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Enrico Torres, Filippo Marri

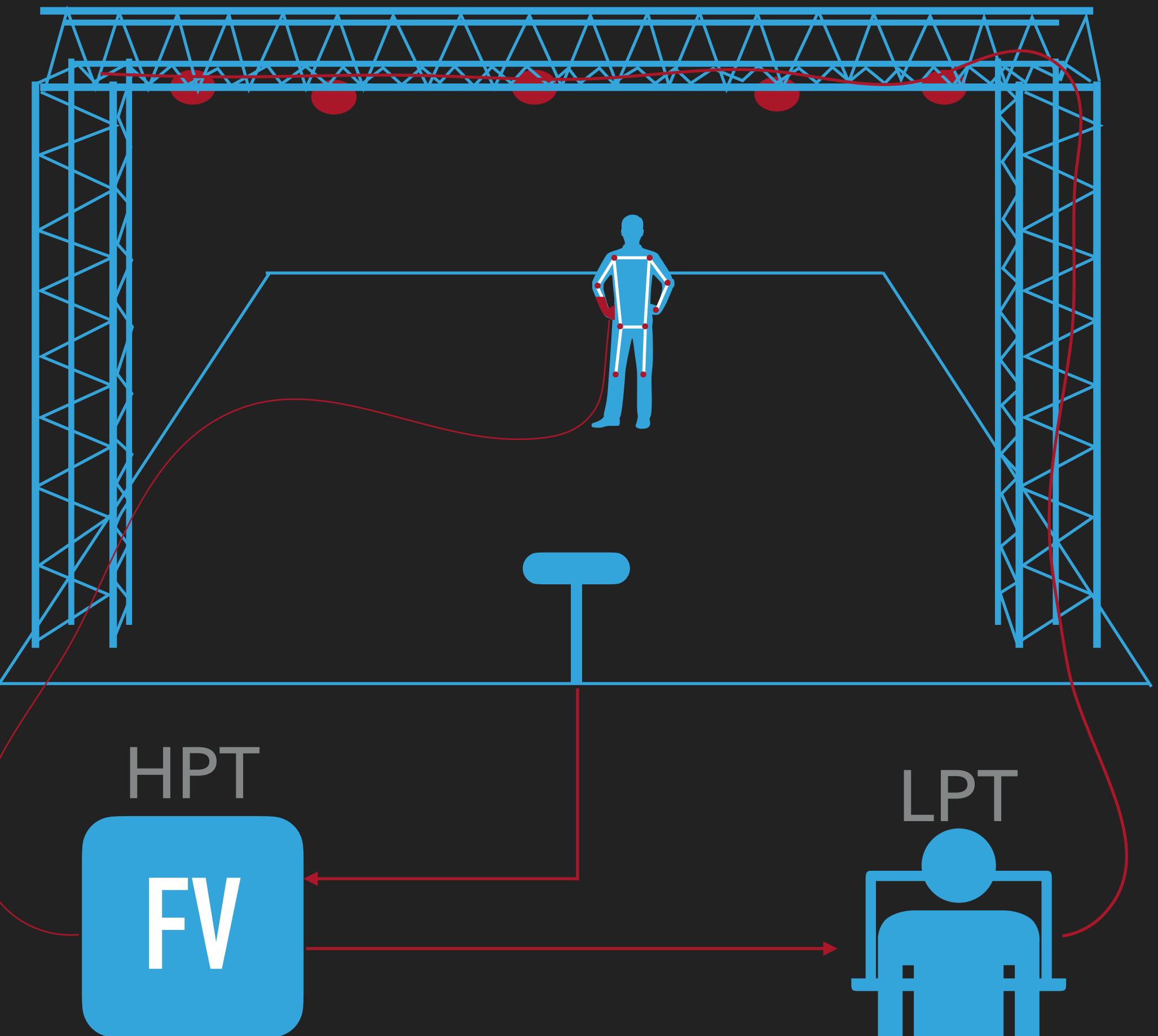
AN INCLUSIVE SOLUTION FOR LIGHT CONTROL

FLOWVISION

CONCEPT

CONCEPT

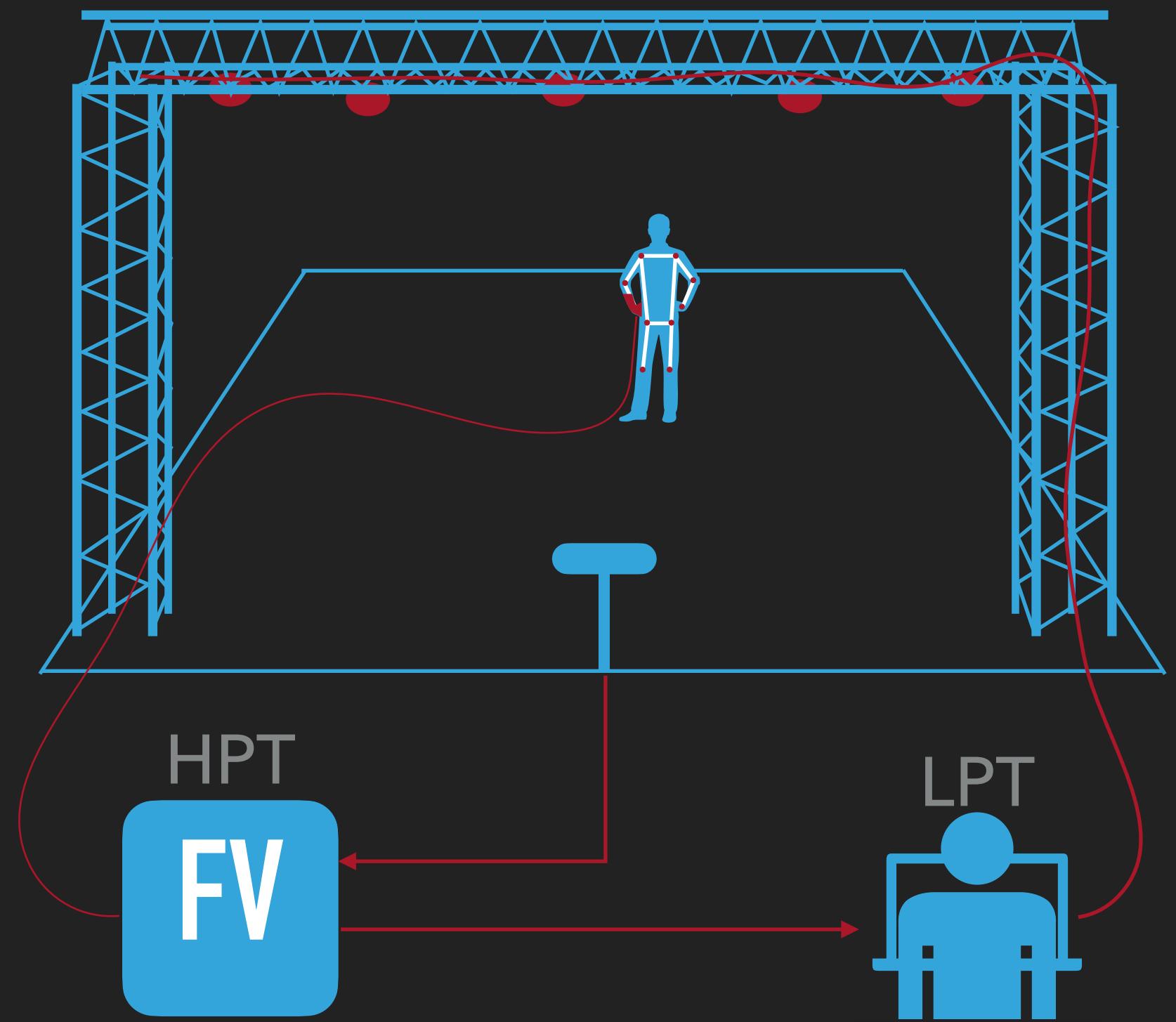
- ▶ A software able to control simple light settings according to the performer's movements
- ▶ Inclusivity: provide haptic feedbacks to the performer in order to give the perception of control



