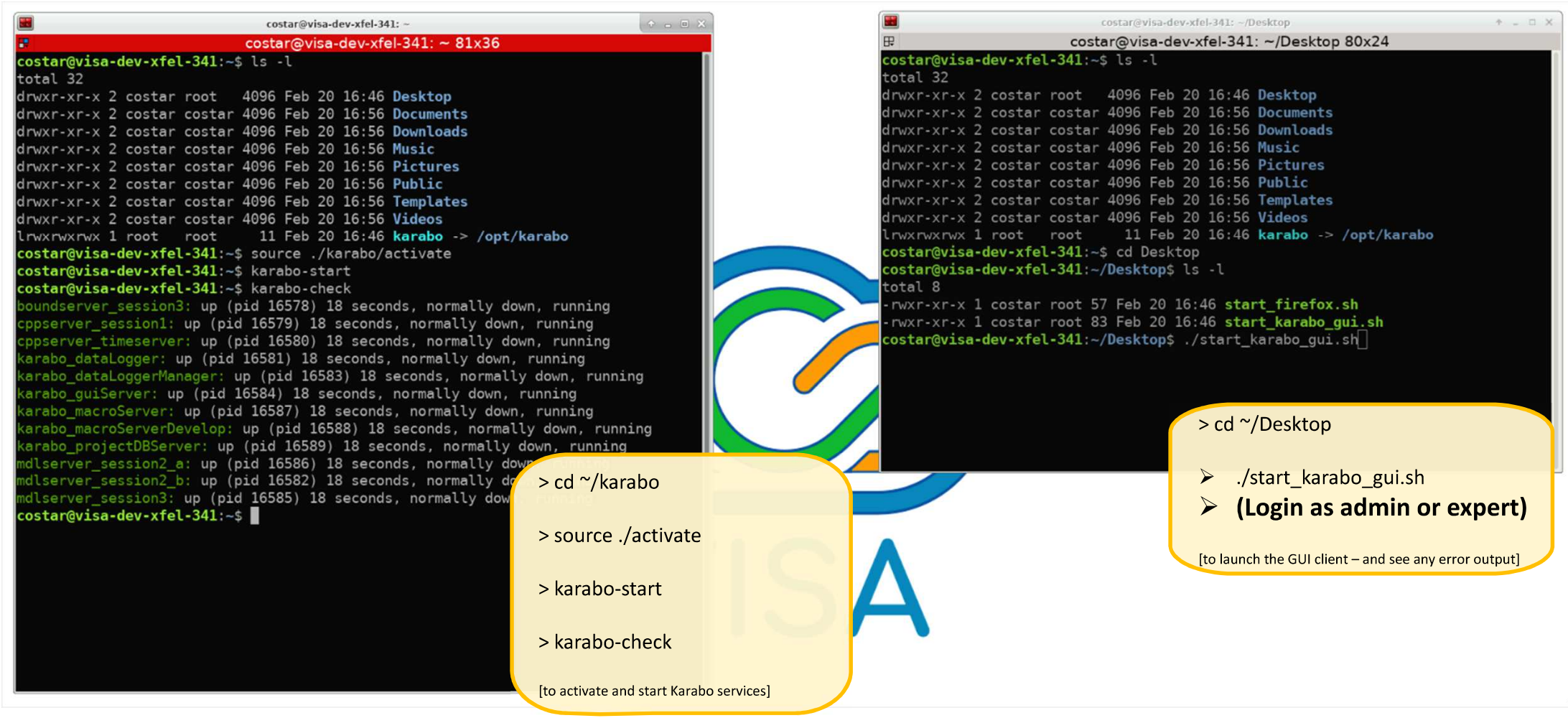
- **Pipelines**:
  - Direct TCP between two Karabo devices for fast Data flows
  - Two ends:
    - ► OutputChannel: produces data
    - ► InputChannel consumes data
- Karabo devices can have any number of Input- and OutputChannels
- InputChannel is the active part
  - Establishes connection to configured OutputChannel
  - Main configuration of data flow
  - Tells OutputChannel that ready to receive more
    - ► Always keeping some data being transferred



