Hardware in the Loop

Training Robot Contact in an Unstructured Environment

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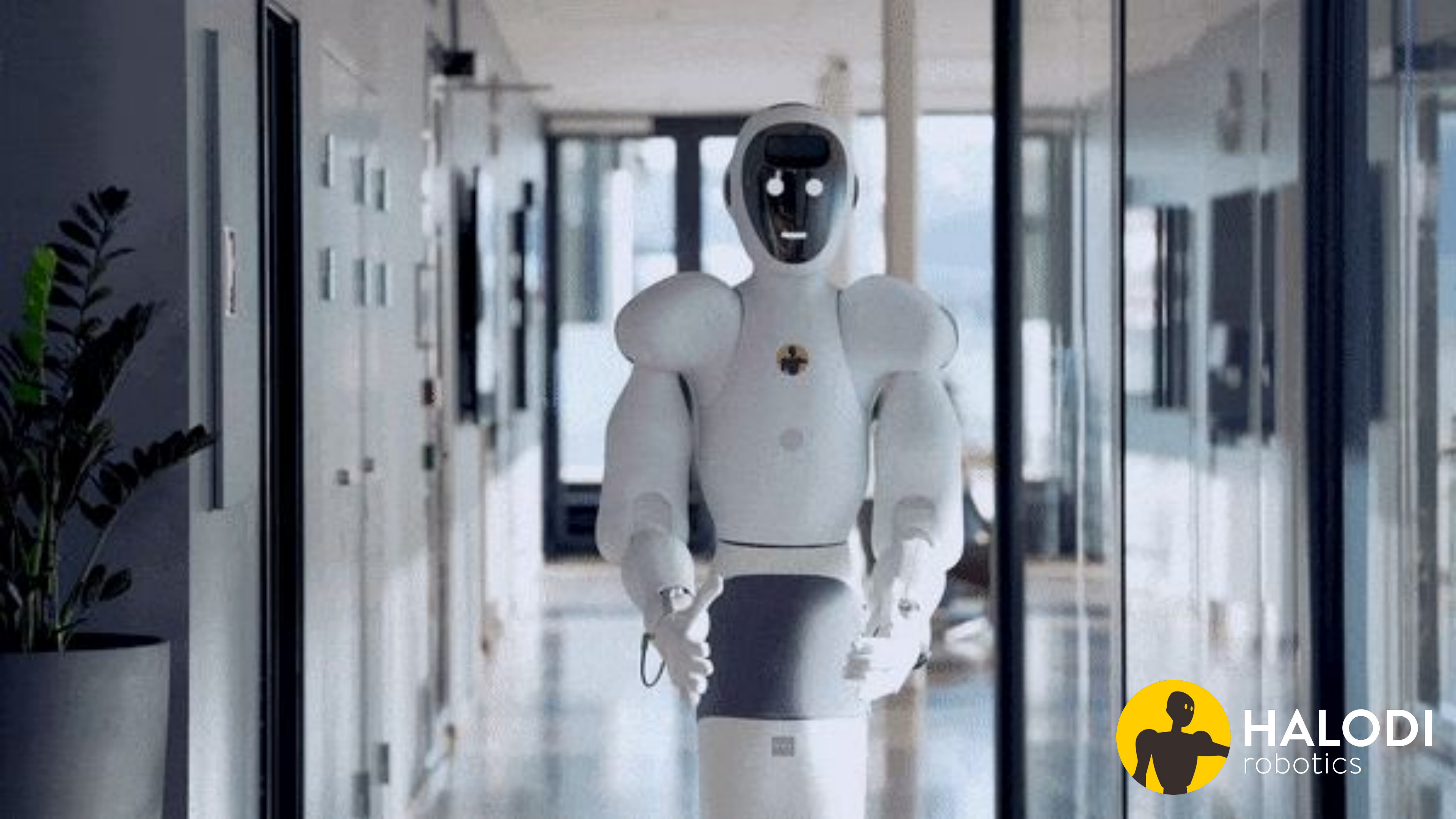
ÉTS
Le génie pour l'industrie