FROM THE HACKATHON TO THE FINAL VERSION

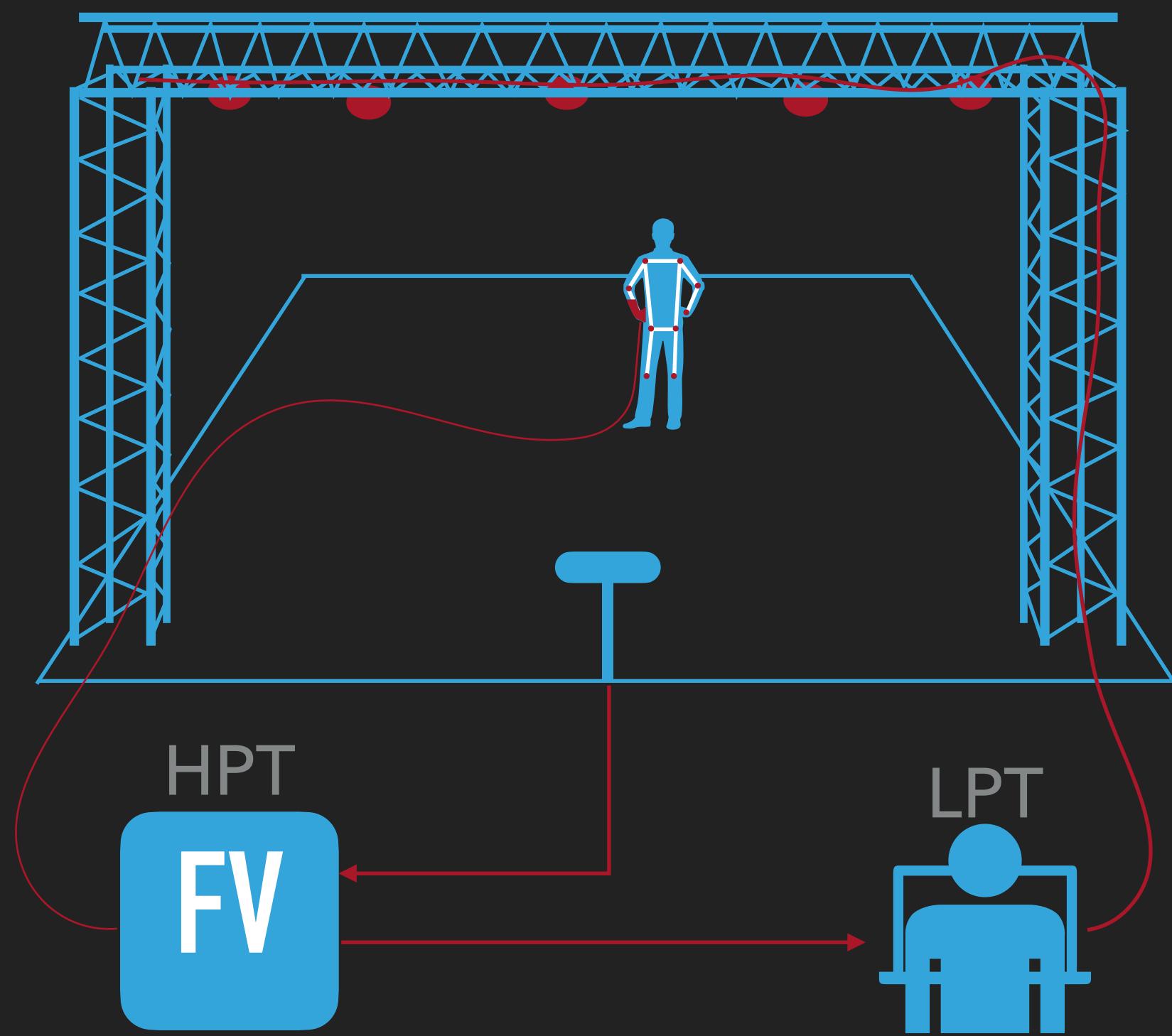
ON STAGE

BEHIND THE SCENE

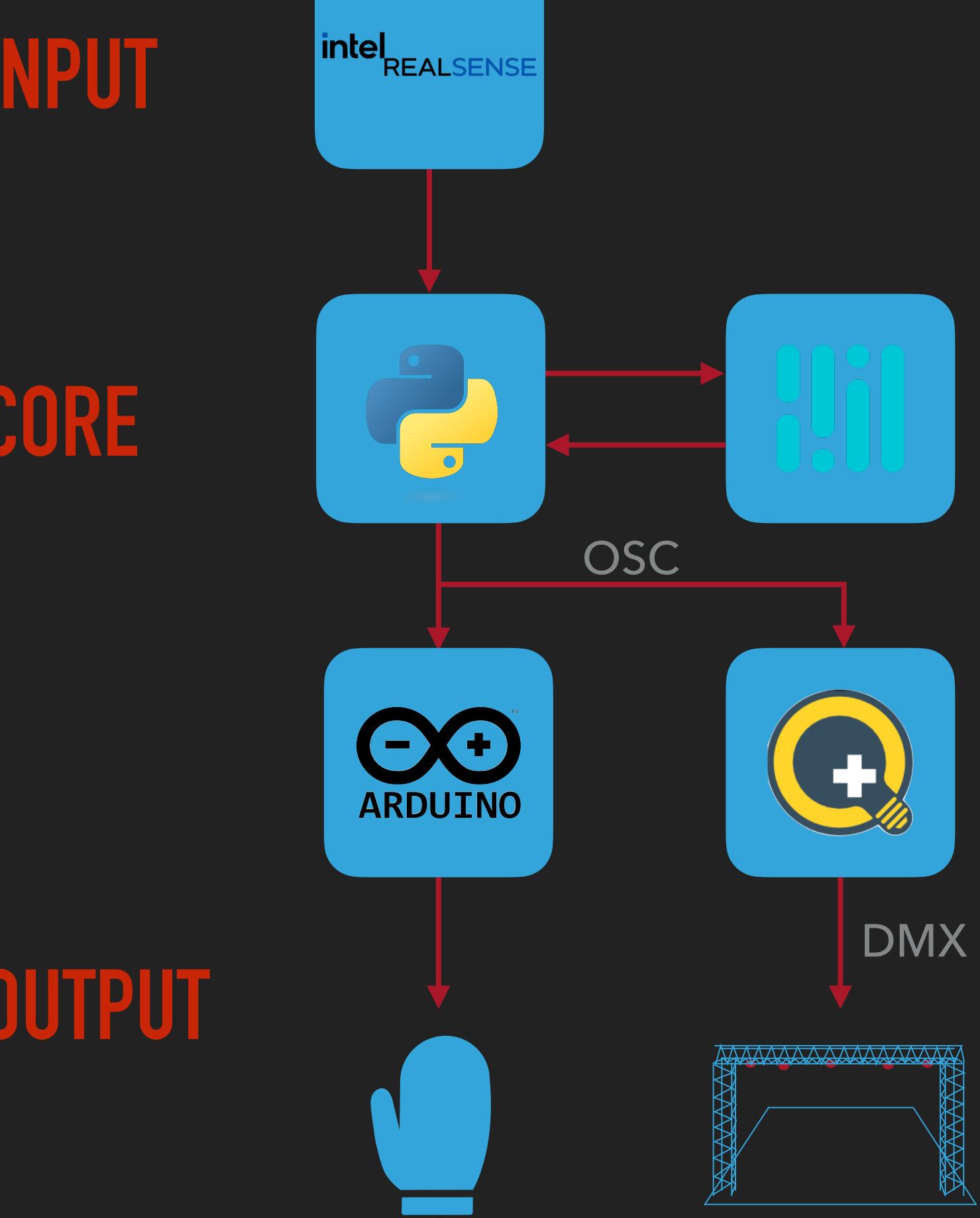


FROM THE HACKATHON TO THE FINAL VERSION

ON STAGE

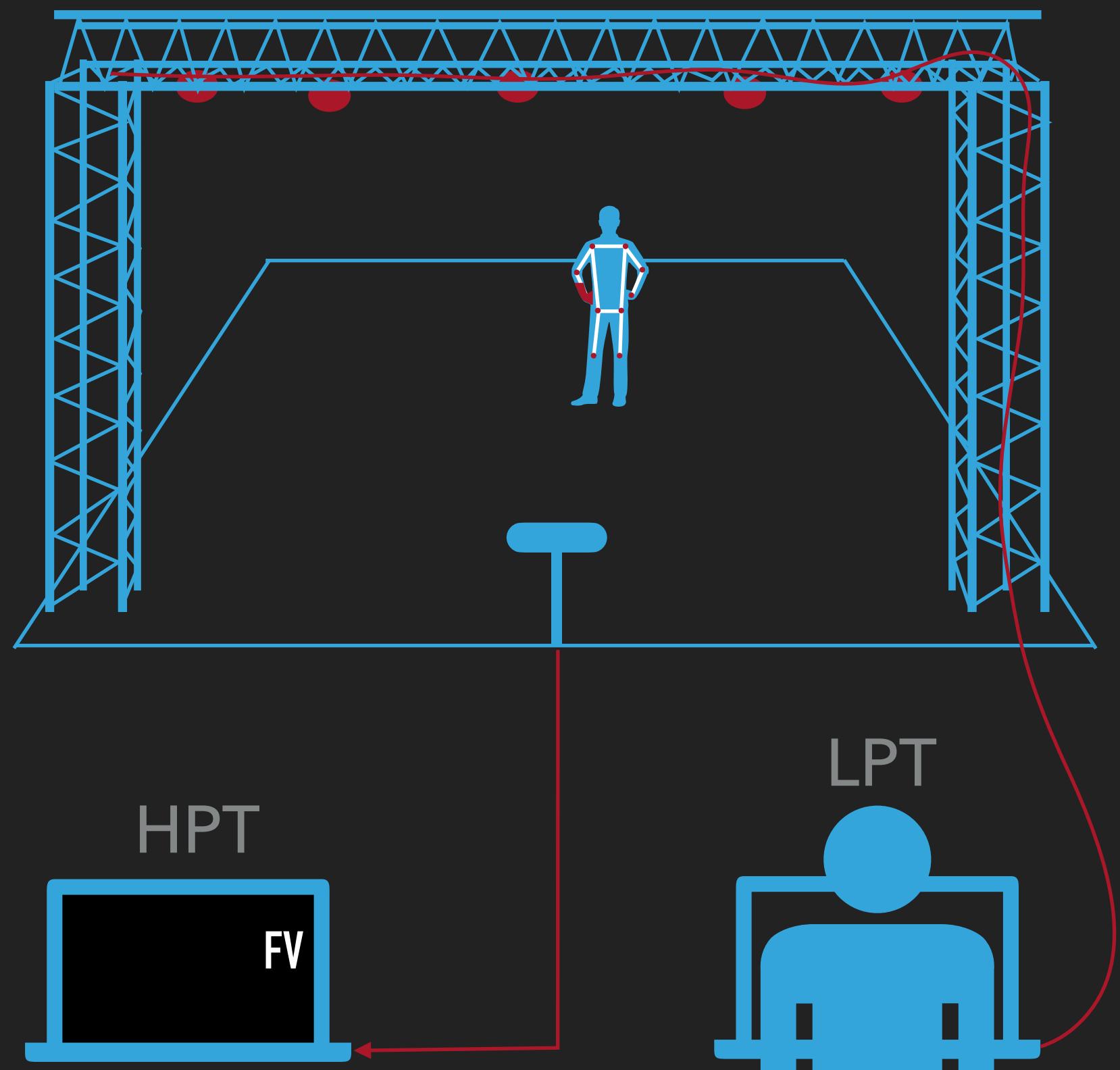


BEHIND THE SCENE



FROM THE HACKATHON TO THE FINAL VERSION

ON STAGE

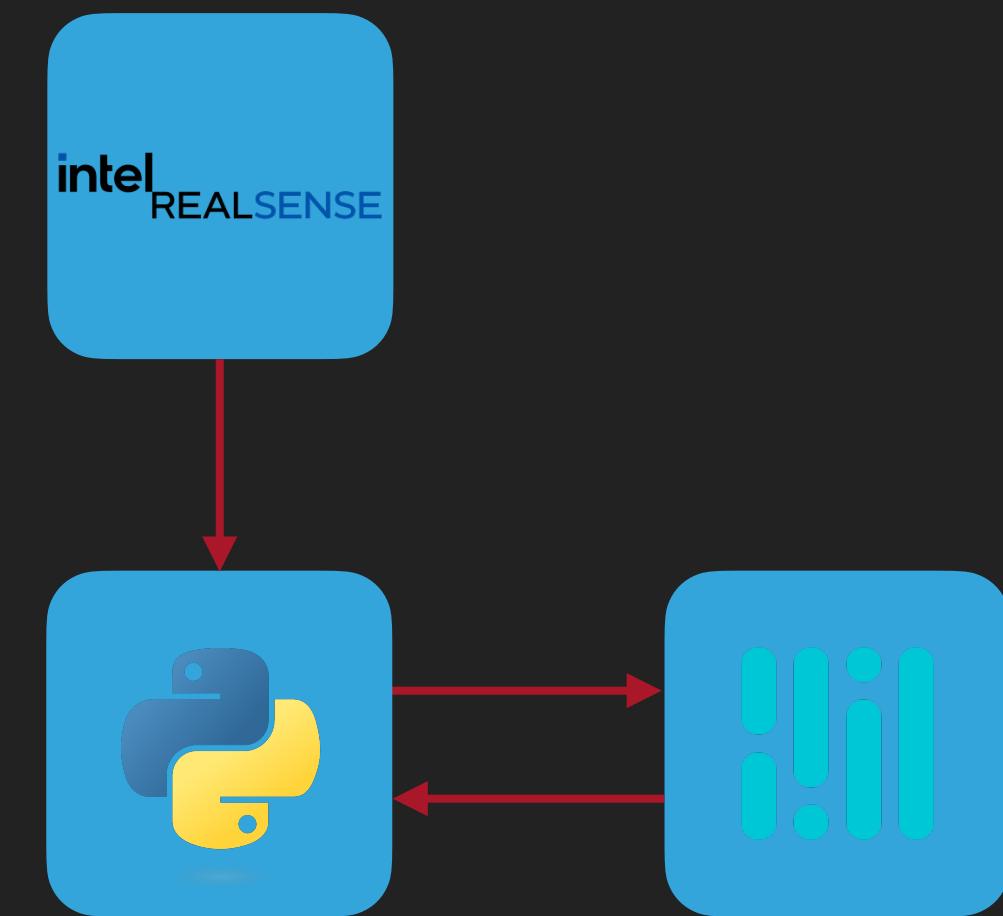


INPUT

CORE

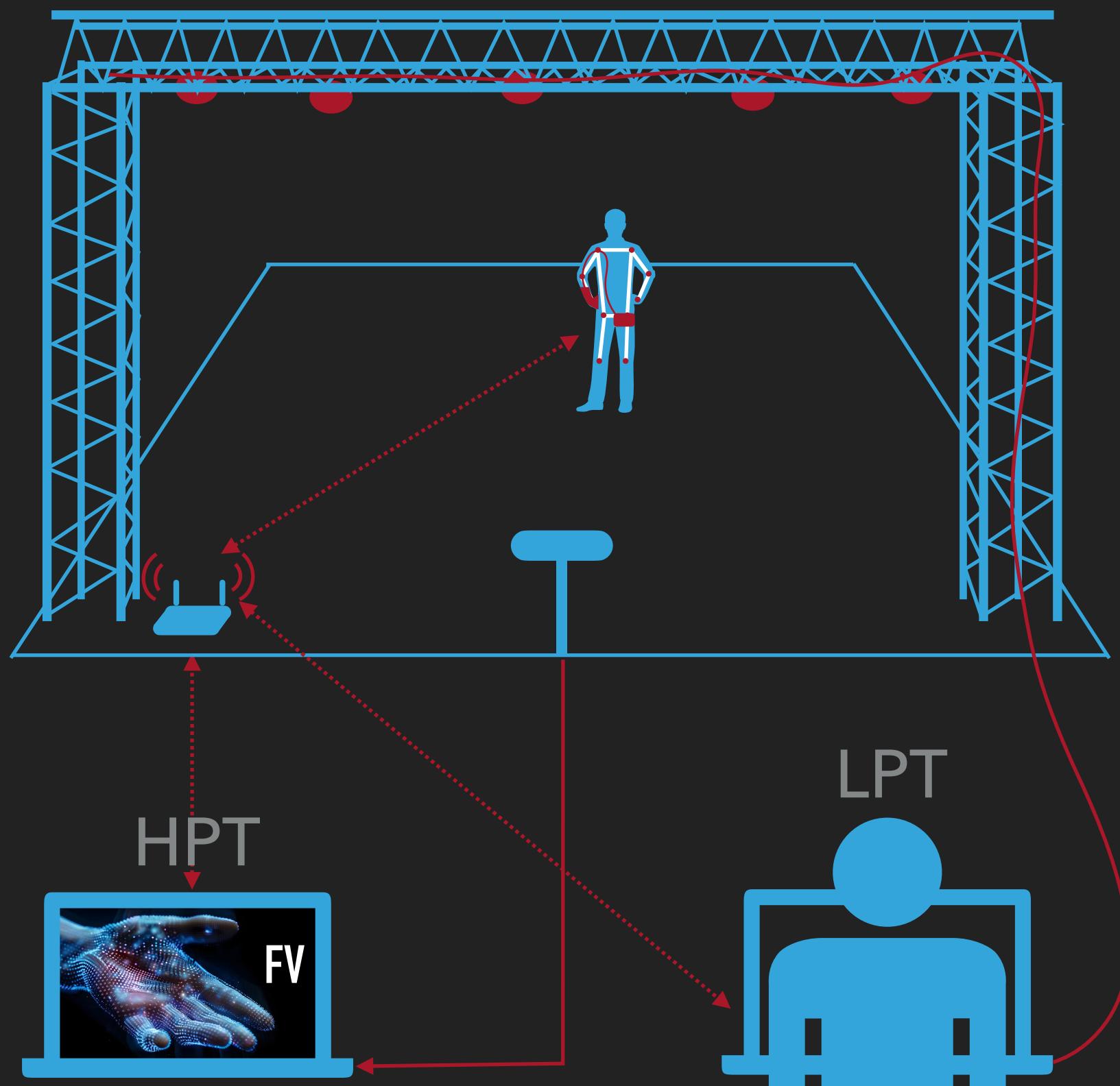
OUTPUT

BEHIND THE SCENE



FROM THE HACKATHON TO THE FINAL VERSION

ON STAGE

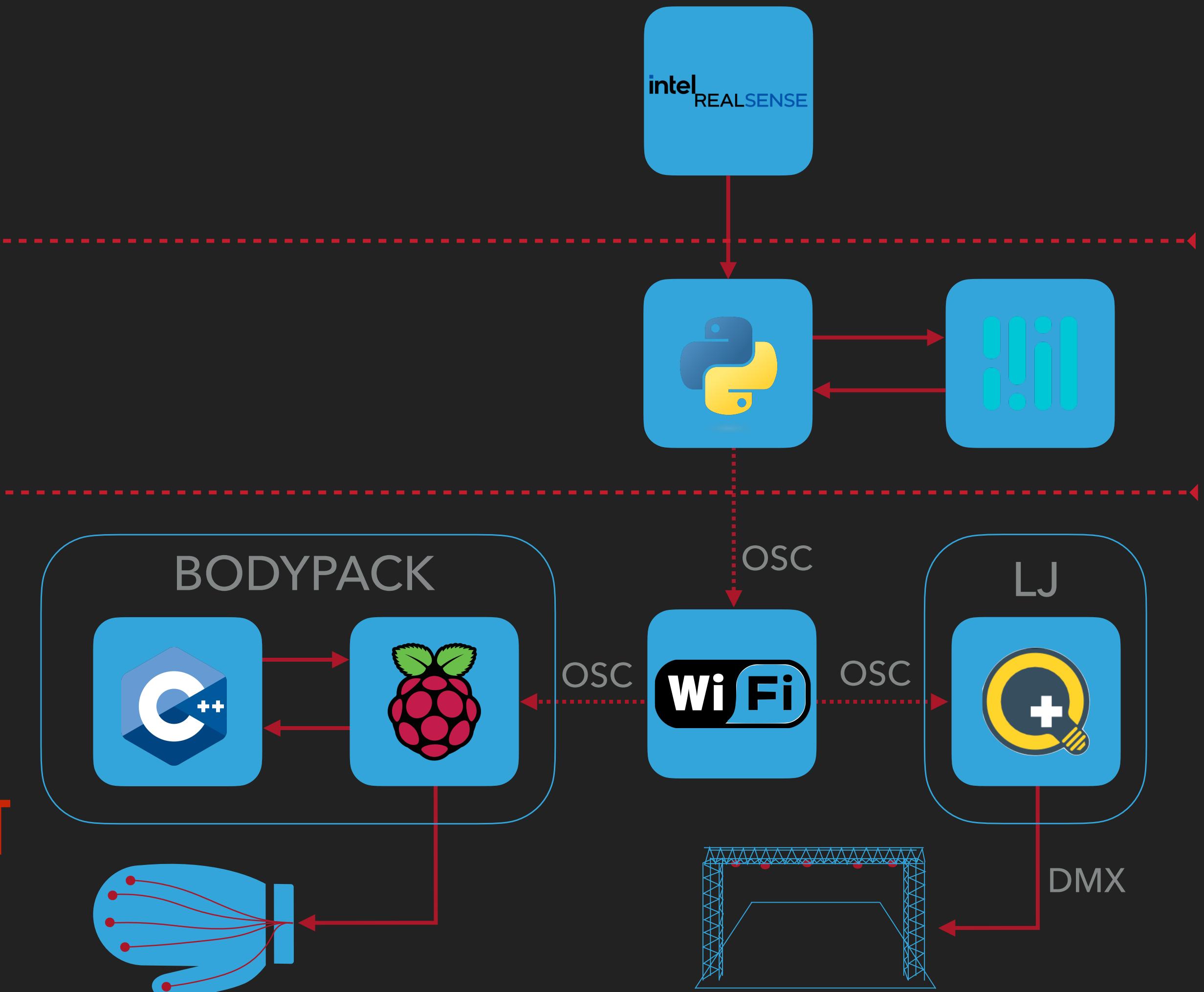


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CORE

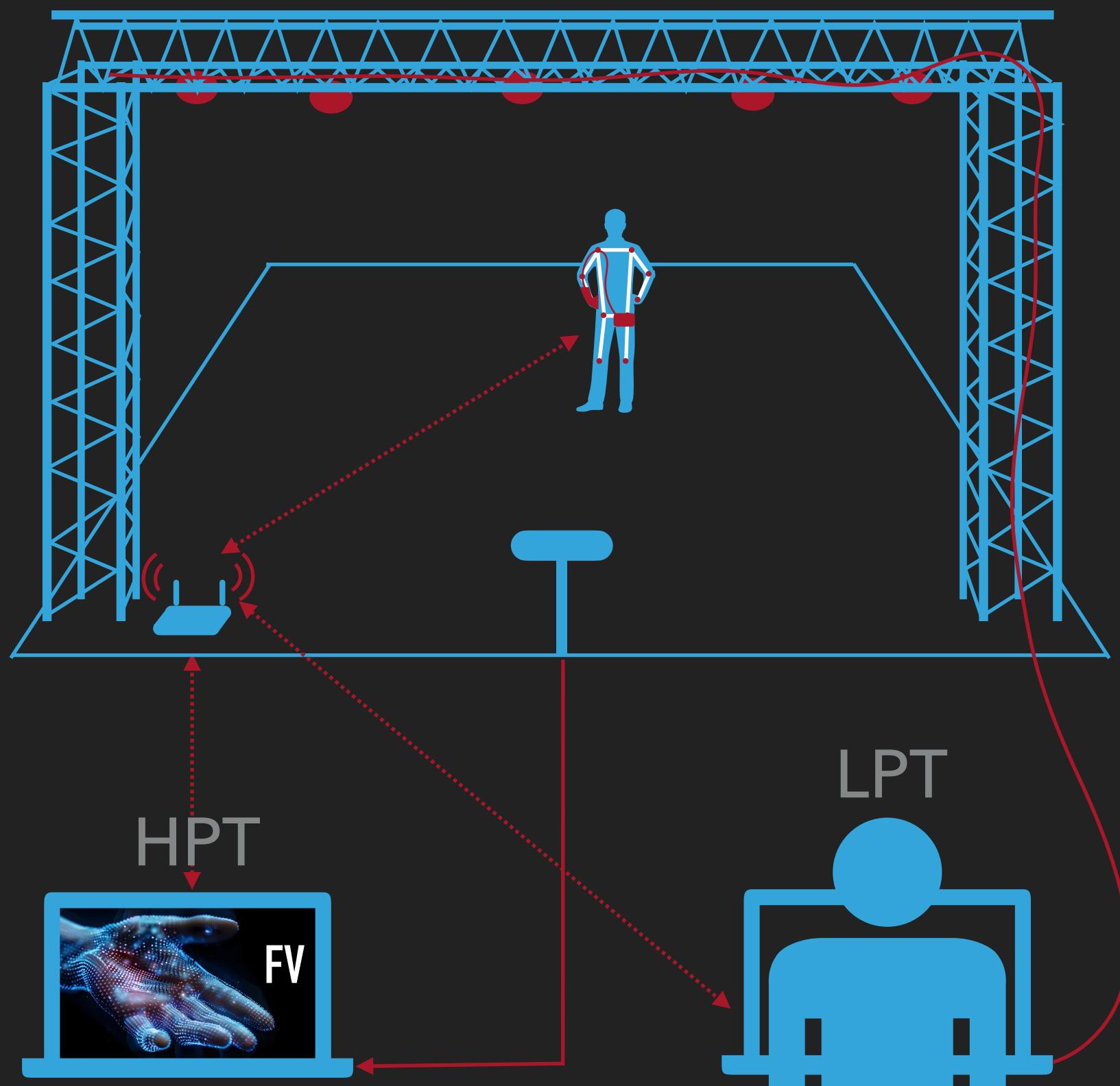
OUTPUT

BEHIND THE SCENE



FROM THE HACKATHON TO THE FINAL VERSION

ON STAGE

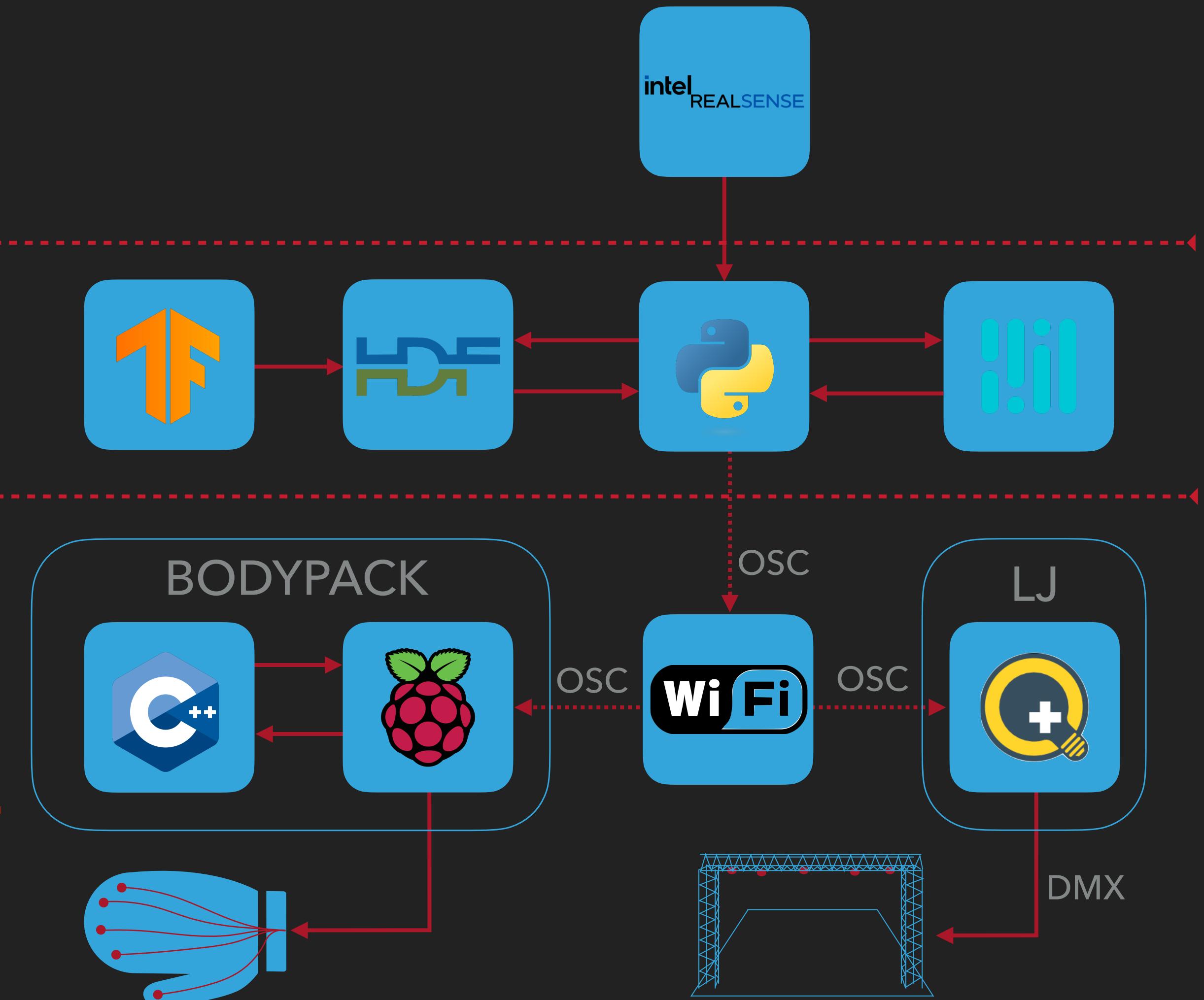


INPUT

CORE

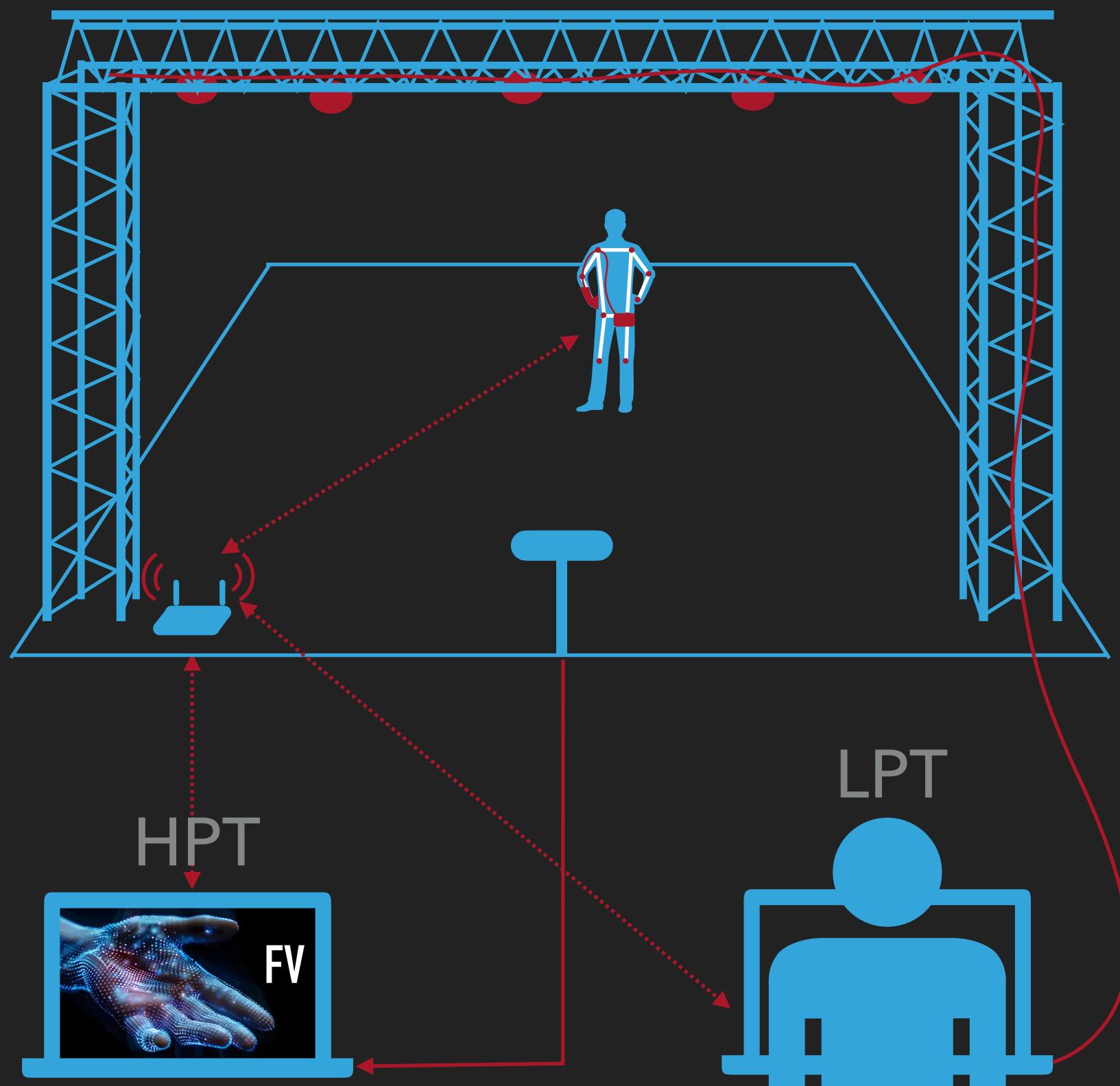
OUTPUT

BEHIND THE SCENE



FROM THE HACKATHON TO THE FINAL VERSION

ON STAGE



INPUT

CORE

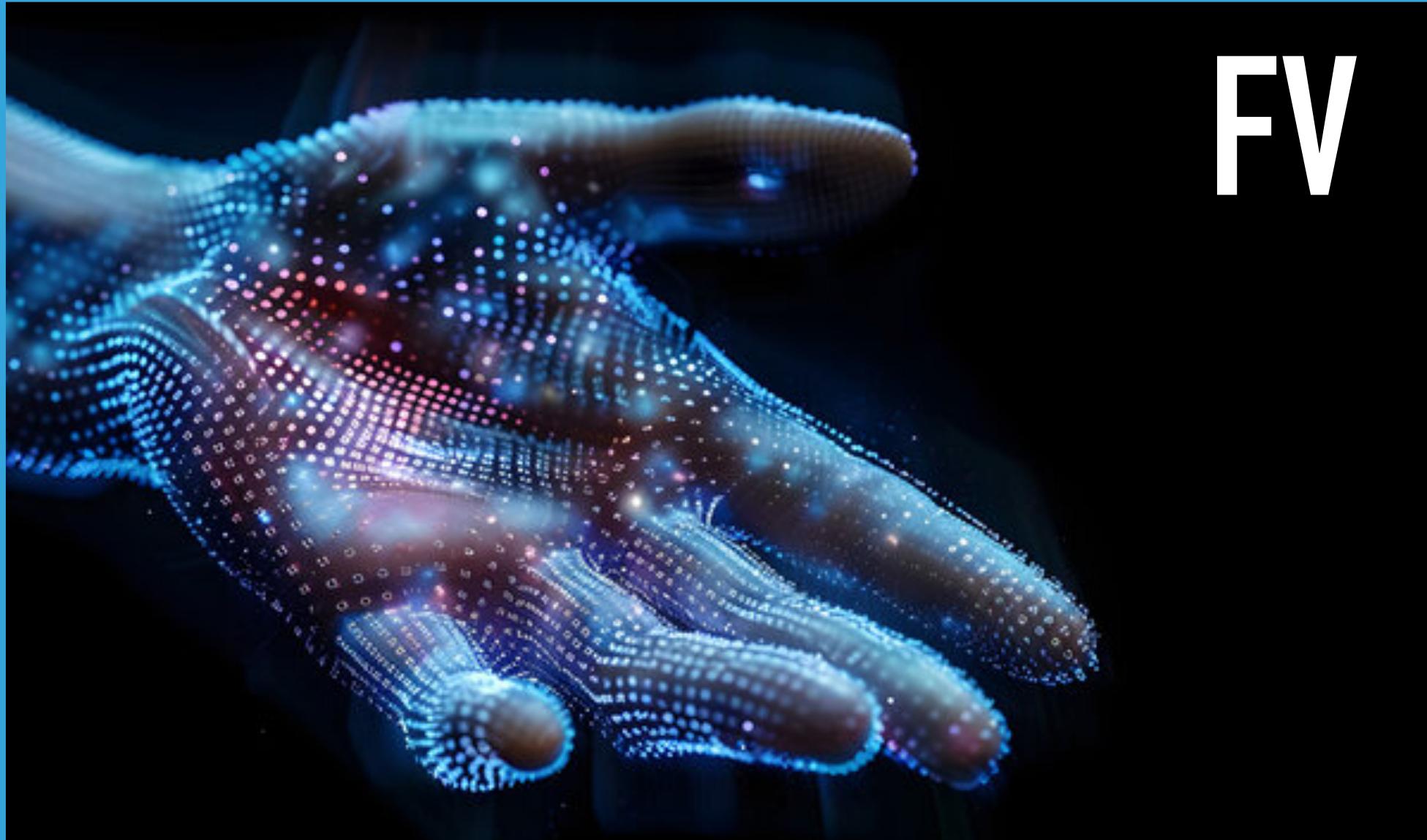
OUTPUT

BEHIND THE SCENE

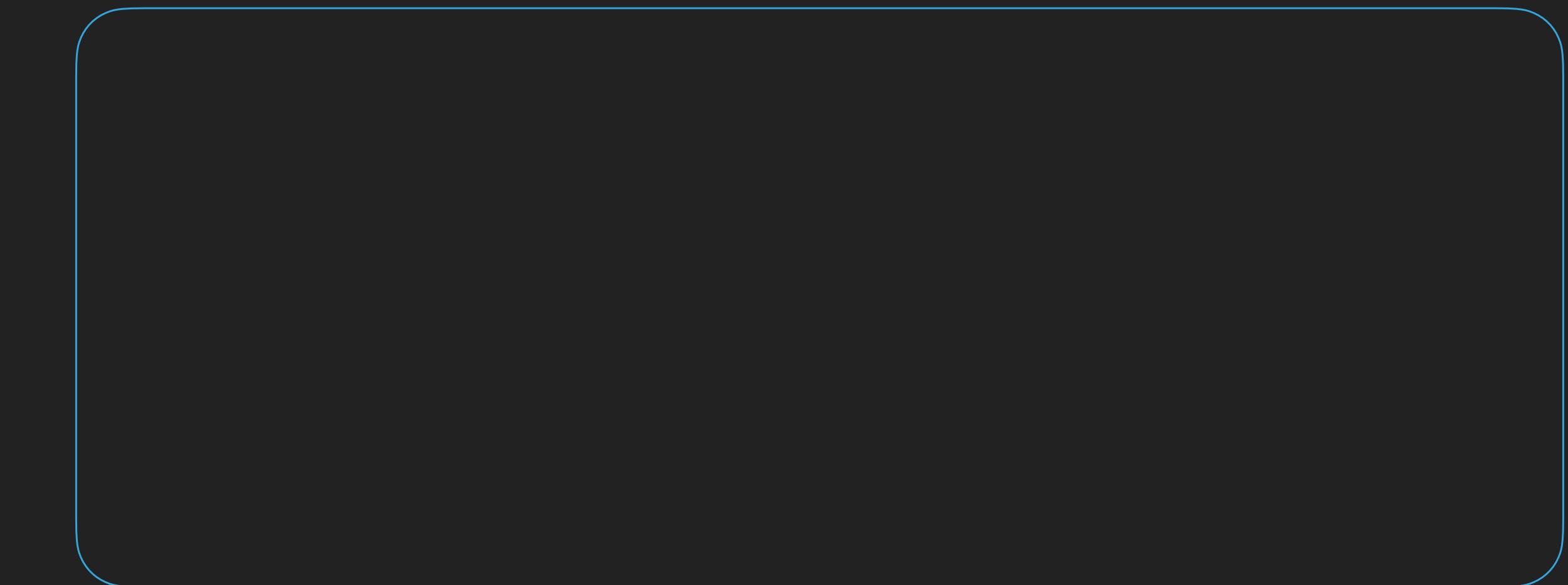


FLOWVISION

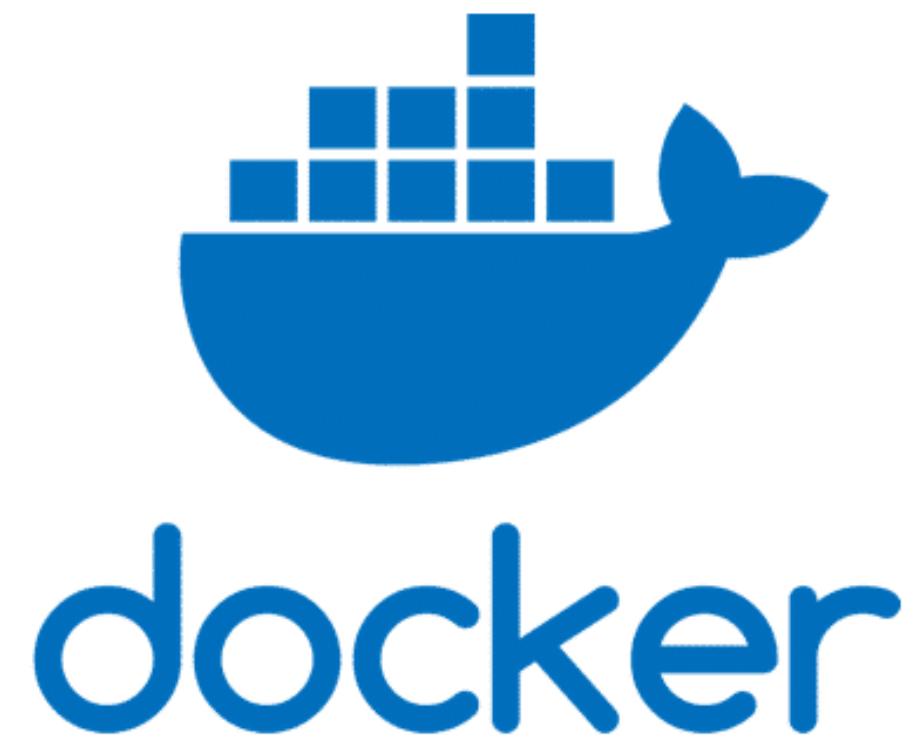
GRAPHIC USER INTERFACE



FV

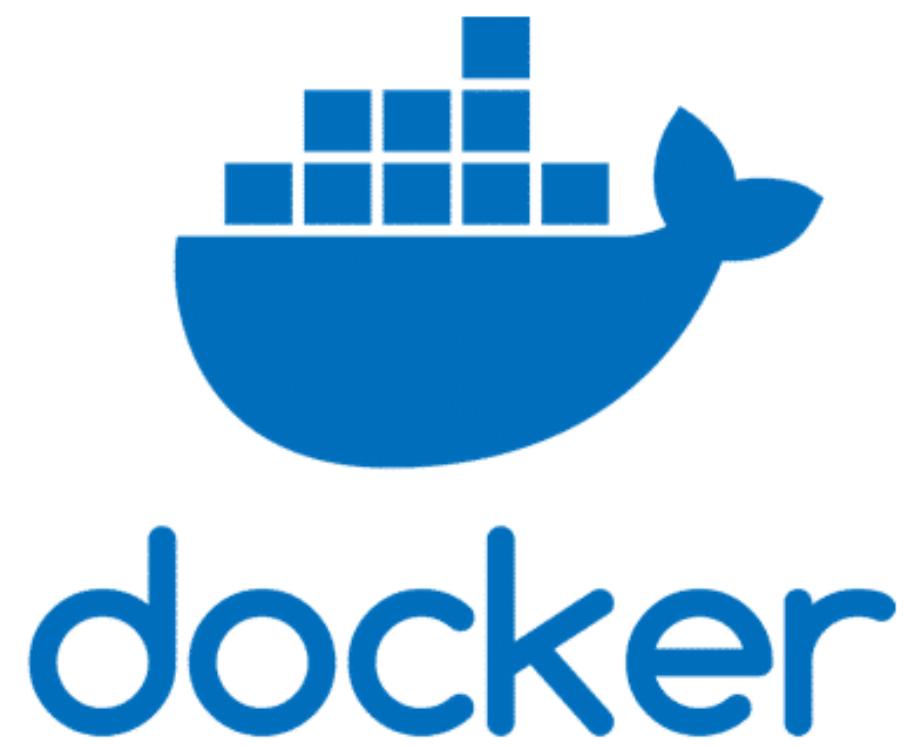


GRAPHIC USER INTERFACE



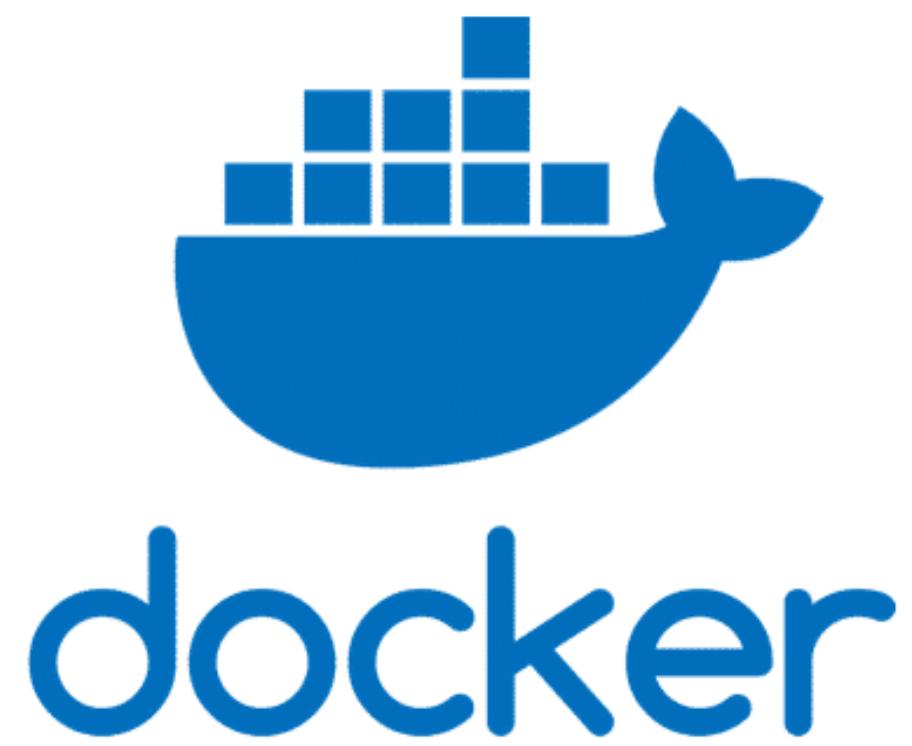
- ▶ Generation of a docker file to make the execution as handy as possible

GRAPHIC USER INTERFACE



► **CHALLENGE:**
MACOS RESTRICTIONS ON EXTERNAL DEVICES ON DOCKER

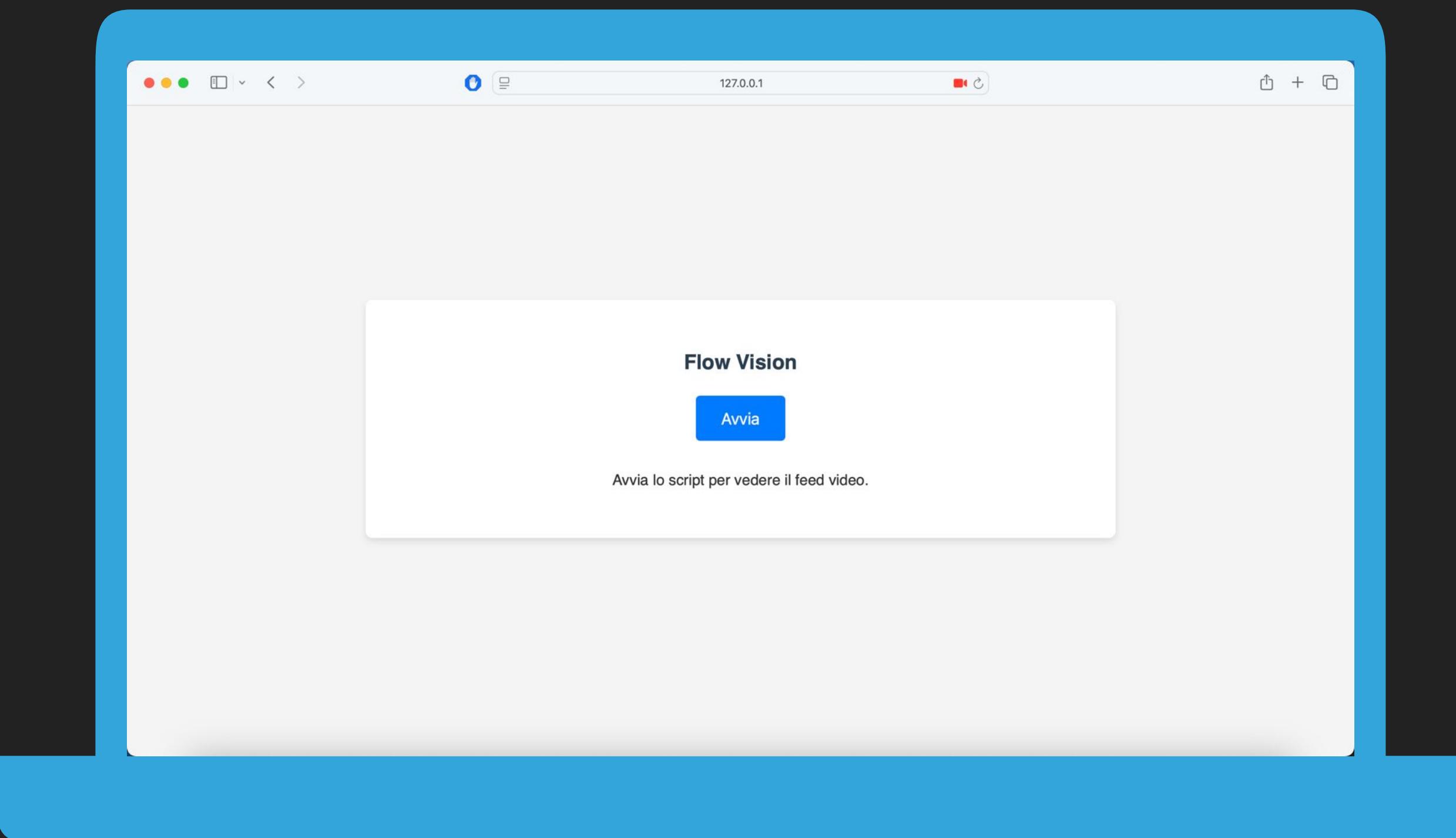
GRAPHIC USER INTERFACE



TRADE-OFF:

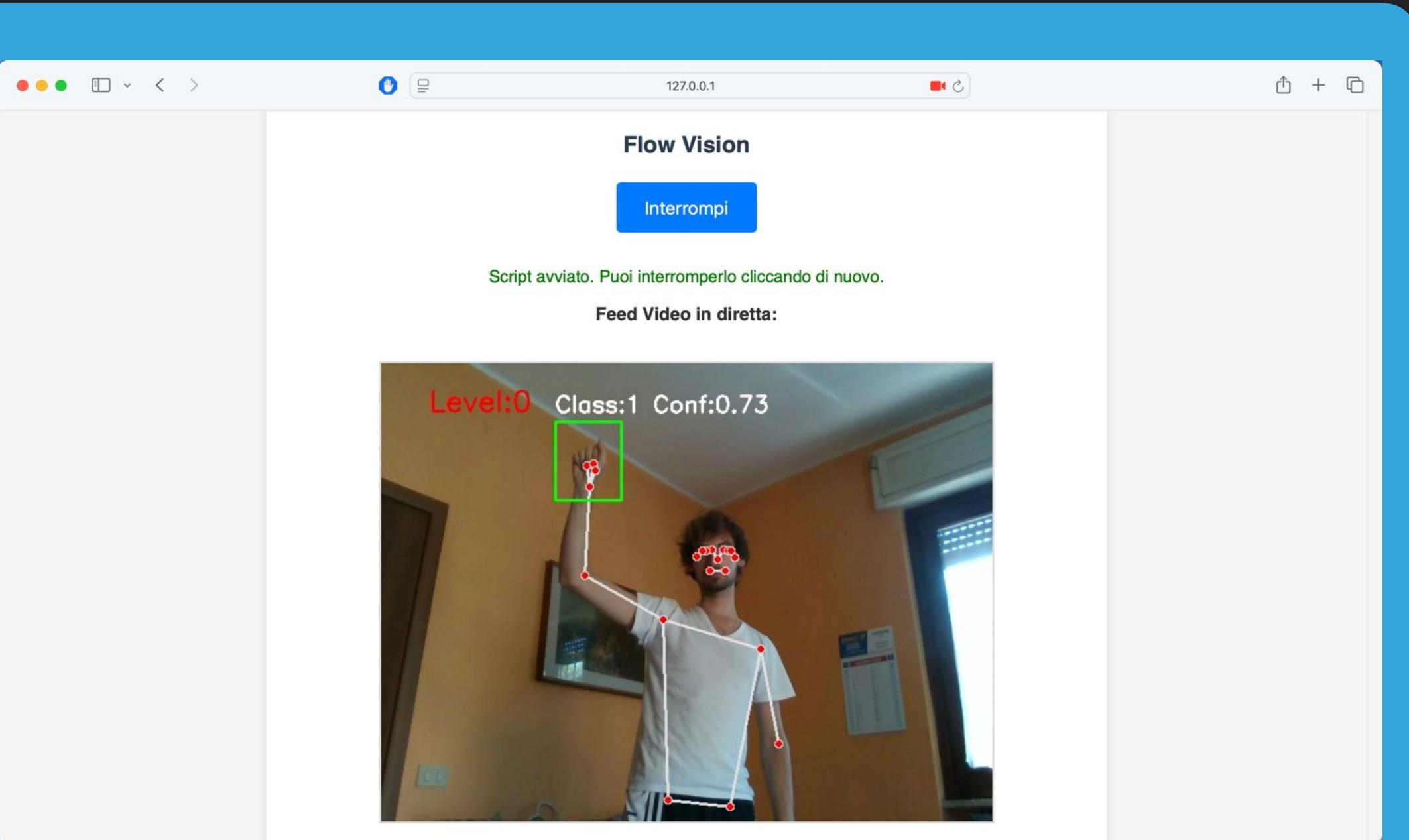
WE DECIDED NOT TO USE DOCKER AND TO IMPLEMENT A SIMPLE GUI FROM WHICH TO RUN EVERYTHING

GRAPHIC USER INTERFACE



- ▶ Implementation of just a simple GUI from which to run the entire application smartly

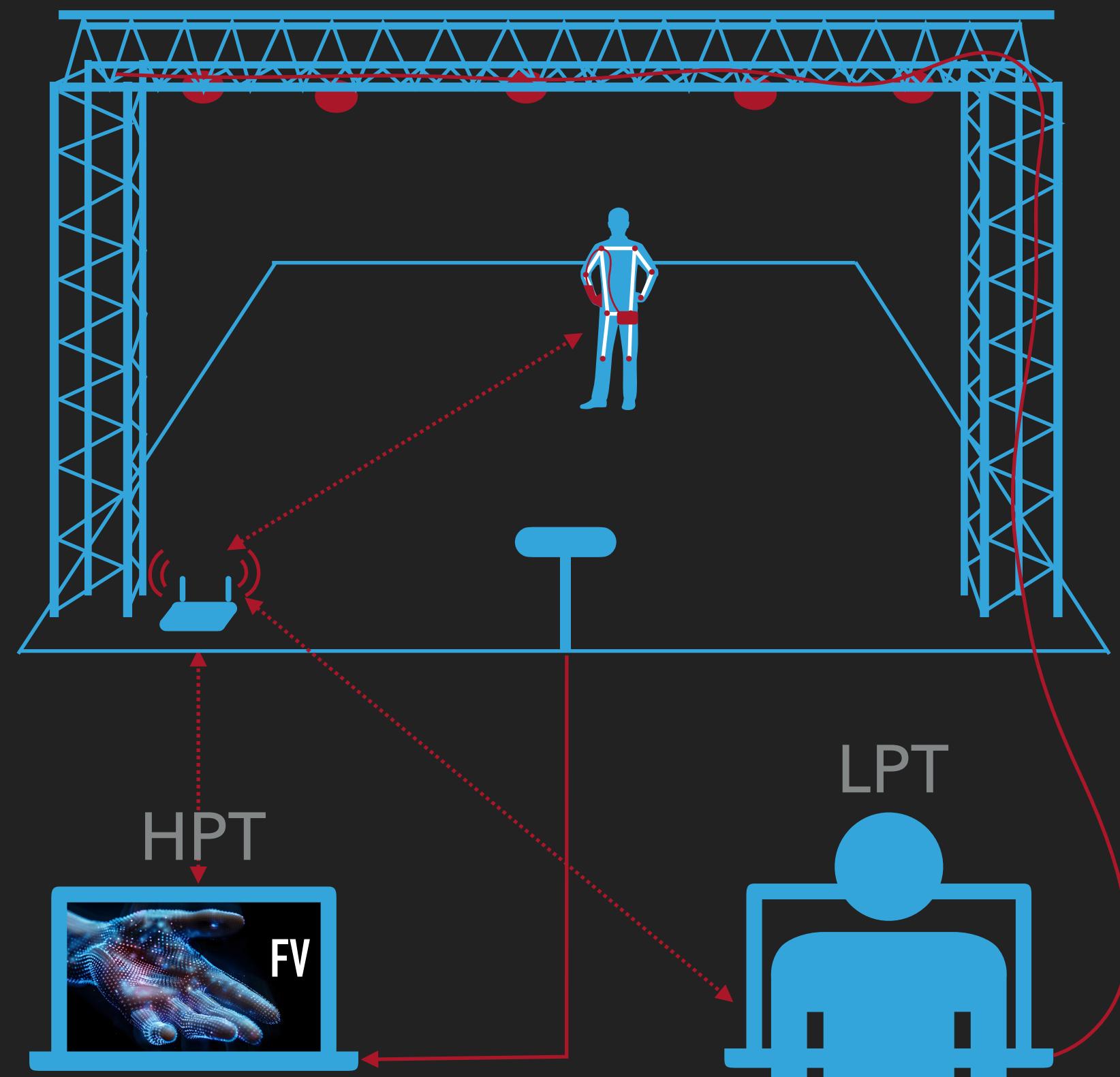
GRAPHIC USER INTERFACE



- ▶ Implementation of just a simple GUI from which to run the entire application smartly
- ▶ Once the code is started, it is possible to control the execution with a video stream

ARCHITECTURE

ON STAGE

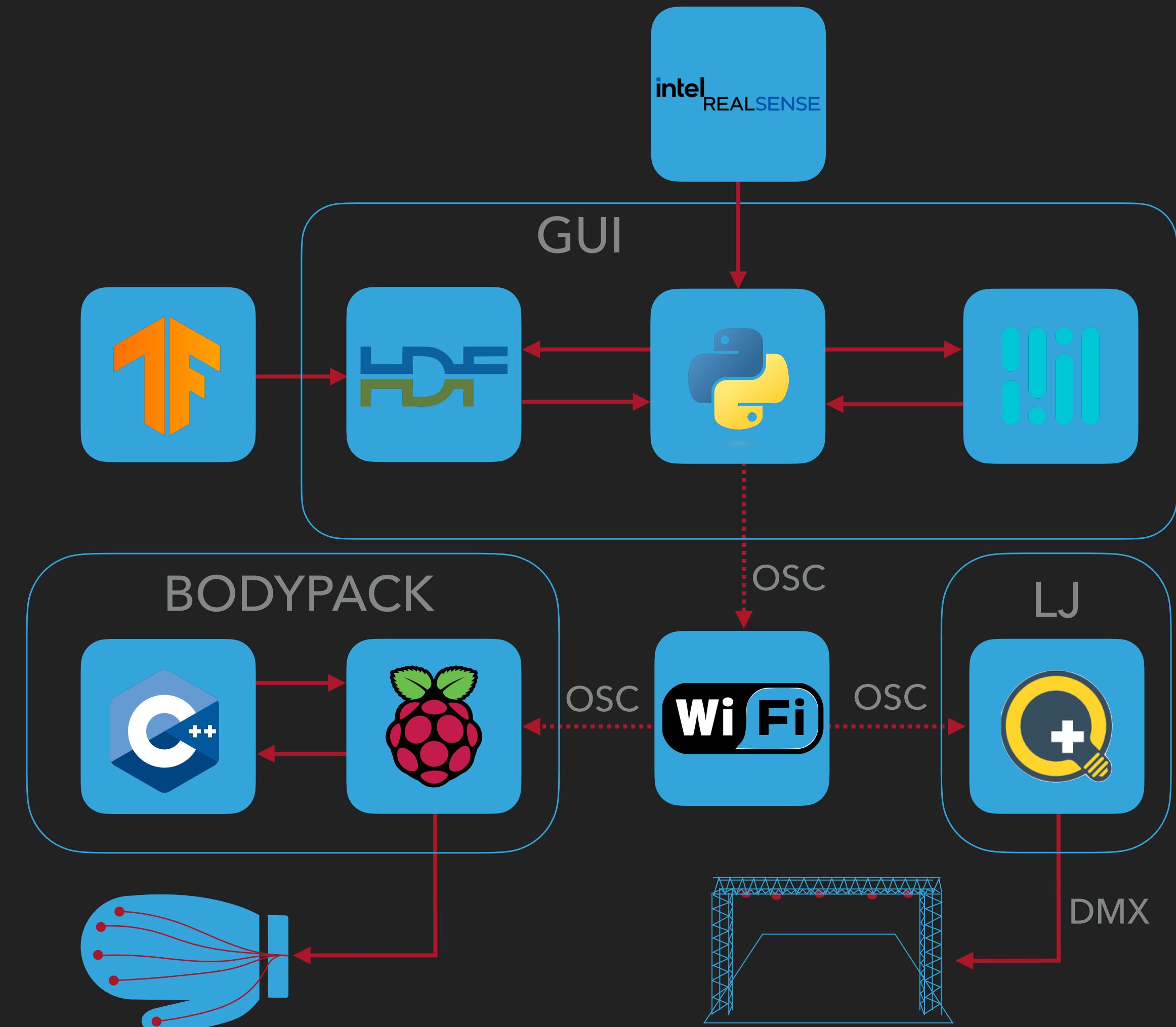


INPUT

CORE

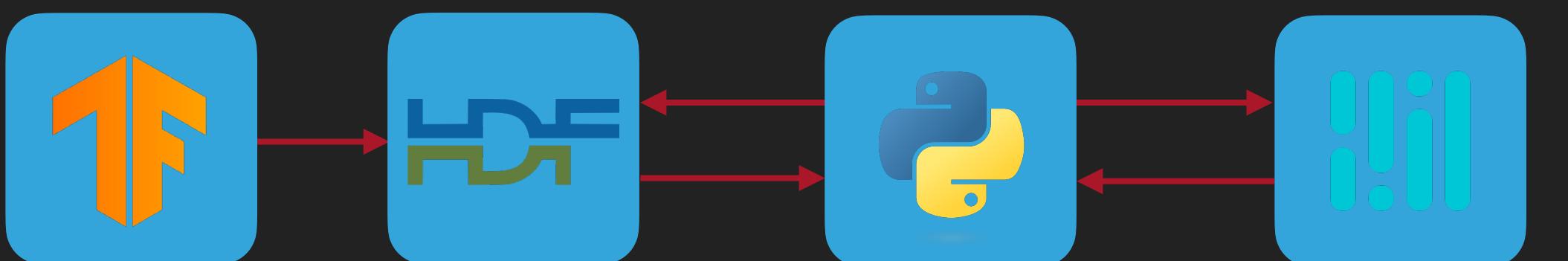
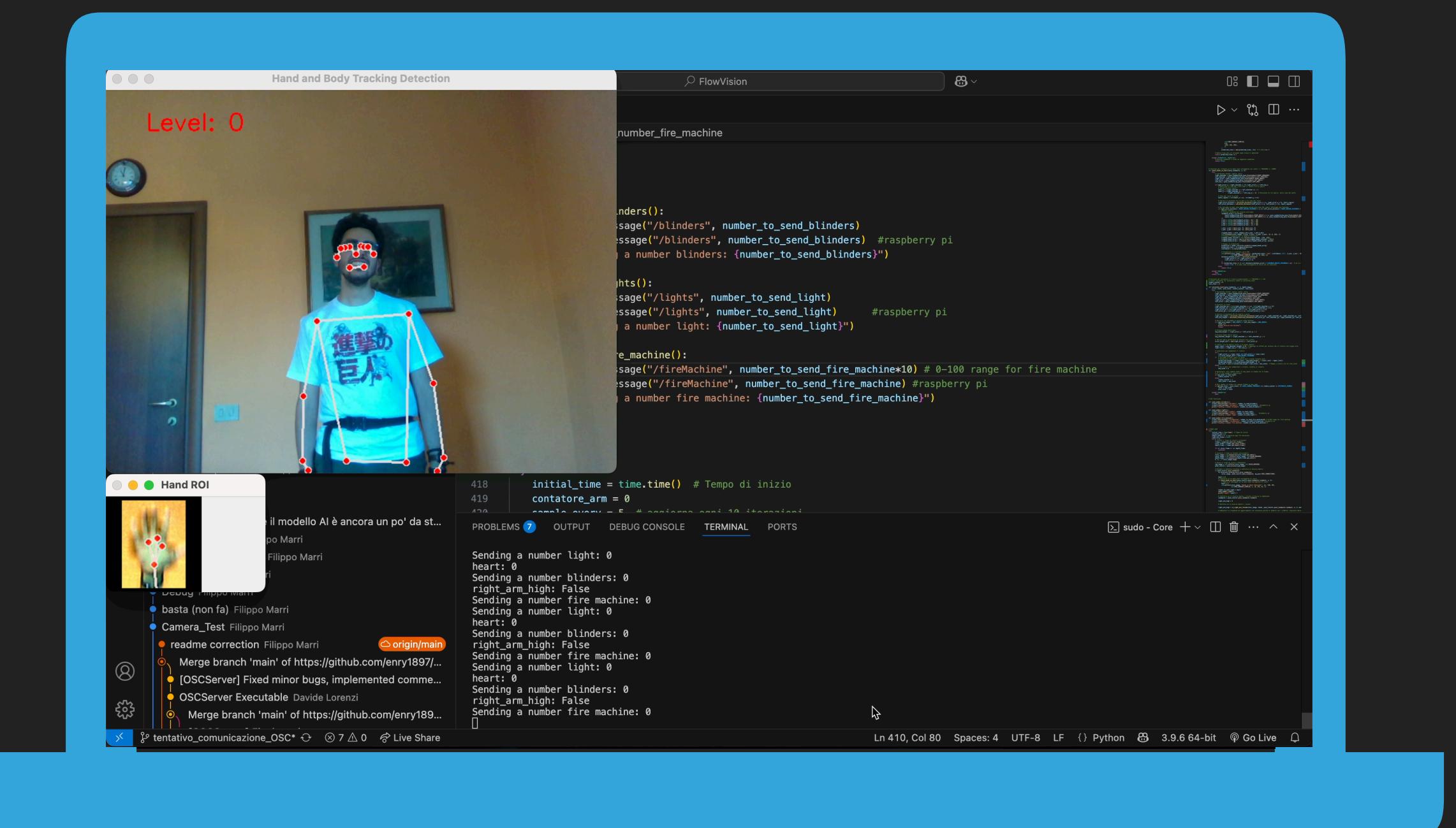
OUTPUT

BEHIND THE SCENE



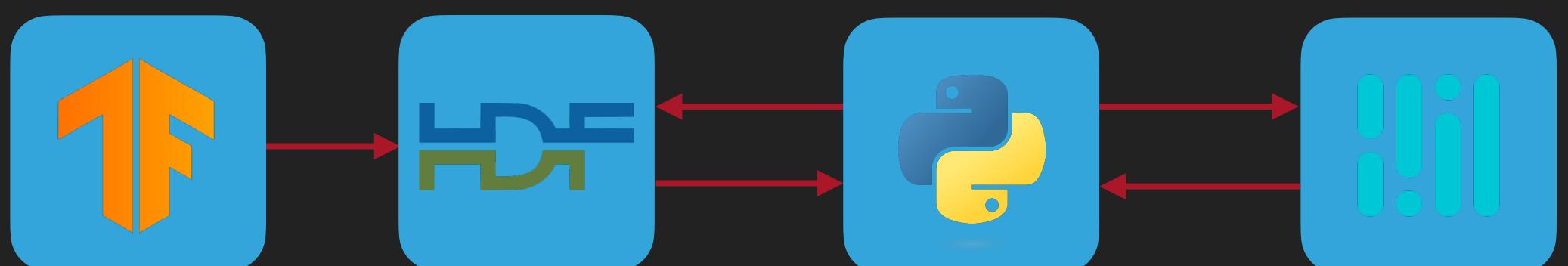
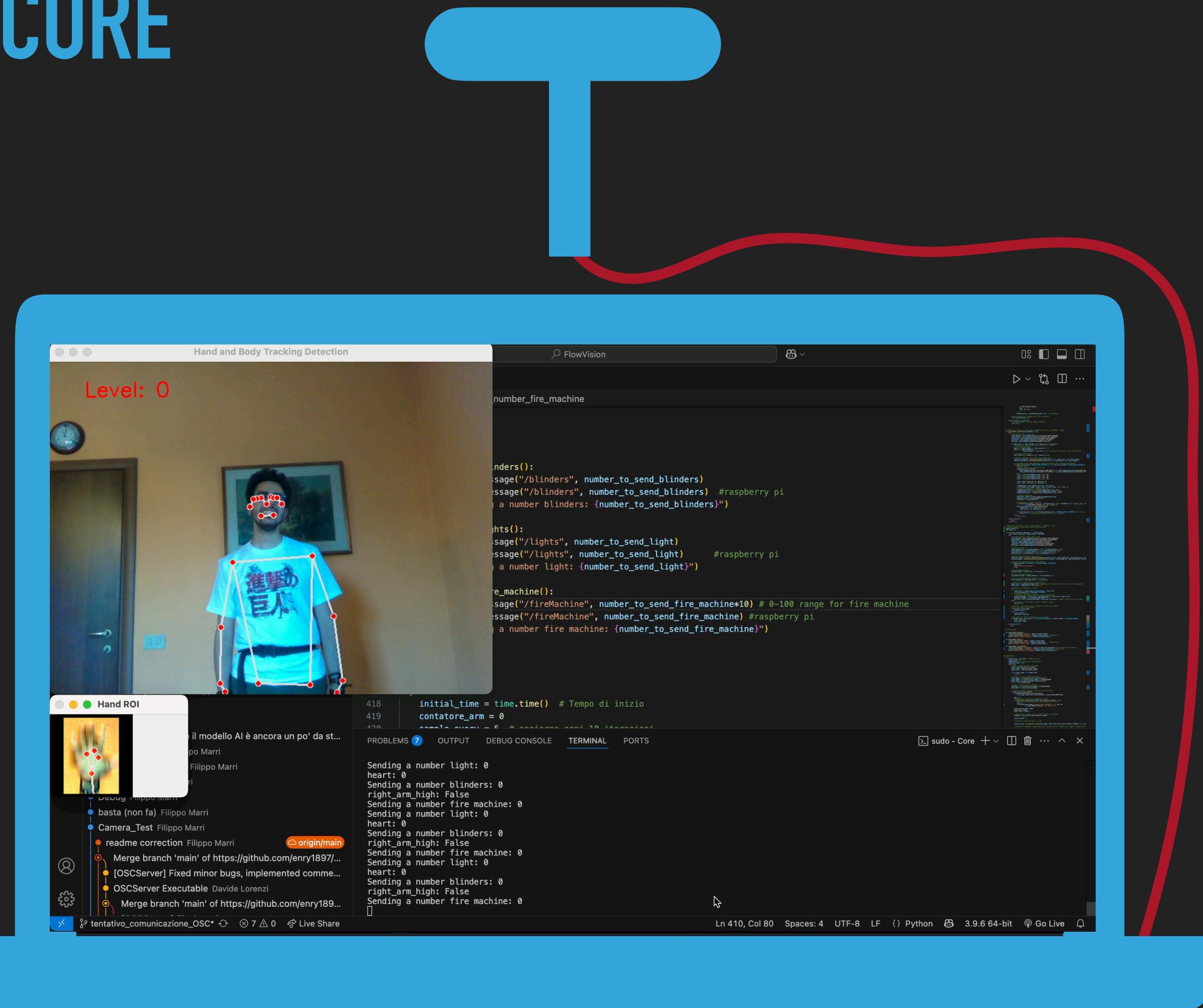
FLOWVISION

CORE



FLOWVISION

CORE

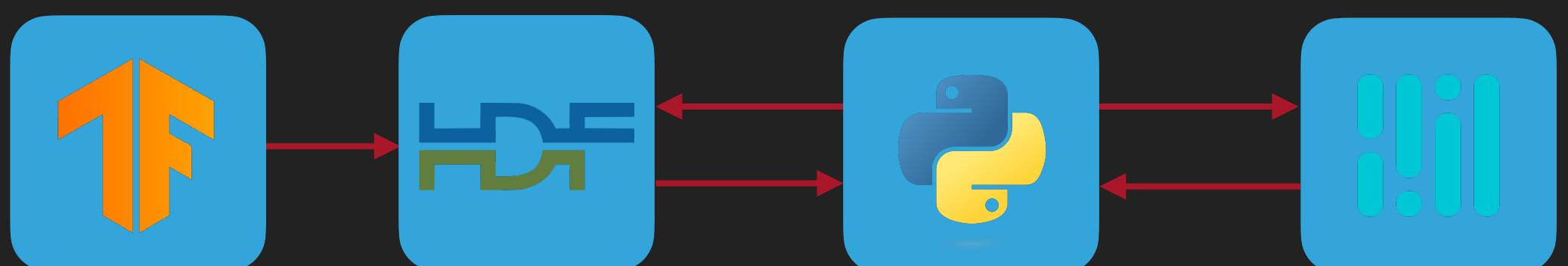
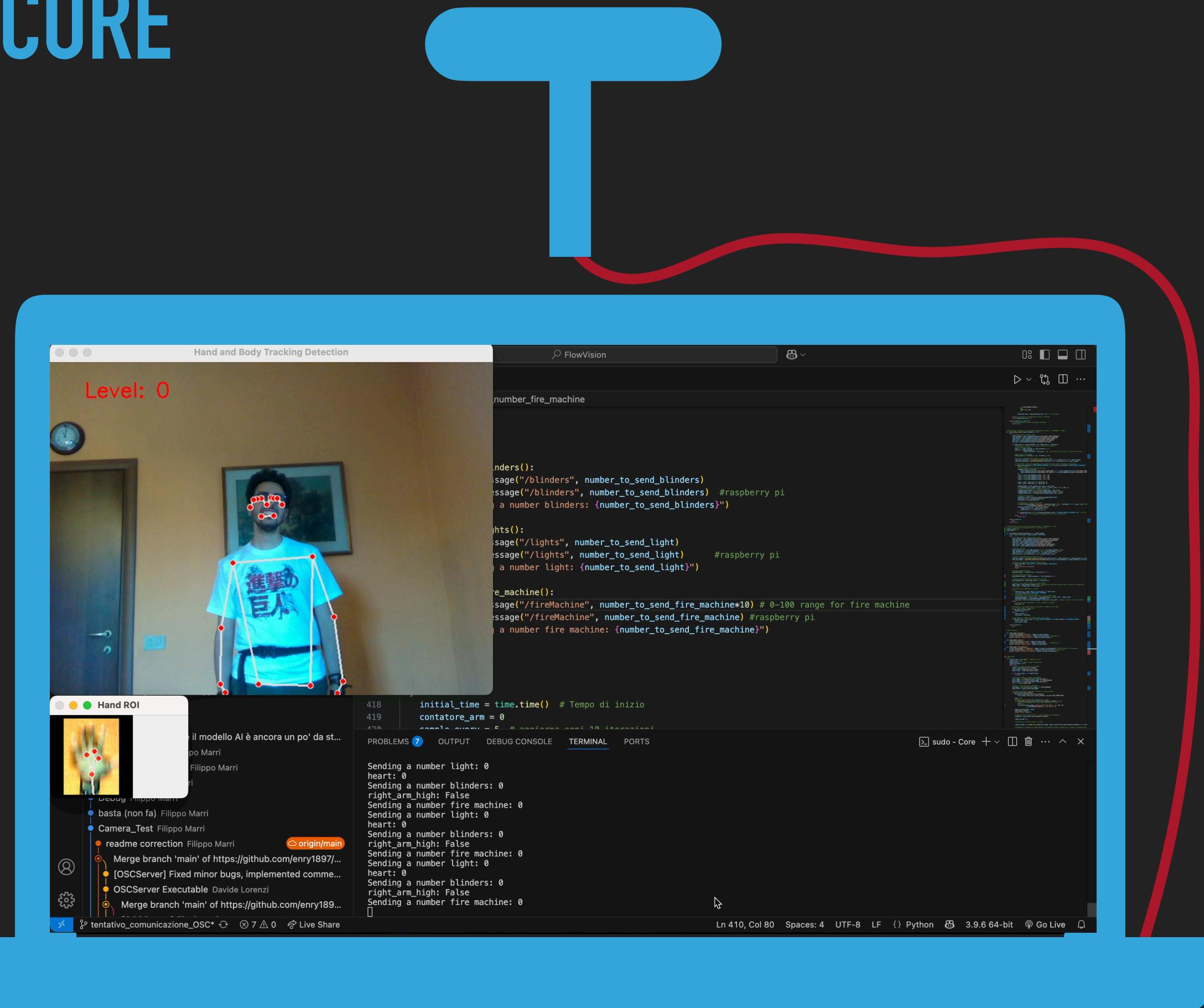


- ▶ MediaPipe module that allows the system to target the position and posture of the user
- ▶ Triggering system
 - ▶ Bigger movements -> Thresholds
 - ▶ Details -> AI models fed with cropped images

Movement	Trigger	Type
Arm lifting on the side	Threshold	Progressive
Heart Gesture	Threshold + AI	ON/OFF
Fist Gesture	Threshold + AI	ON/OFF

FLOWVISION

CORE



- ▶ Medium movements -> Threshold
- ▶ target movements -> AI
- ▶ WHEN THE HAND IS CLOSED, ITS COORDINATES ARE NOT AVAILABLE
- ▶ Triggering system
- ▶ Bigger movements -> Thresholds
- ▶ Details -> AI models fed with cropped images

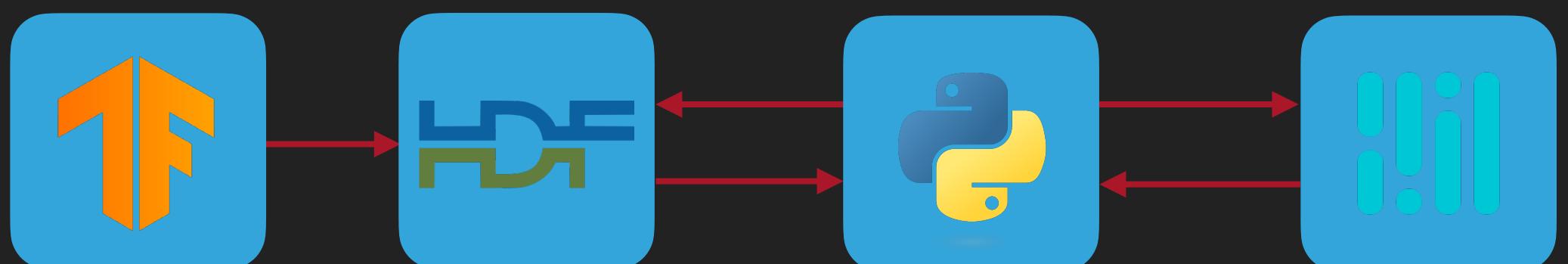
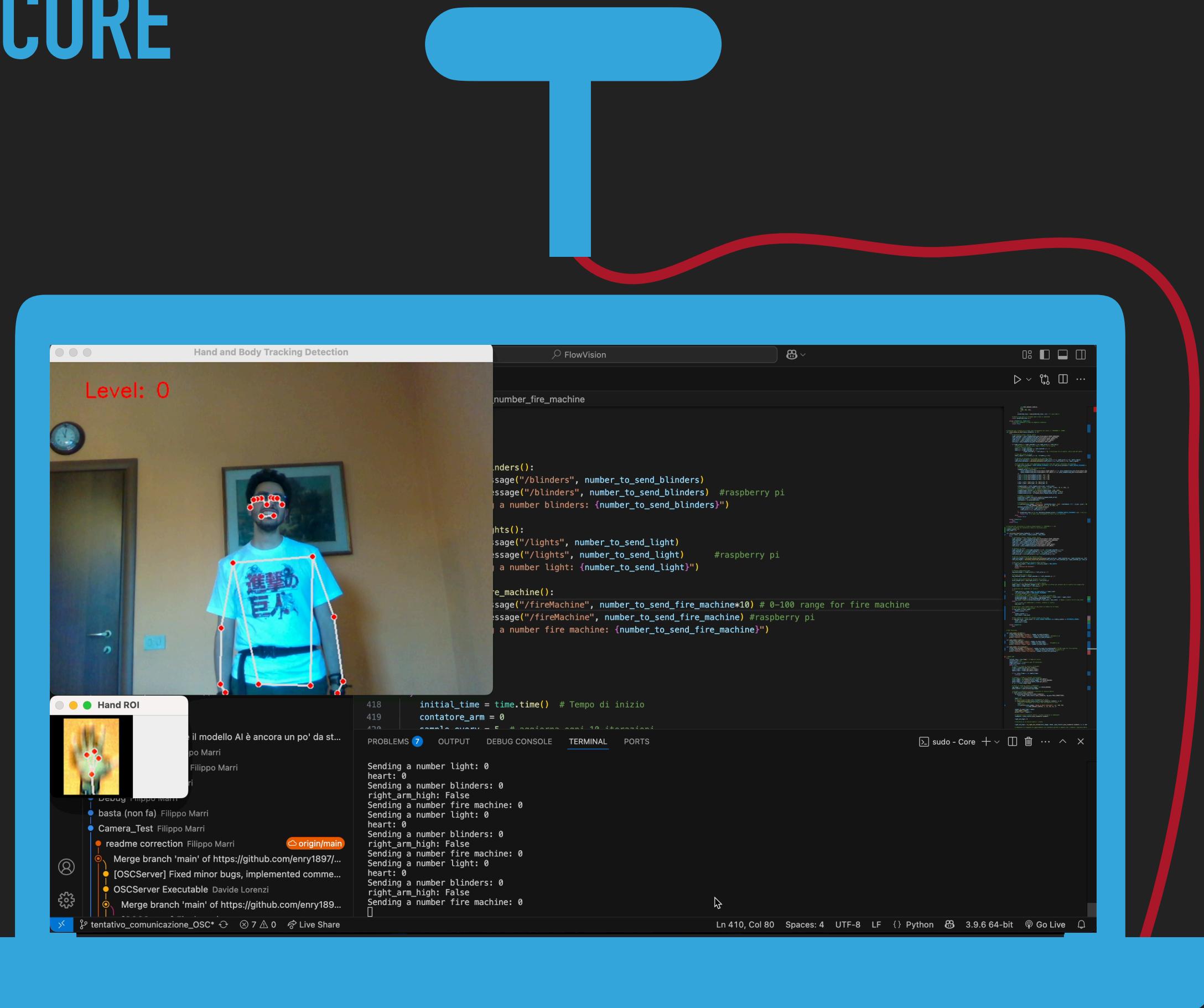
Movement	Trigger	Type
Arm lifting on the side	Threshold	Progressive
Heart Gesture	Threshold + AI	ON/OFF
Fist Gesture	Threshold + AI	ON/OFF

CHALLENGE:

WHEN THE HAND IS CLOSED, ITS COORDINATES ARE NOT AVAILABLE

FLOWVISION

CORE



SOLUTION:

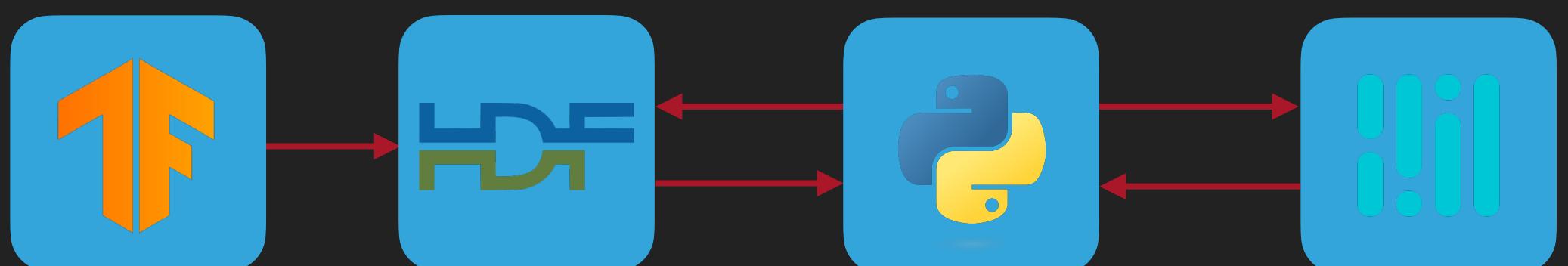
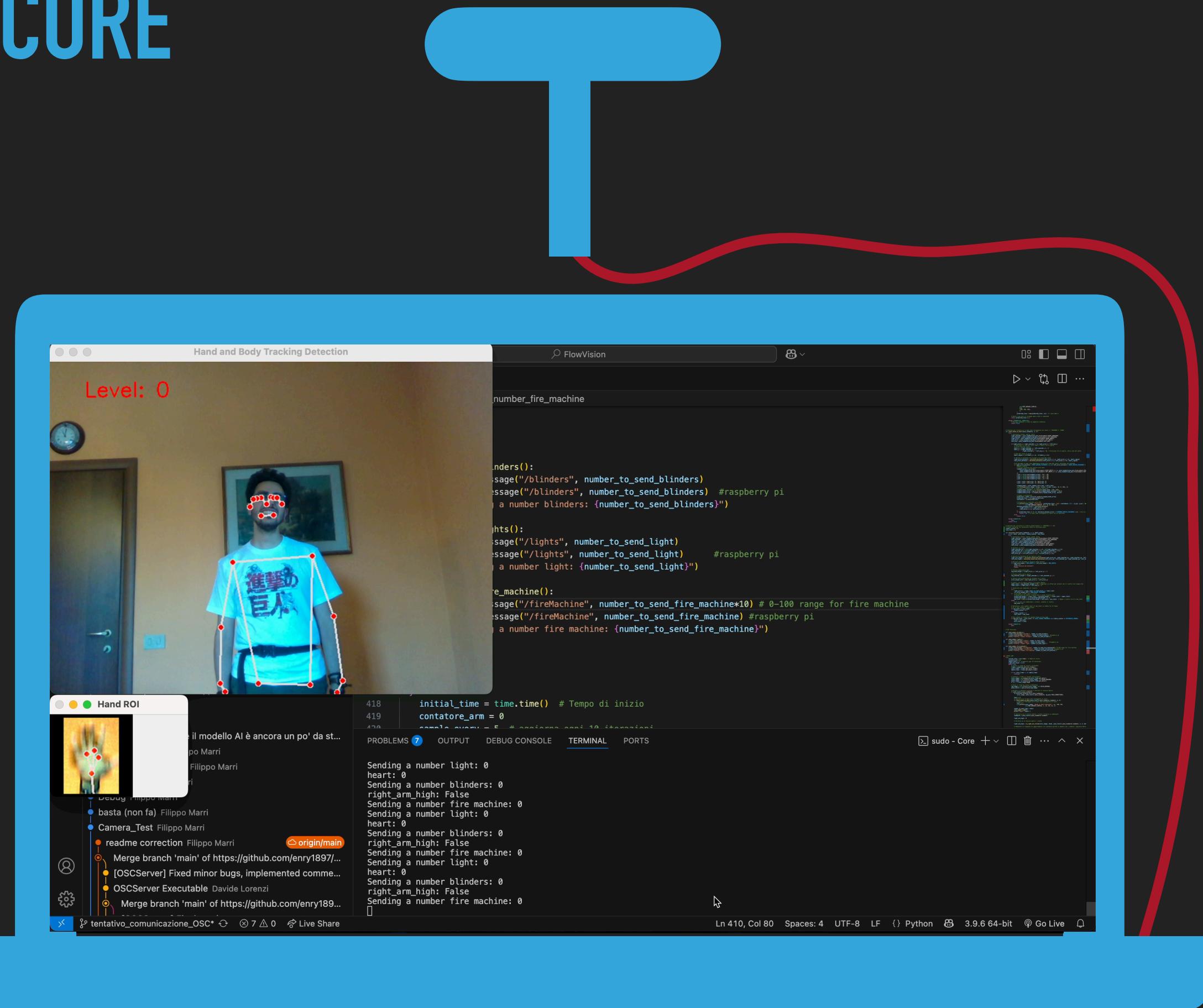
IMPLEMENTATION OF A FALBACK CODE IN WHICH THE
REFERENCE POINT IS THE WRIST WHEN THE COORDINATE
OF THE HAND ARE NOT AVAILABLE

- ▶ Median filter target
- ▶ Triggering system
- ▶ Bigger movements -> Thresholds
- ▶ Details -> AI models fed with cropped images

Movement	Trigger	Type
Arm lifting on the side	Threshold	Progressive
Heart Gesture	Threshold + AI	ON/OFF
Fist Gesture	Threshold + AI	ON/OFF

FLOWVISION

CORE



- ▶ Medium target
- ▶ Triggering system

SOLUTION:

IMPLEMENTATION OF A FALBACK CODE IN WHICH THE REFERENCE POINT IS THE WRIST WHEN THE COORDINATE OF THE HAND ARE NOT AVAILABLE

- ▶ Backend
- ▶ Detection

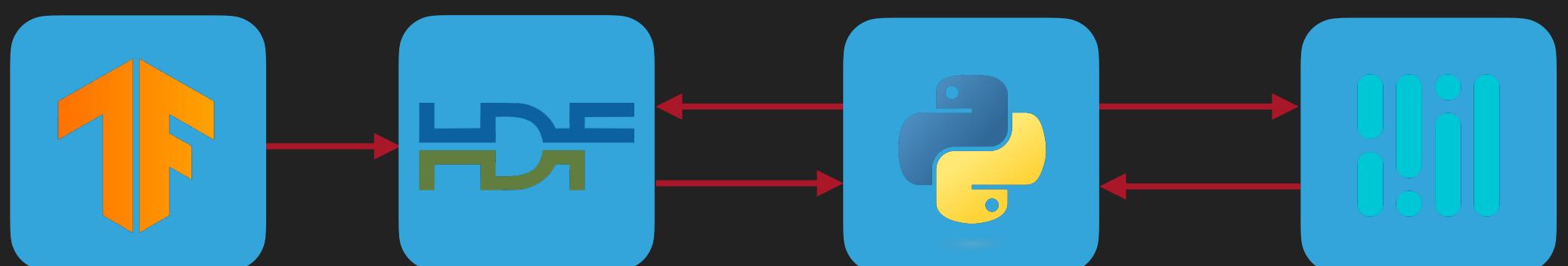
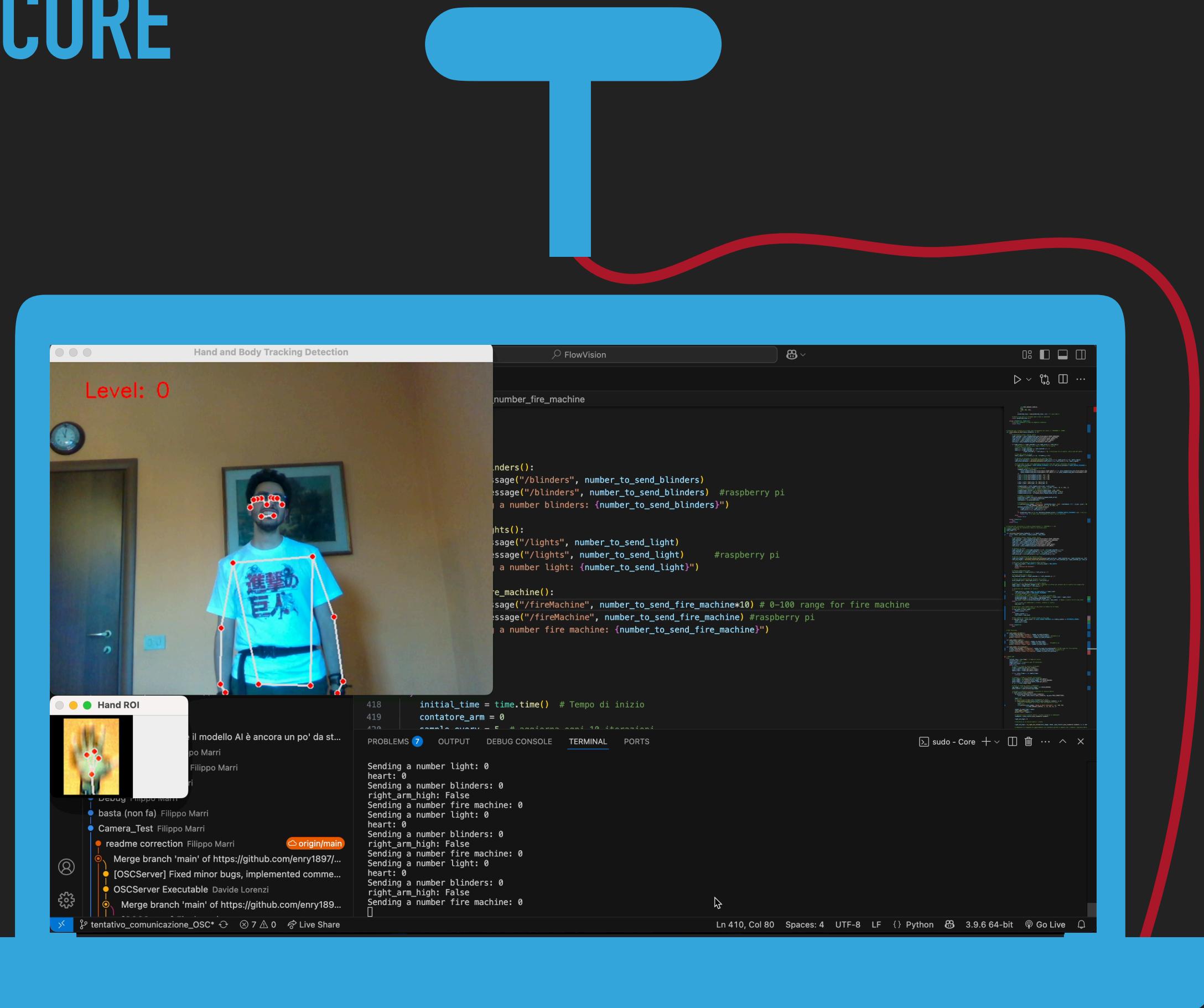
CHALLENGE:

WHEN THE HANDS ARE PLACED ON THE CHEST, WE GET A MISTAKE: THEY ARE CLASSIFIED AS HEART GESTURE

Movement	Trigger	Type
Arm lifting on the side	Threshold	Progressive
Heart Gesture	Threshold + AI	ON/OFF
Fist Gesture	Threshold + AI	ON/OFF

FLOWVISION

CORE



- ▶ Median target
- ▶ Triggering system
- ▶ Body movement
- ▶ Detection

SOLUTION:

IMPLEMENTATION OF A FALBACK CODE IN WHICH THE REFERENCE POINT IS THE WRIST WHEN THE COORDINATE OF THE HAND ARE NOT AVAILABLE

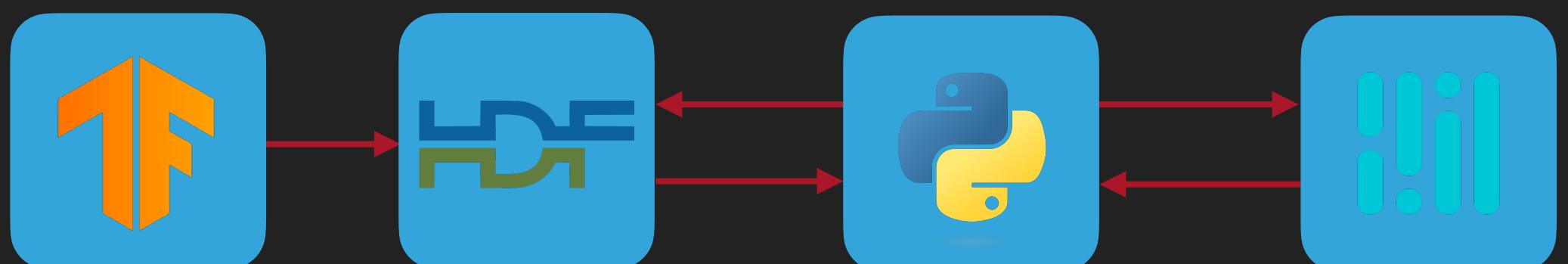
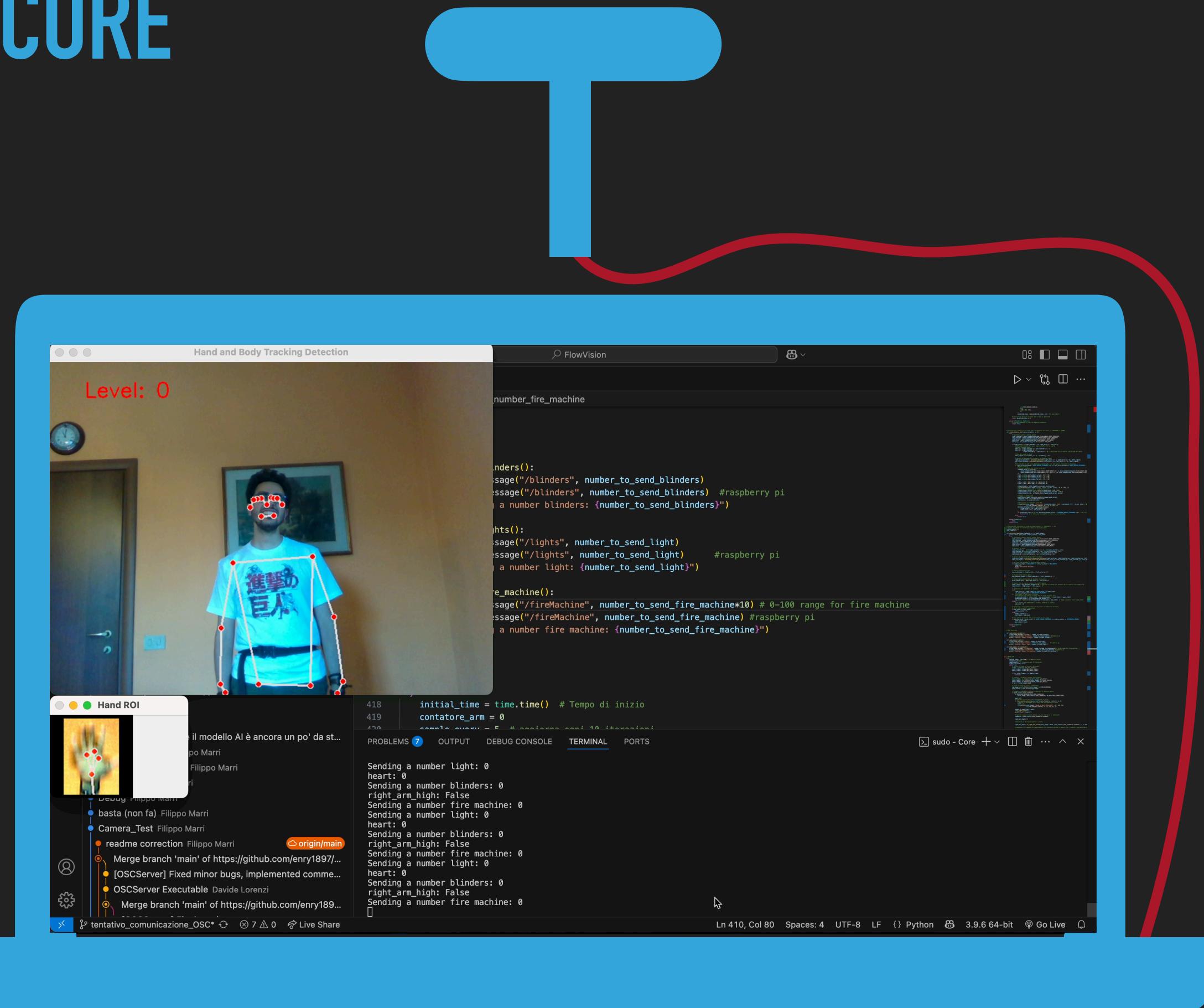
SOLUTION:

IMPLEMENTATION OF A SCRIPT THAT IMPOSE THE CONDITION THAT THE WRIST ARE NOT OVERLAPPED DURING THE HEART GESTURE

Movement	Trigger	Type
Arm lifting on the side	Threshold	Progressive
Heart Gesture	Threshold + AI	ON/OFF
Fist Gesture	Threshold + AI	ON/OFF

FLOWVISION

CORE



- ▶ Median target
 - ▶ Triggering system
 - ▶ Body
 - ▶ Detection
- SOLUTION:**
IMPLEMENTATION OF A FALBACK CODE IN WHICH THE
REFERENCE POINT IS THE WRIST WHEN THE COORDINATE
OF THE HAND ARE NOT AVAILABLE
- SOLUTION:**
IMPLEMENTATION OF A SCRIPT THAT IMPOSE THE
CONDITION THAT THE WRIST ARE NOT OVERLAPPED
DURING THE HEART GESTURE
- CHALLENGE:**
NO AVAILABLE DATASET TO IMPLEMENT A RNN NETWORK

Heart Gesture

Threshold +
AI

ON/OFF

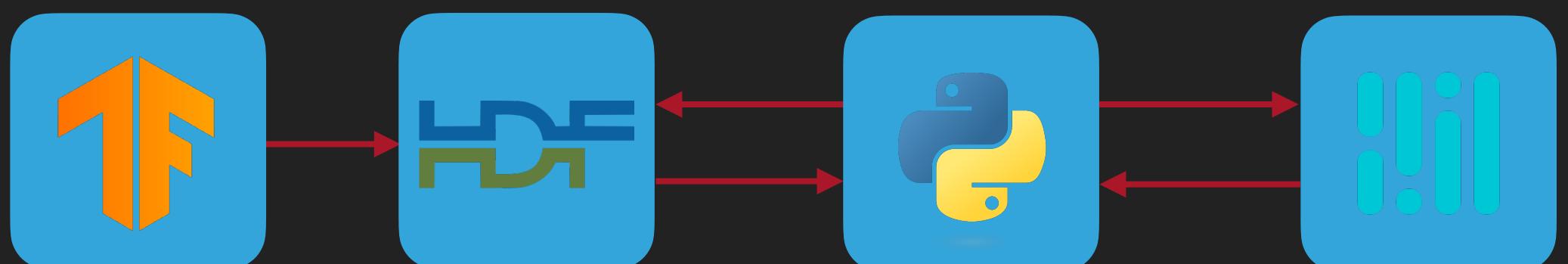
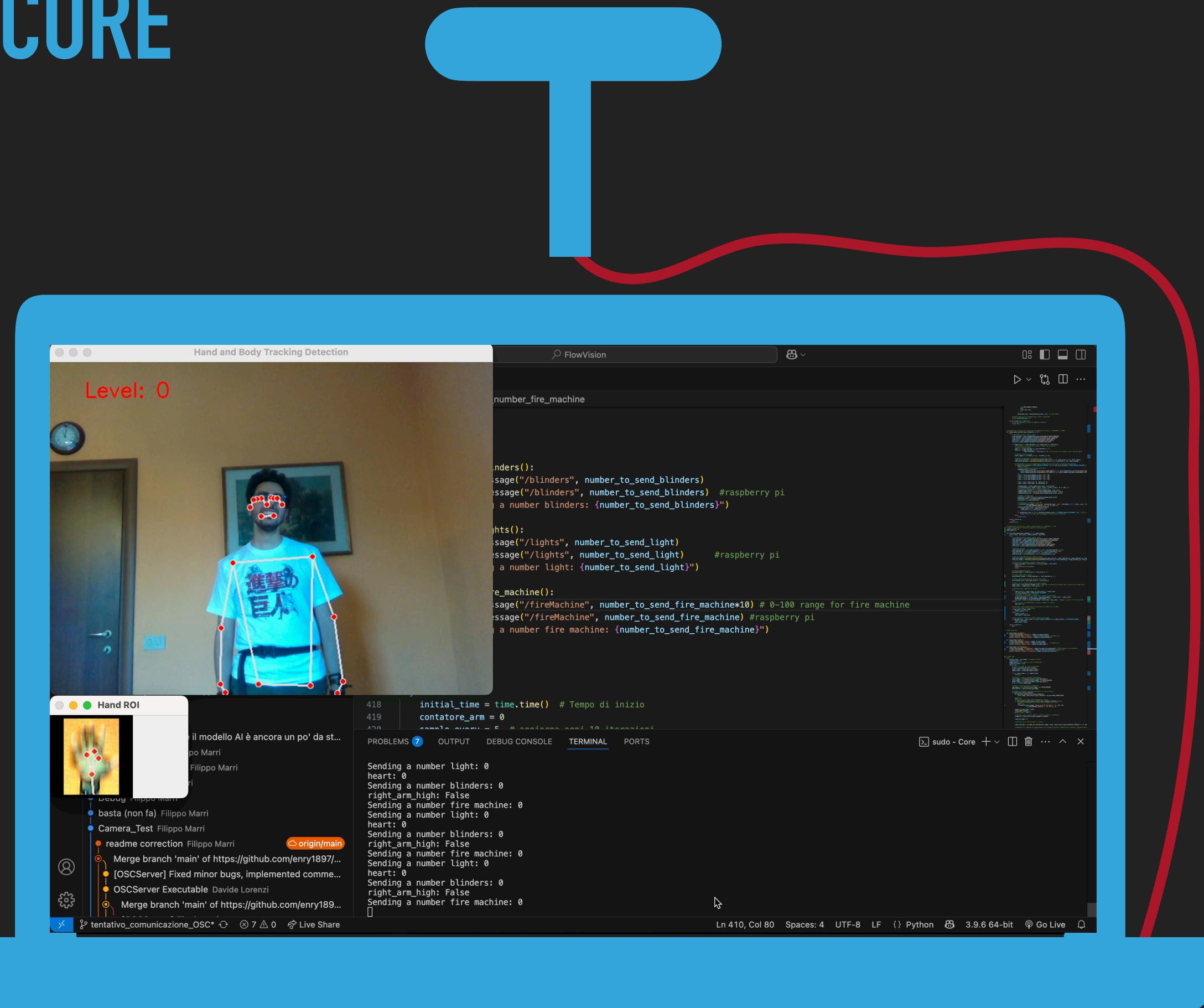
Fist Gesture

Threshold +
AI

ON/OFF

FLOWVISION

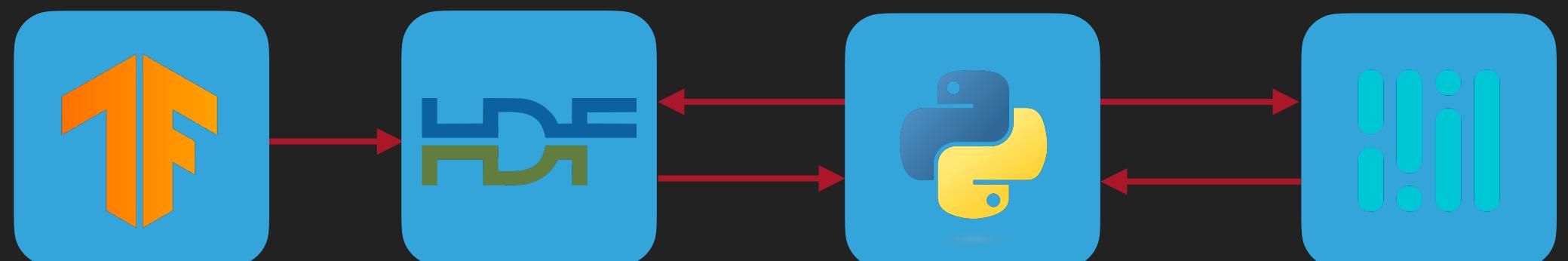
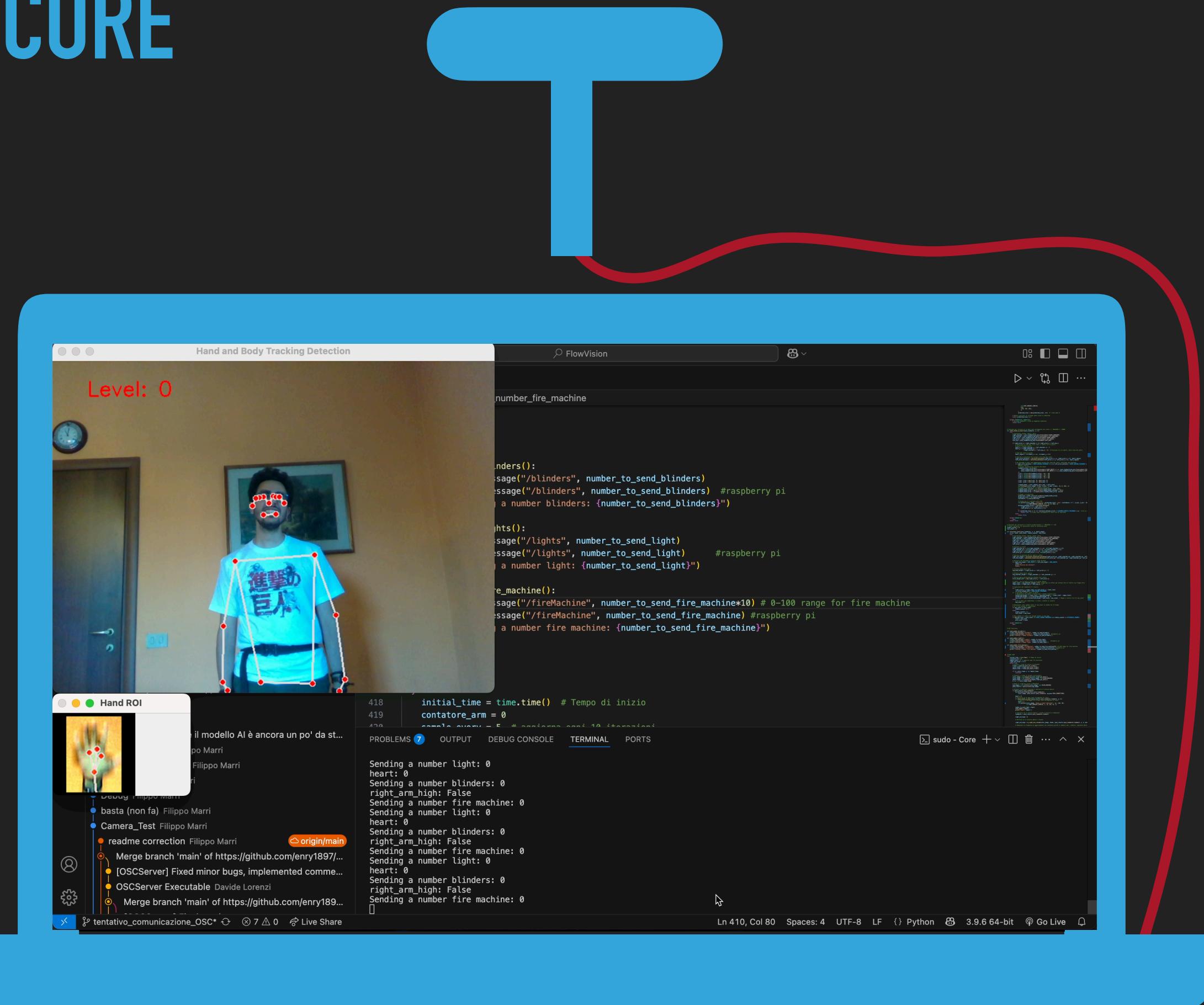
CORE



- ▶ Median target
- ▶ Triggering system
- ▶ Body detection
- ▶ Depth camera
- ▶ Model
- ▶ Arm lifting on the side
- ▶ Heart Gesture
- ▶ Fist Gesture
- ▶ Solution:
IMPLEMENTATION OF A FALBACK CODE IN WHICH THE
REFERENCE POINT IS THE WRIST WHEN THE COORDINATE
OF THE HAND ARE NOT AVAILABLE
- ▶ Solution:
IMPLEMENTATION OF A SCRIPT THAT IMPOSE THE
CONDITION THAT THE WRIST ARE NOT OVERLAPPED
DURING THE HEART GESTURE
- ▶ Solution:
HYBRID MODELS (THRESHOLD + CNN)
- ▶ ON/OFF
- ▶ ON/OFF

FLOWVISION

CORE



- ▶ Median target
 - ▶ Triggering system
 - ▶ Body
 - ▶ Detection
 - ▶ Model
 - ▶ Arm
 - ▶ Hand
 - ▶ Gesture
 - ▶ Hearing
 - ▶ Fist Gesture
 - ▶ ...
 - ▶ ON/OFF
- ## SOLUTION:

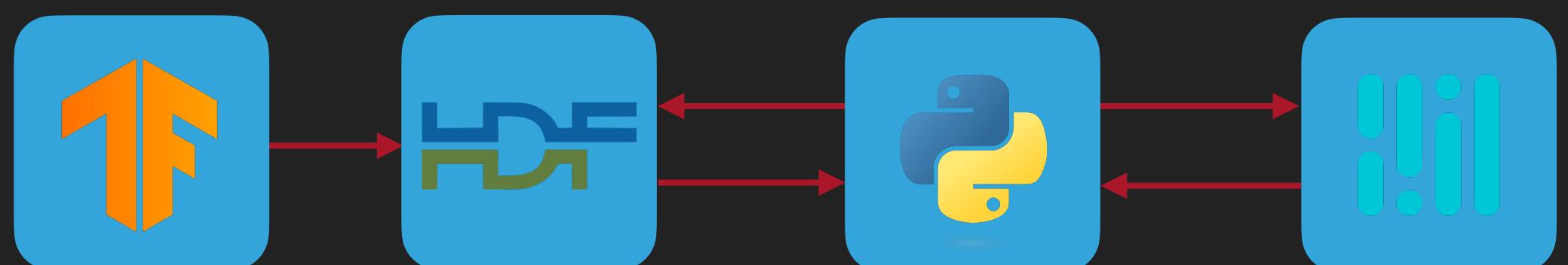
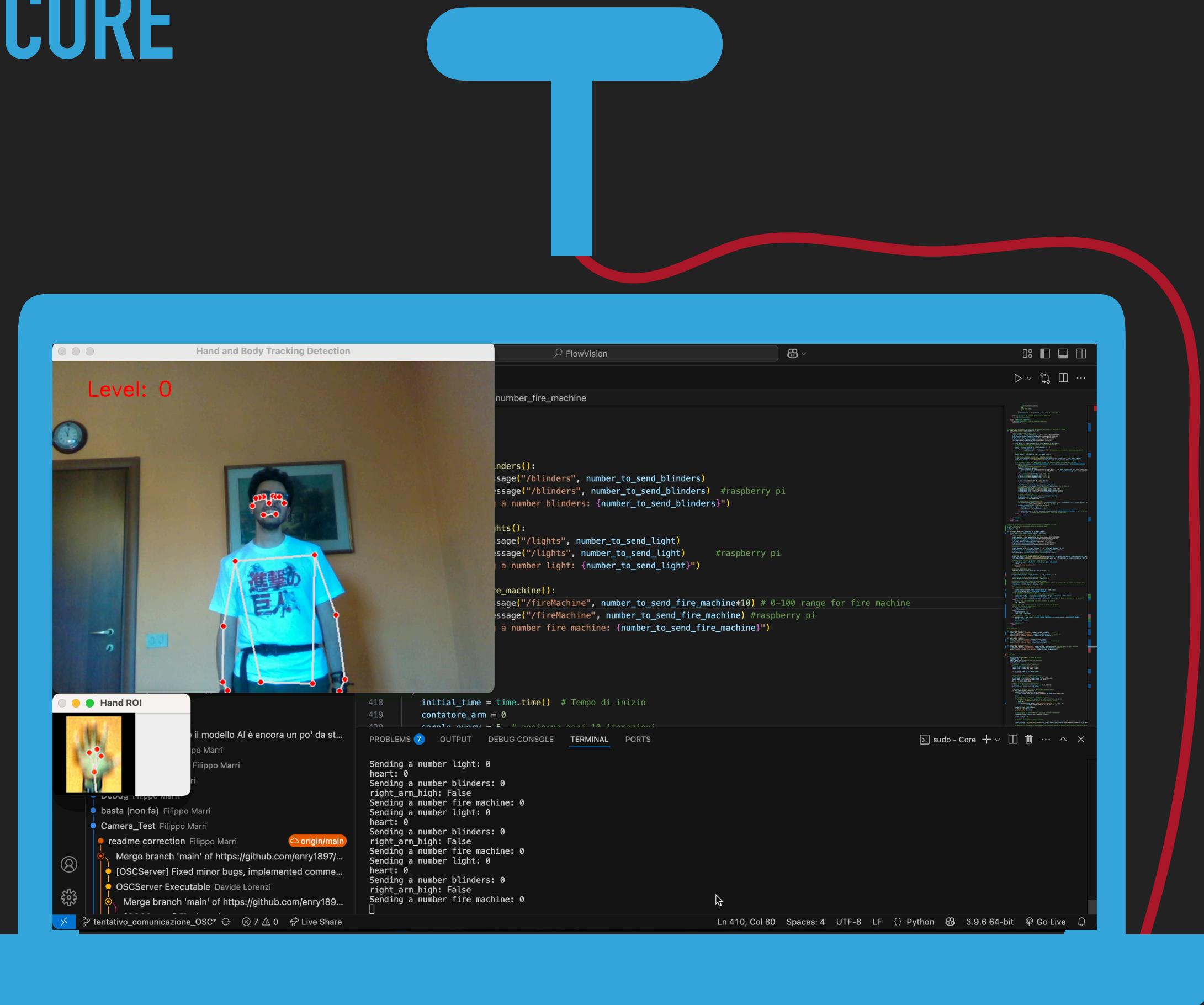
IMPLEMENTATION OF A FALBACK CODE IN WHICH THE REFERENCE POINT IS THE WRIST WHEN THE COORDINATE OF THE HAND ARE NOT AVAILABLE
- ## SOLUTION:

IMPLEMENTATION OF A SCRIPT THAT IMPOSE THE CONDITION THAT THE WRIST ARE NOT OVERLAPPED DURING THE HEART GESTURE
- ## CHALLENGE:

THE MODEL DOES NOT WORK WELL IF THERE IS NO PROPER ILLUMINATION

FLOWVISION

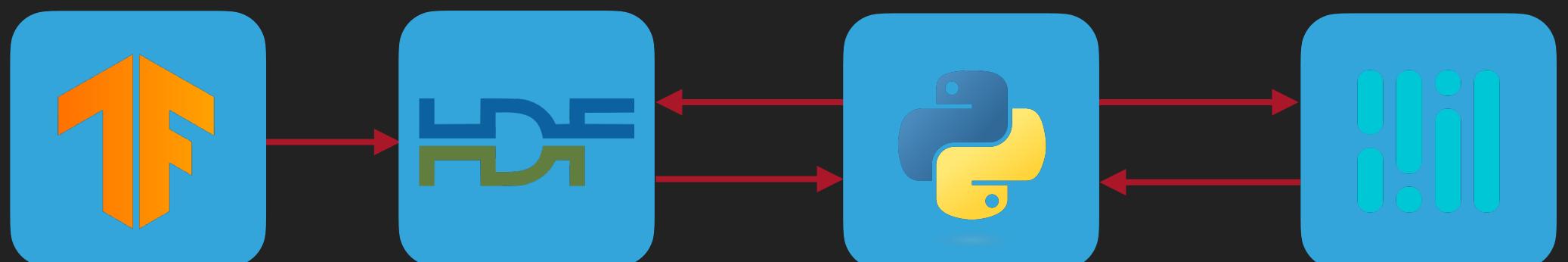
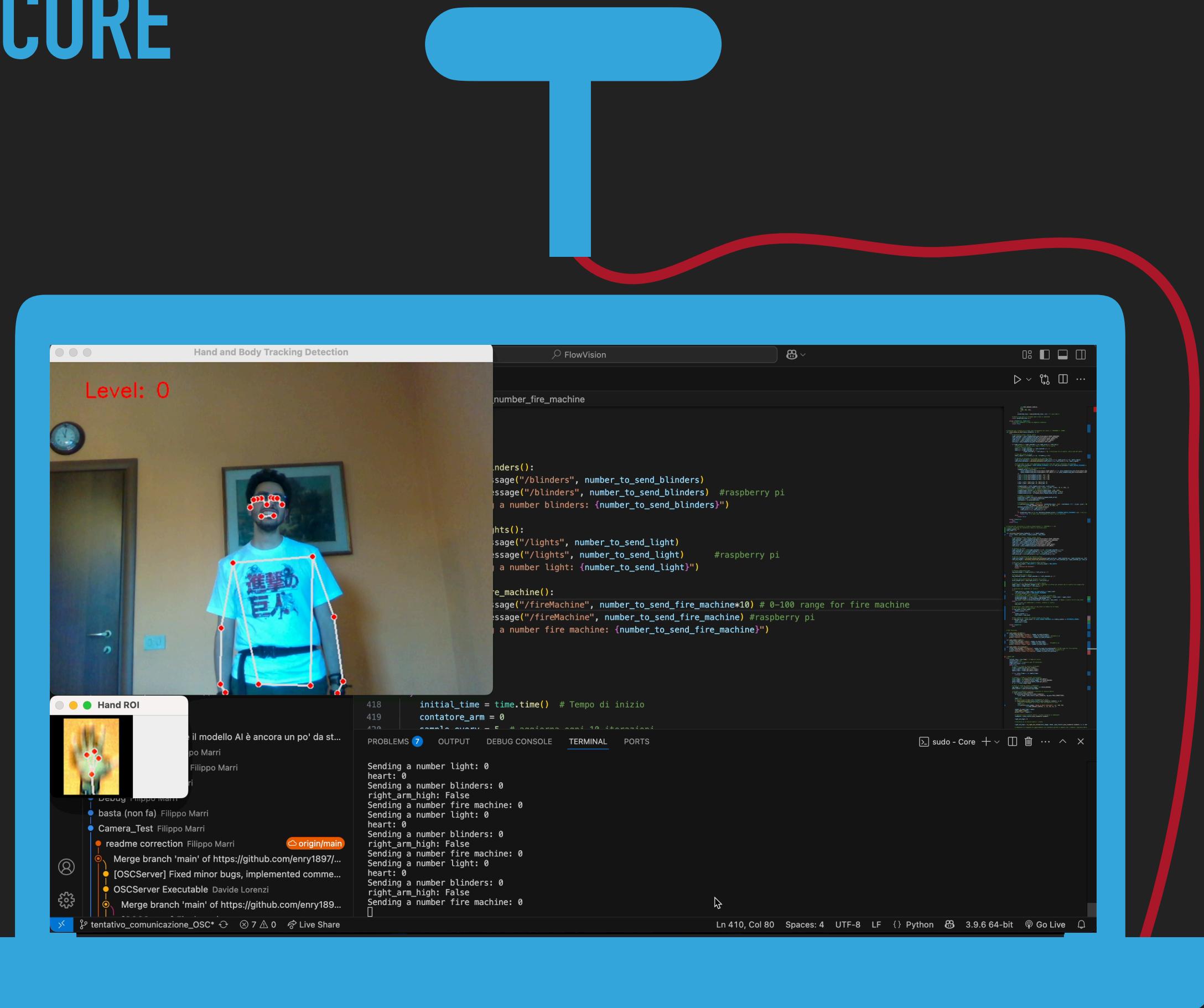
CORE



- ▶ **SOLUTION:**
IMPLEMENTATION OF A FALBACK CODE IN WHICH THE
REFERENCE POINT IS THE WRIST WHEN THE COORDINATE
OF THE HAND ARE NOT AVAILABLE
- ▶ **SOLUTION:**
IMPLEMENTATION OF A SCRIPT THAT IMPOSE THE
CONDITION THAT THE WRIST ARE NOT OVERLAPPED
DURING THE HEART GESTURE
- ▶ **SOLUTION:**
HYBRID MODELS (THRESHOLD + CNN)
- ▶ **SOLUTION:**
INCREASING THE RESOLUTION OF THE IMAGE, WE GET
BETTER PERFORMANCE

FLOWVISION

CORE



- ▶ Median target
 - ▶ Triggering system
 - ▶ Body detection
 - ▶ Depth camera
 - ▶ Motion detection
 - ▶ Arm tracking
 - ▶ Hand tracking
 - ▶ Gesture recognition
 - ▶ Fist detection
 - ▶ Heart detection
 - ▶ AI
- ### SOLUTION:

IMPLEMENTATION OF A FALBACK CODE IN WHICH THE REFERENCE POINT IS THE WRIST WHEN THE COORDINATE OF THE HAND ARE NOT AVAILABLE
- ### SOLUTION:

IMPLEMENTATION OF A SCRIPT THAT IMPOSE THE CONDITION THAT THE WRIST ARE NOT OVERLAPPED DURING THE HEART GESTURE
- ### SOLUTION:

HYBRID MODELS (THRESHOLD + CNN)