Hands-On Exercises - Outline

- Connect a skeleton MDL device to a simulated camera
- Code Part I: Process data sent by the camera
  - Step 1: Show the number of frames sent by the camera
  - Step 2: Show the min, max and average of the pixels of each frame
  - Step 3: Add PROCESSING and ERROR states, handle end-of-stream (optional)
- Code Part II: Forward processed data via an output channel
  - Step 4: Forward min, max and average of the pixels of each frame
  - Step 5: Capture and forward frame timestamp (optional)
  - Step 6: Forward camera acquisition cycles (end-of-stream events) (optional)

Start Karabo's Working Environment on the VISA VM



Launch and Explore the Simulated Camera

- In the VISA VM, activate the Karabo GUI Client and open the project **`Session_3`**.
- Find the simulated camera device – its name is **`SIM_BL_SYS/CAM/CAM`** - and instantiate it.
- Double-click on the simulate camera device node in the project tree – the scene for the camera will be displayed. This scene will be used multiple times throughout the exercises.
- In the Configuration Editor, expand the **`Output`** property of the simulated camera. This is the camera's output channel. Click on the **`Table Element`** button in front of the **`Output > Connections`** properties – those are the input channels currently connected to the camera's output channel. One connection should be present – the connection used by the device scene to show the camera image.
- Still in the Configuration Editor, expand the **`Output > schema`** property. This shows how the data the camera sends through its output channel is structured. Take a look at the **`Data > Image > Pixel Data`** path of the schema.

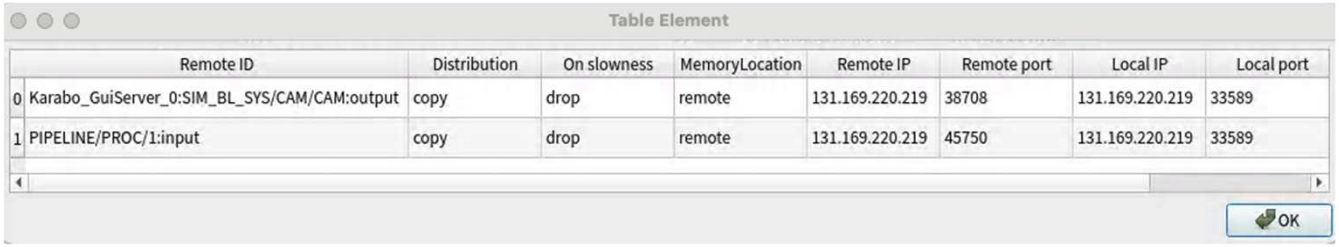
Instantiate the Skeleton MDL Device and connect it to the camera

- Still in the project **`Session_3`** opened in the previous step, find the device we will be working on, **`PIPELINE/PROC/1,`** and select it (no instantiation yet).

- In the Configuration Editor, check that the **`Input > Configured Connections`** property has the value **`SIM_BL_SYS/CAM/CAM:output`**. This the ID of the simulated camera output channel, formed by the concatenation of the DeviceID of the channel hosting device, a **`':'`**, and the ID of the output channel.

- Check the **`Output > Connections`** property of the simulated camera: the connection to **`PIPELINE/PROC/1:input`** should be there. If the simulated camera scene is open, it should be also listed there (image below).

- Pressing the **`Acquire`** and **`Stop`** buttons in the camera scene doesn't do anything on our device ... not for long!