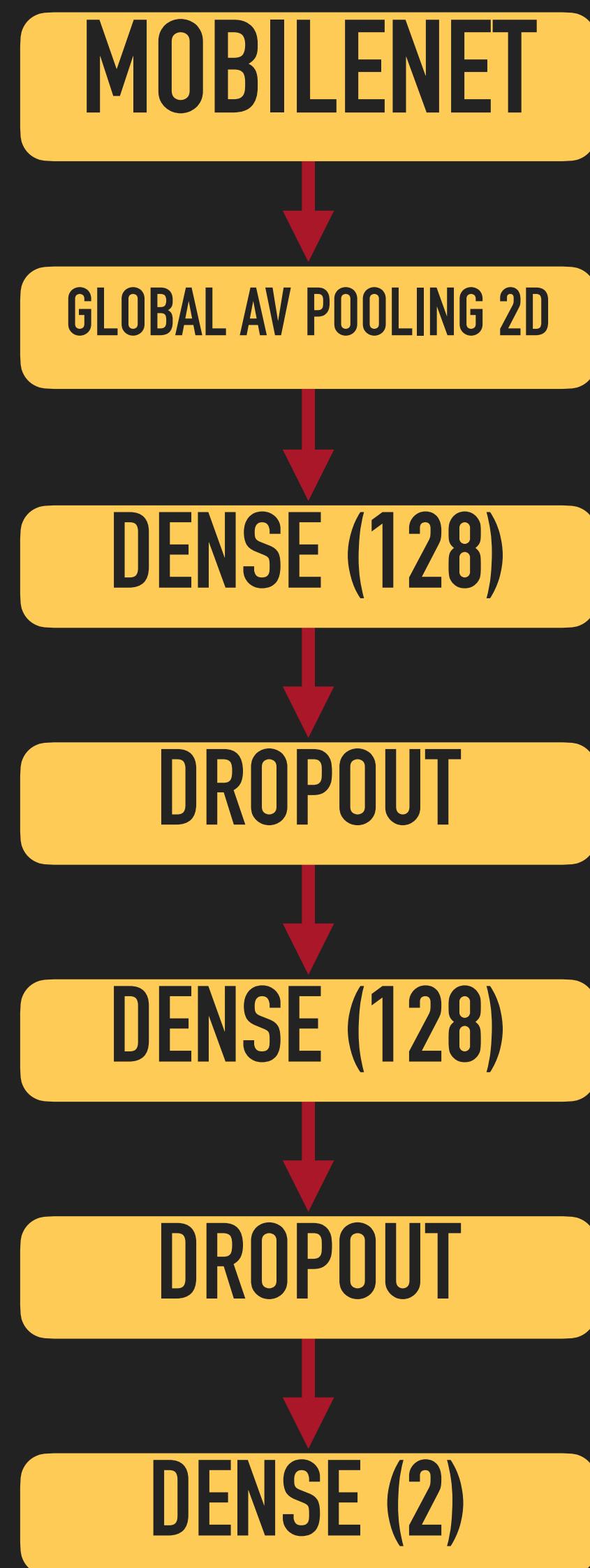
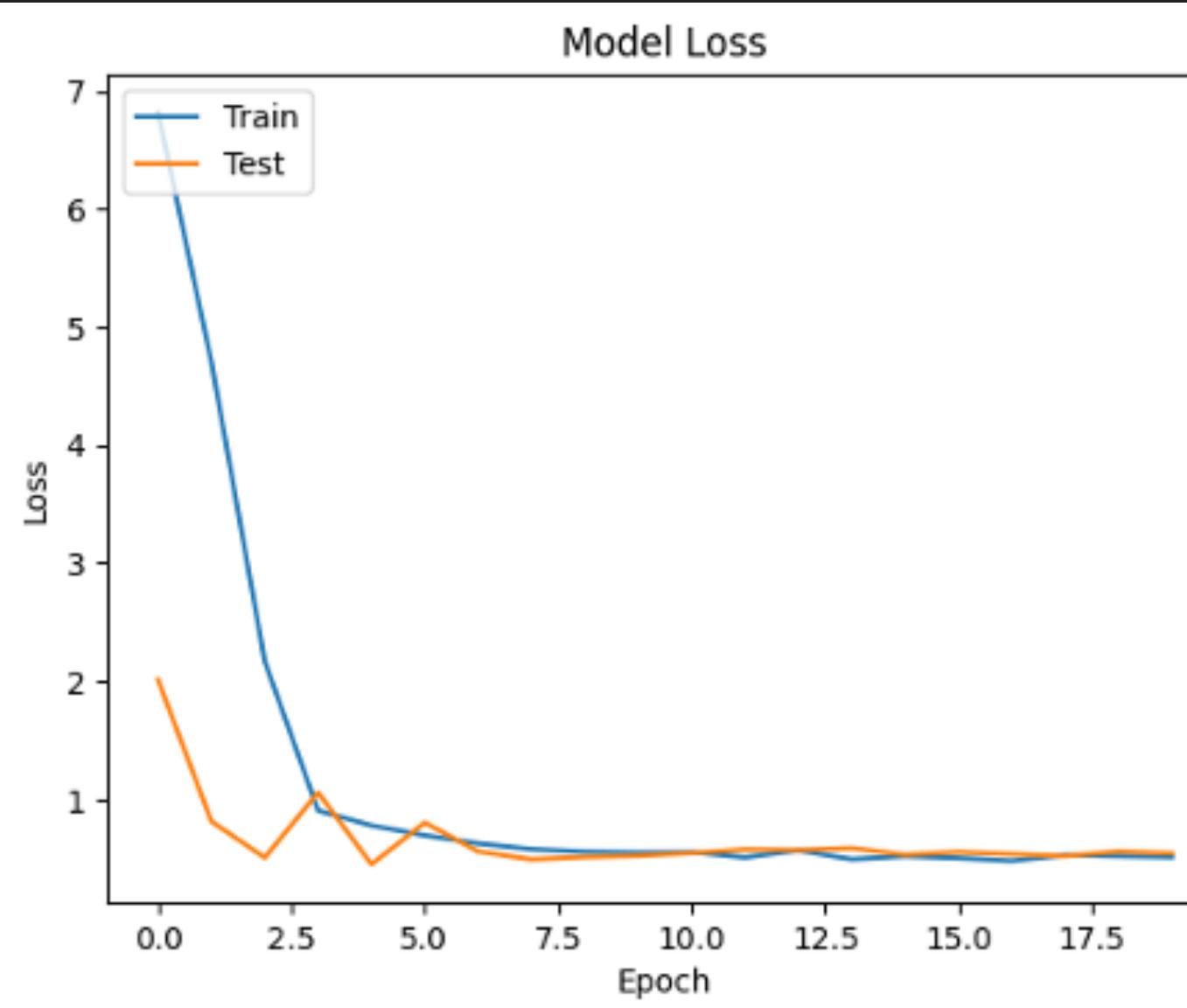
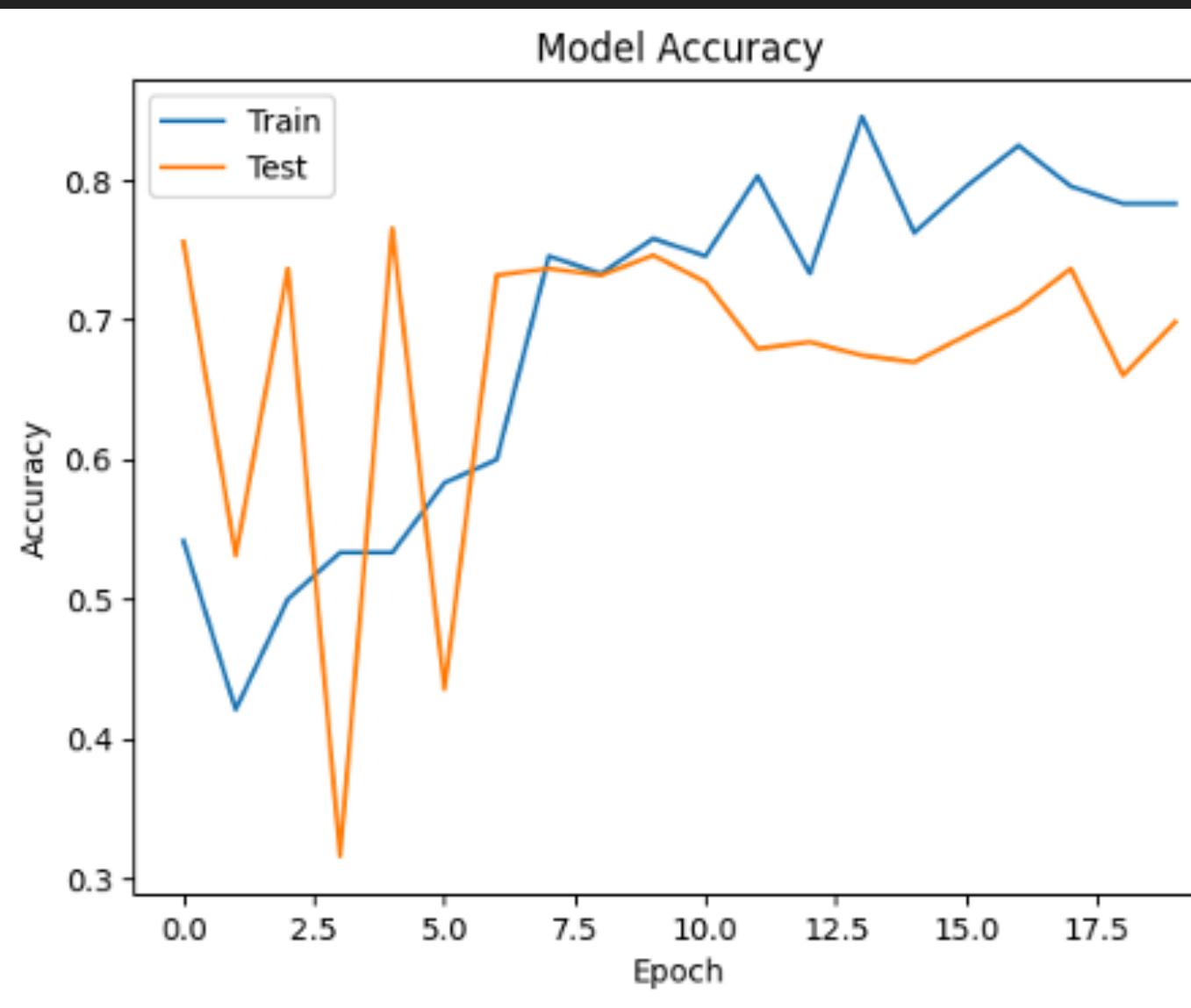
TRADE-OFF:

A HIGHER RESOLUTION IS NOT SUPPORTED WITH OUR COMPUTATIONAL POWER SO WE DECIDED TO WORK AS MUCH AS POSSIBLE ON THE IMAGE PRE-PROCESSING

FLOWVISION

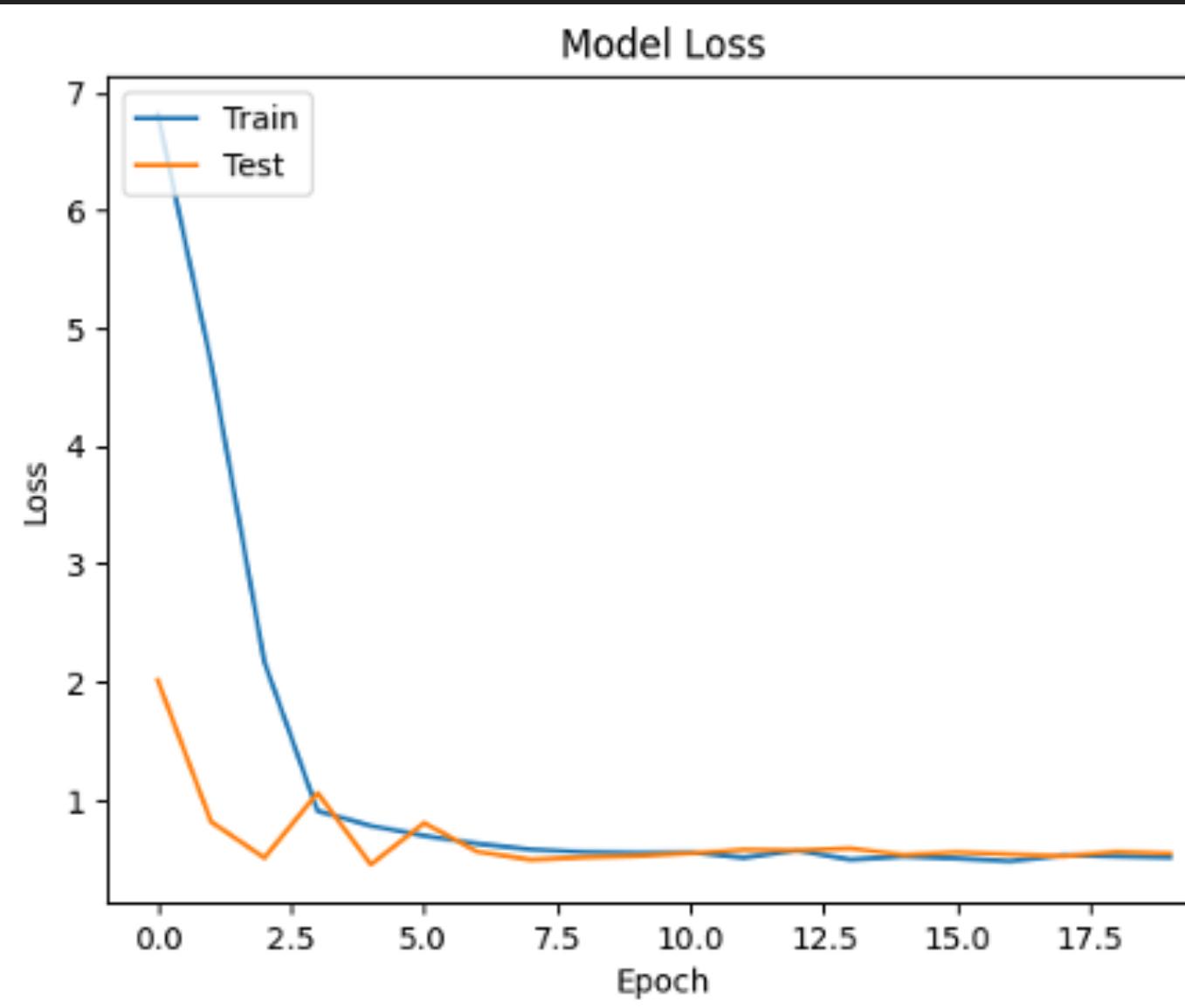
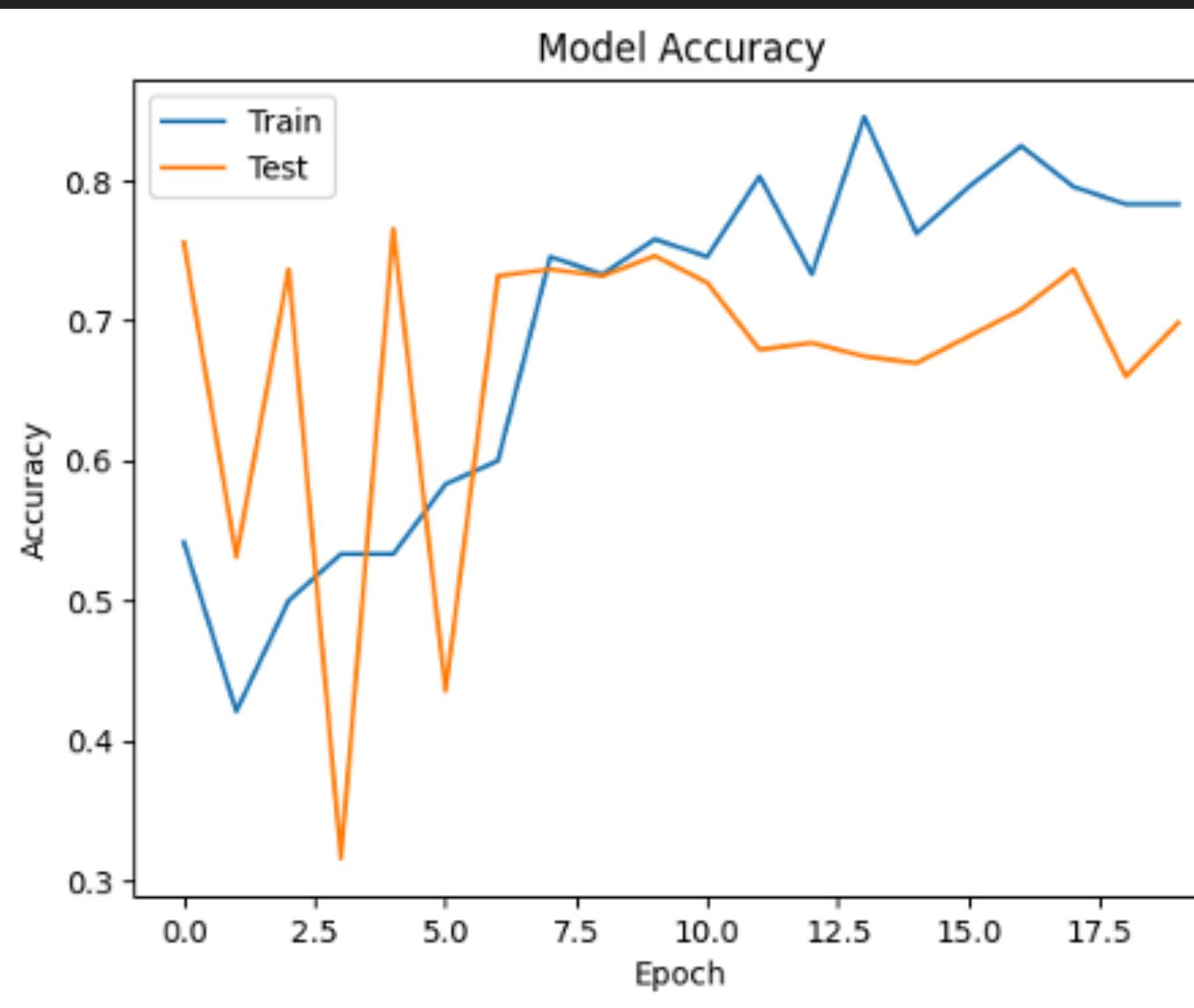
CORE - AI MODELS: FIST GESTURE

CORE - AI MODELS: FIST GESTURE



- ▶ Complex model
- ▶ More than 3 million of parameters
- ▶ Strong-pre processing on the image that feeds the Neural Network

CORE - AI MODELS: FIST GESTURE



MOBILENET

GLOBAL AV POOLING 2D

DENSE (128)

DROPOUT

DENSE (128)

DROPOUT

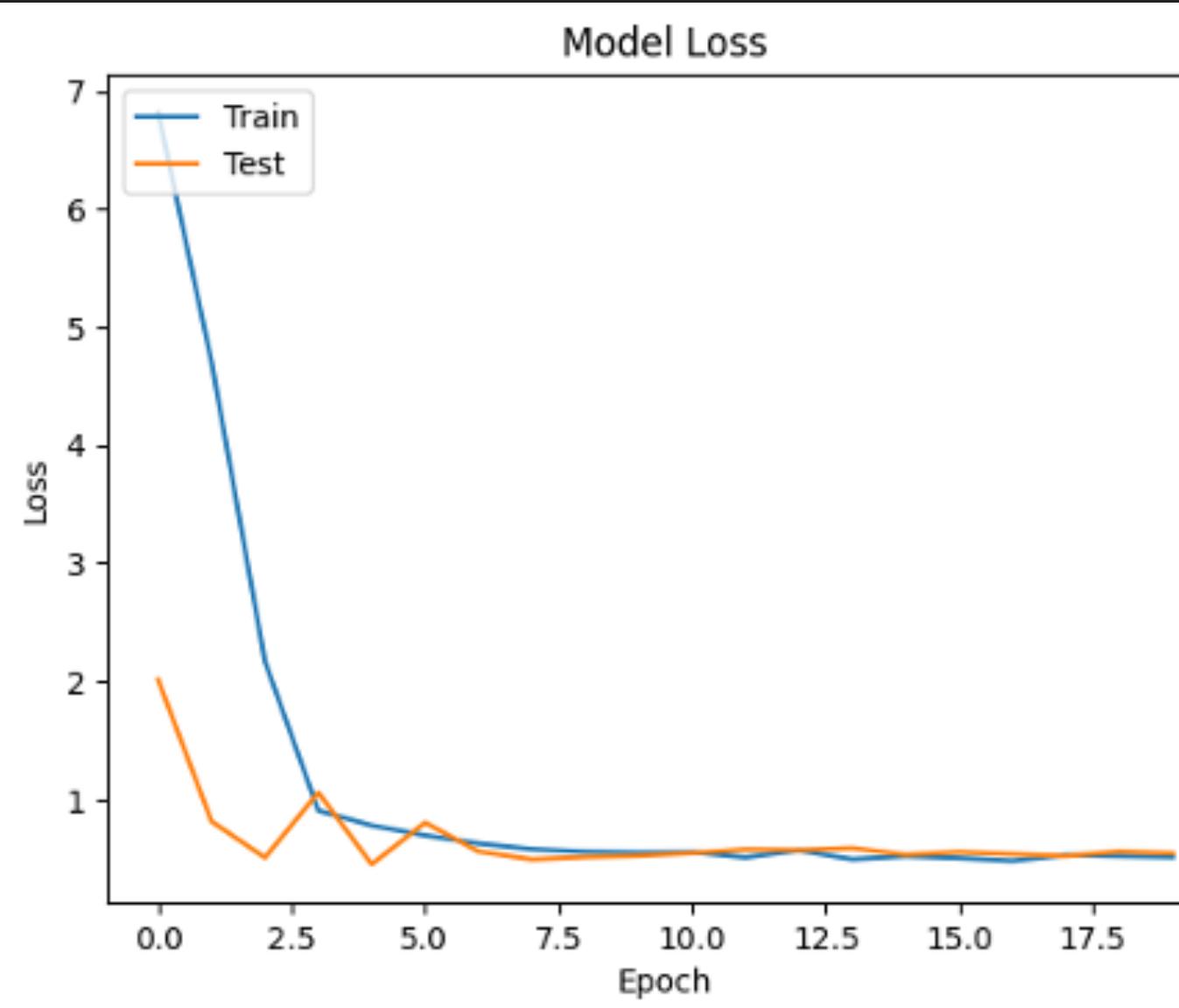
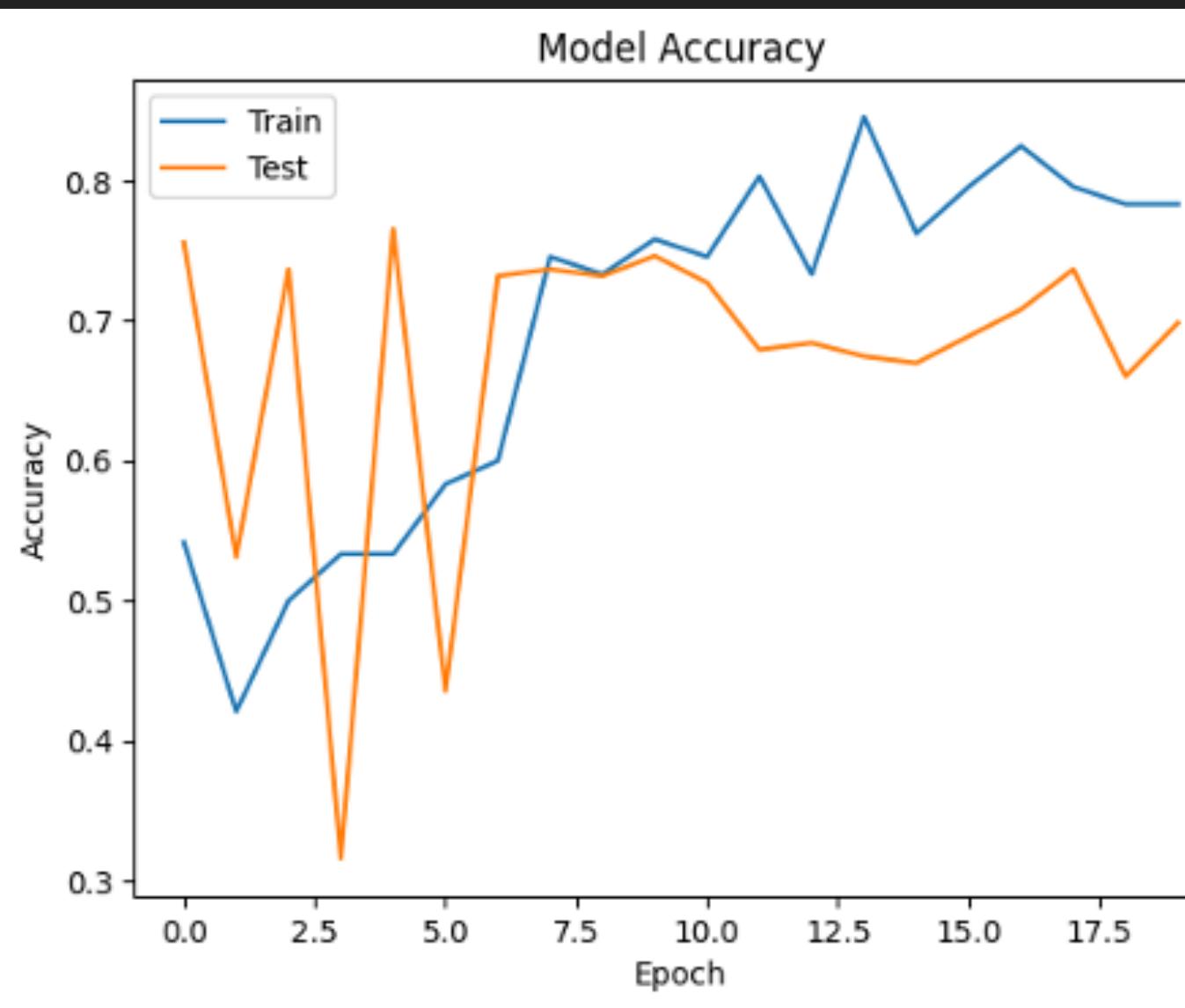
DENSE (2)

- ▶ Complex model
- ▶ More than 3 million of parameters
- ▶ Strong-pre processing on the image that feeds the Neural Network

CHALLENGE:

AFTER AN UPDATING OF THE LIBRARIES OF KERAS AND TENSOR FLOW, THE FIRST MODEL STOPPED WORKING

CORE - AI MODELS: FIST GESTURE



MOBILENET

GLOBAL AV POOLING 2D

DENSE (128)

DROPOUT

DENSE (128)

DROPOUT

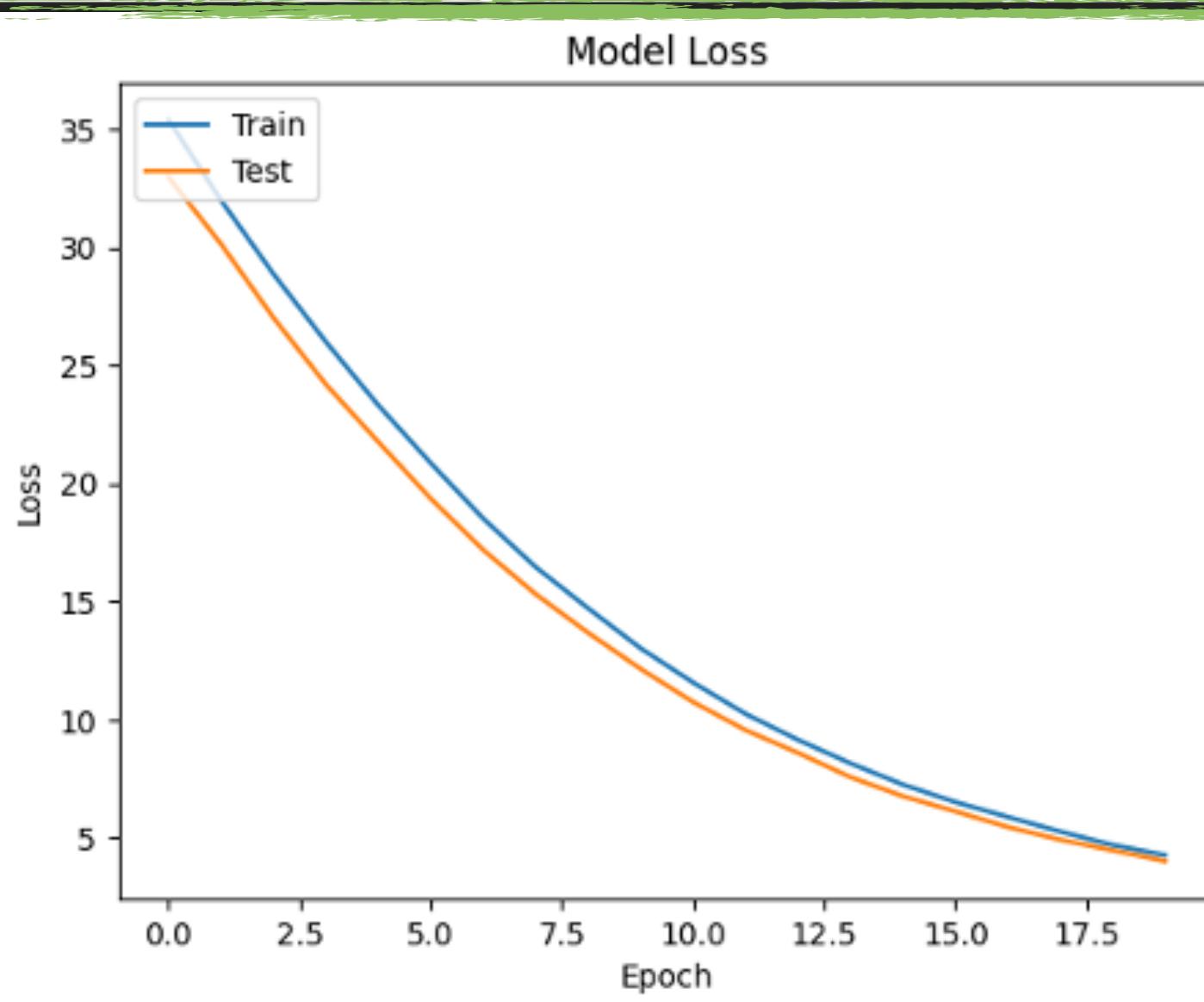
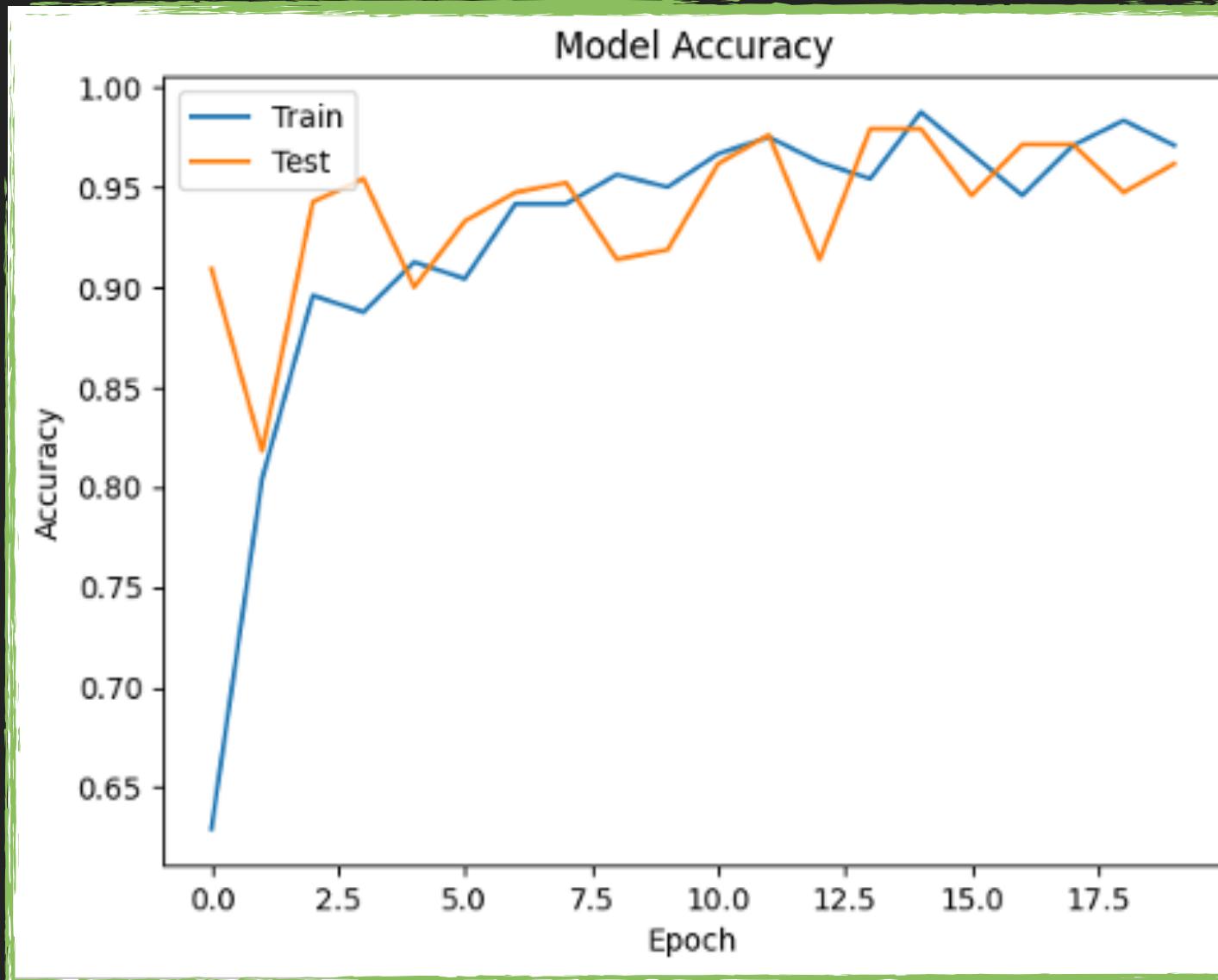
DENSE (2)

- ▶ Complex model
- ▶ More than 3 million of parameters
- ▶ Strong-pre processing on the image that feeds the Neural Network

SOLUTION:

GENERATION OF A NEW MODEL AND IMPLEMENTATION OF A REQUIREMENT FILE INCLUDED IN THE GITHUB REPO THAT CONTAINS THE RIGHT VERSIONS OF THE LIBRARIES

CORE - AI MODELS: FIST GESTURE



MOBILENET

GLOBAL AV POOLING 2D

DENSE (128)

DROPOUT

DENSE (128)

DROPOUT

DENSE (2)

- ▶ Complex model
- ▶ More than 3 million of parameters
- ▶ Strong-pre processing on the image that feeds the Neural Network

Layer (type)	Output Shape	Param #
mobilenet_1.00_224 (Functional)	(None, 3, 3, 1024)	3,228,864
global_average_pooling2d_6 (GlobalAveragePooling2D)	(None, 1024)	0
dense_31 (Dense)	(None, 128)	131,200
dropout_16 (Dropout)	(None, 128)	0
dense_32 (Dense)	(None, 128)	16,512
dropout_17 (Dropout)	(None, 128)	0
dense_33 (Dense)	(None, 2)	258

Total params: 3,376,834 (12.88 MB)

FLOWVISION

CORE - AI MODELS: HEART GESTURE

CORE - AI MODELS: HEART GESTURE

CHALLENGE:
DATASET NOT AVAILABLE

CORE - AI MODELS: HEART GESTURE

SOLUTION:

WE CREATED A DATASET MERGING SOME RANDOM IMAGES OF
HANDS AND A SET OF PICTURE OF HANDS GESTURE

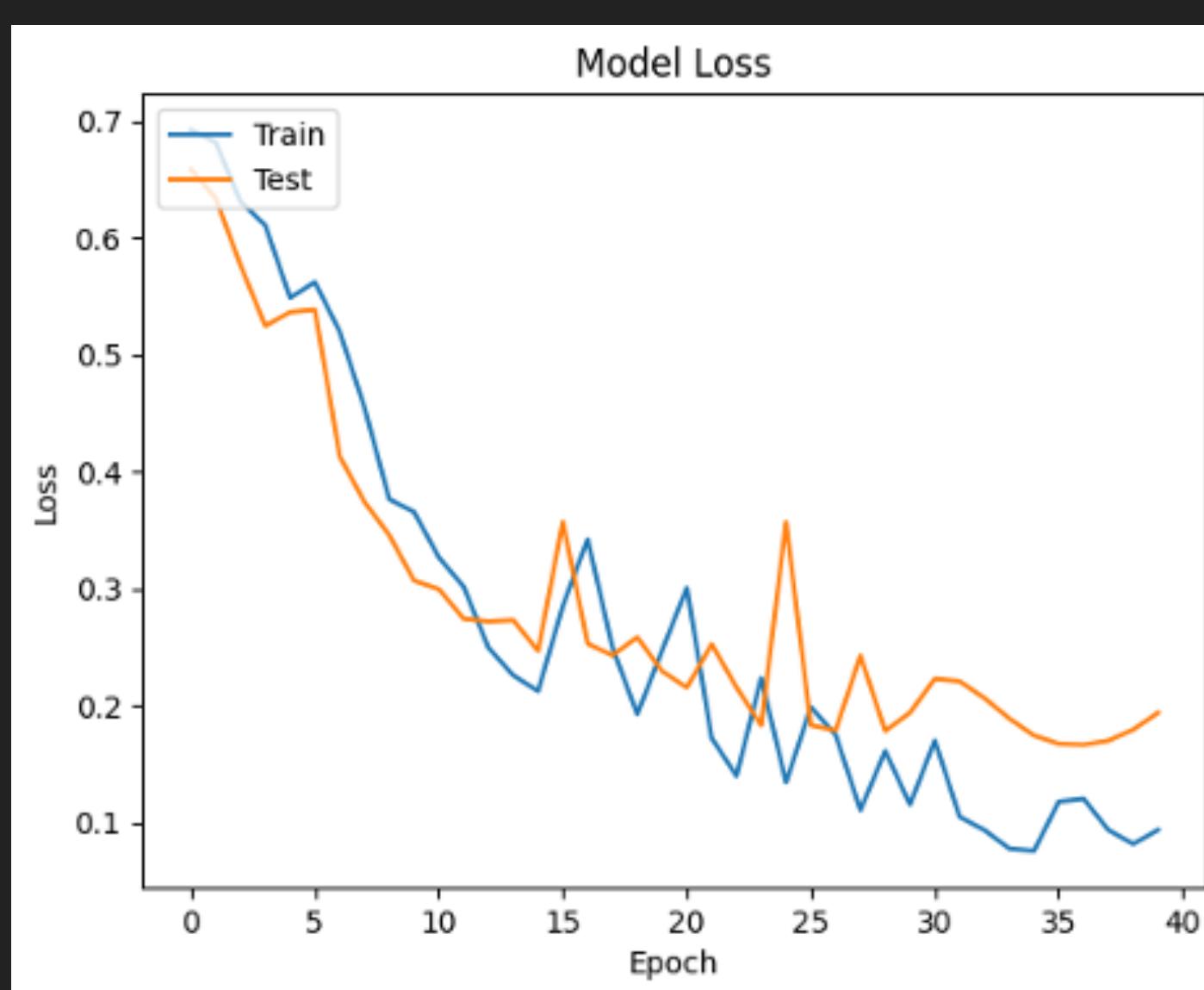
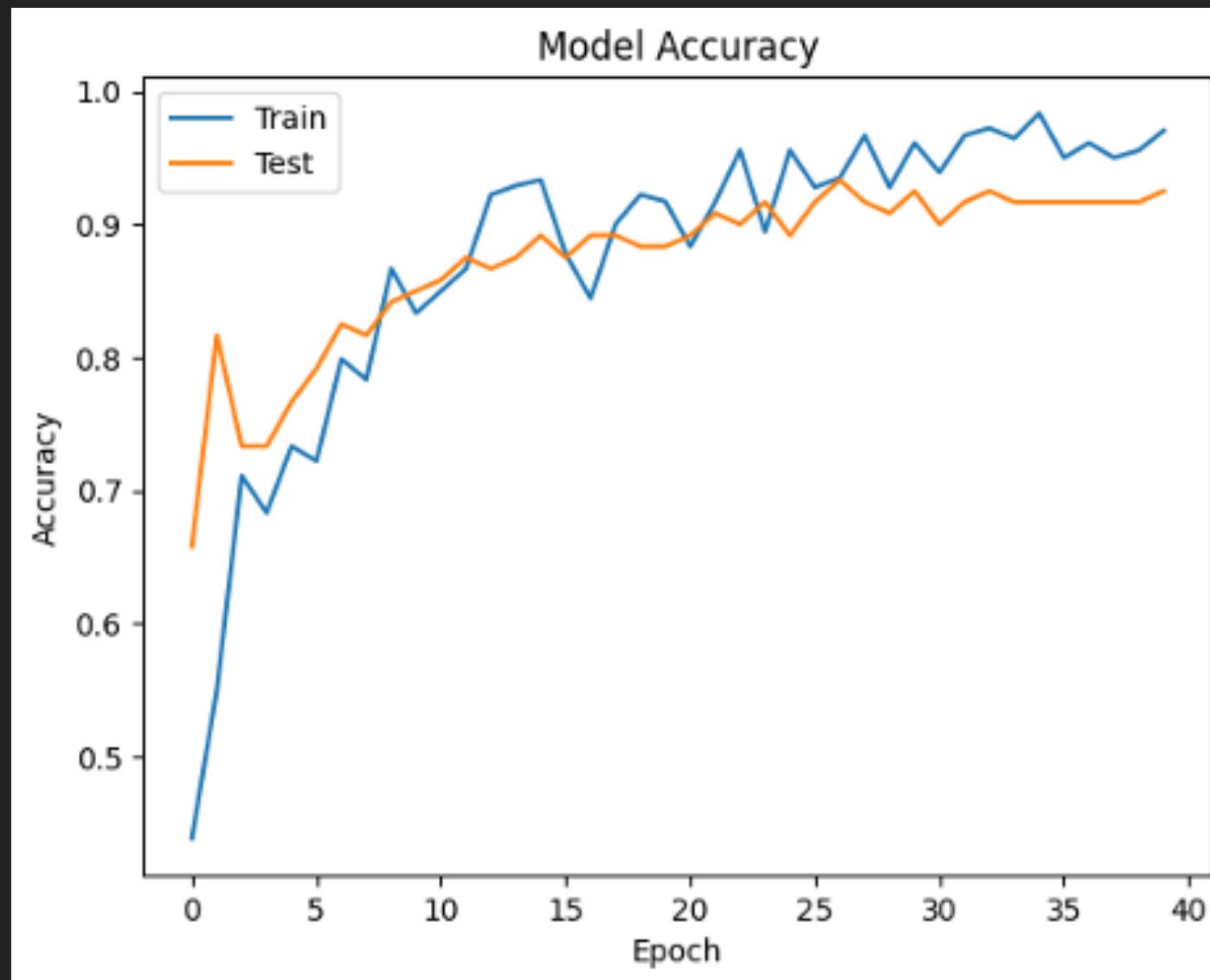
CORE - AI MODELS: HEART GESTURE

SOLUTION:

WE CREATED A DATASET MERGING SOME RANDOM IMAGES OF HANDS AND A SET OF PICTURE OF HANDS GESTURE

- ▶ Simpler model
- ▶ Less than 1 million of parameters
- ▶ Light processing on the image that feeds the Neural Network

CORE - AI MODELS: HEART GESTURE



CONV2D(16, 118X118)

MAXPOOLING 2D

CONV2D(32, 57X57)

MAXPOOLING 2D

- ▶ Simpler model

- ▶ Less than 1 million of parameters

- ▶ Light processing on the image that feeds the Neural Network

CONV2D(64, 26X26)

MAXPOOLING 2D

FLATTEN

MAXPOOLING 2D

CONV2D(128, 11X11)

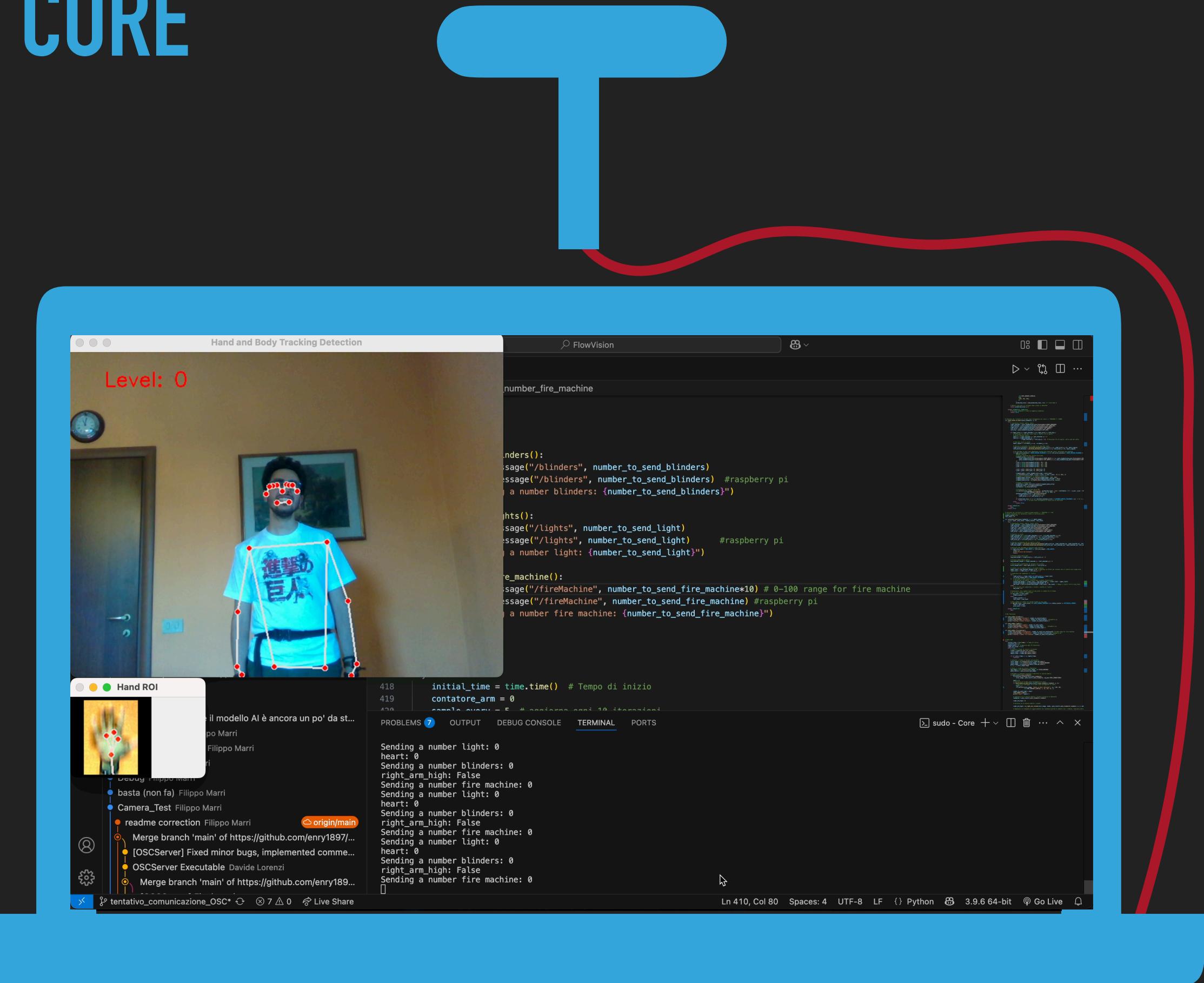
DENSE (256)

DENSE (128)

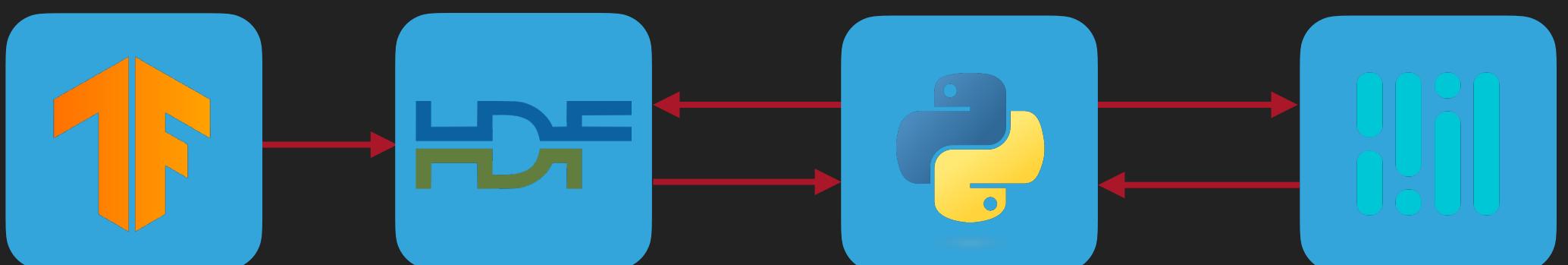
DENSE (2)

FLOWVISION

CORE

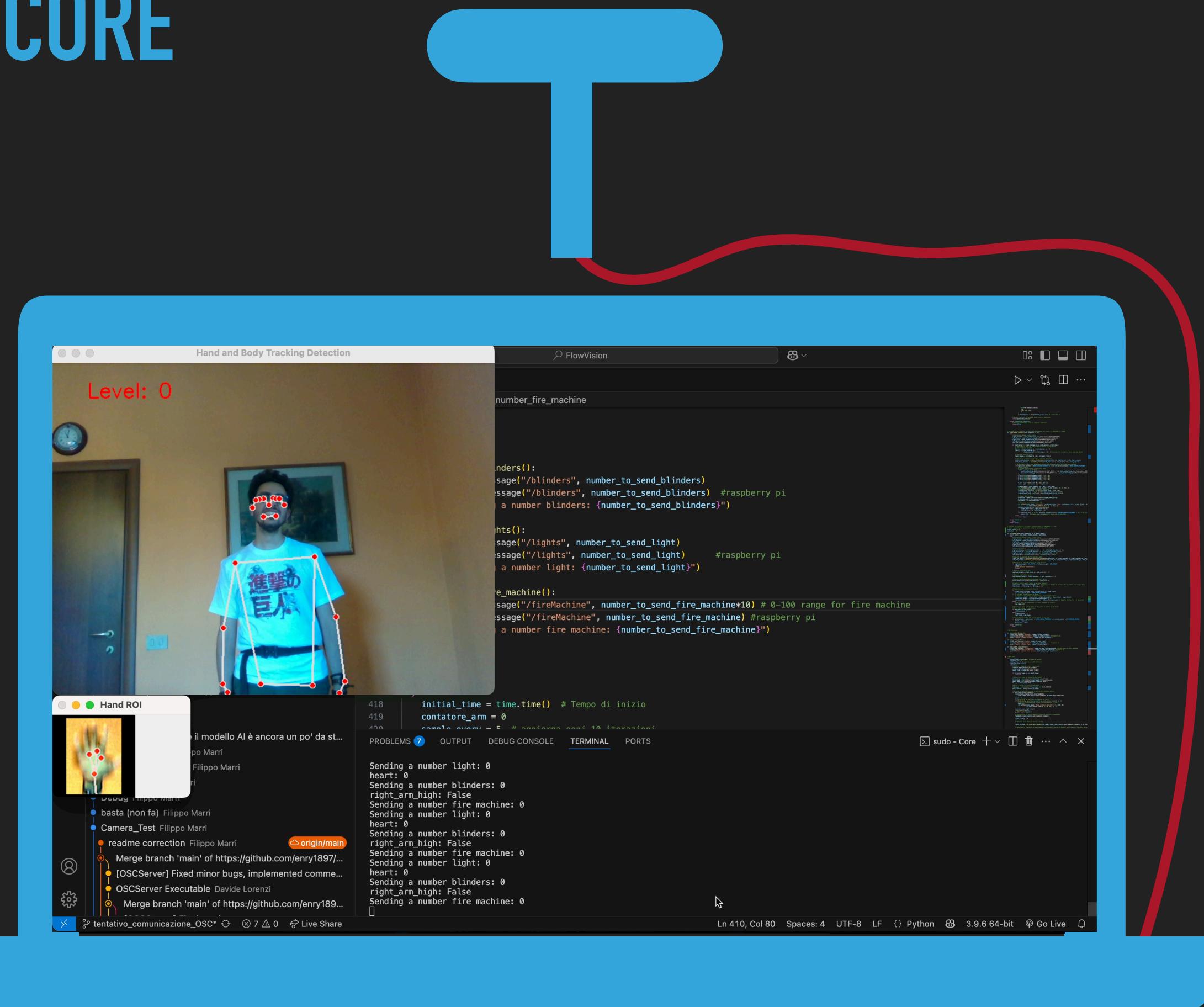


- ▶ MediaPipe module that allows the system to target the position and posture of the user
 - ▶ Triggering system
 - ▶ Bigger movements -> Thresholds
 - ▶ Details -> AI models fed with cropped images

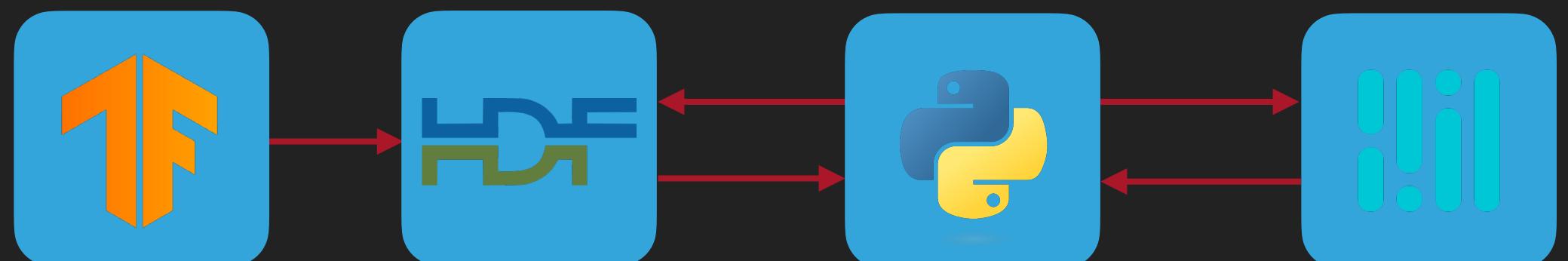


FLOWVISION

CORE

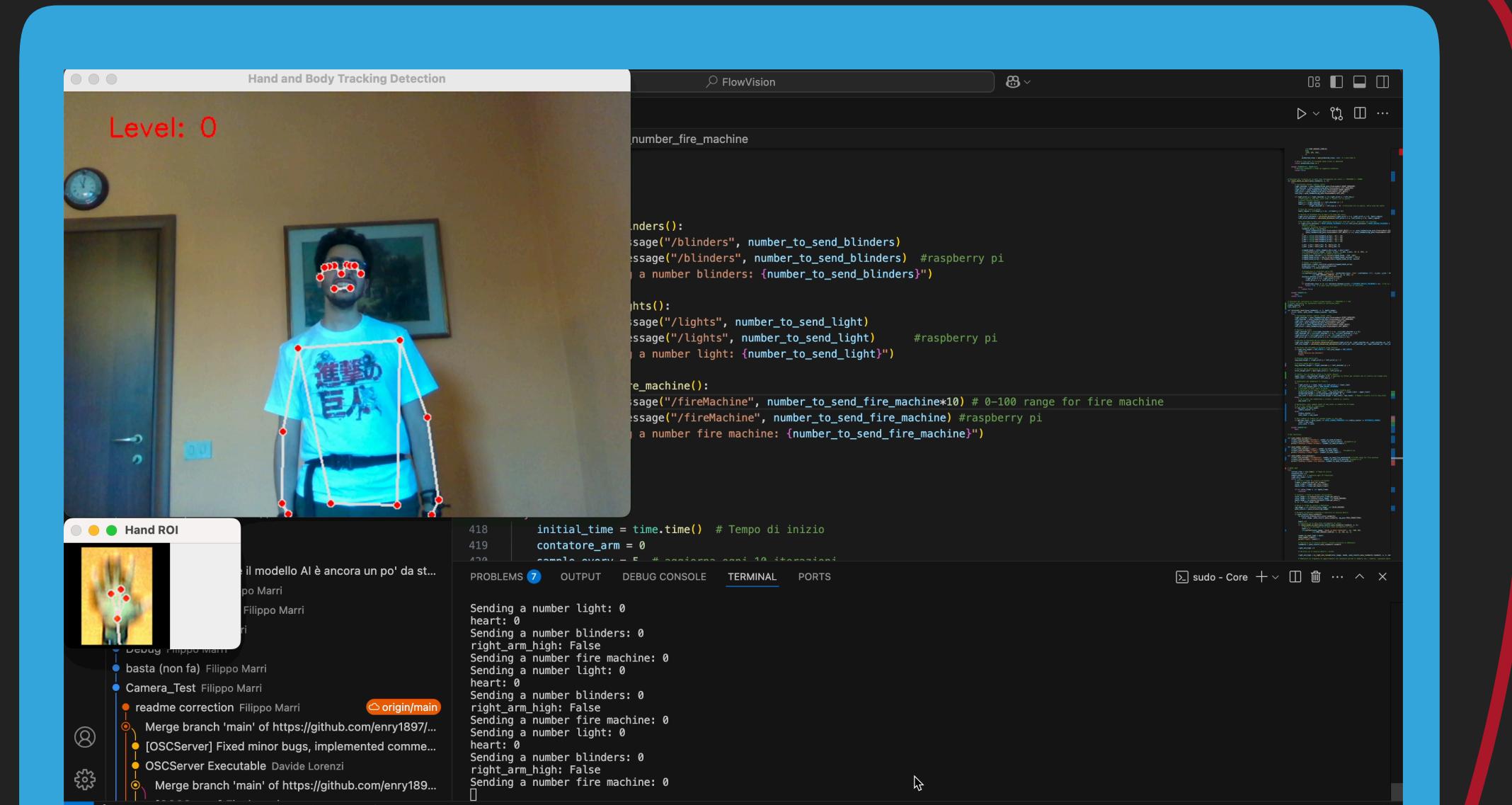


- ▶ MediaPipe module that allows the system to target the position and posture of the user
- ▶ Triggering system
 - ▶ Bigger movements -> Thresholds
 - ▶ Details -> AI models fed with cropped images



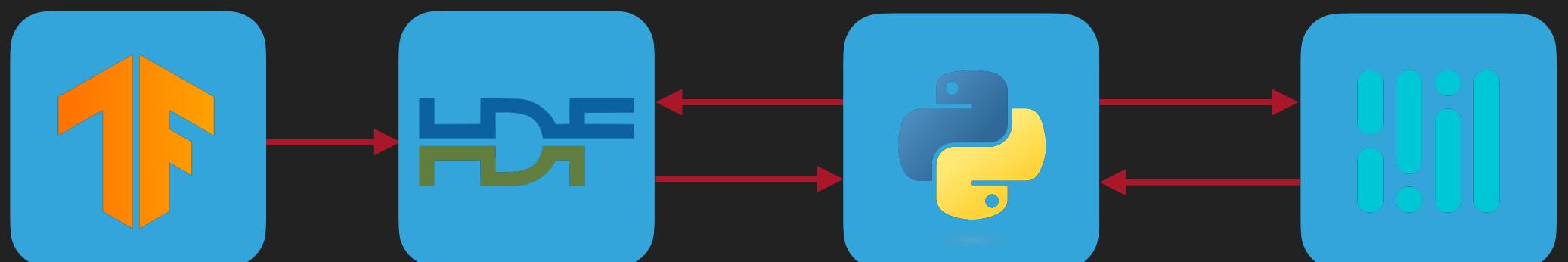
FLOWVISION

CORE



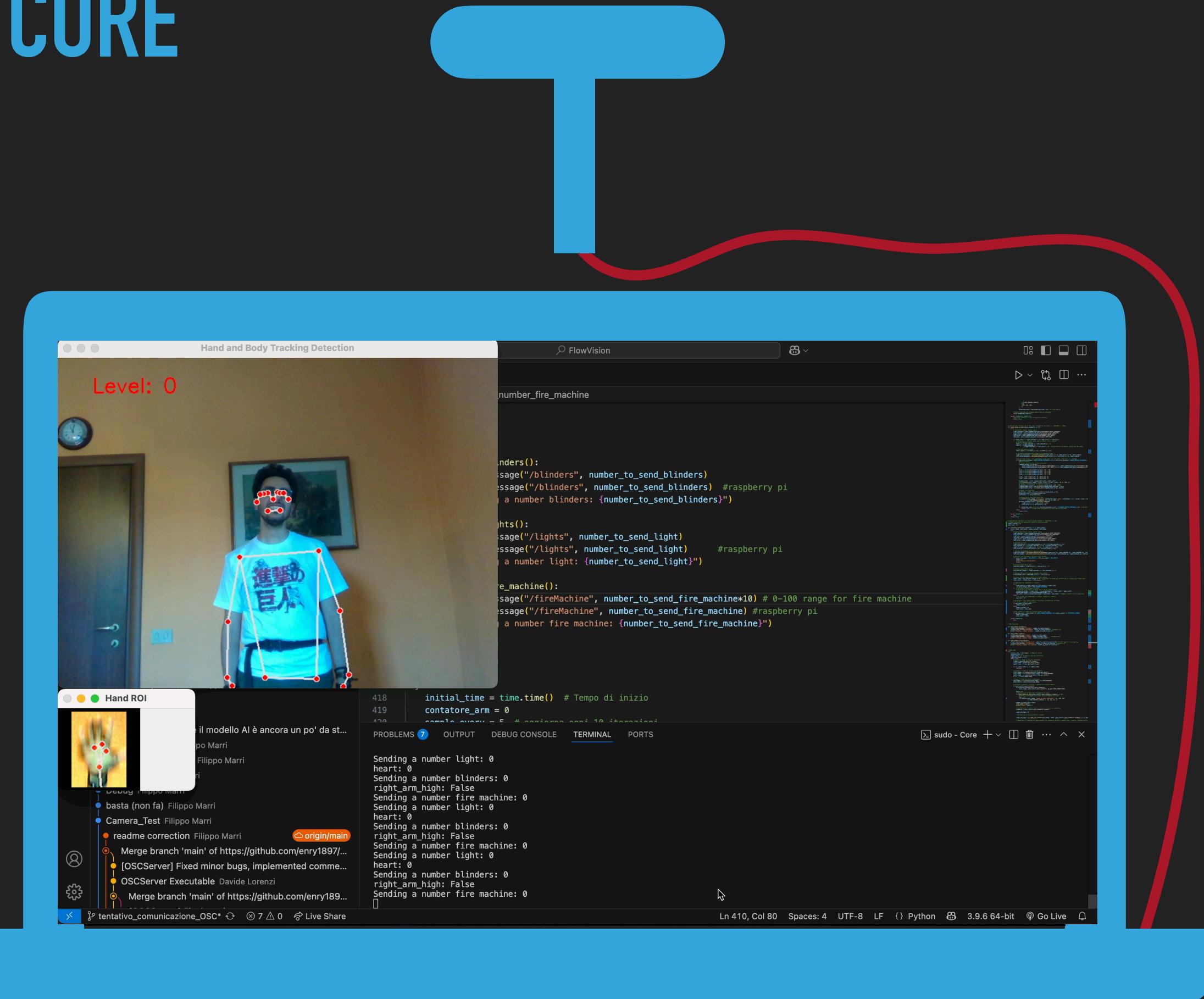
- ▶ MediaPipe module that allows the system to target the position and posture of the user
- ▶ Triggering system
 - ▶ Bigger movements -> Thresholds
 - ▶ Details -> AI models fed with cropped images

CHALLENGE:
BLINKING DUE TO THE HIGH FPS



FLOWVISION

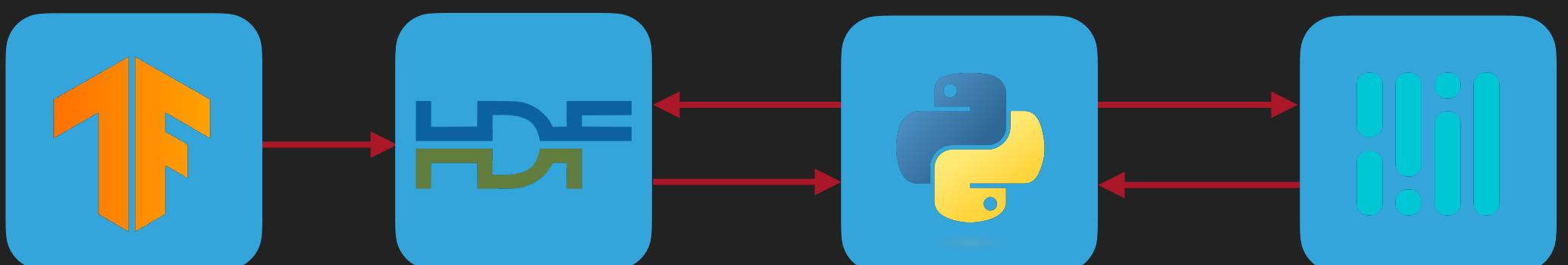
CORE



- ▶ MediaPipe module that allows the system to target the position and posture of the user
 - ▶ Triggering system
 - ▶ Bigger movements -> Thresholds
 - ▶ Details -> AI models fed with cropped images

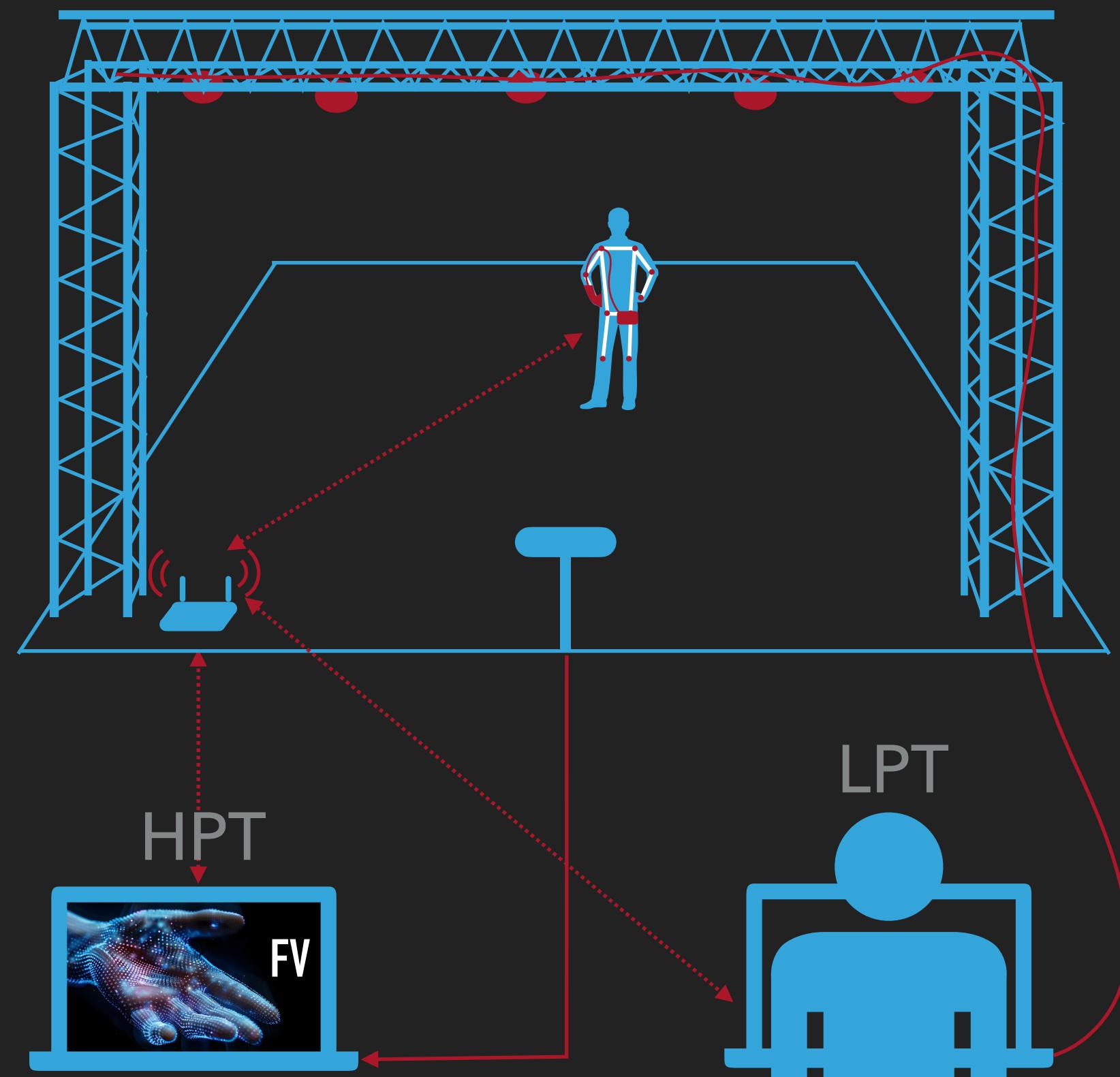
SOLUTION:

IMPLEMENTATION OF A HYSTERESIS CODE THAT ACTS AS A SAMPLE-AND-HOLD BLOCK TO REDUCE THE SPEED OF THE UPDATE



ARCHITECTURE

ON STAGE

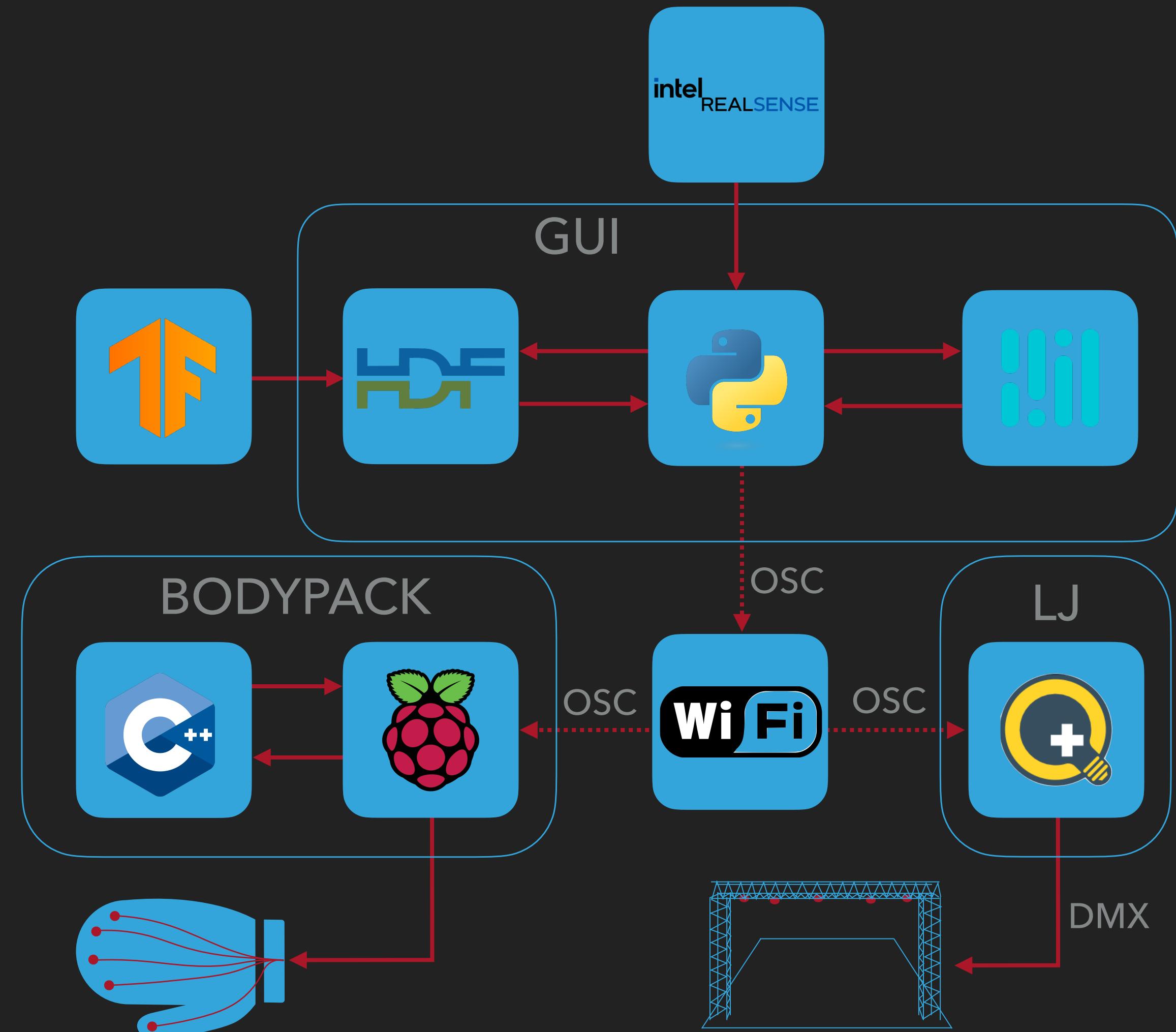


INPUT

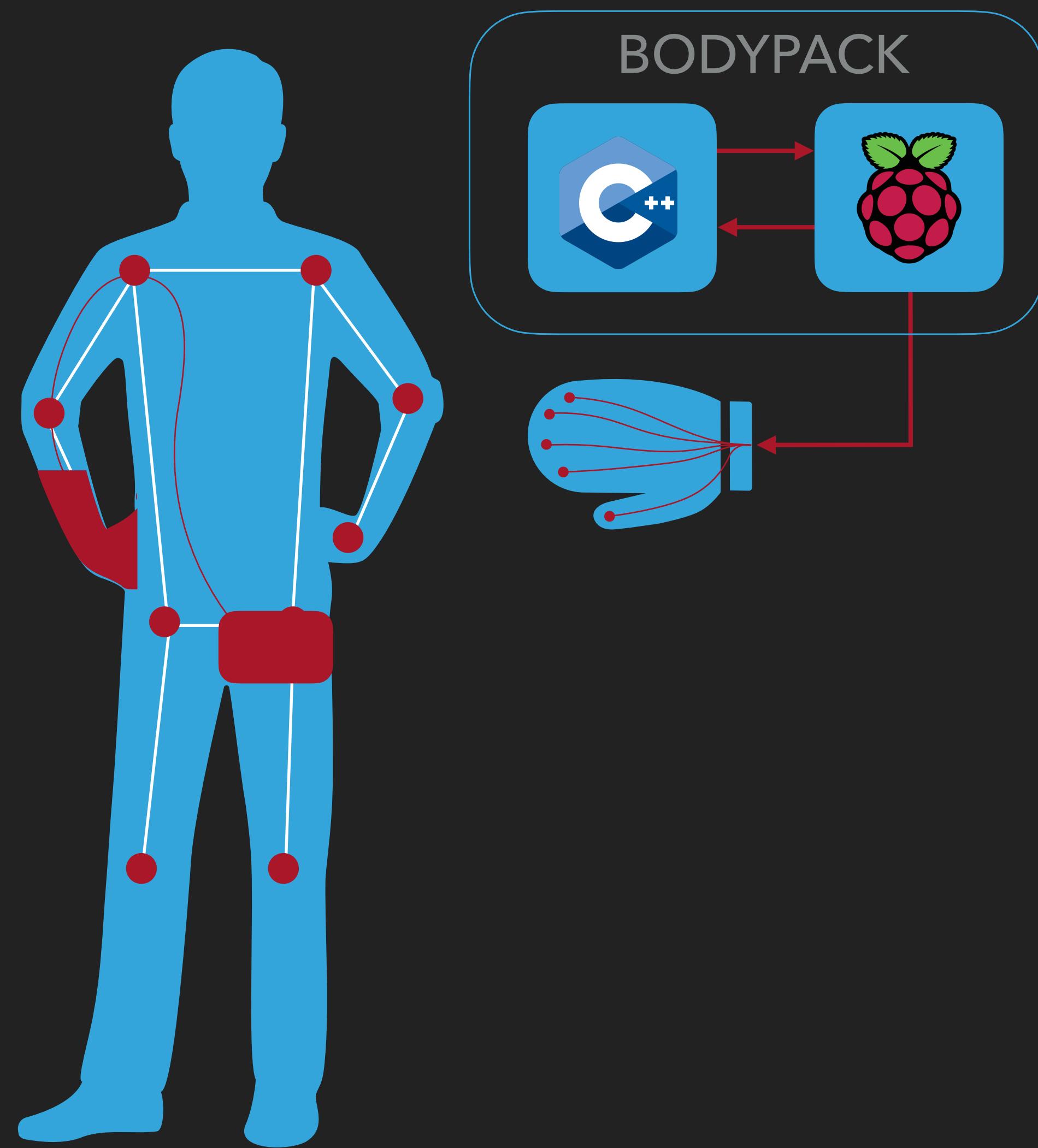
CORE

OUTPUT

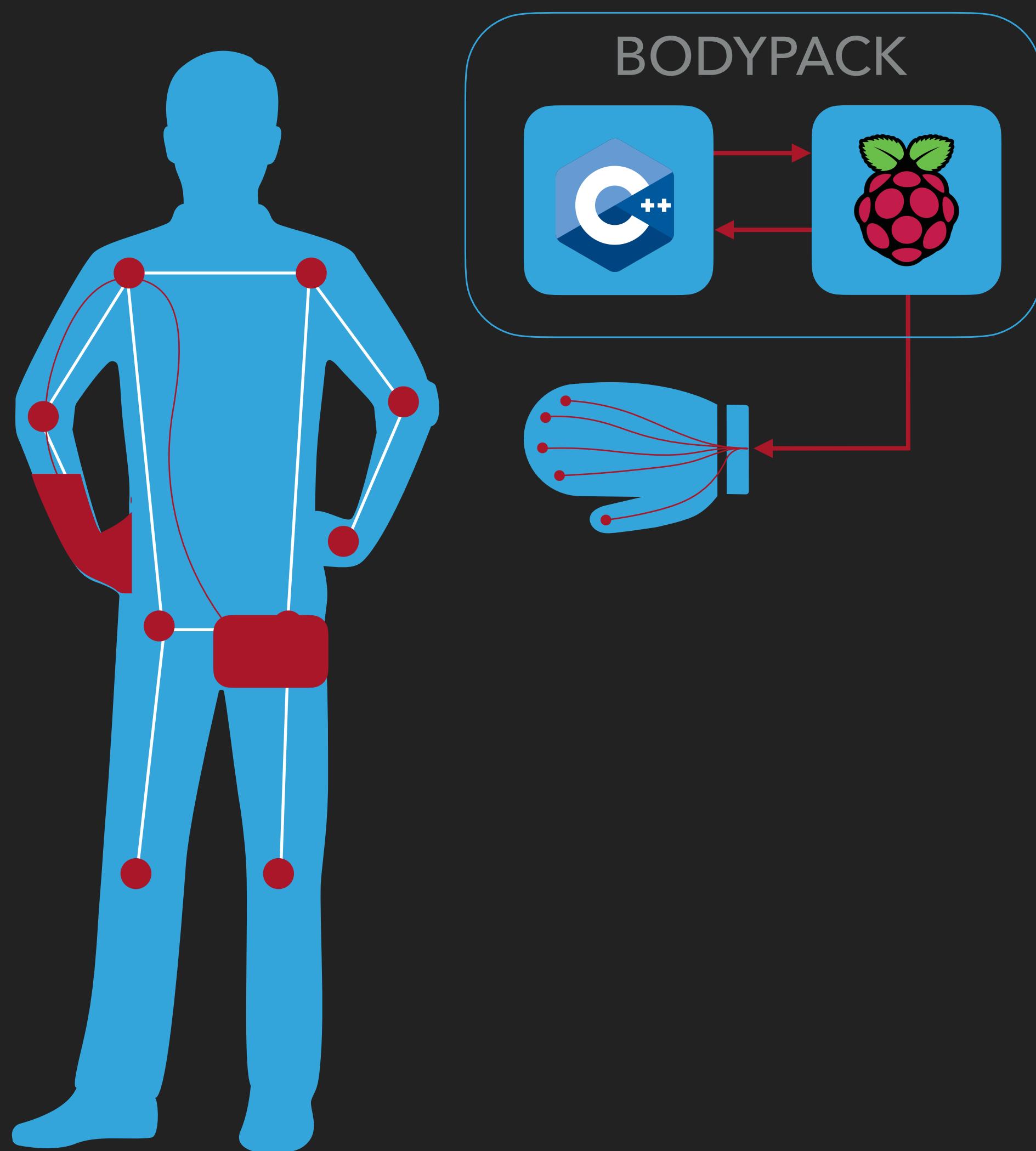
BEHIND THE SCENE



OUTPUT - BODYPACK

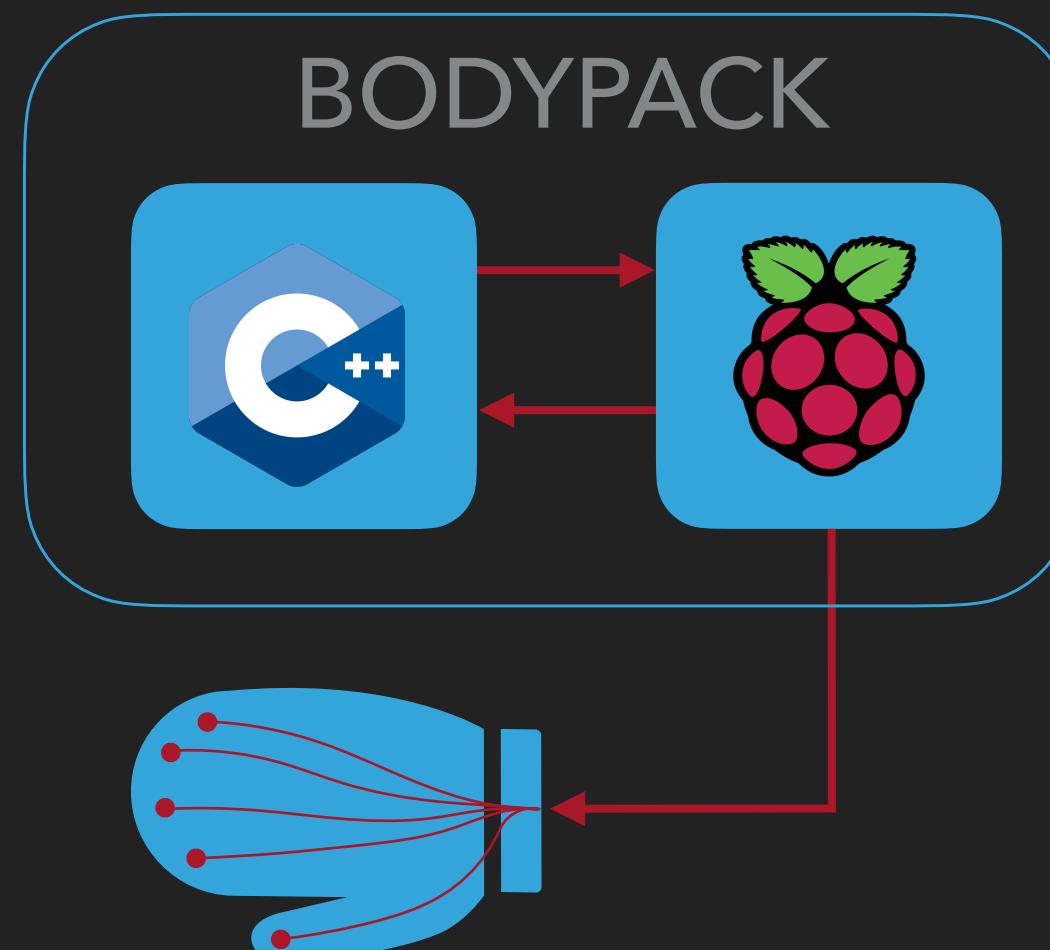
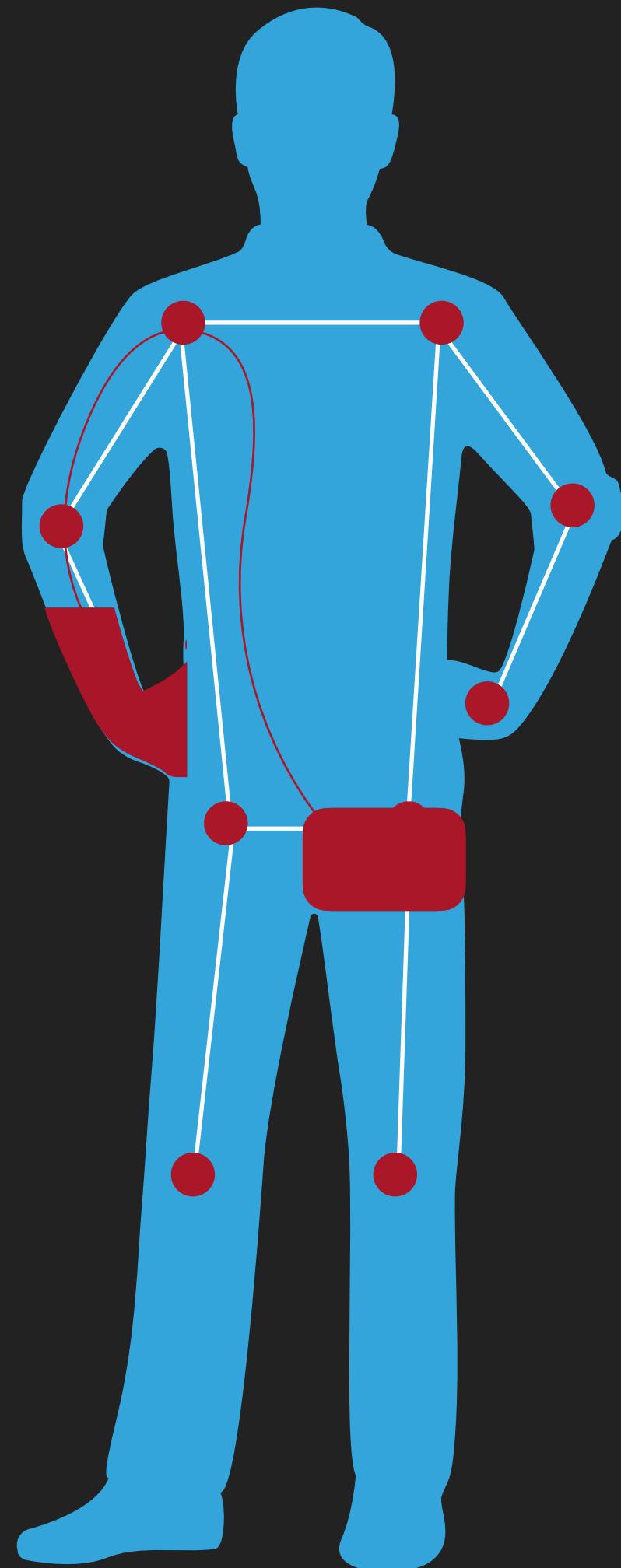


OUTPUT - BODYPACK



- ▶ RaspberryPi5 wi-fi that works as interface between the software and the actuator circuit driven directly by a module of the main function

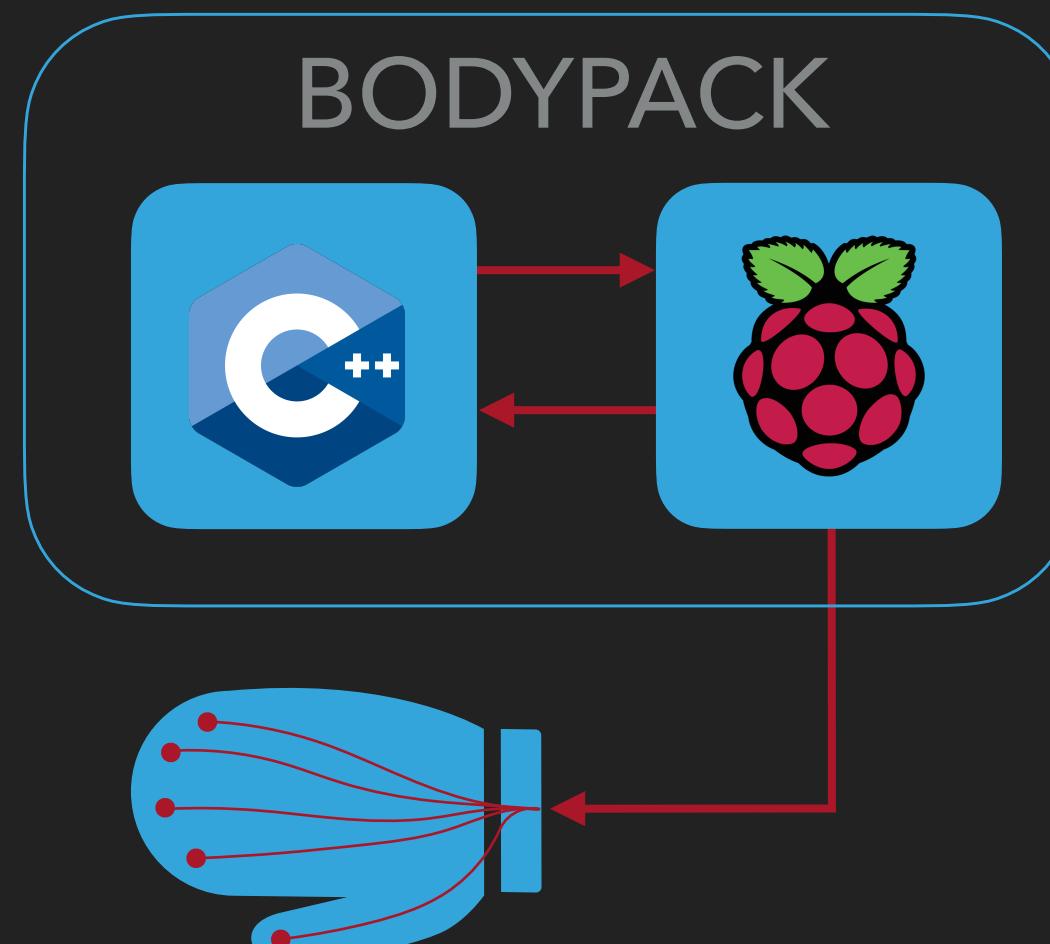
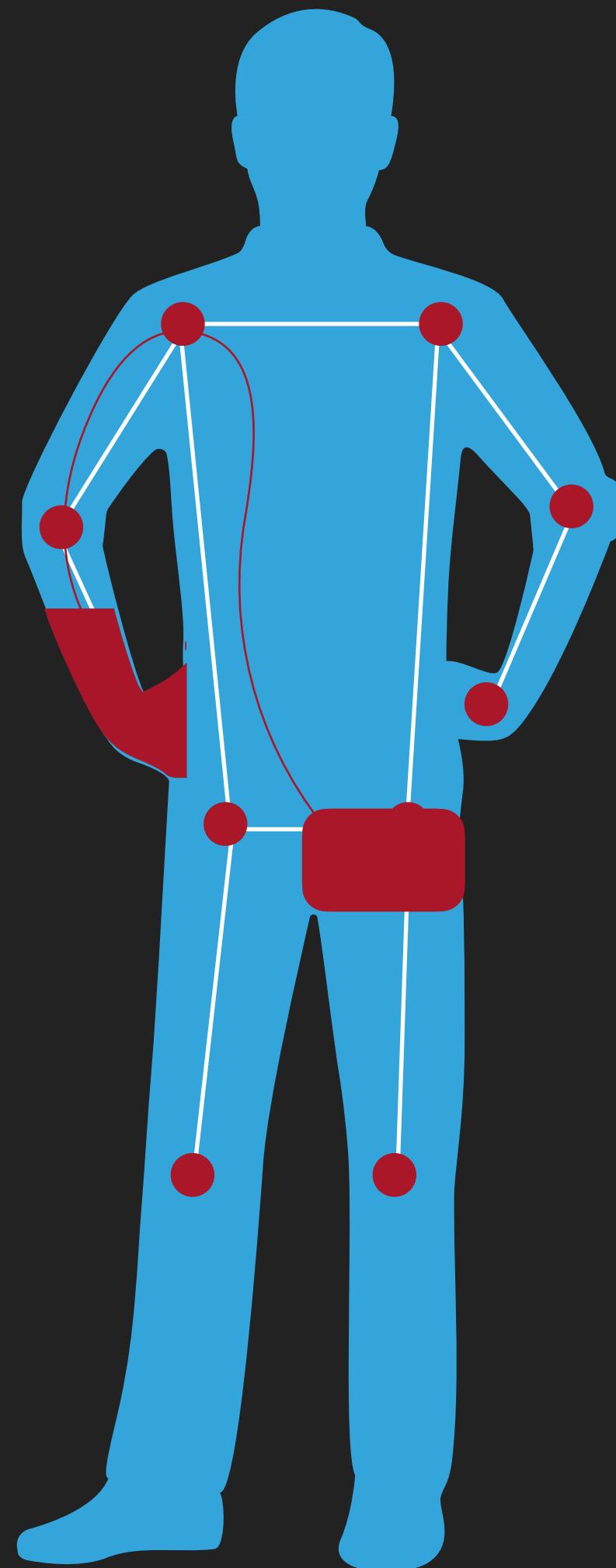
OUTPUT - BODYPACK



- ▶ RaspberryPi5 wi-fi that works as interface between C++ driver functions.