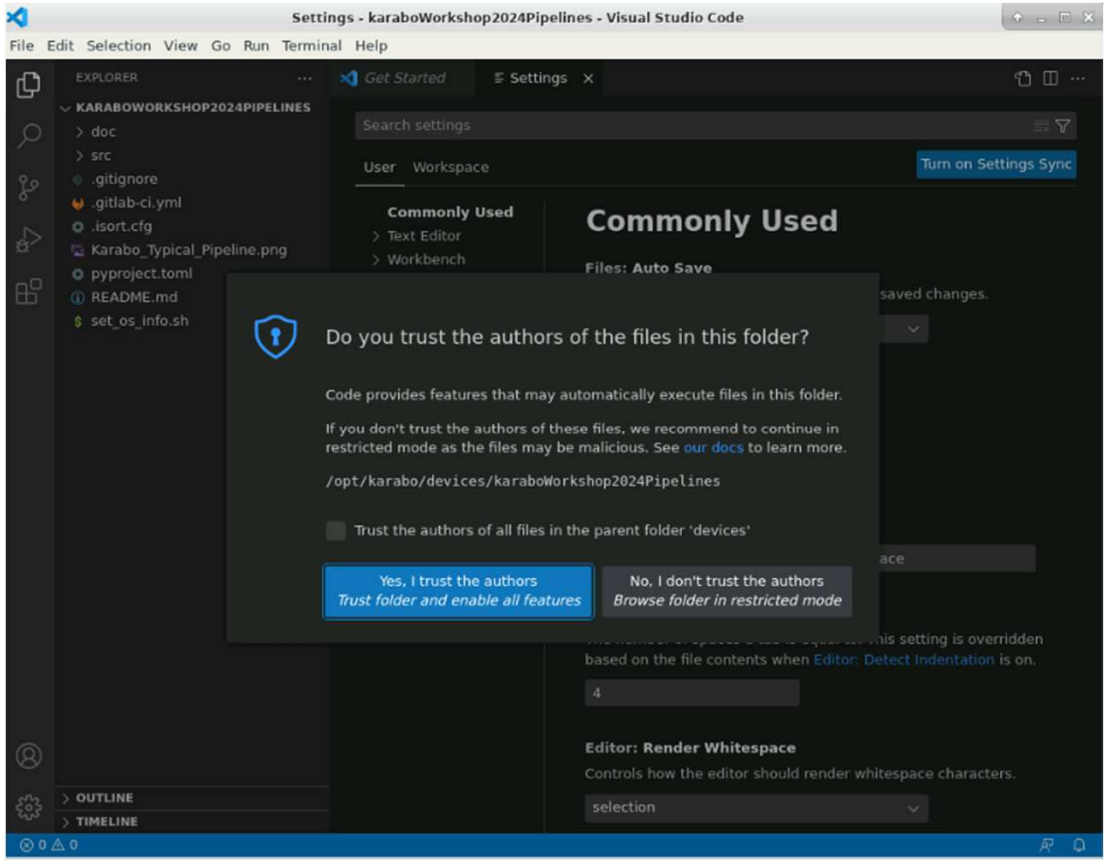


Coding Part I

Process Data Sent by the Camera

Step 1 – Show the number of frames sent by the camera

- Issue a **[> `karabo -g https://git.xfel.eu develop karaboWorkshop2024Pipelines`]**
  - i.e. git checkout to `~/karabo/devices/karaboWorkshop2024Pipelines` and `pip install -e`
- Go to that that directory
  [> `cd ~/karabo/devices/karaboWorkshop2024Pipelines`]
- Launch VS code: **[> `code .`]**
  - Trust us ;-)



Step 1 – Show the number of frames sent by the camera (ctd.)

- The initial version of our camera image processing device already comes with a input channel defined: the **`@InputChannel`** decorator for the **`async def input`** coroutine defines an input channel property for the device and establishes the coroutine as the handler for data received from an output channel.

- When the input channel is connected to a camera, each frame sent by the camera will activate the **`input`** coroutine once, passing the frame data via the **`data`** parameter. The structure of the parameter matches the schema of the camera's output channel. The second parameter, **`meta`**, is unused for now; it'll be used in Step 4.

- **The task of this step is** to add a **`framesAcquired`** property of type **`UInt32`** to our device - the number of frames received from the camera since the device instantiation.

- To test your progress, shutdown the device server of our device on the GUI client. As soon as the device server is back, instantiate the processing device - this syncs the running device with its latest version saved in Visual Studio Code.

- **`[> git diff hands_on_1_initial hands_on_1_done]`** will display the solution for this step.

Step 2 – Show the min, max, and average of the pixels values of each frame

- Issue [> **`git checkout hands_on_1_done`**] in terminal (in **`…/karaboWorkshop2024Pipelines`** directory.