CHALLENGE:
COMPATIBILITY PROBLEM BETWEEN PYTHON AND RASPBERRY PI 5

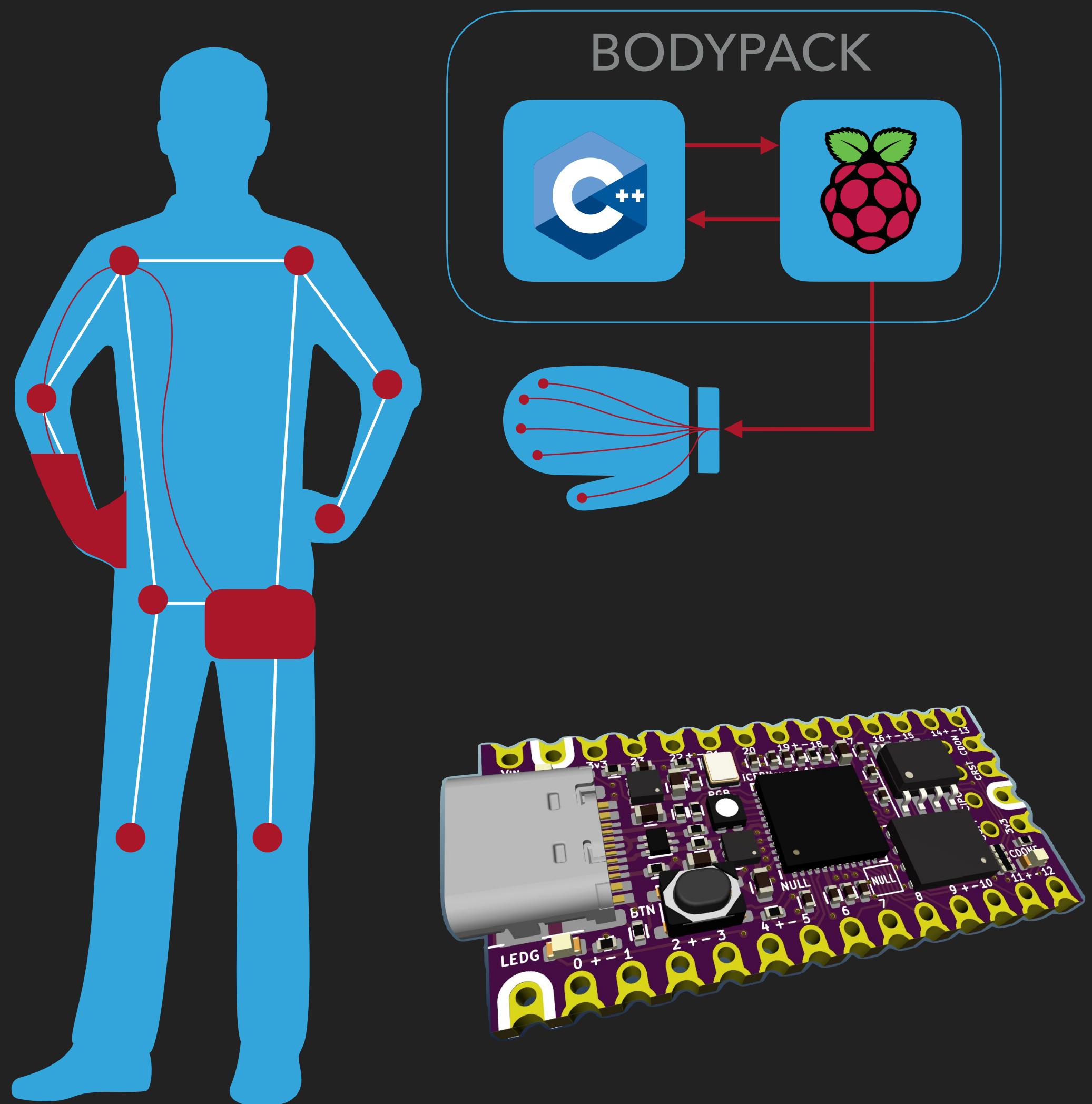
OUTPUT - BODYPACK



- ▶ RaspberryPi5 wi-fi that works as interface between driver functions

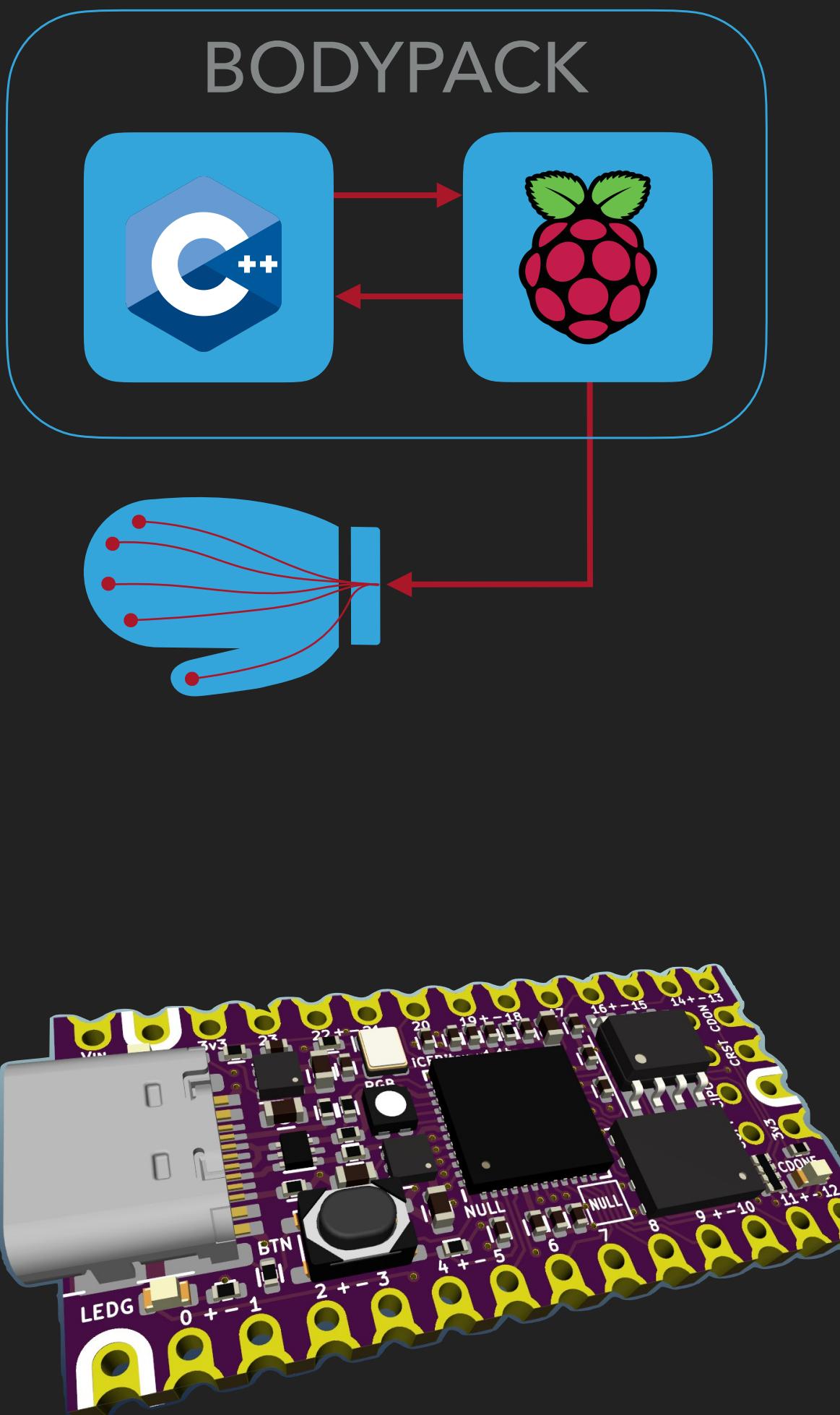
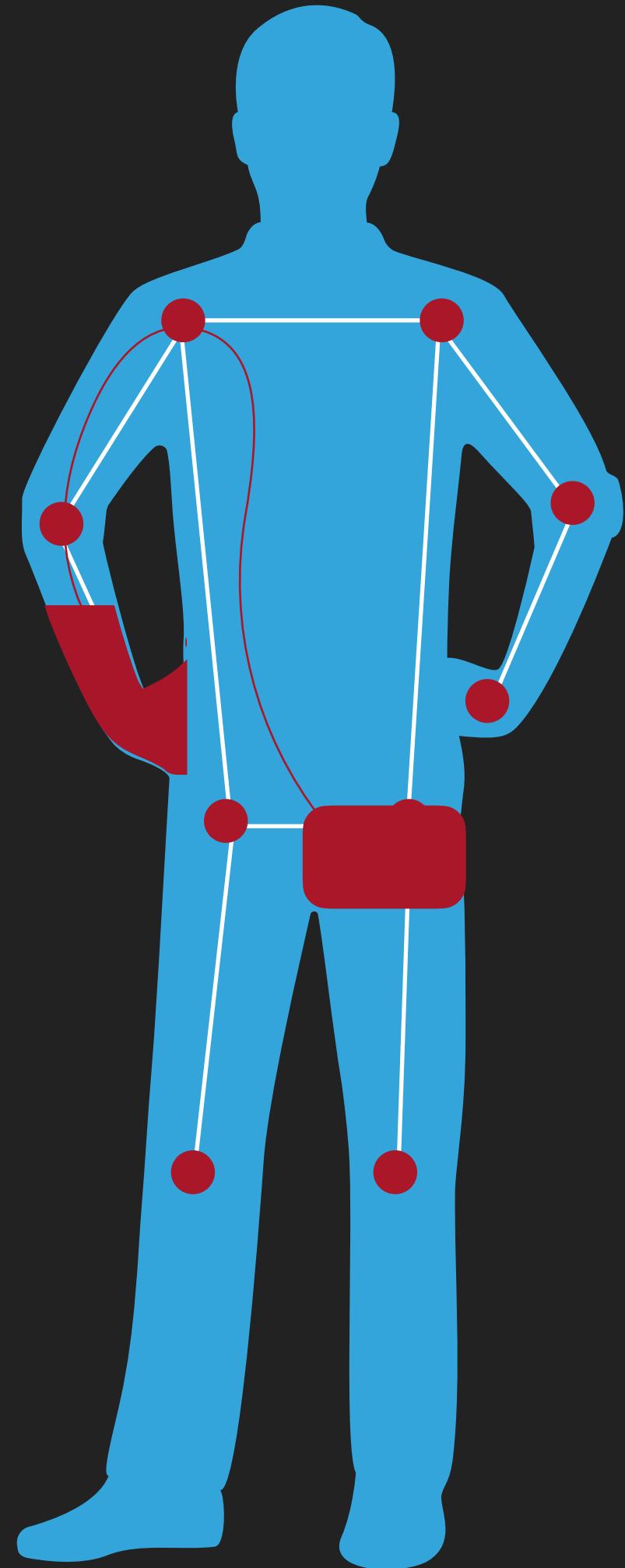
SOLUTION:
RE-IMPLEMENTATION OF THE FIRMWARE IN C++
INSTEAD OF PYTHON

OUTPUT - BODYPACK



- ▶ RaspberryPi5 wi-fi that works as interface between the software and the actuator circuit driven by a specific firmware written in C++ due to compatibility reasons
 - ▶ Actuator integrated circuit designed in KiCad powered by a power bank able to give two types of feedback:
 - ▶ ON/OFF feedback -> On/Off MOS
 - ▶ Continuous feedback -> PWM + Low pass filter

OUTPUT - BODYPACK



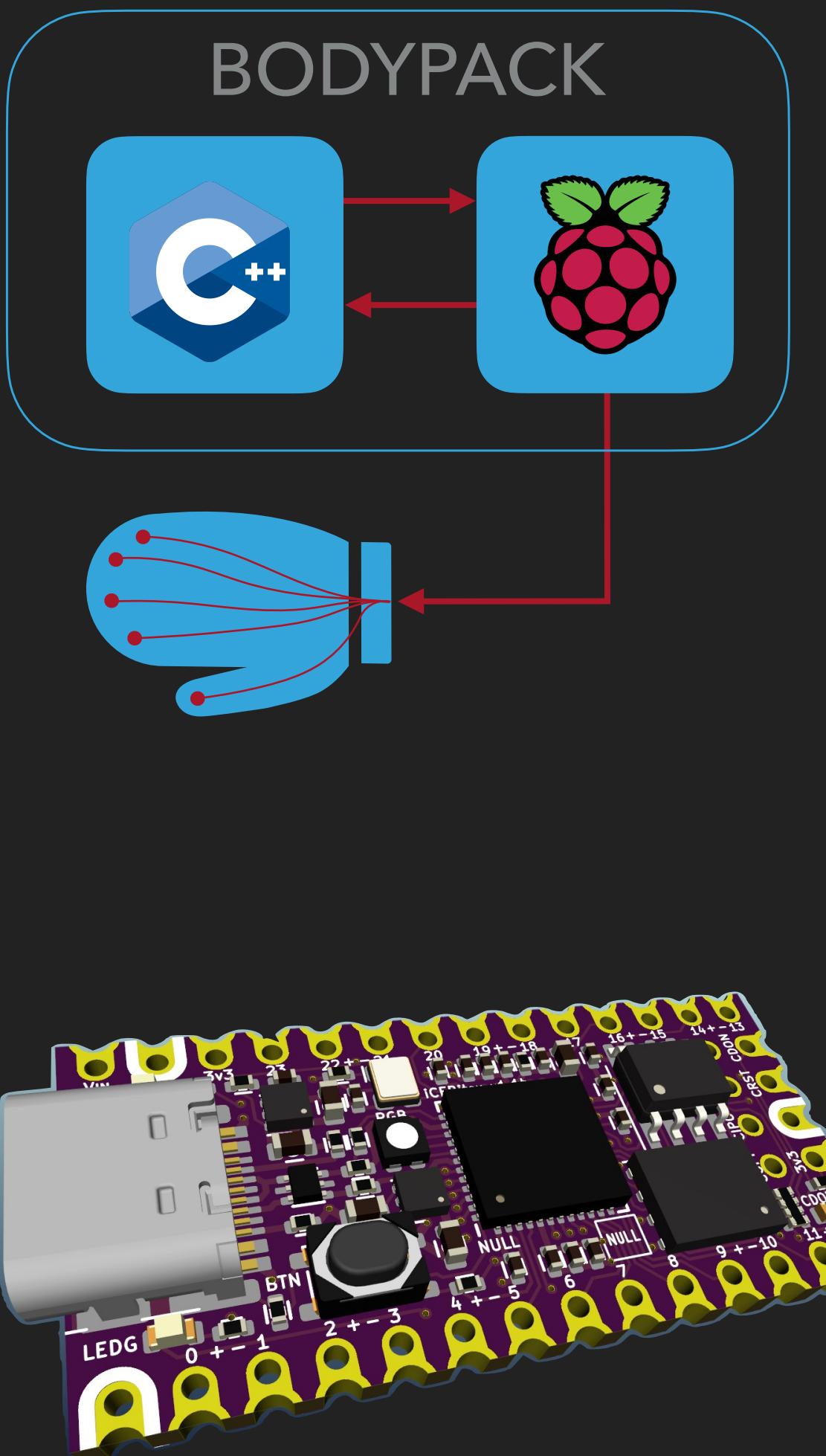
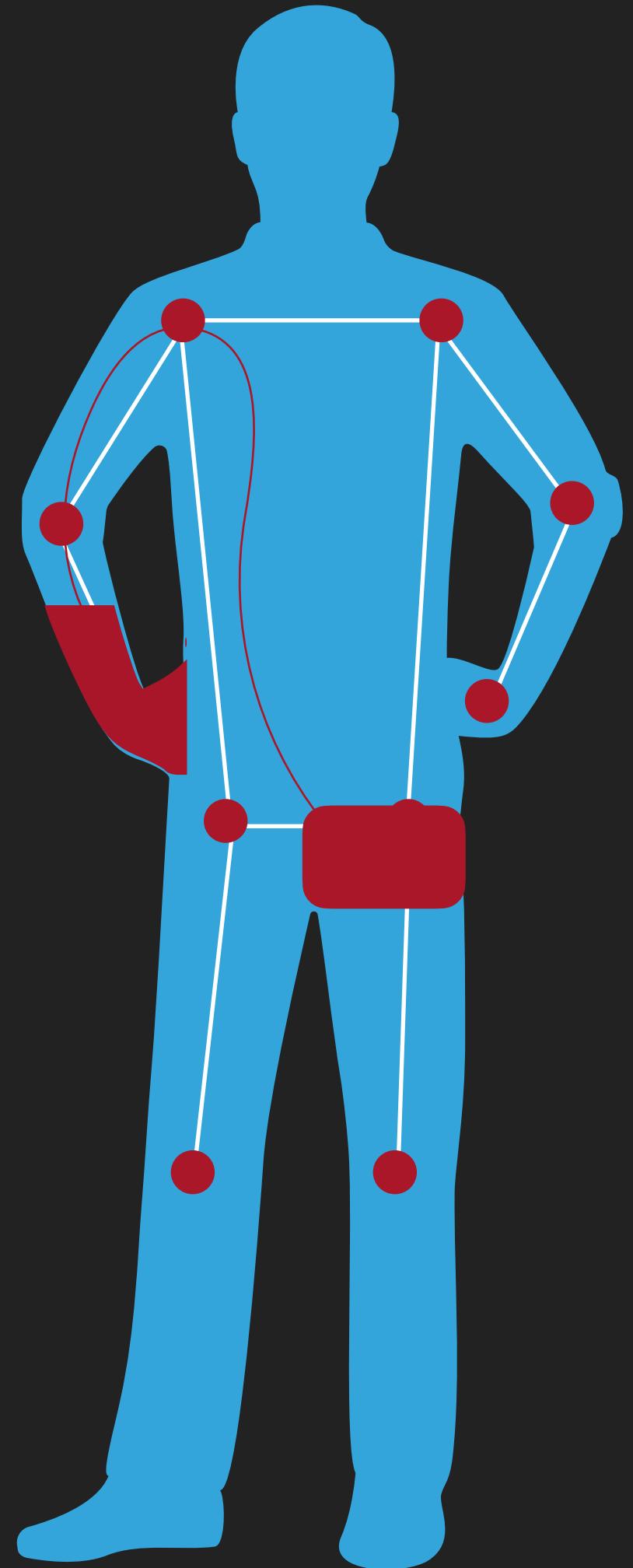
- ▶ RaspberryPi5 wi-fi that works as interface between the software and the actuator circuit driven by a specific firmware written in C++ due to compatibility reasons

- ▶ Actuator interface: interface between the RaspberryPi5 and the actuators. It is composed of two types of readbacks:

CHALLENGE:
TOO LONG SHIPPING TIME FROM CHINA TO MILAN

- ▶ ON/OFF feedback -> On/Off MOS
- ▶ Continuous feedback -> PWM + Low pass filter

OUTPUT - BODYPACK



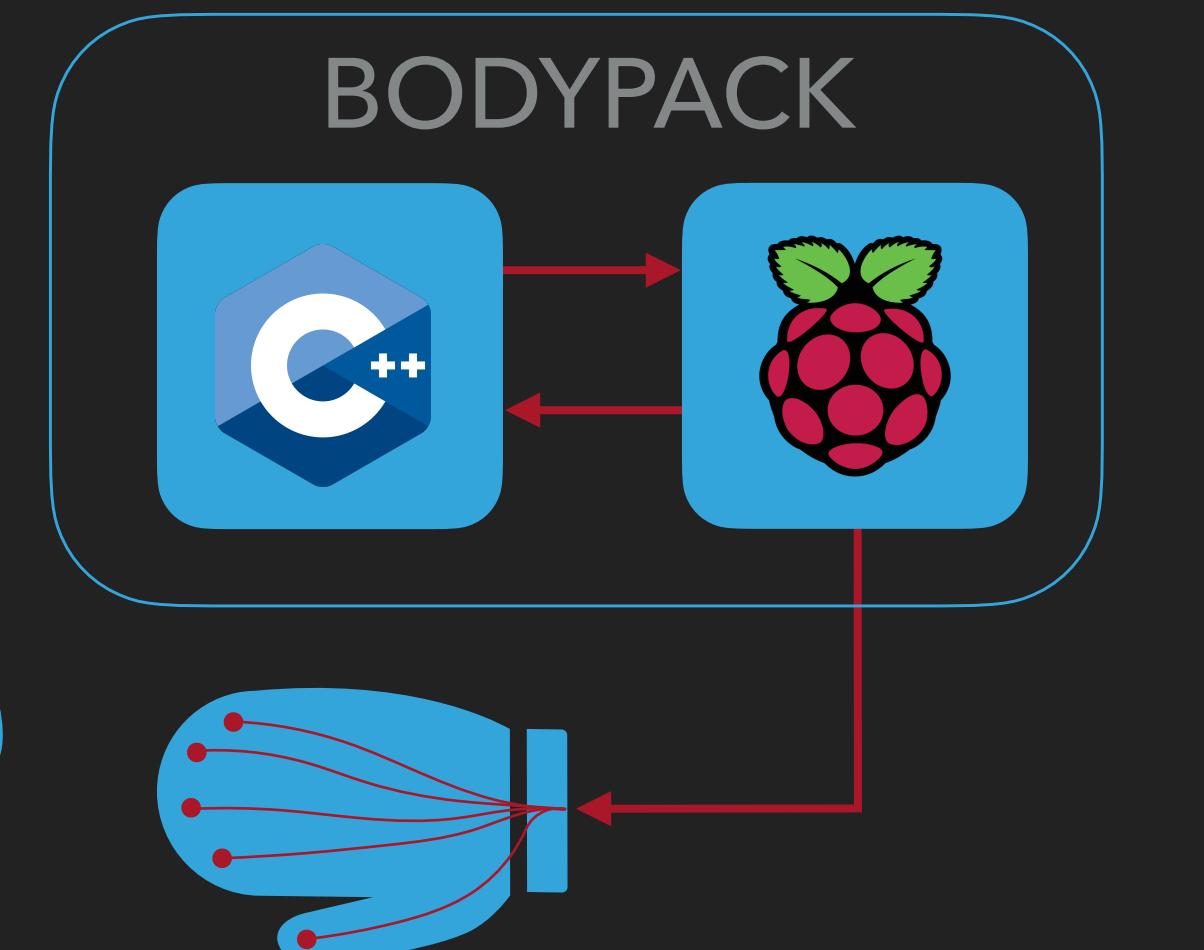
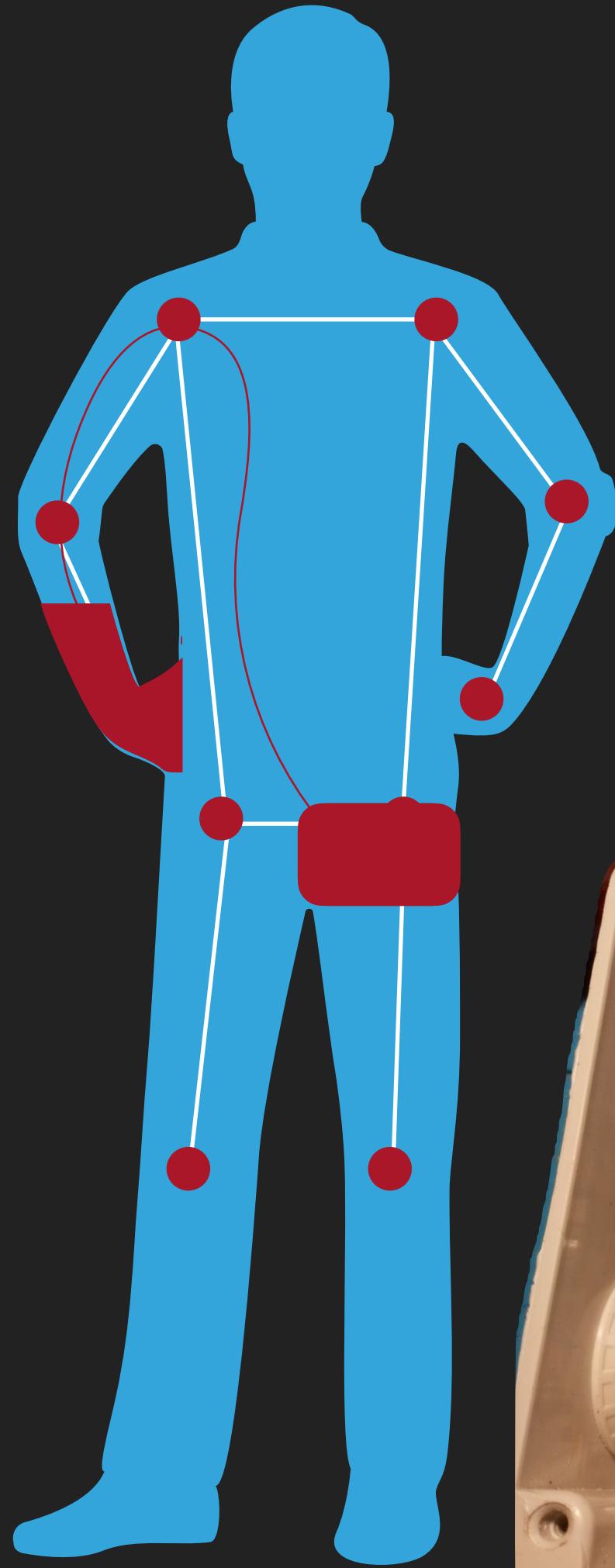
- ▶ RaspberryPi5 wi-fi that works as interface between the software and the actuator circuit driven by a specific firmware written in C++ due to compatibility reasons

- ▶ Actuator

SOLUTION:
SIMPLER CIRCUIT BASED ON RELAYS INSTEAD OF TRANSISTORS

- ▶ ON/OFF feedback -> On/Off MOS
- ▶ Continuous feedback -> PWM + Low pass filter

OUTPUT - BODYPACK



- ▶ RaspberryPi5 wi-fi that works as interface between the software and the actuator circuit driven by a specific firmware written in C++ due to compatibility reasons
- ▶ Relays-based actuator circuit powered by a power bank able to give two types of feedback:
 - ▶ ON/OFF feedback -> On/Off MOS
 - ▶ Continuous feedback -> PWM + Low pass filter

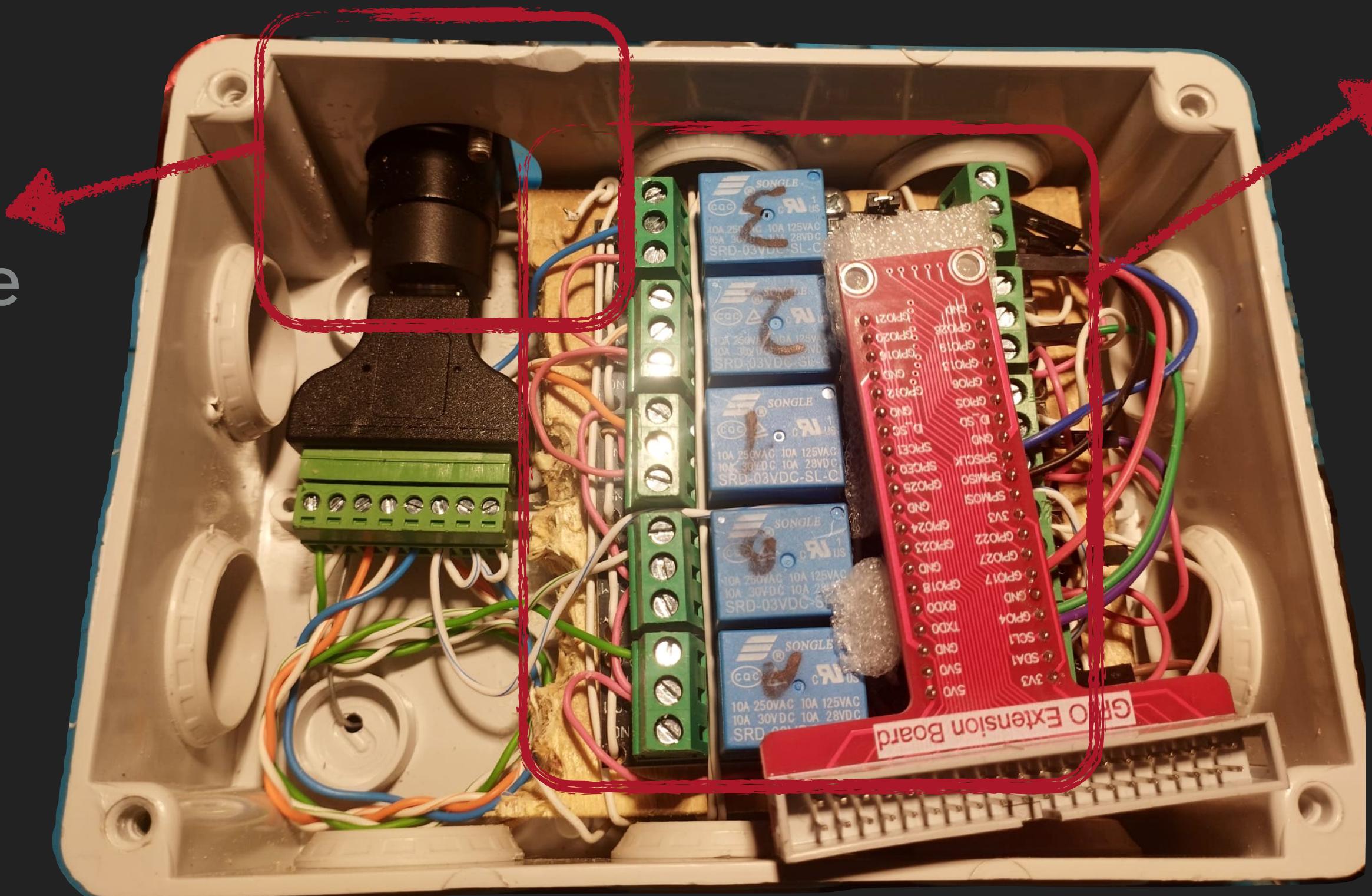
FLOWVISION

OUTPUT - CIRCUIT

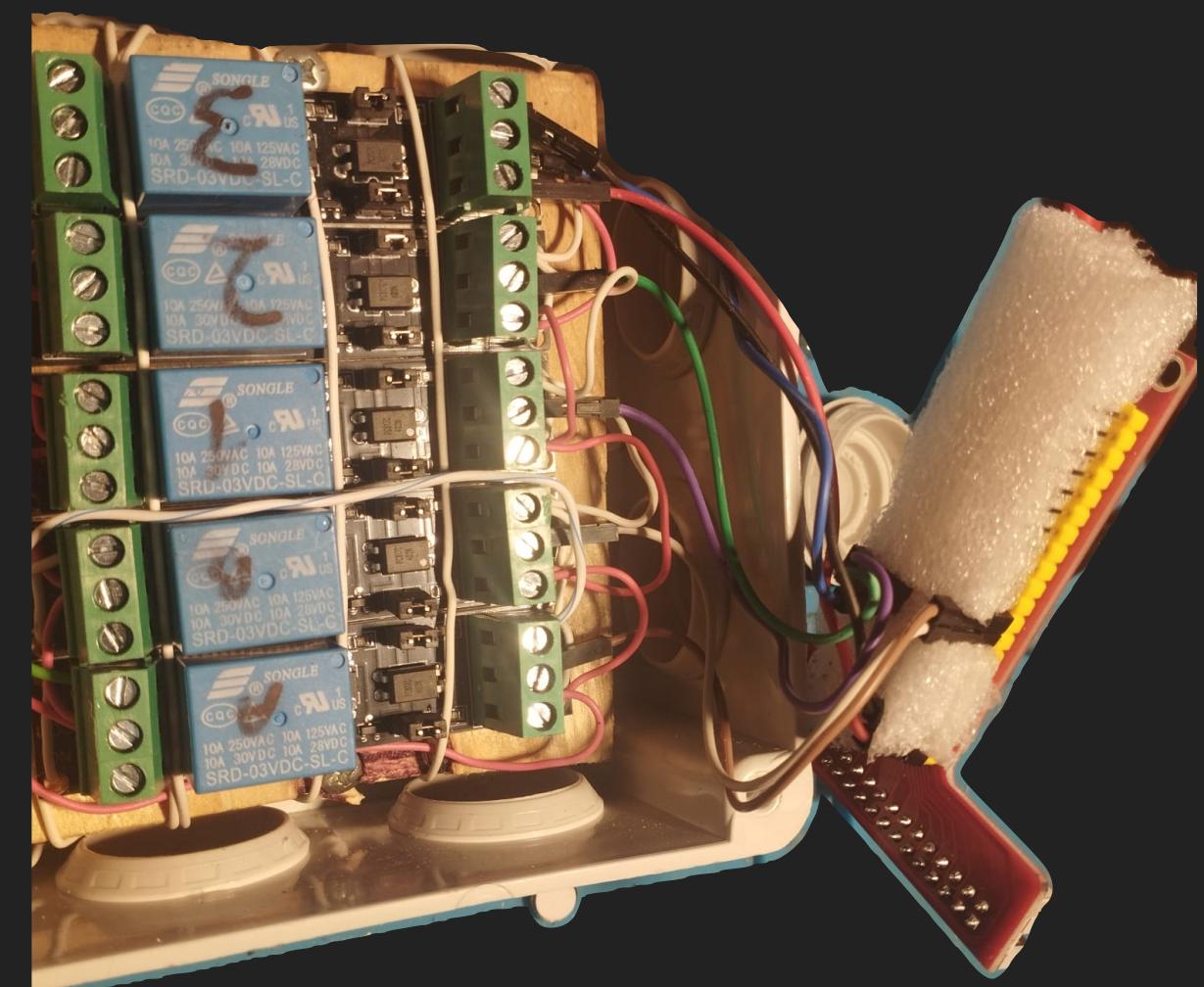


OUTPUT - CIRCUIT

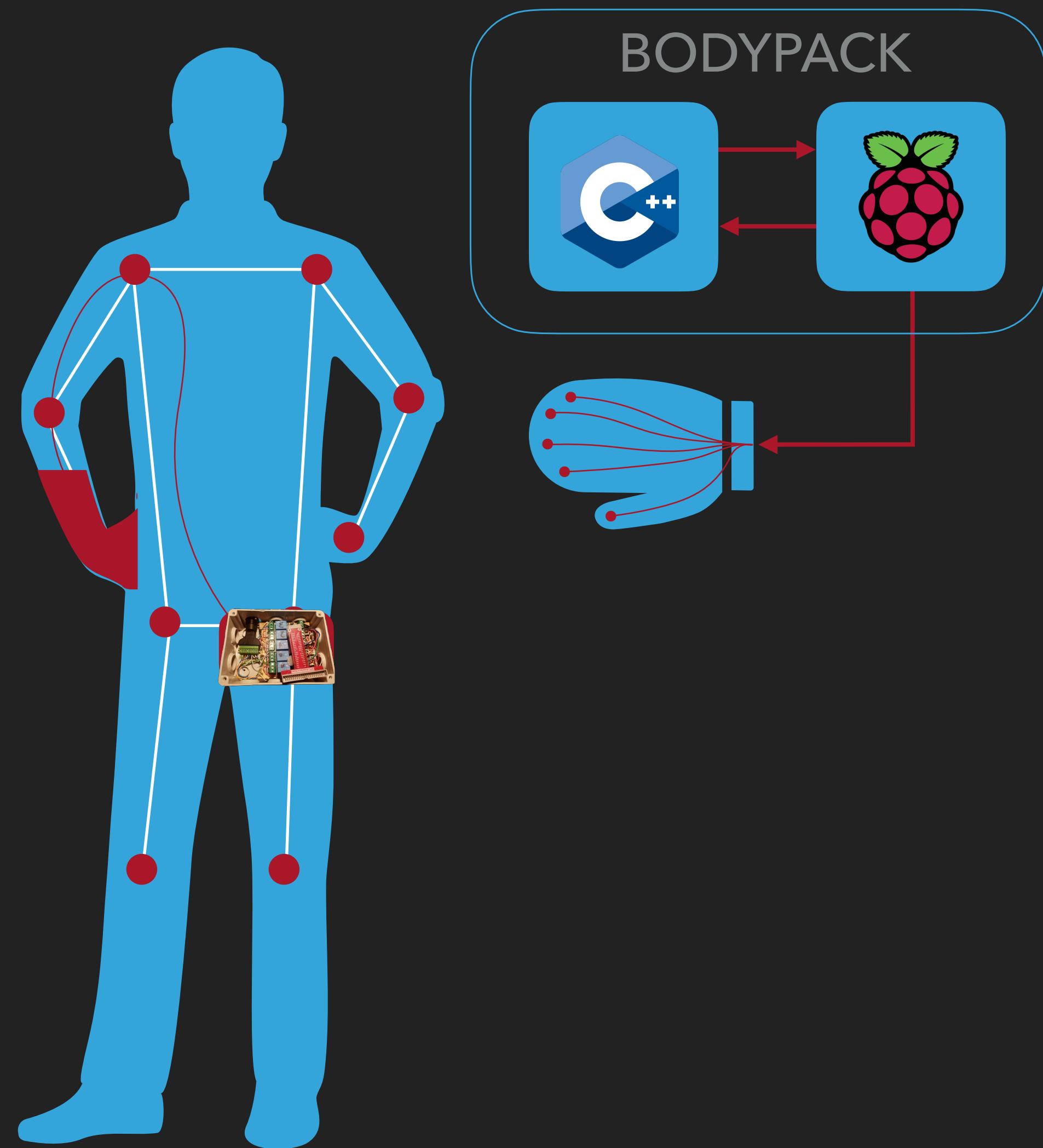
Ethernet socket to have a quick and comfortable plug for the glove



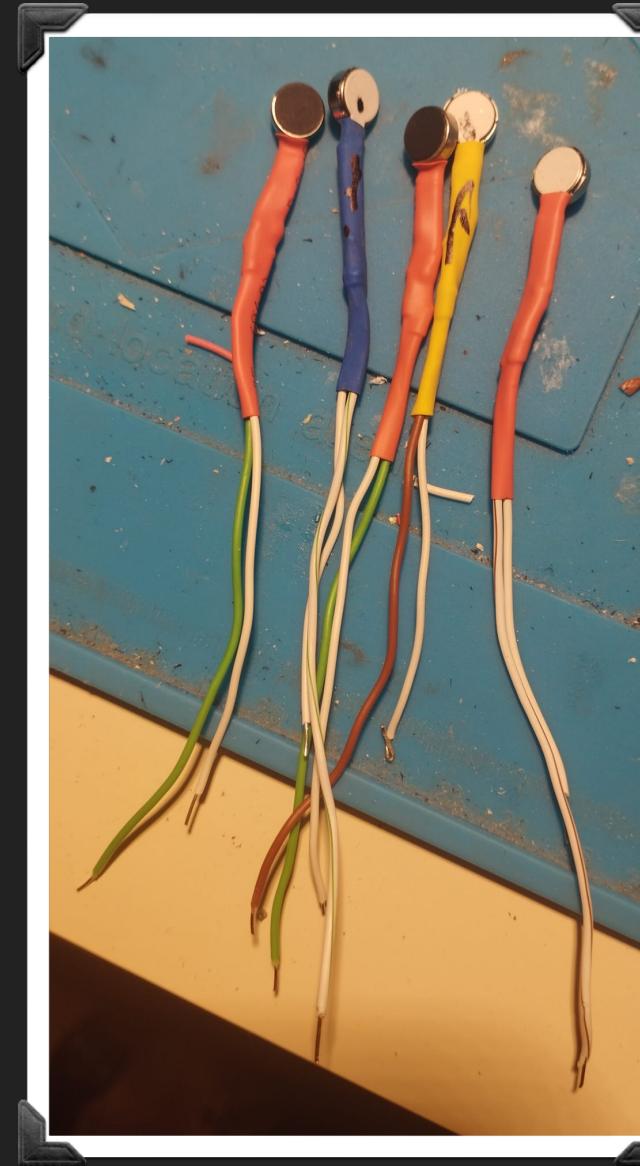
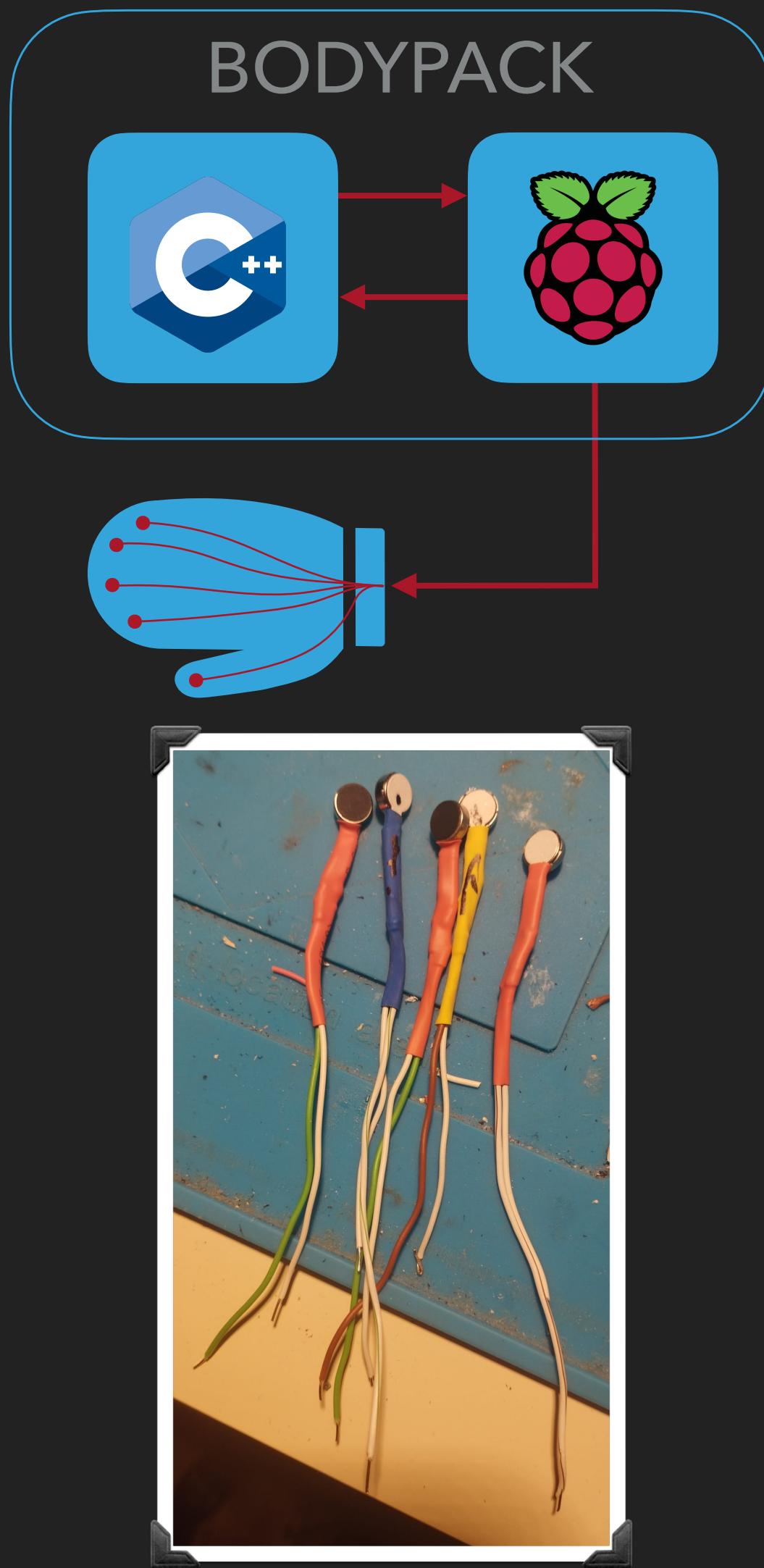
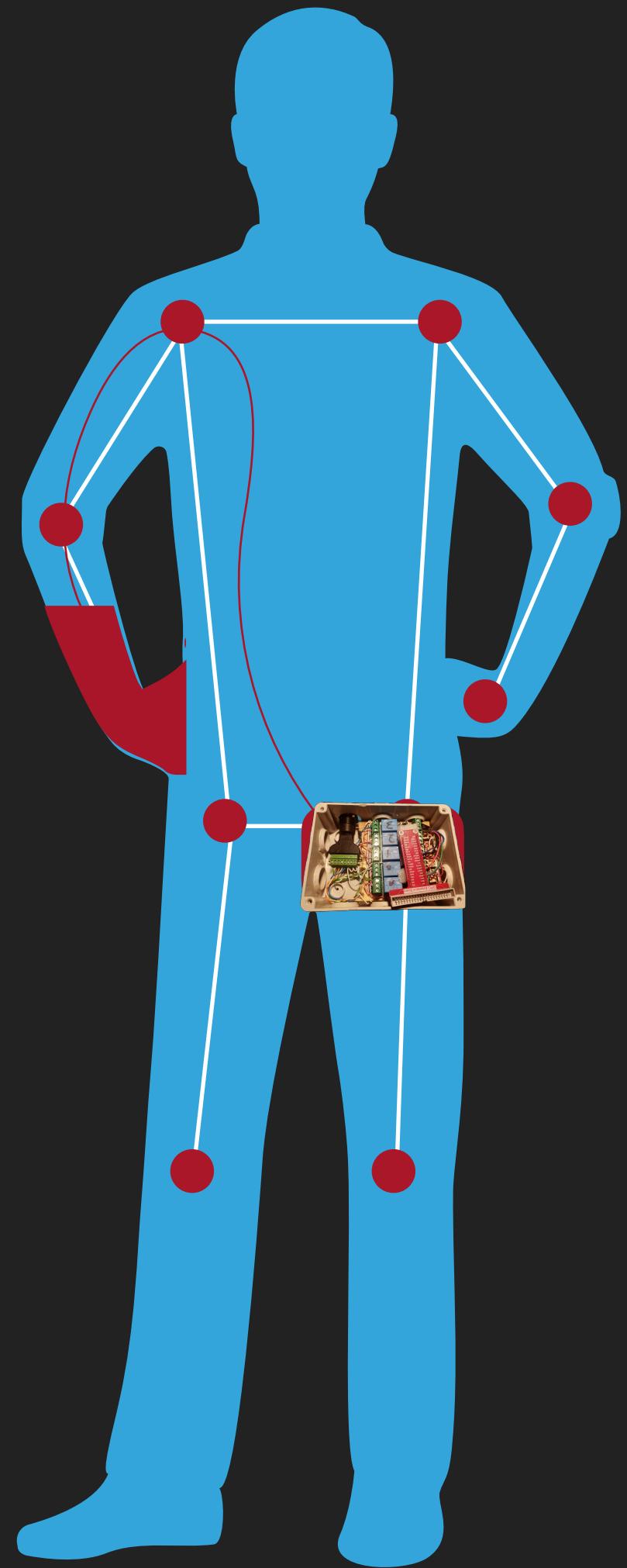
Five relays
connected to the
GPIO interface of
the Raspberry Pi to
control the actuators
of the glove



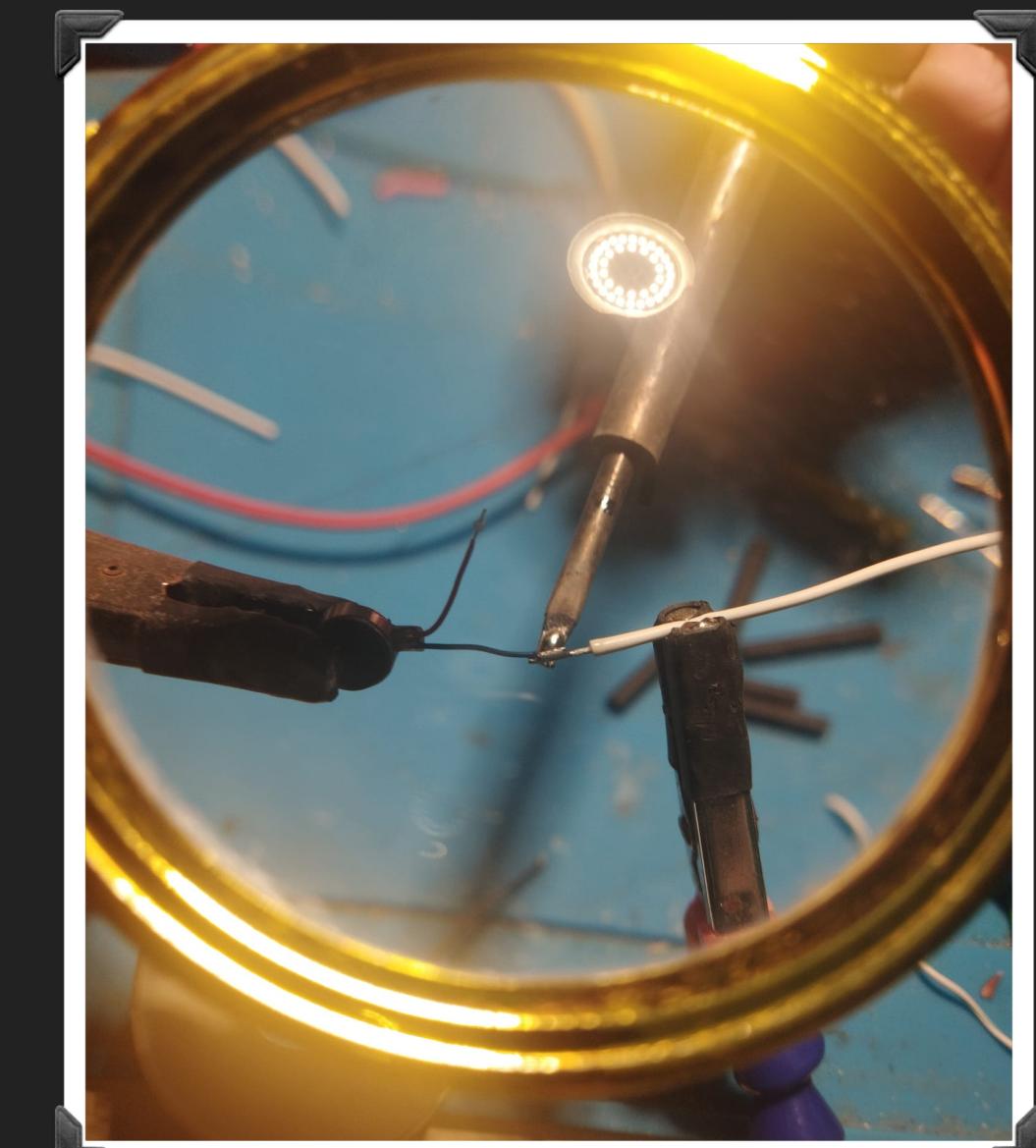
OUTPUT - GLOVE



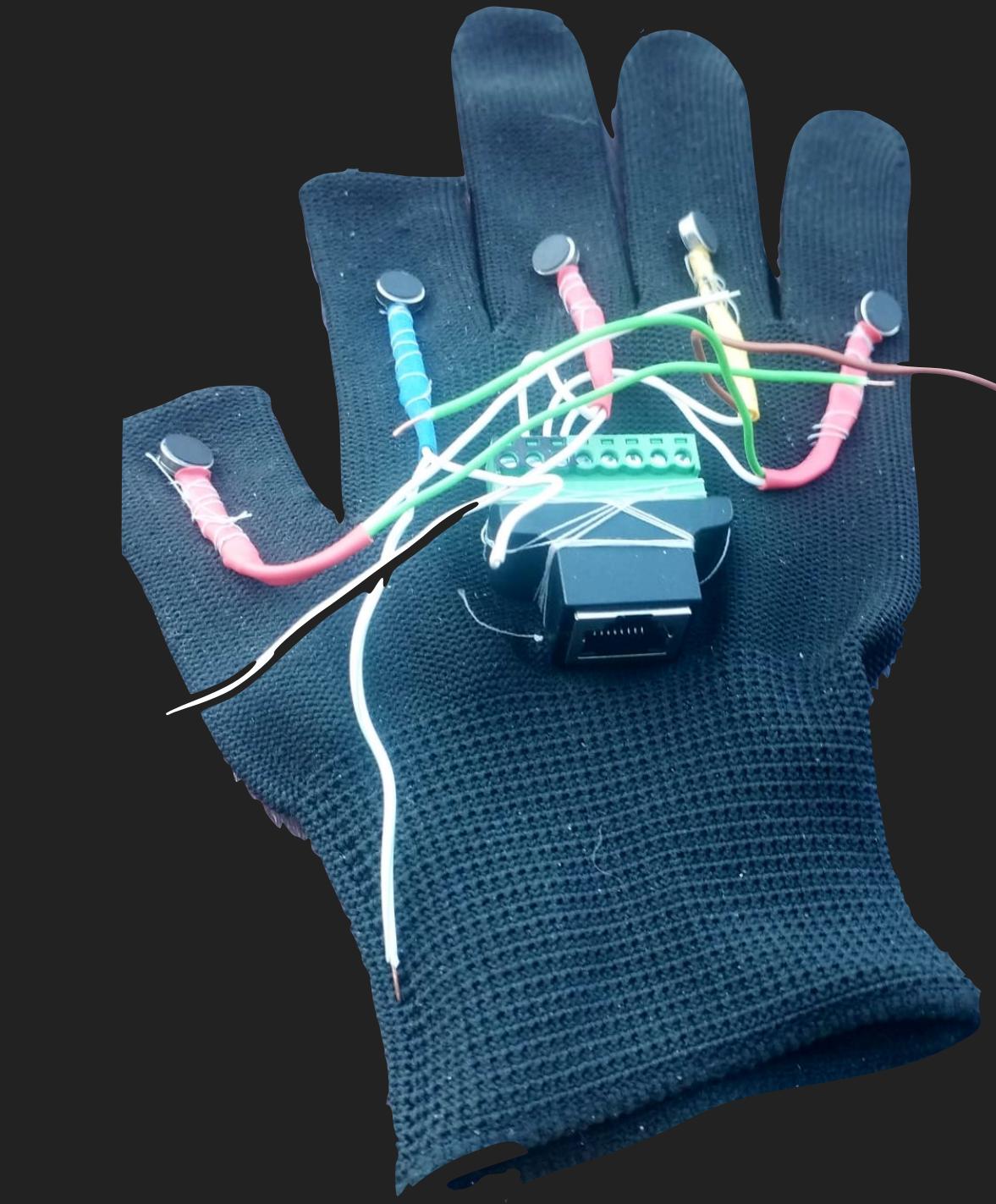
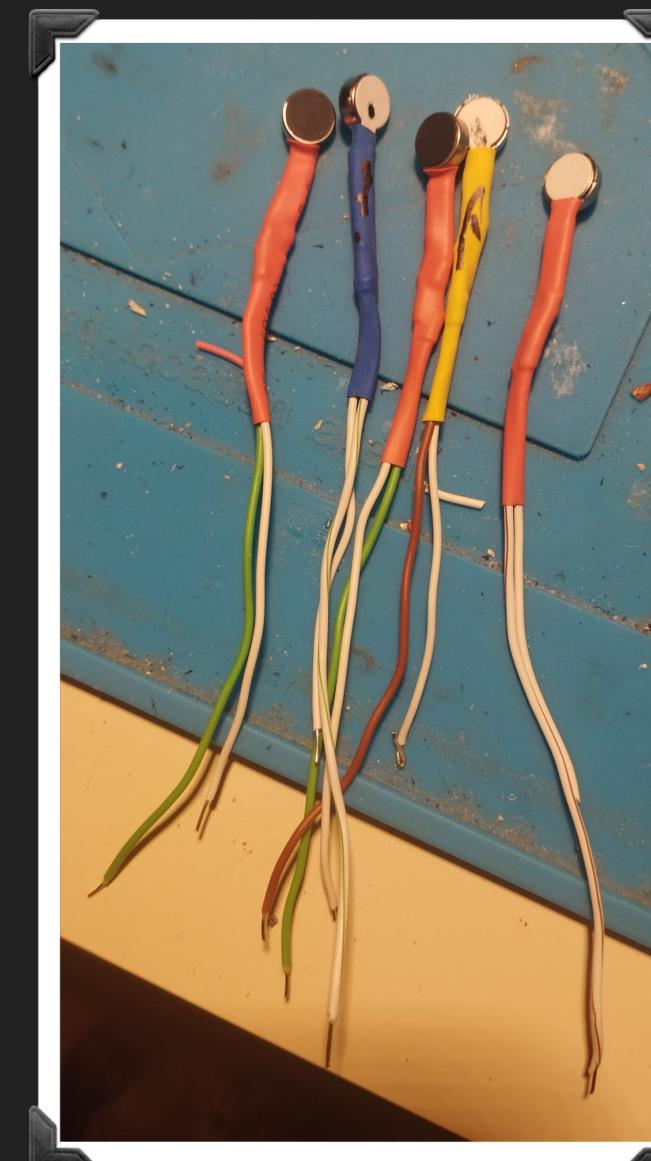
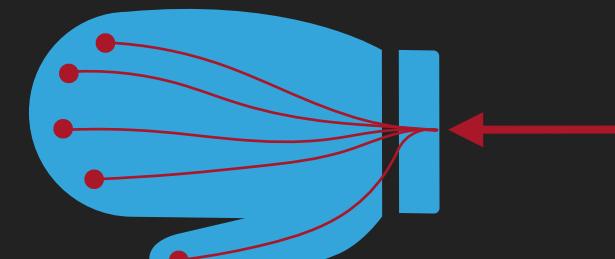
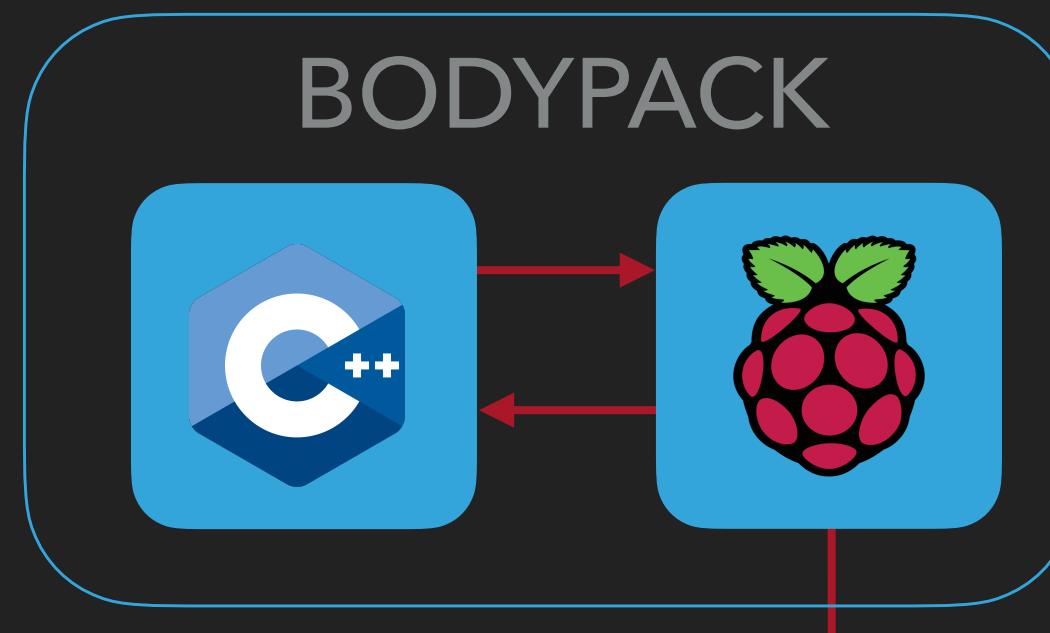
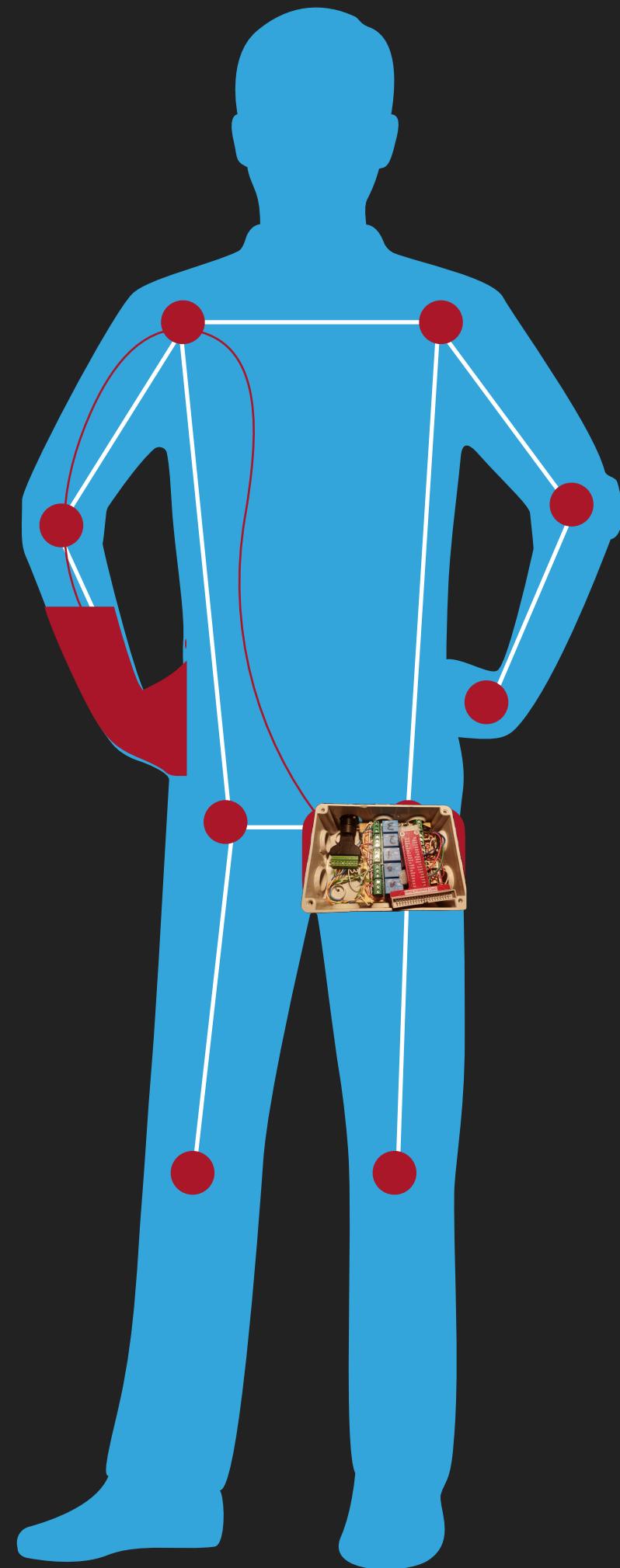
OUTPUT - GLOVE



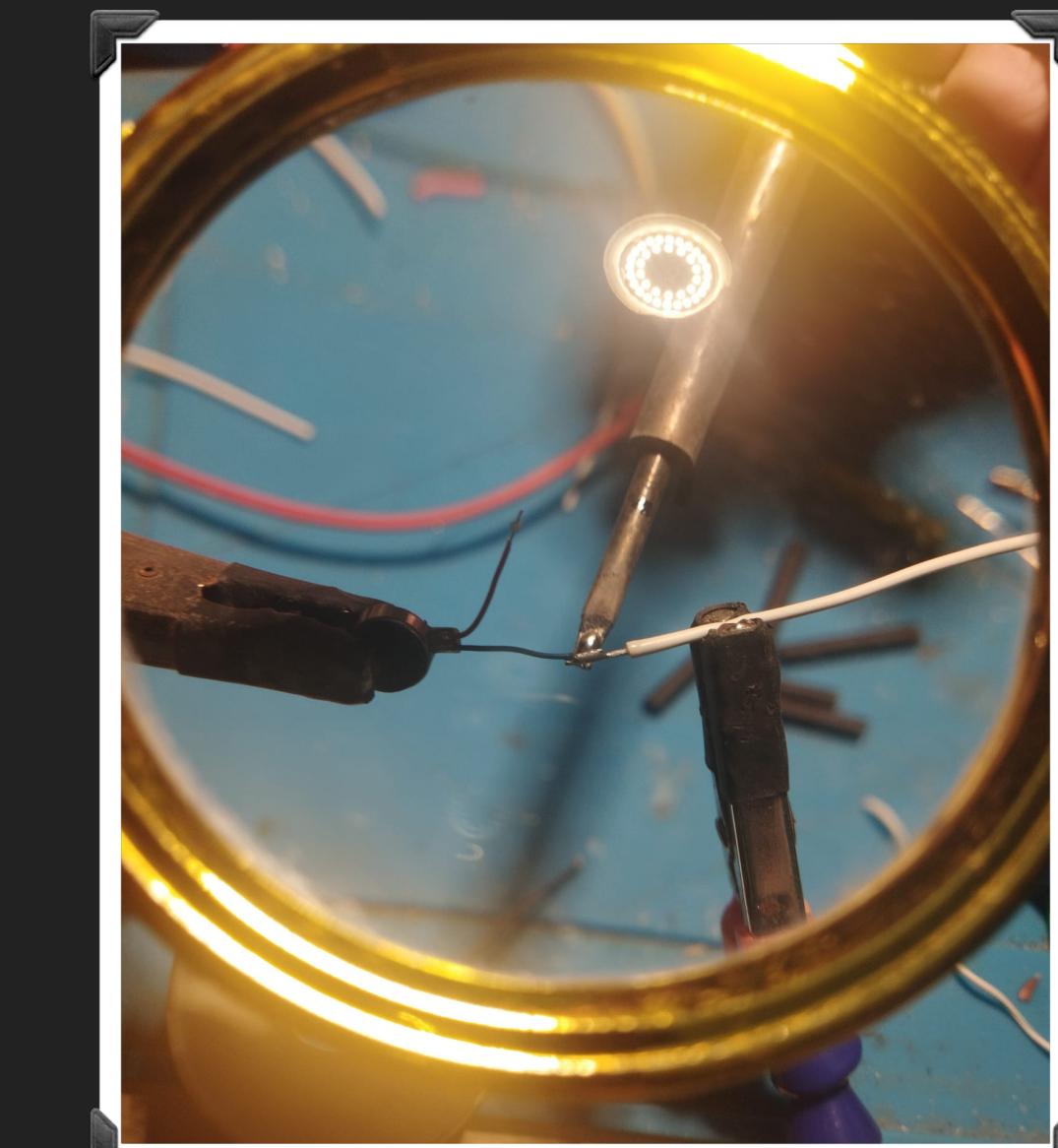
- ▶ Haptic feedback given by vibrating actuators placed on the fingers of a glove working at 3.3V



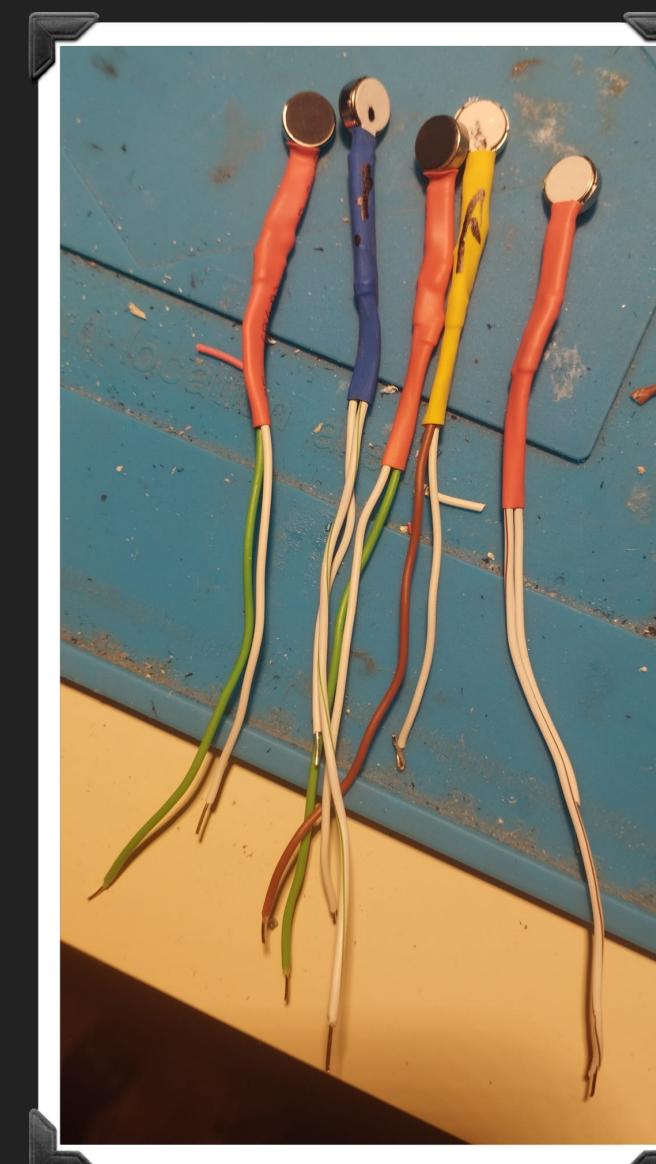
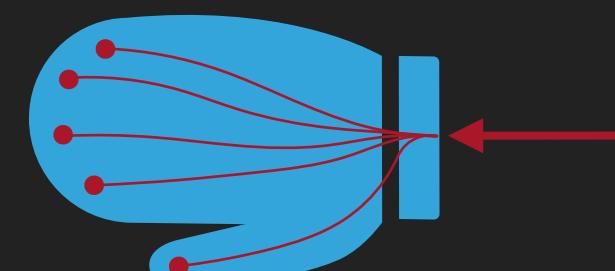
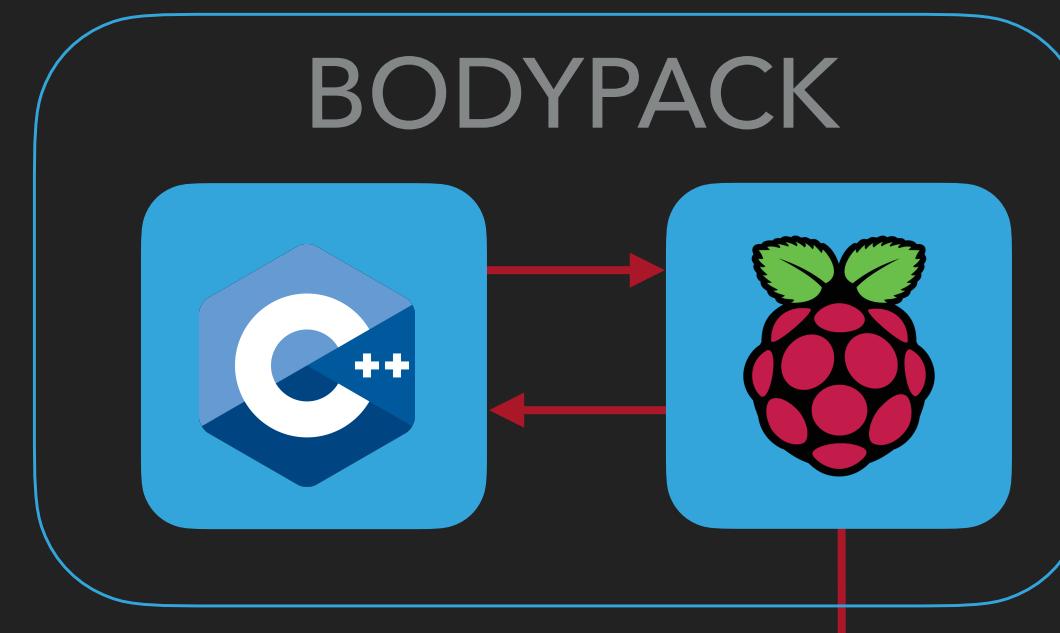
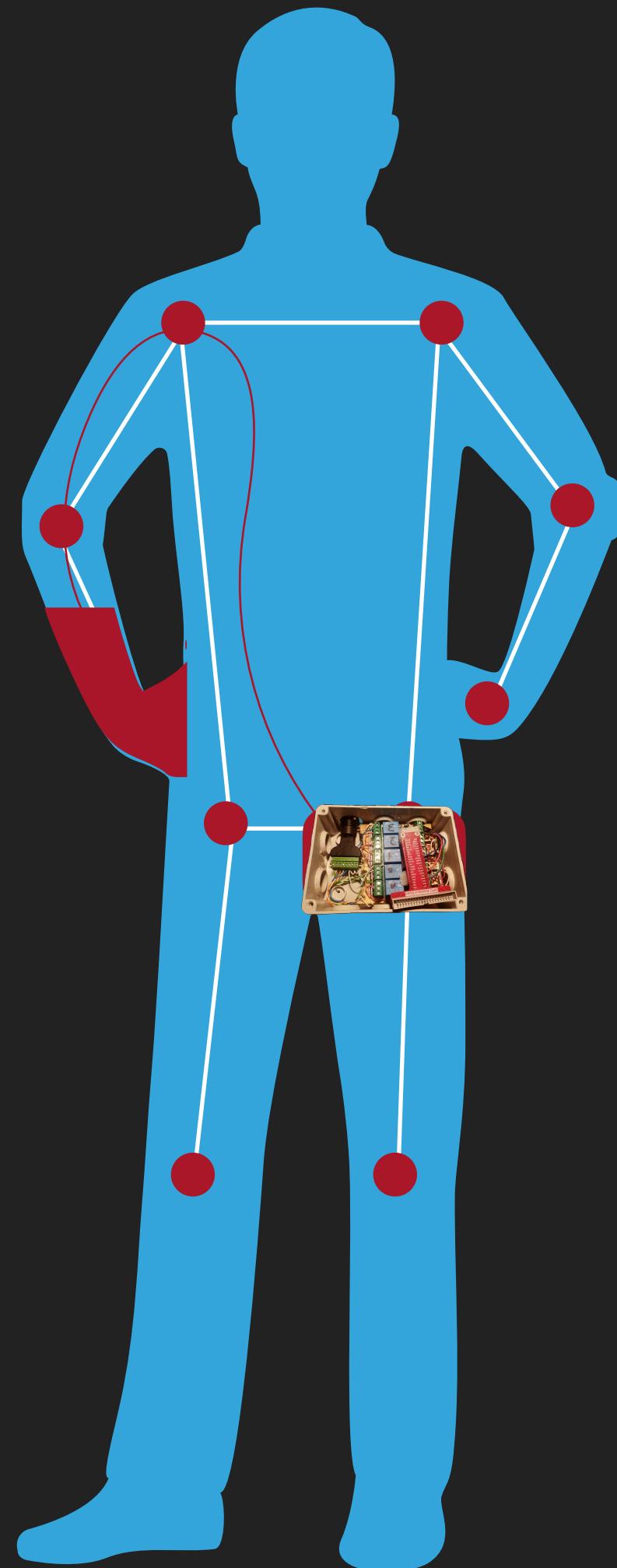
OUTPUT - GLOVE



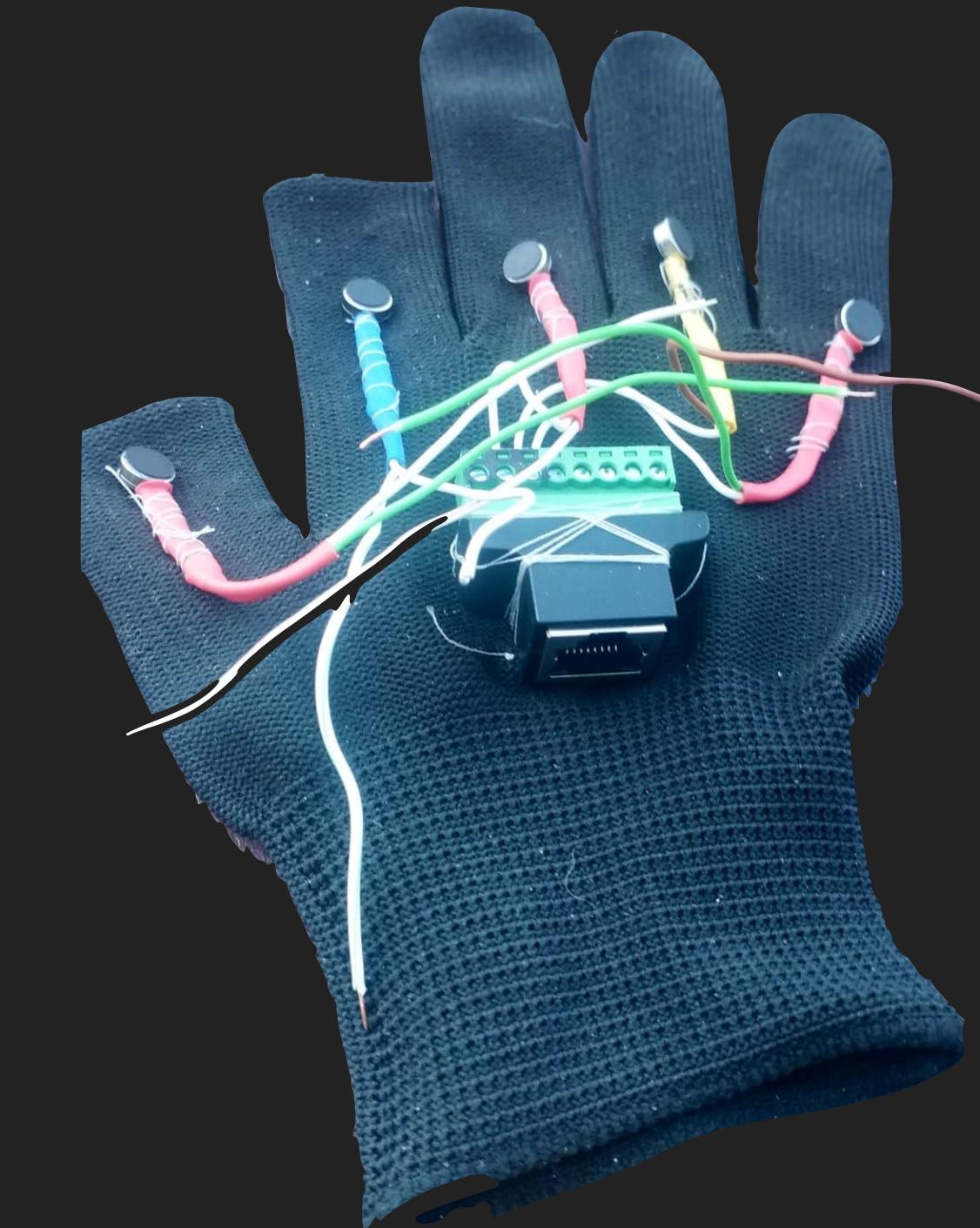
- ▶ Haptic feedback given by vibrating actuators placed on the fingers of a glove working at 3.3V
- ▶ Installation of an ethernet socket to have a quick and comfort plug



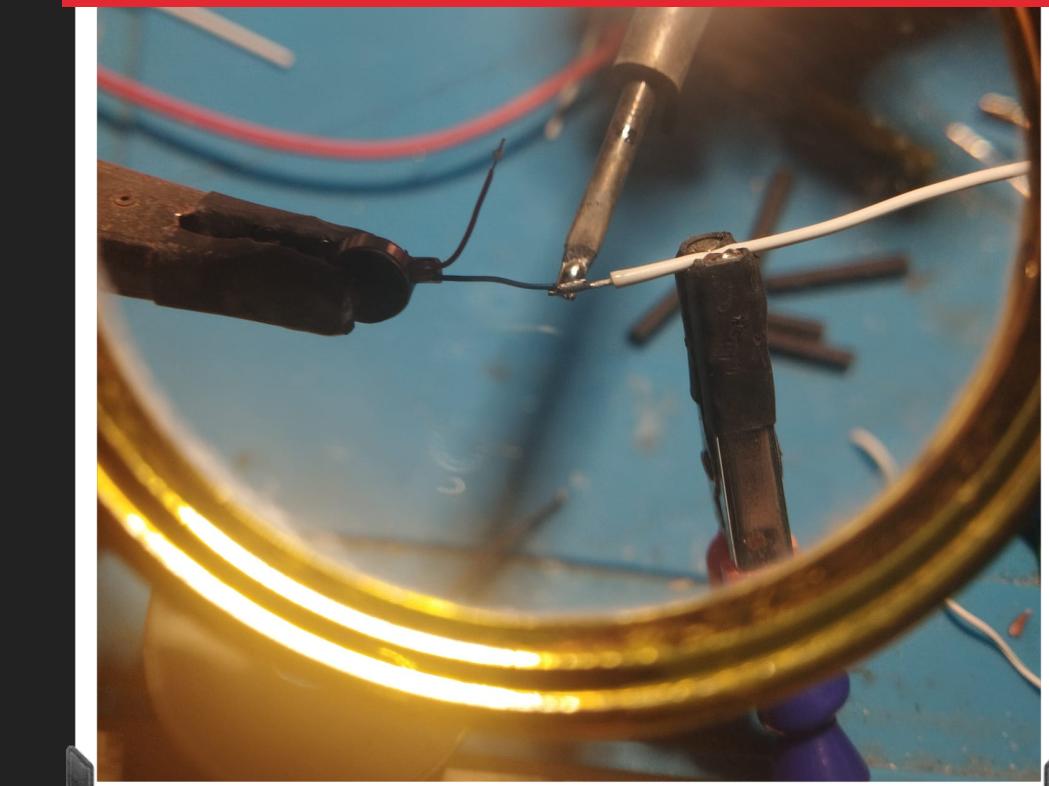
OUTPUT - GLOVE



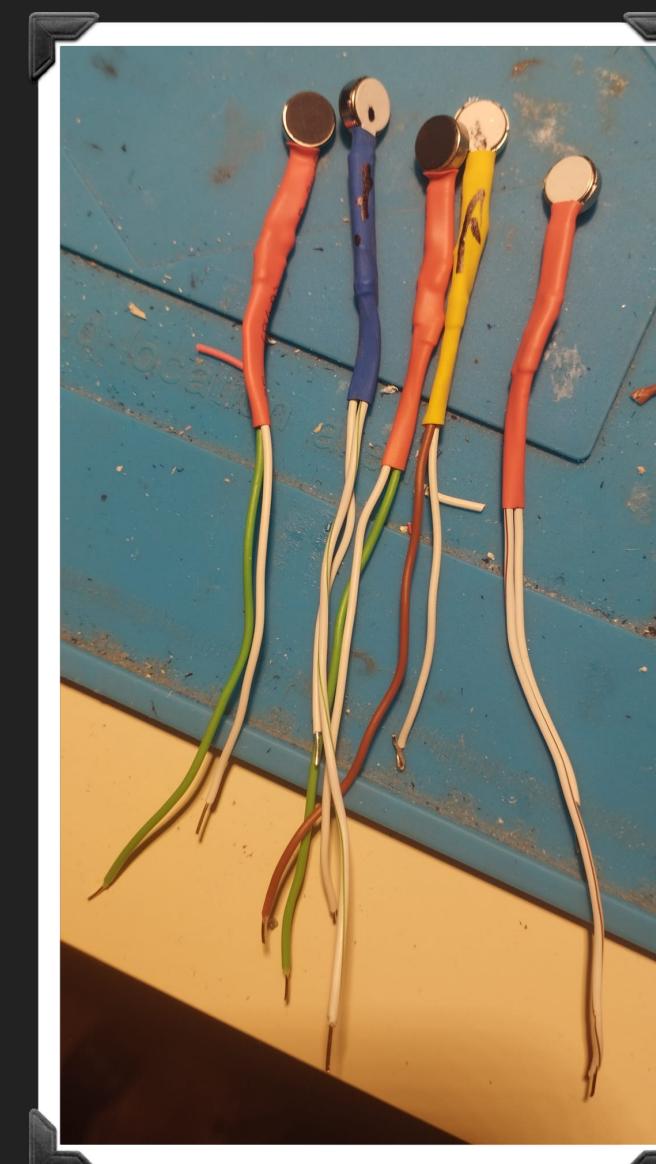
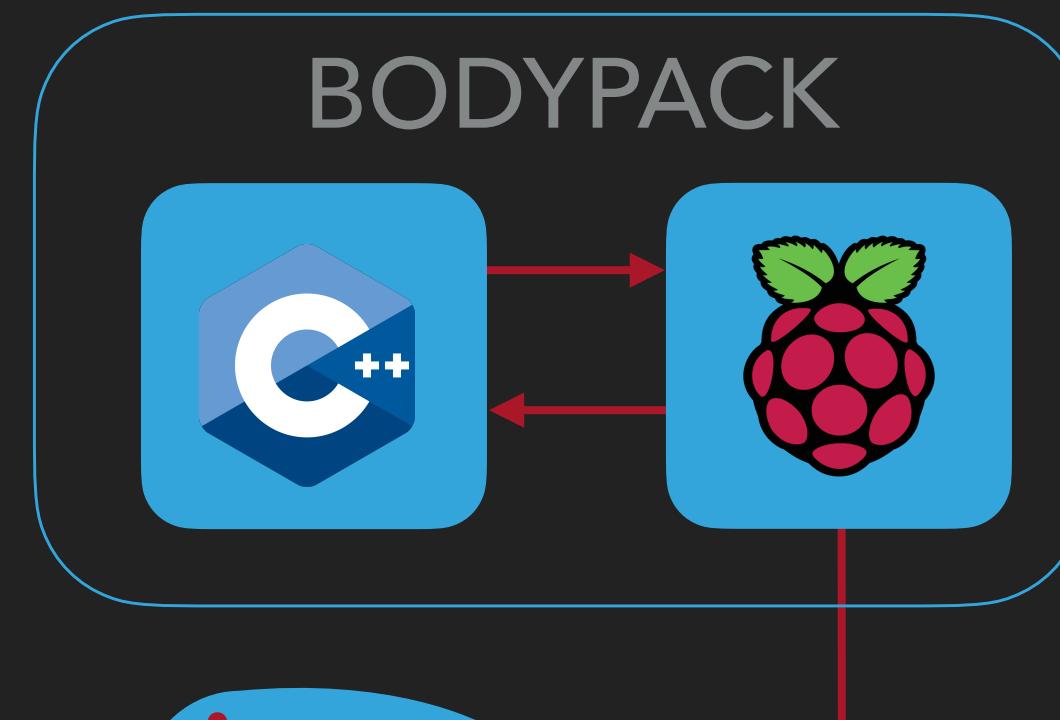
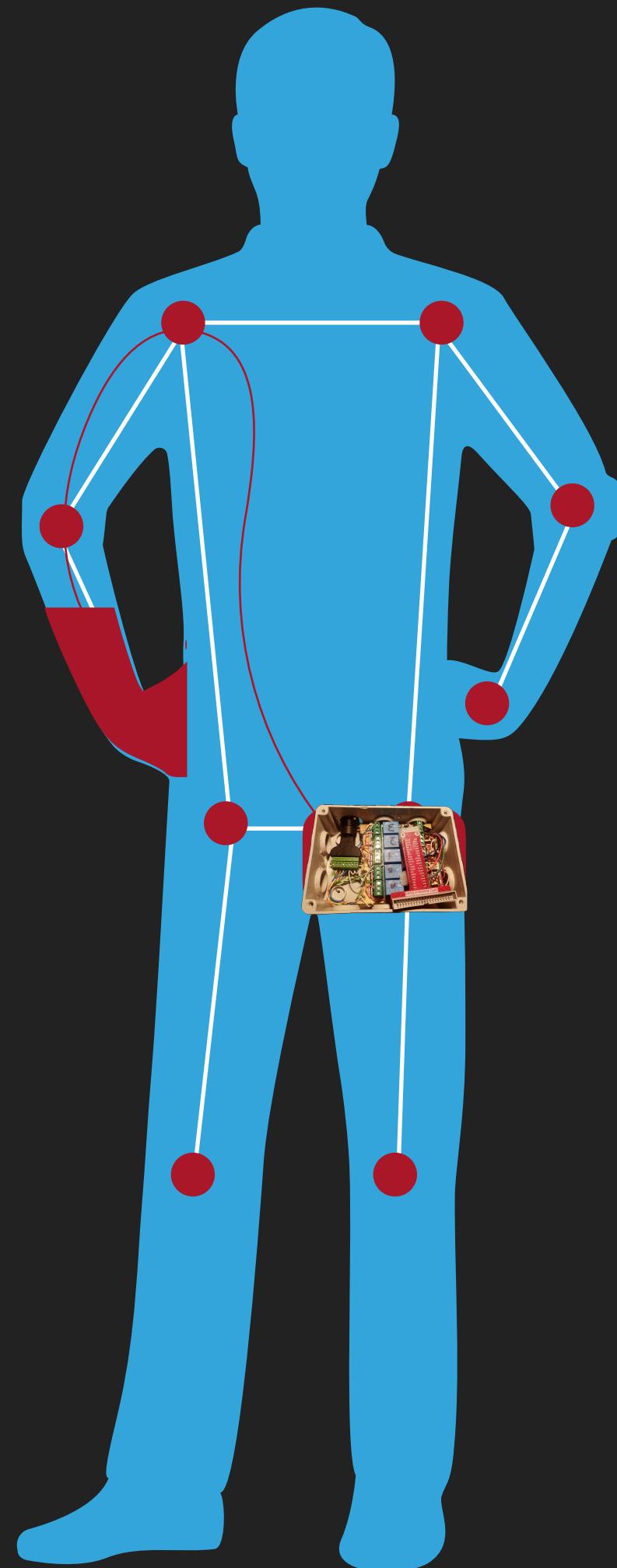
- ▶ Haptic feedback given by vibrating actuators placed on the fingers of a glove working at 3.3V
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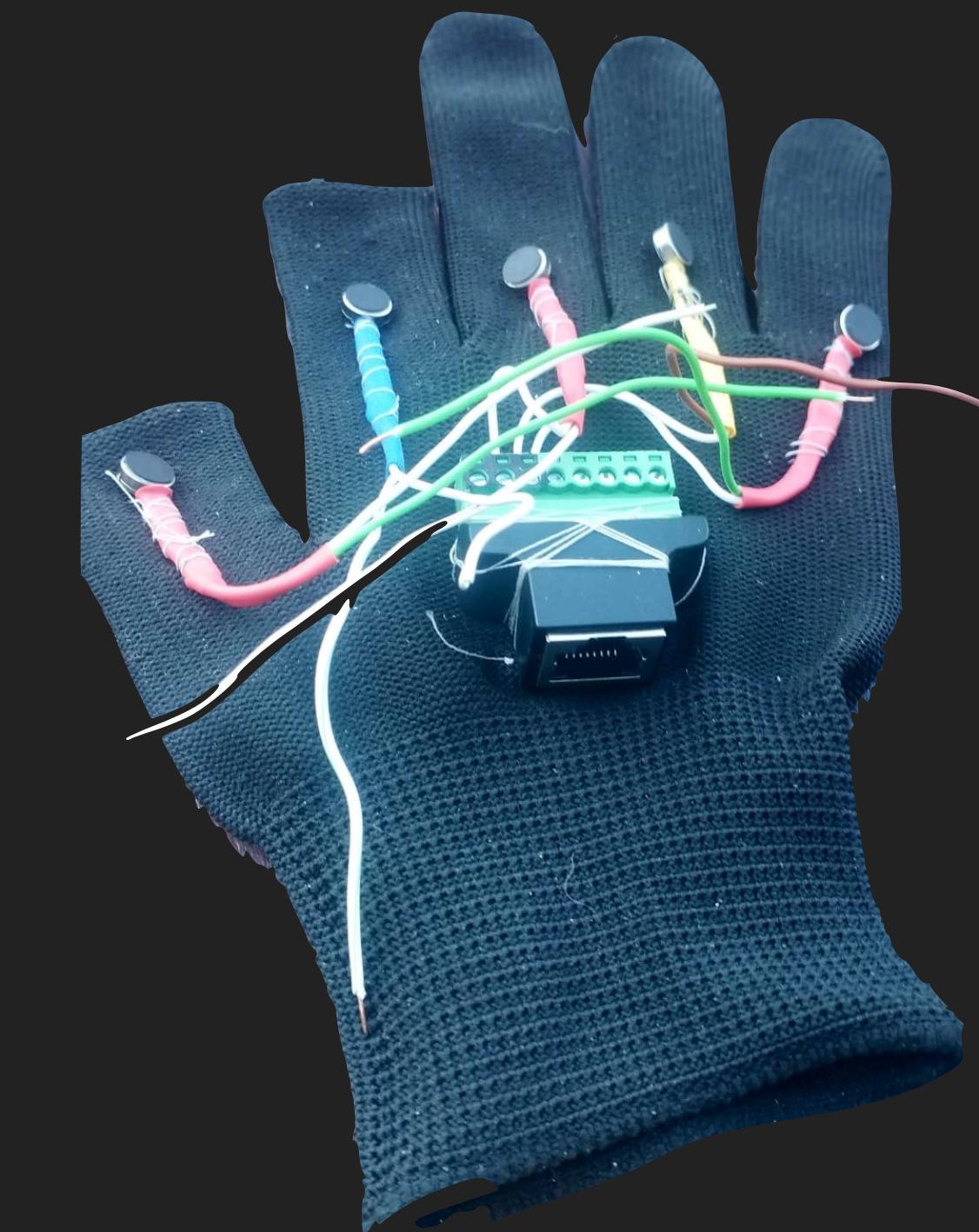
CHALLENGE:
EXTREMELY THIN AND DELICATE WIRES FOR THE ACTUATORS