- The method **`async def process_image(self, pixels)`** currently does nothing. It's called from the **`async def input`** coroutine, which sends it the pixels of the current frame sent by the camera as the value for the **`pixels`** parameter.

- **The task of this step is** to add the properties **`pixelMean`** (of type **`Double`**), **`pixelMin`** (of type **`UInt16`**), and **`pixelMax`** (of type **`UInt16`**) to our device. Those properties values should be the average, minimum, and maximum values of the pixels of the most recent frame sent by the camera. **Hint:** the **`pixels`** argument passed to **`process_image`** is an object of type **`ndarray`** and has the methods **`min()`**, **`max()`**, and **`mean()`**.

- **`[> git diff hands_on_1_done hands_on_2_done]`** will display the solution for this step.

Step 3 (optional) – Add PROCESSING and ERROR states, handle end-of-stream

- Do [> **`git checkout hands_on_2_done`**].

- An end-of-stream event is sent by a camera when it stops acquiring images.
  To handle end-of-stream events, an input channel has to declare
  an **`async input(self, output_channel_id)`** method decorated with **@input.endOfStream**.

- **The task of this step are:**

  - Add a **`PROCESSING`** state to the device to indicate that data is being received from the camera.

  - Add an **`ERROR`** state to the device to indicate any error while processing data sent by the camera. Error details should be shown in the device's **`status`** property. Successful processing data while in **`ERROR`** state should take the device back to **`PROCESSING`** state.

  - Handle end-of-stream events from the camera by putting the device back in **`ON`** state and indicating that no processing is taking place by showing **`IDLE`** in the device's **status** property. Reset the **`framesAcquired`** value when the camera starts a new acquisition cycle.

- **`[> git diff hands_on_2_done hands_on_3_done]`** will display the solution for this step.

Coding Part II

Forward Processed Data Via an Output Channel

Step 4 – Forward min, max and average of the pixels of each frame

- Do [> **`git checkout hands_on_4_initial`**]

- We start with the device already with an output channel: its data structure is defined by **`class DataNode`** (line 22), which becomes the field **`data`** of **`class ChannelNode`** (line 39). **`Channel Node`** is then specified as the schema of the **`output`** OutputChannel (line 88).

- **The task of this step is** to forward the values computed for the **`pixelMean`**, **`pixelMin`**, **`pixelMax`** properties of the device through its output channel. **`Hint:`** reinstantiate the device after shutting down its device server. Take a look at the **`Output > schema > data`** property of the device in the Configuration Editor to see how the data must be structured. Await for the **`self.output.writeData()`** coroutine to send the data.

- **`[> git diff hands_on_4_initial hands_on_4_done]`** will display the solution for this step.

  - The forwarded content can be seen in the scene **`PIPELINE_PROC_1_OUTPUT`** in the same project that has our device and the simulated camera

Step 5 (optional) **– Capture and forward frame timestamp**

- Do [> **`git checkout hands_on_4_done]`**

- The metadata (data about data) for the data received by an input channel is available as the second parameter of the **`async def input handler`** coroutine – **`meta`** parameter in line 50.

- The timestamp of the data received can be accessed within the input handler method as **`meta.timestamp.timestamp`**.

- **The task of this step is** to forward the timestamp of the data received by the input channel of our device to its output channel. **Hint:** the **`self.output.writeData`** call, currently using no argument, supports a keyword parameter called **`timestamp`** which allows specifying a timestamp for the data being written to the output channel.

- **`[> git diff hands_on_4_done hands_on_5_done]`** will display the solution for this step.

Step 6 (optional) **– Forward camera acquisition cycles (end-of-stream events)**

- Do [> **`git checkout hands_on_5_done]`**.

- **The task of this step is** to forward any end-of-stream event received from the camera to the output channel of the device. Hint: the output channel has a coroutine that sends an end-of-stream through the channel. For our device it can be invoked with **`self.output.writeEndOfStream()`**.

- **`[> git diff hands_on_5_done hands_on_6_done]`** will display the solution for this step.