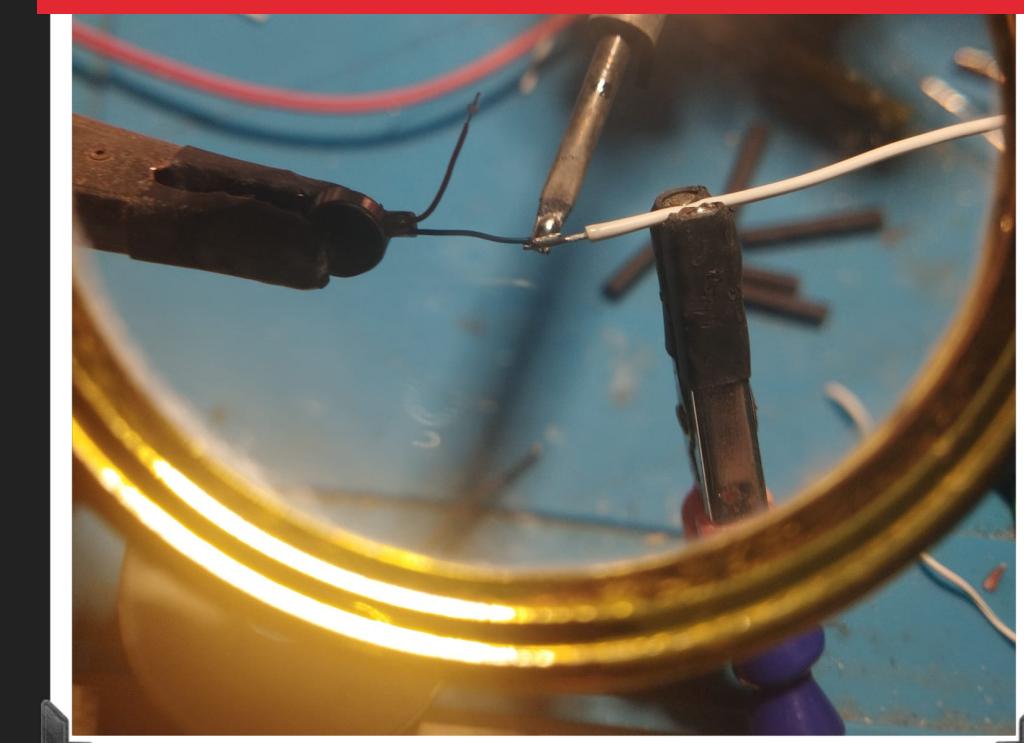
OUTPUT - GLOVE



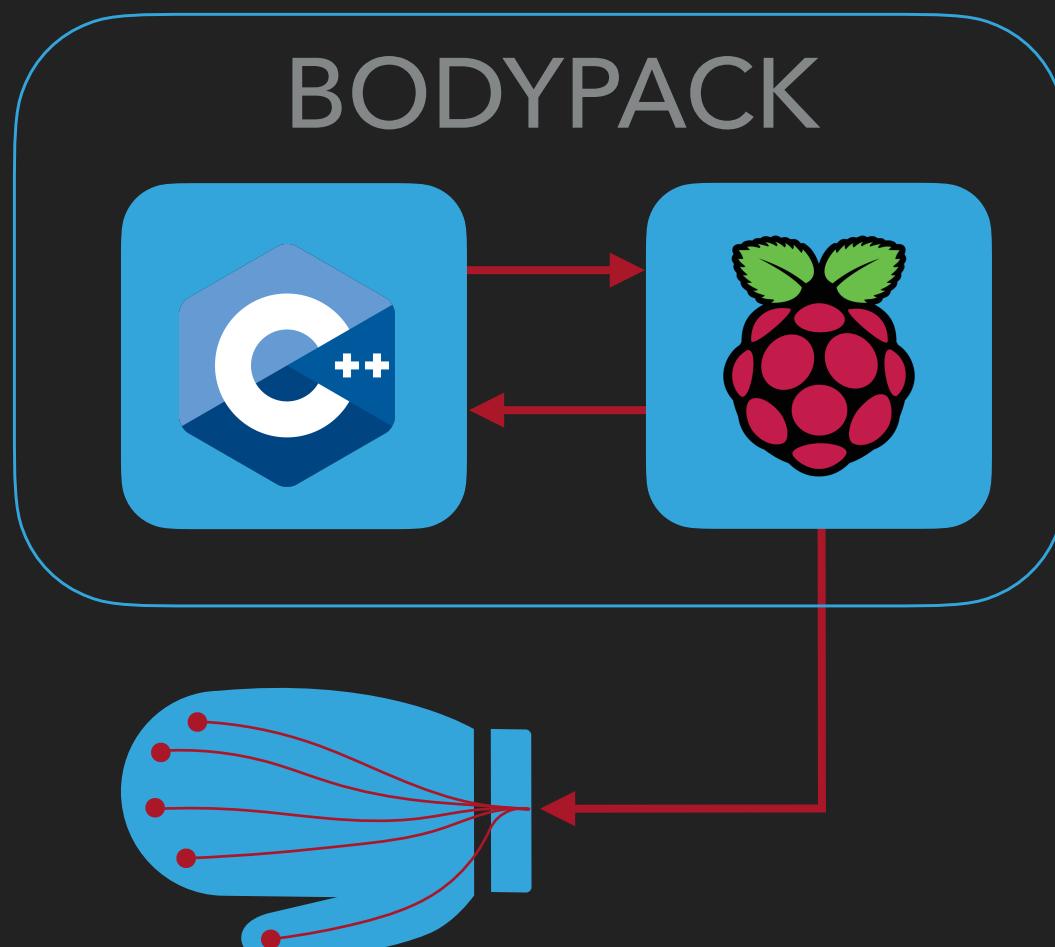
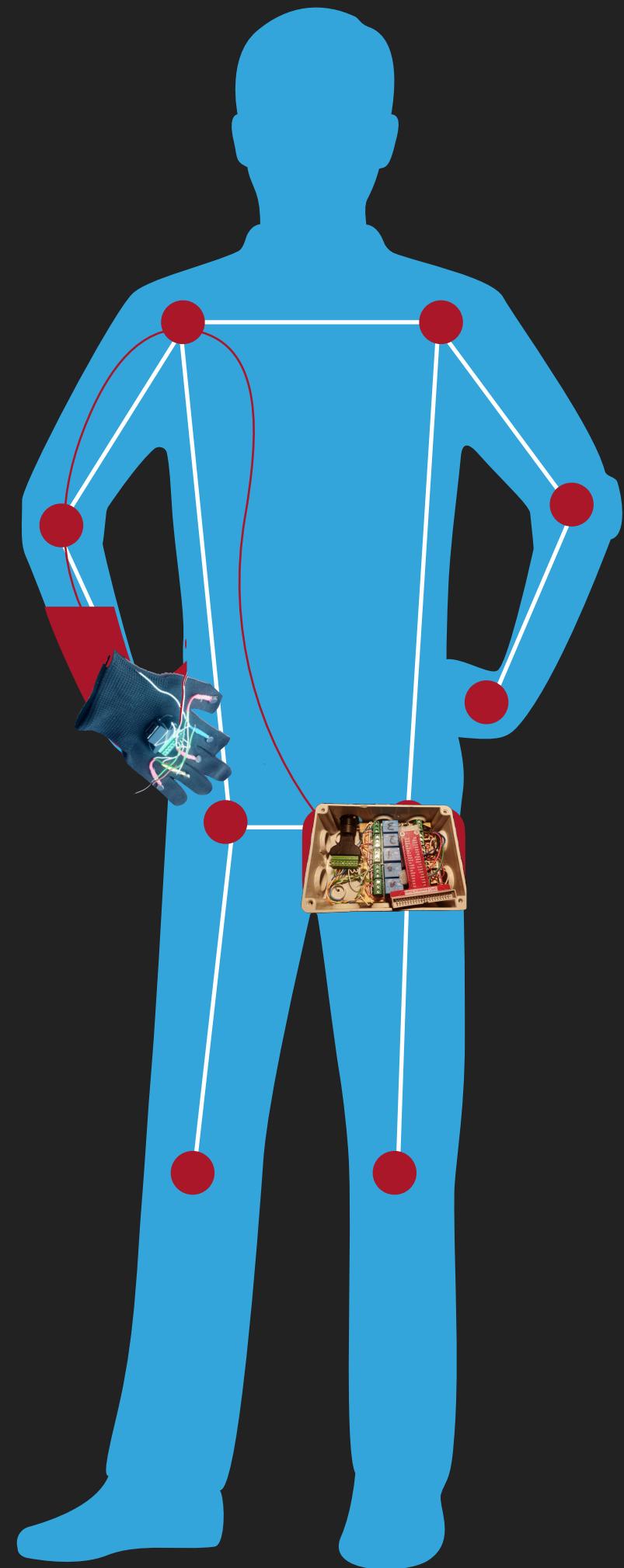
- ▶ Haptic feedback given by vibrating actuators placed on the fingers of a glove working at 3.3V
- ▶ Installation of an ethernet socket to have a quick and comfort plug



NO SOLUTION:
ONE WIRE BROKE LAST WEEK AND
THE MID FINGER ACTUATOR DOES
NOT WORK ANYMORE :(



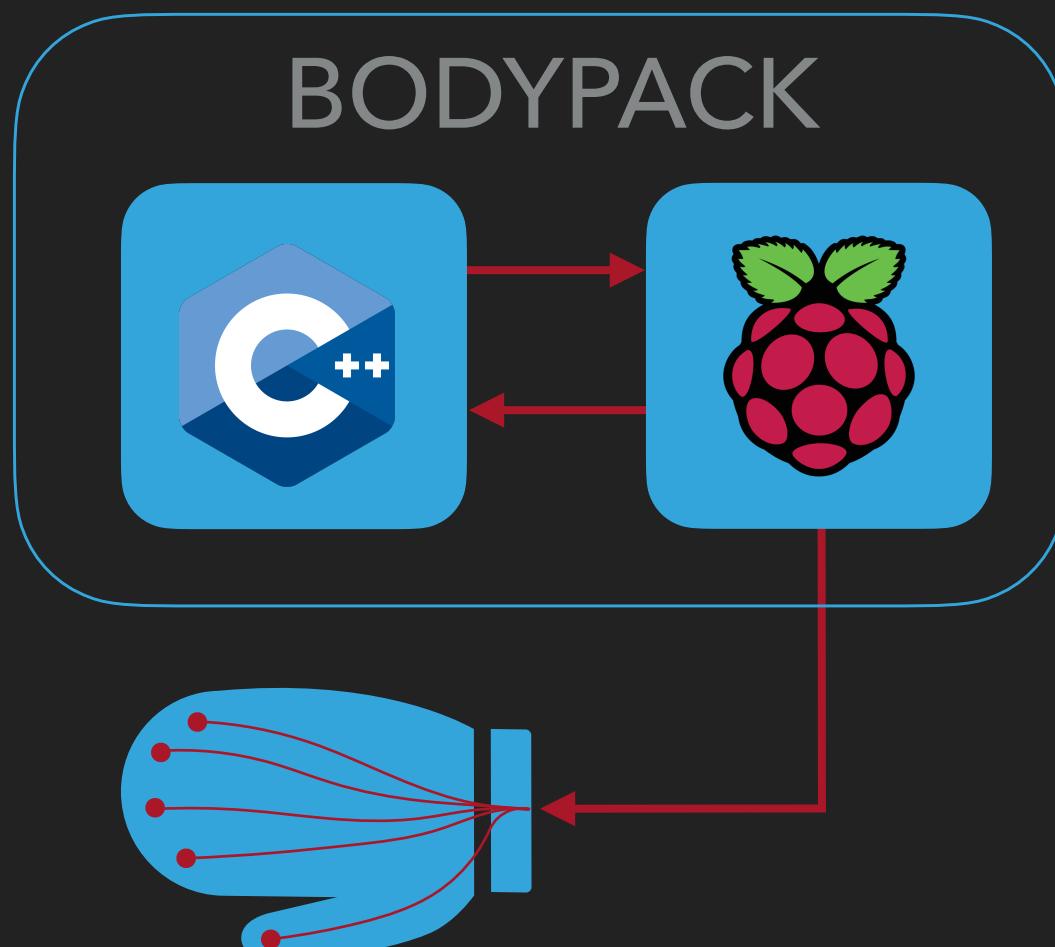
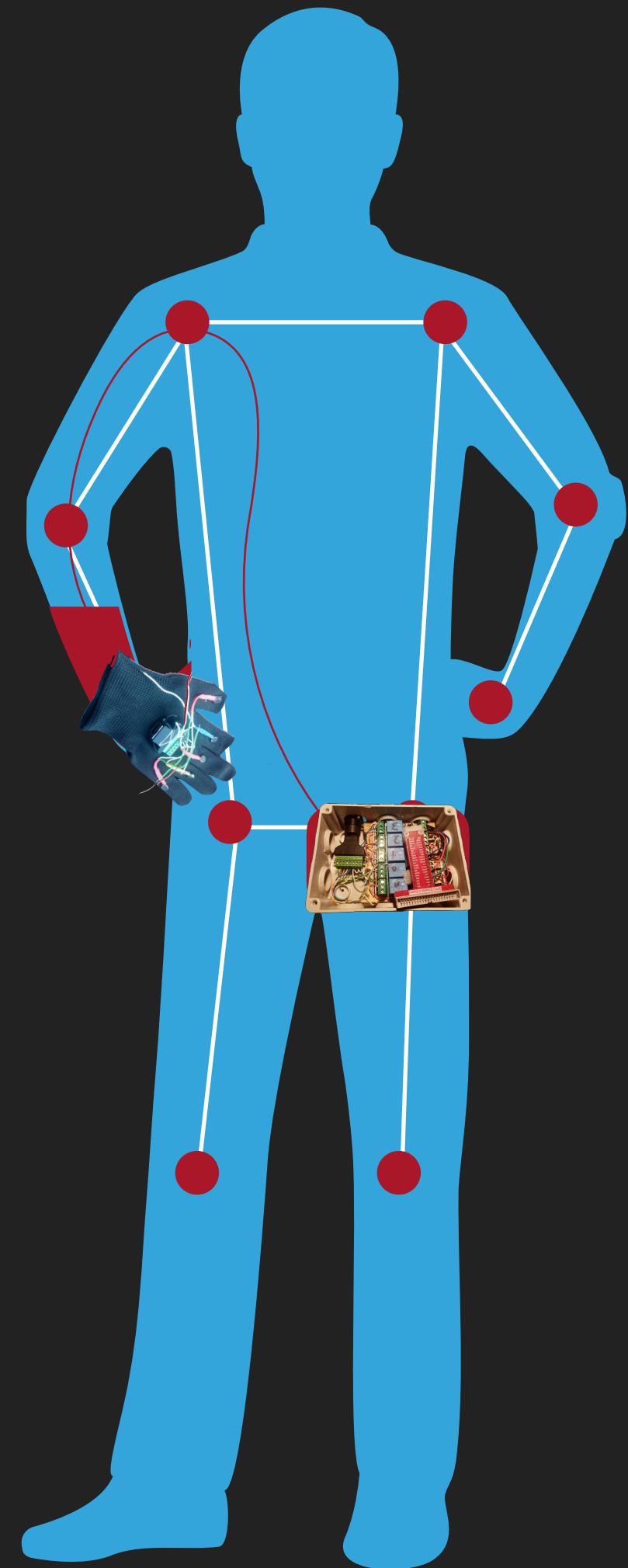
OUTPUT - GLOVE



- ▶ Haptic feedback given by vibrating actuators placed on the finger of a glove working at 3.3 V



OUTPUT - GLOVE

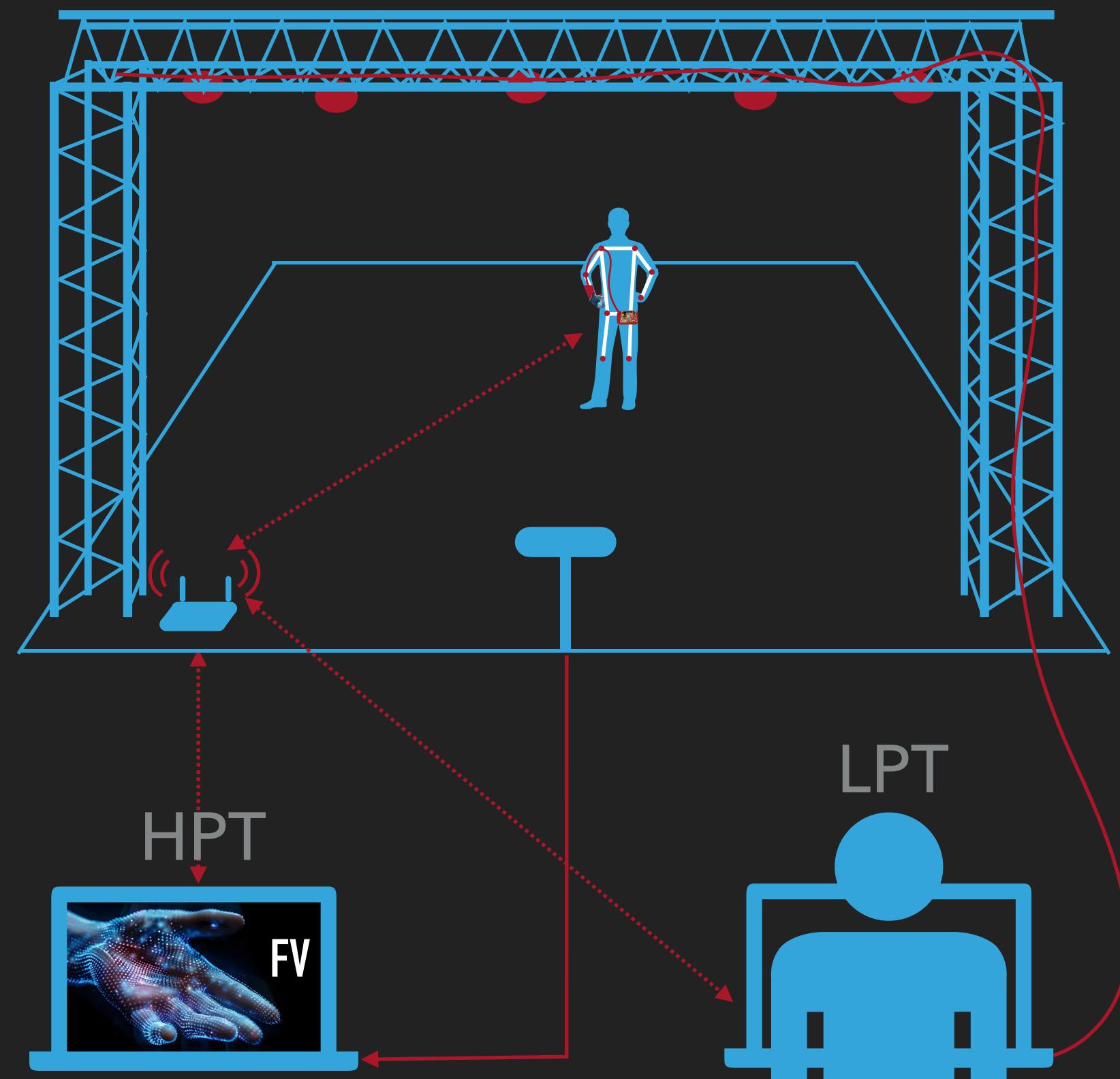


- ▶ Haptic feedback given by vibrating actuators placed on the finger of a glove working at 3.3 V



ARCHITECTURE

ON STAGE

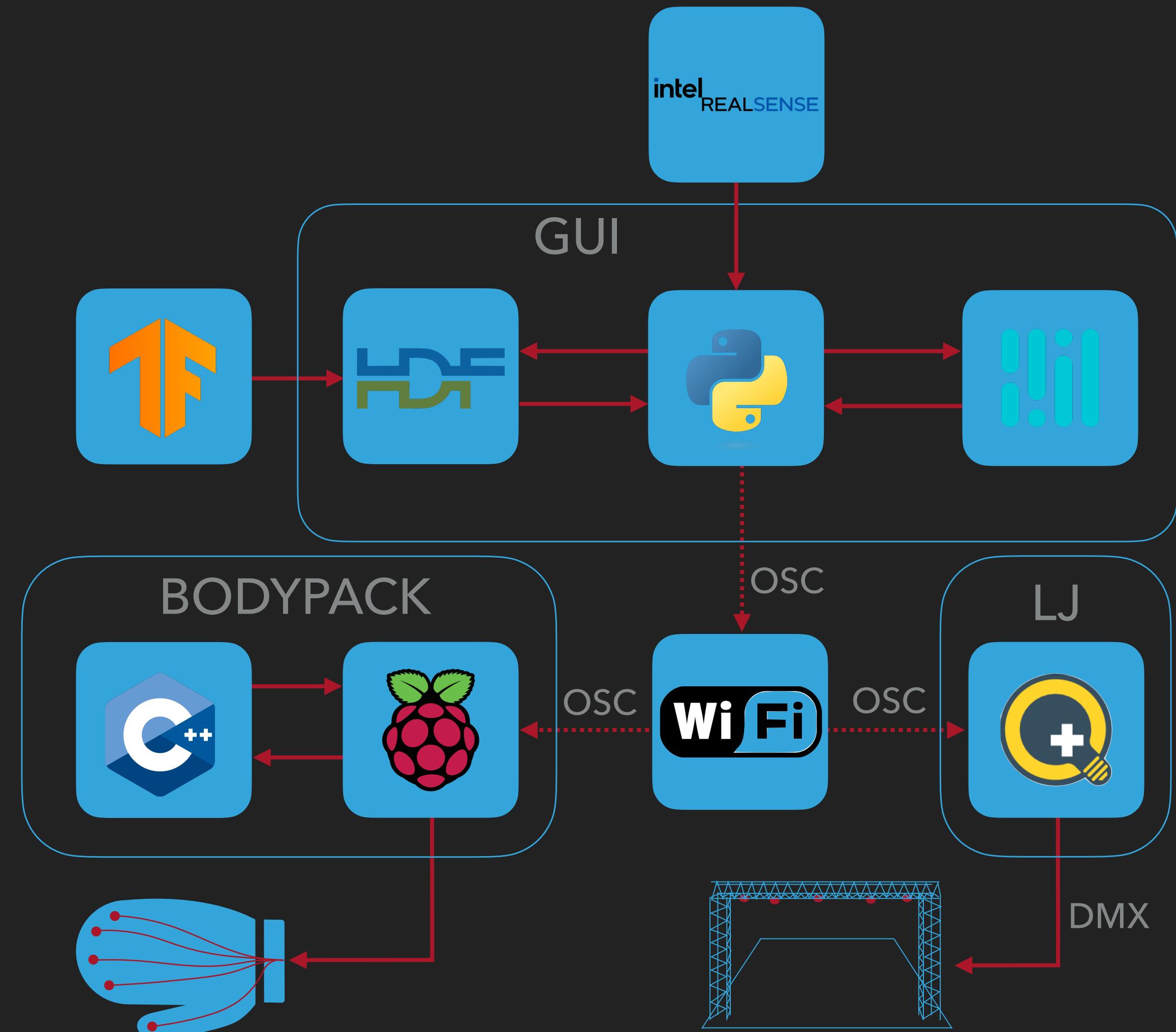


INPUT

CORE

OUTPUT

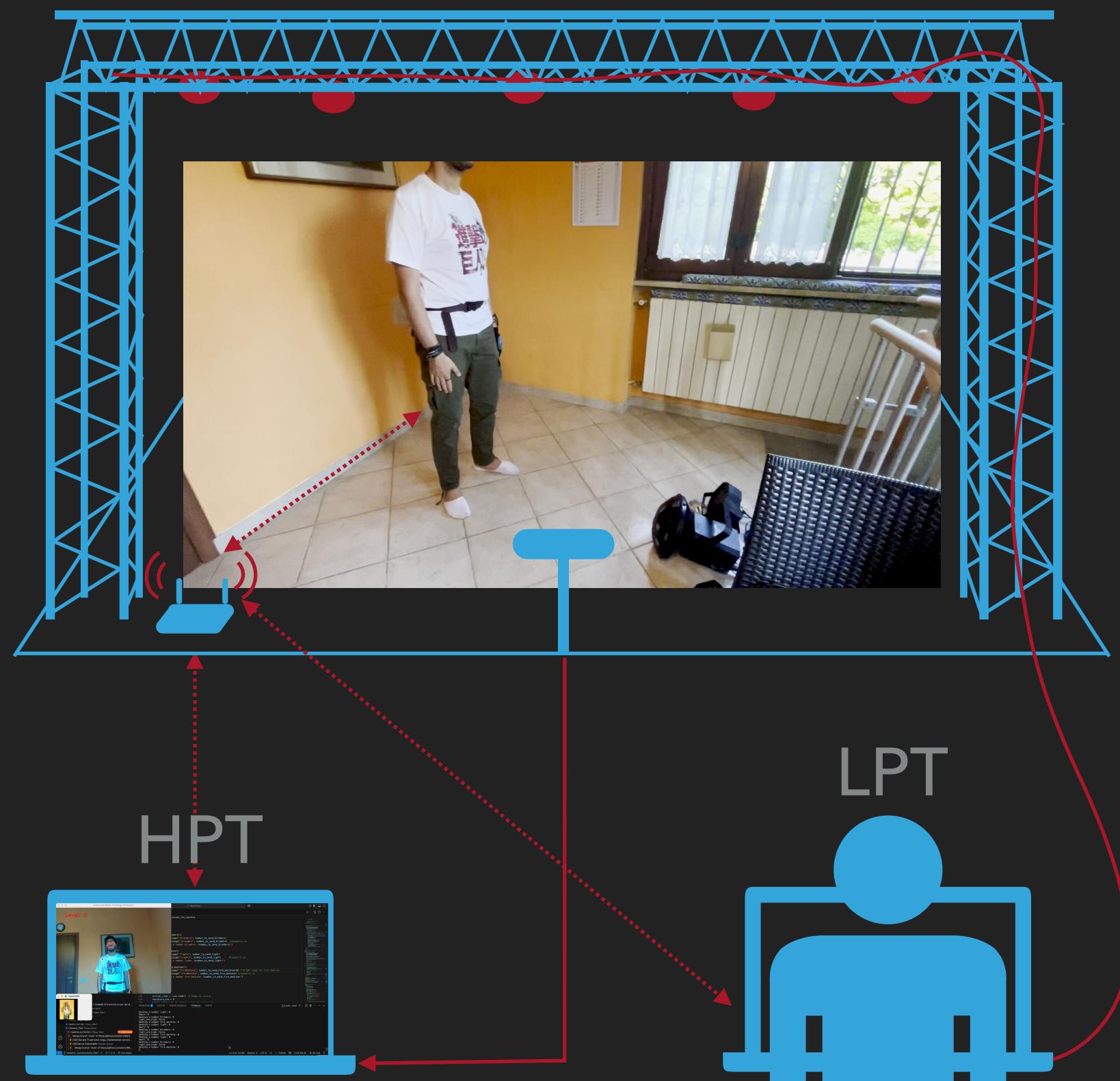
BEHIND THE SCENE



FINAL VERSION

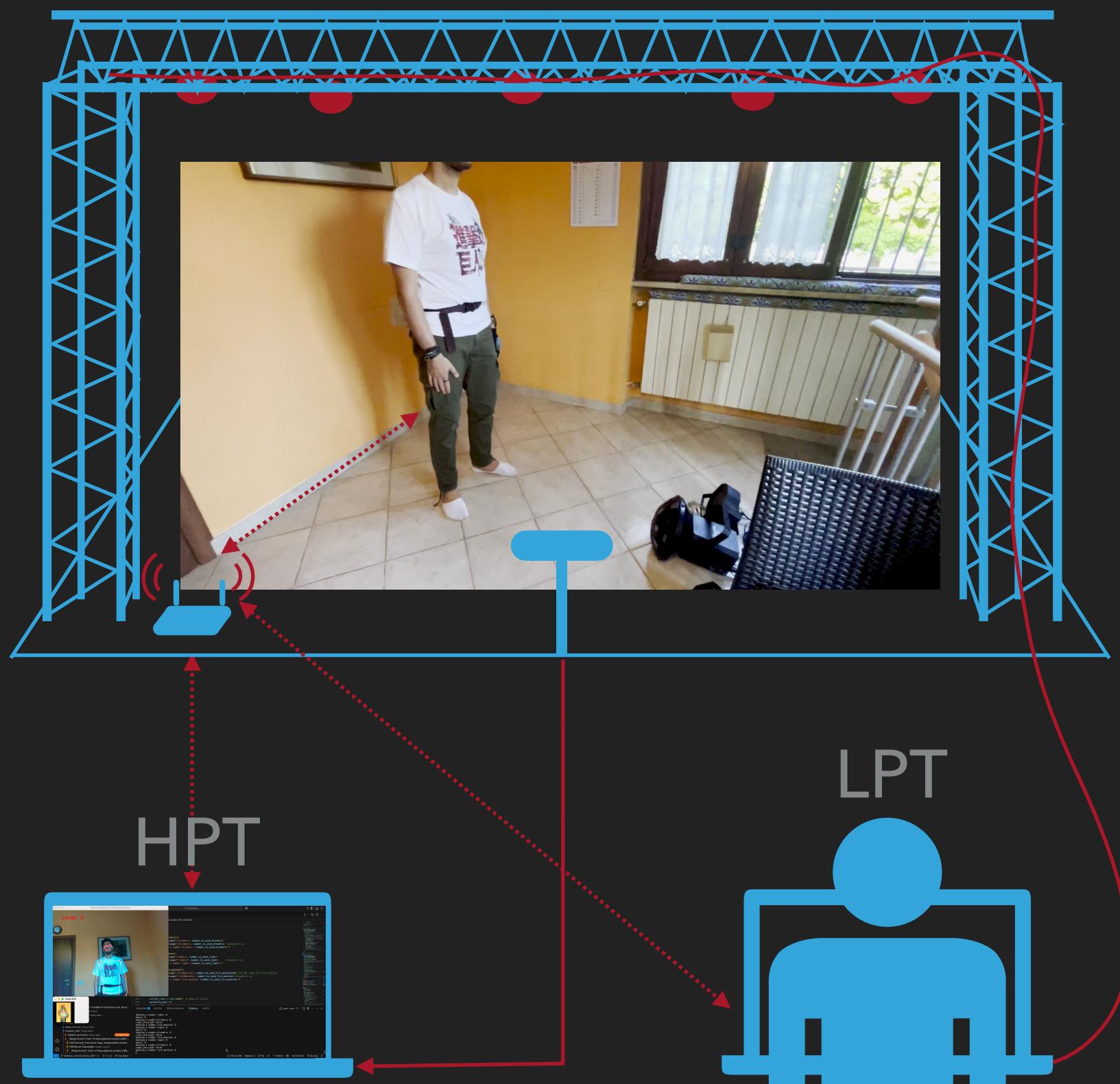
ON STAGE

POSSIBLE IMPROVEMENTS



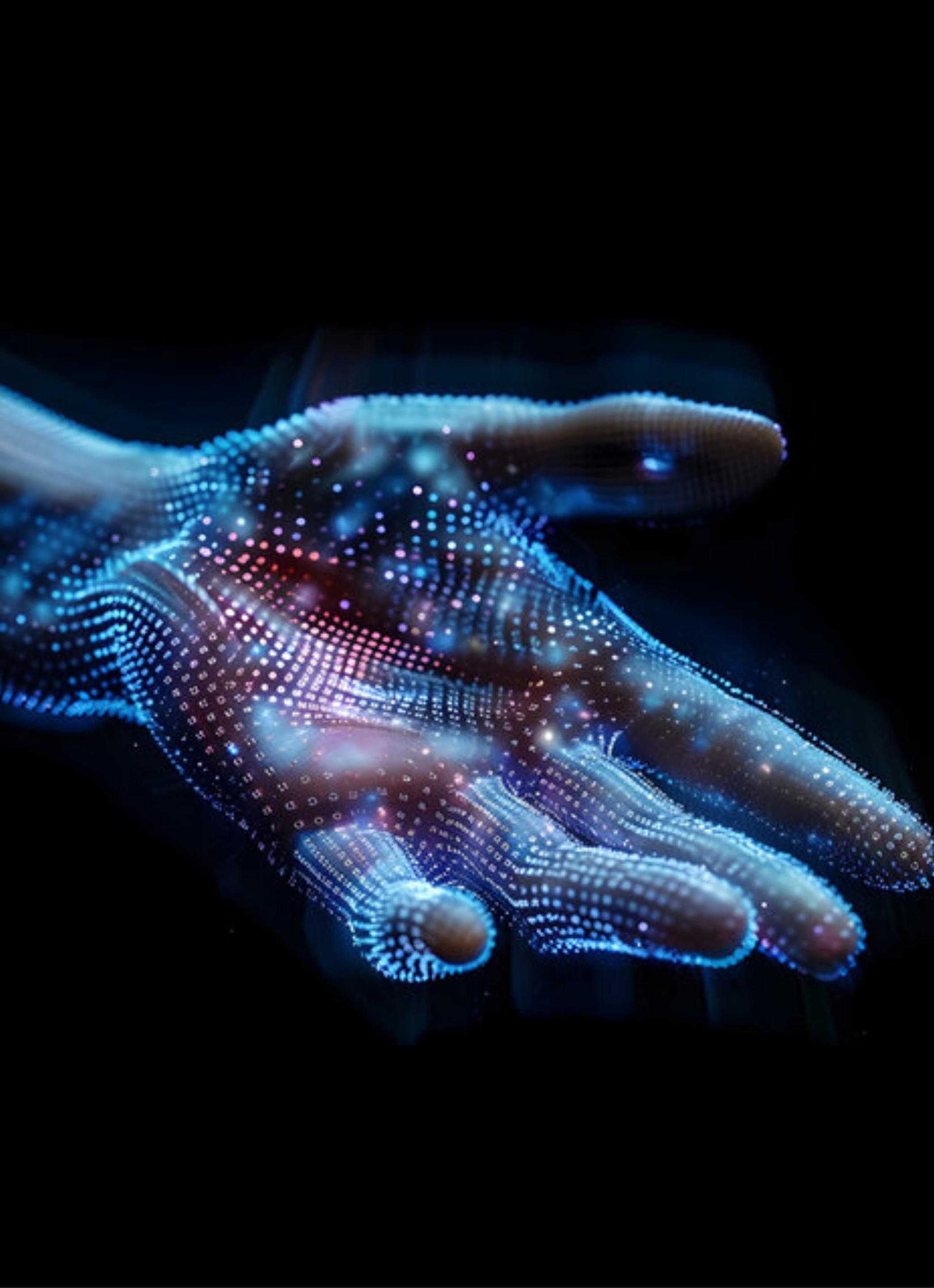
FINAL VERSION

ON STAGE



POSSIBLE IMPROVEMENTS

- ▶ Creating a set of movements that can be recognized and making the model customizable
- ▶ Print the integrated circuit
- ▶ Optimize the computational effort in order to increase the definition and, therefore, the performance of the overall system



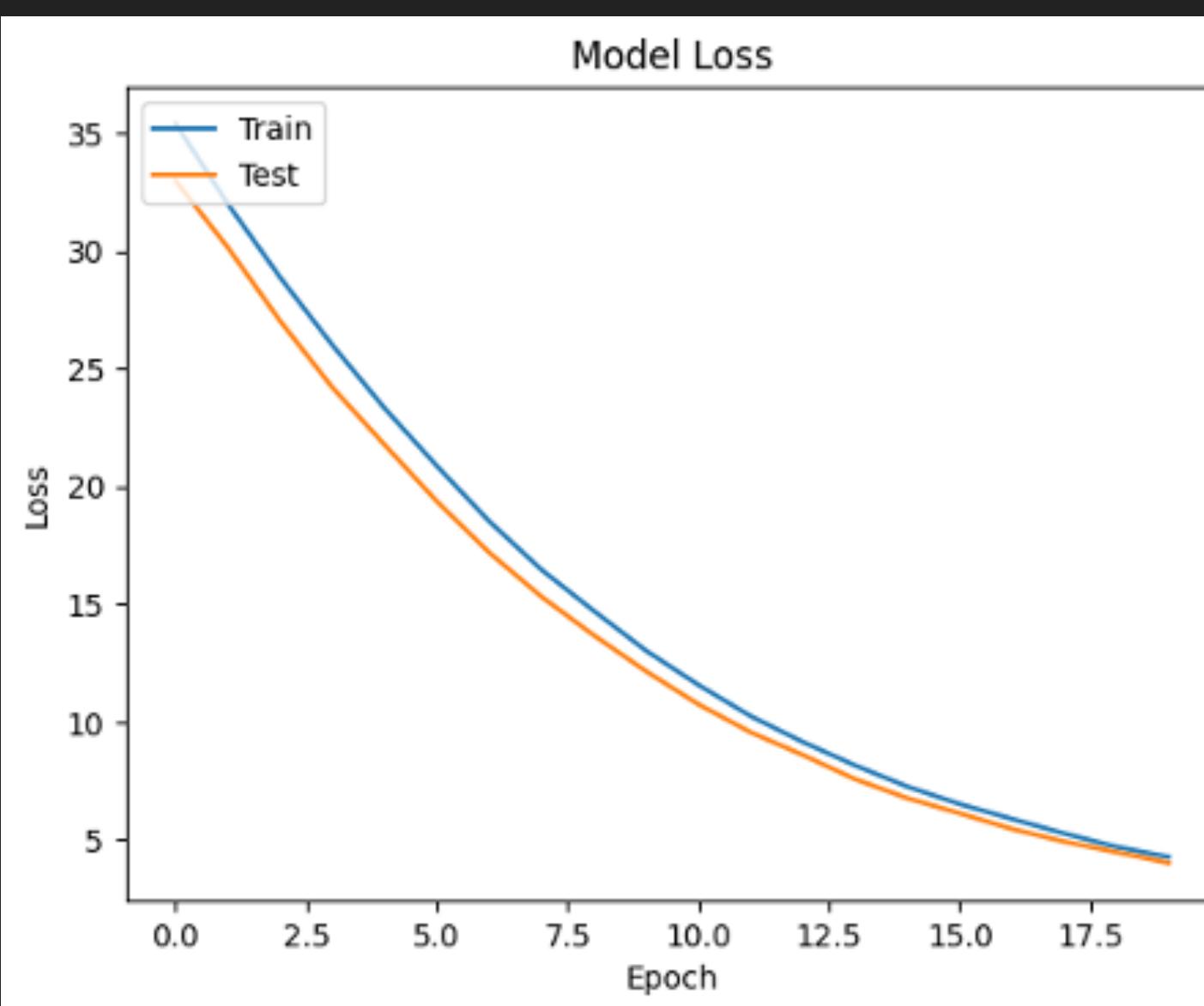
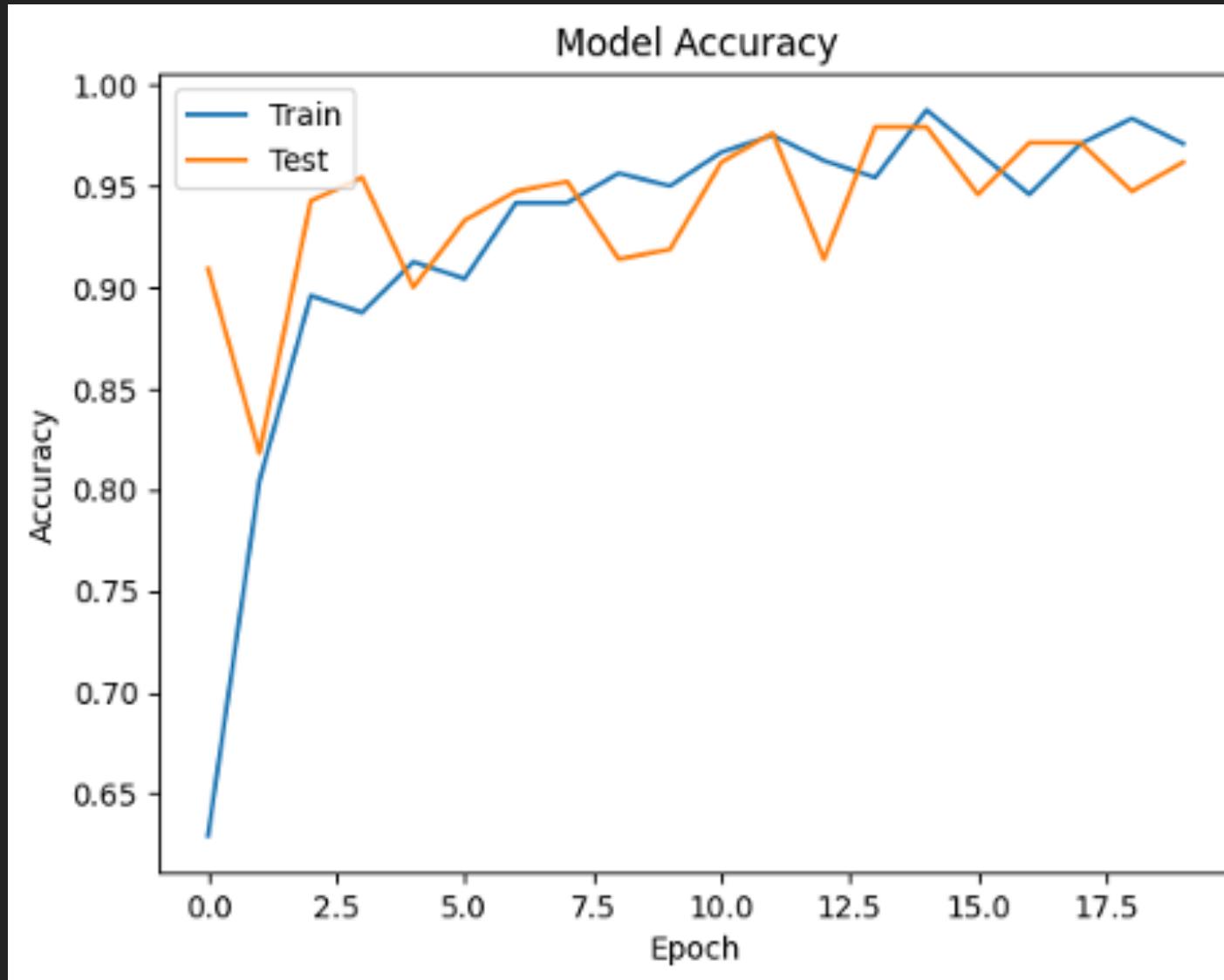
THANKS FOR YOUR
ATTENTION

FLOWVISION

APPENDEX

APPENDEX

AI MODEL: HAND



Layer (type)	Output Shape	Param #
mobilenet_1.00_224 (Functional)	(None, 3, 3, 1024)	3,228,864
global_average_pooling2d_6 (GlobalAveragePooling2D)	(None, 1024)	0
dense_31 (Dense)	(None, 128)	131,200
dropout_16 (Dropout)	(None, 128)	0
dense_32 (Dense)	(None, 128)	16,512
dropout_17 (Dropout)	(None, 128)	0
dense_33 (Dense)	(None, 2)	258

Total params: 3,376,834 (12.88 MB)

Epoch: 40

Train Accuracy: 0.9667

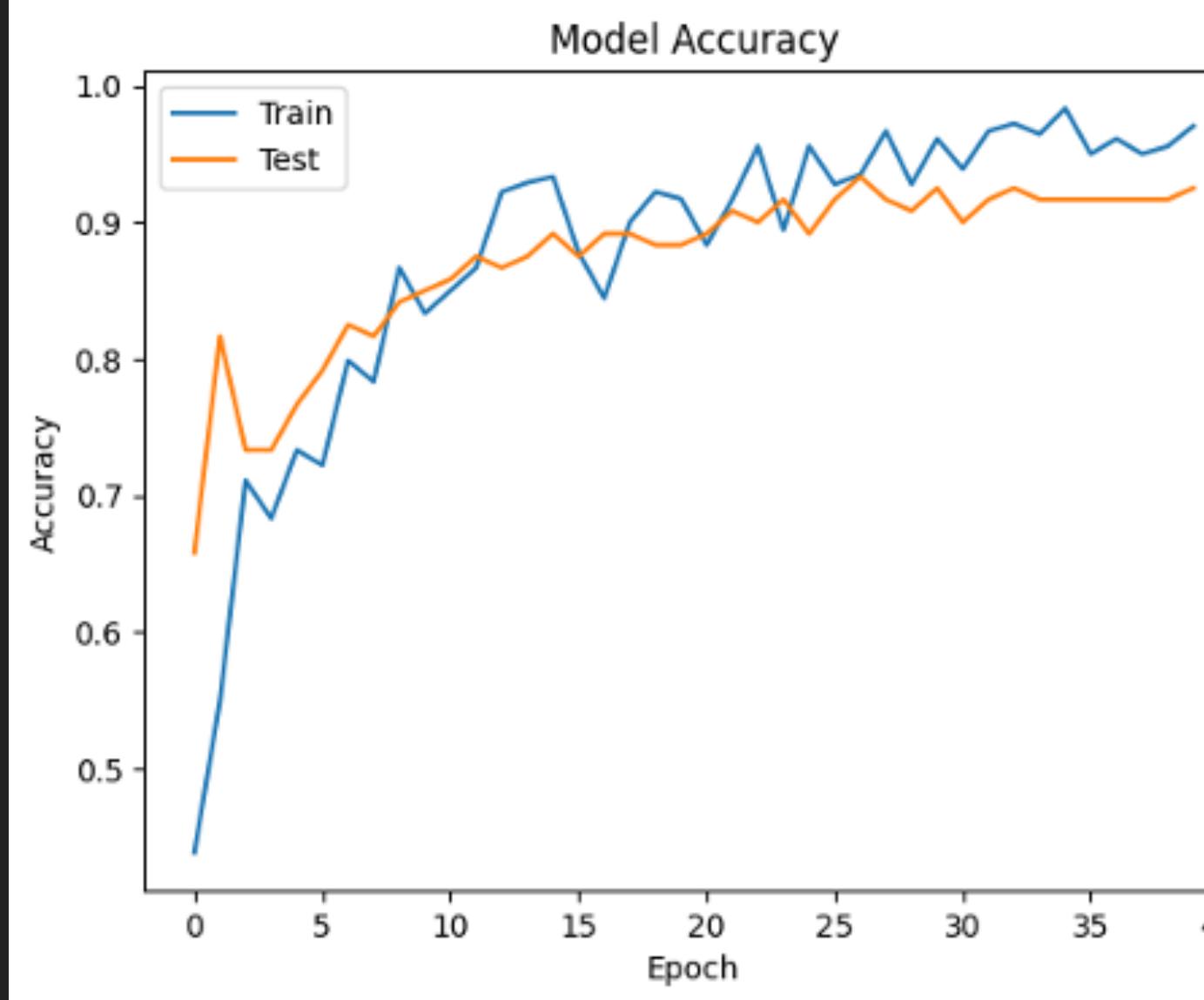
Val Accuracy: 0.9617

Train Loss: 4.3496

Val Loss: 4.0218

APPENDEX

AI MODEL: HEART



Epoch: 40

Train Accuracy:
0.9602

Val Accuracy:
0.9250

Train Loss:
0.0794

Val Loss:
0.1886

CHALLENGE REPORT

Context	Challenge	Solution
Docker	MacOS restrictions on external devices on docker	Trade-off: we decided not to use docker and to implement a simple gui from which to run everything
Fist Gesture recognition NN	WHEN THE HAND IS CLOSED, ITS COORDINATES ARE NOT AVAILABLE	IMPLEMENTATION OF A FALBACK CODE IN WHICH THE REFERENCE POINT IS THE WRIST WHEN THE COORDINATE OF THE HAND ARE NOT AVAILABLE
Heart Gesture Recognition NN	No dataset available for the heart gesture	Creation of a dataset by merging two others
Heart Gesture Recognition NN	WHEN THE HANDS ARE PLACED ON THE CHEST, WE GET A MISTAKE: THEY ARE CLASSIFIED AS HEART GESTURE	IMPLEMENTATION OF A SCRIPT THAT IMPOSE THE CONDITION THAT THE WRIST ARE NOT OVERLAPPED DURING THE HEART GESTURE
Neural Network	NO AVAILABLE DATASET TO IMPLEMENT A RNN NETWORK	HYBRID MODELS (THRESHOLD + CNN)
Neural Netowkr	THE MODEL DOES NOT WORK WELL IF THERE IS NO PROPER ILLUMINATION	A higher resolution is not supported with our computational power so we decided to work as much
Neural Netowkr	Blinking due to instability of the images	Hysteresis code
RaspberryPi5		

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