McGill

HALODI robotics

FounderFuel

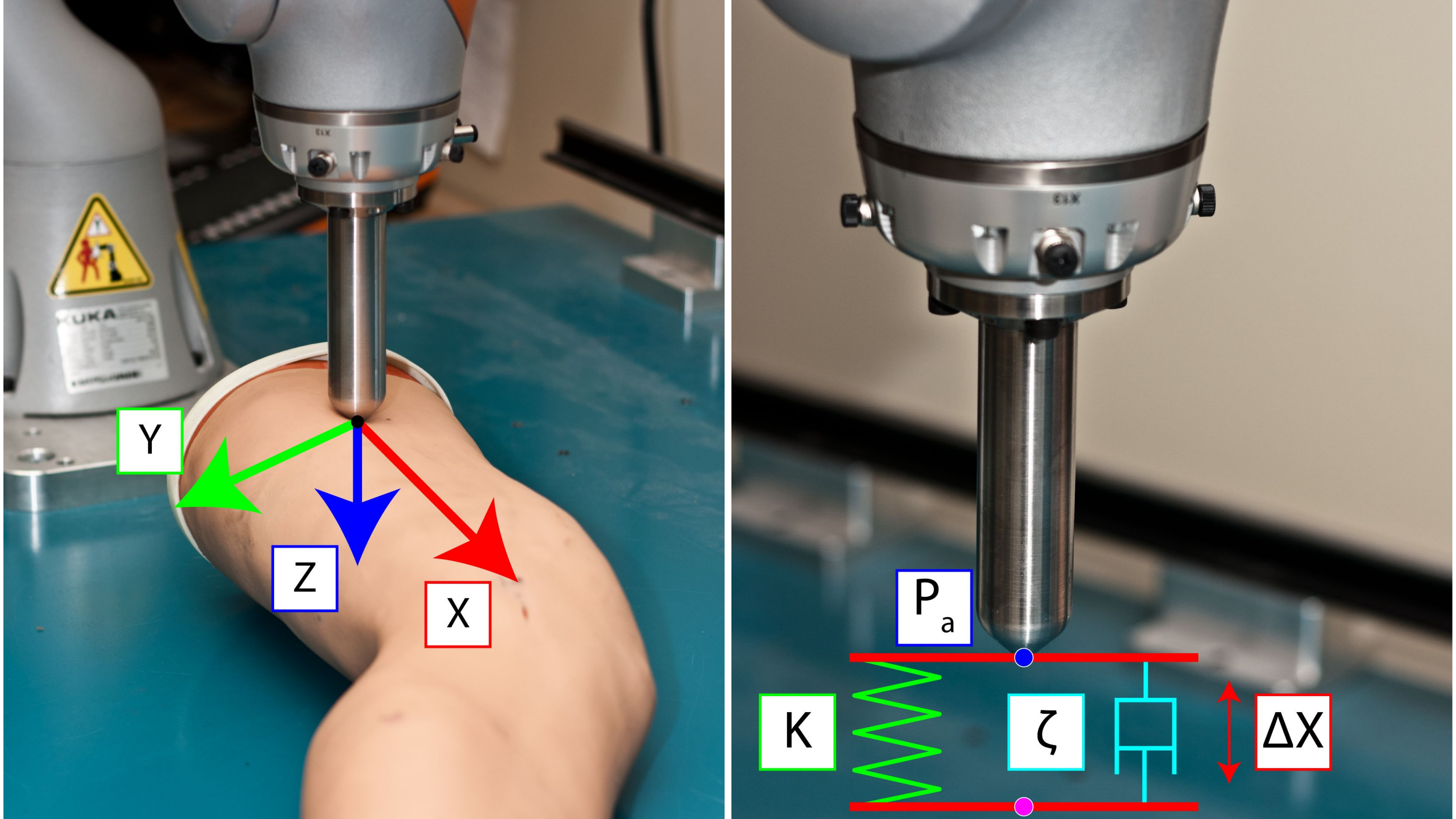
techstars_

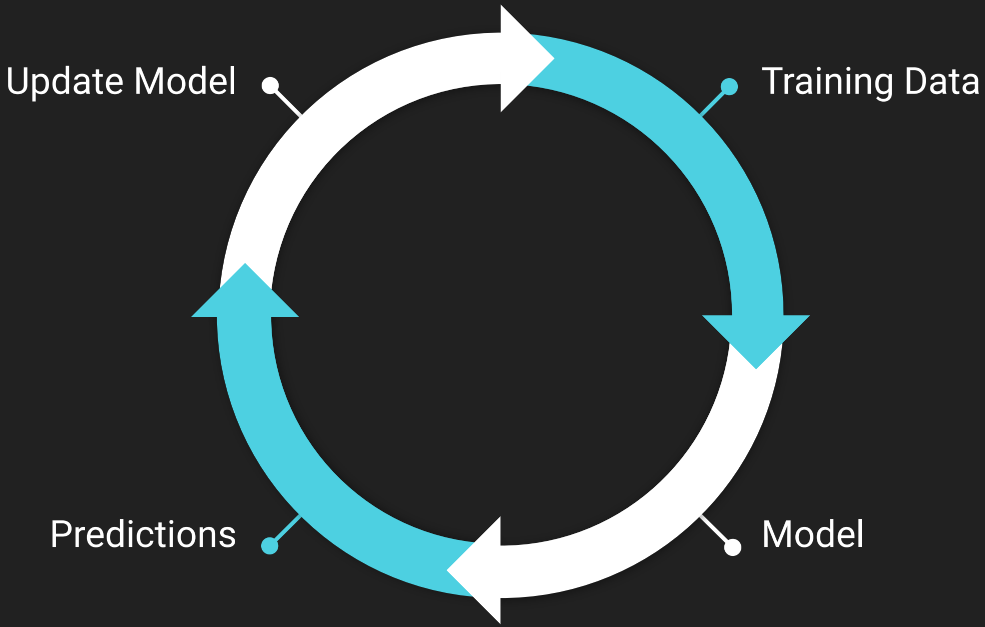


HALODI robotics

How do we make physical human-robot interaction safe?

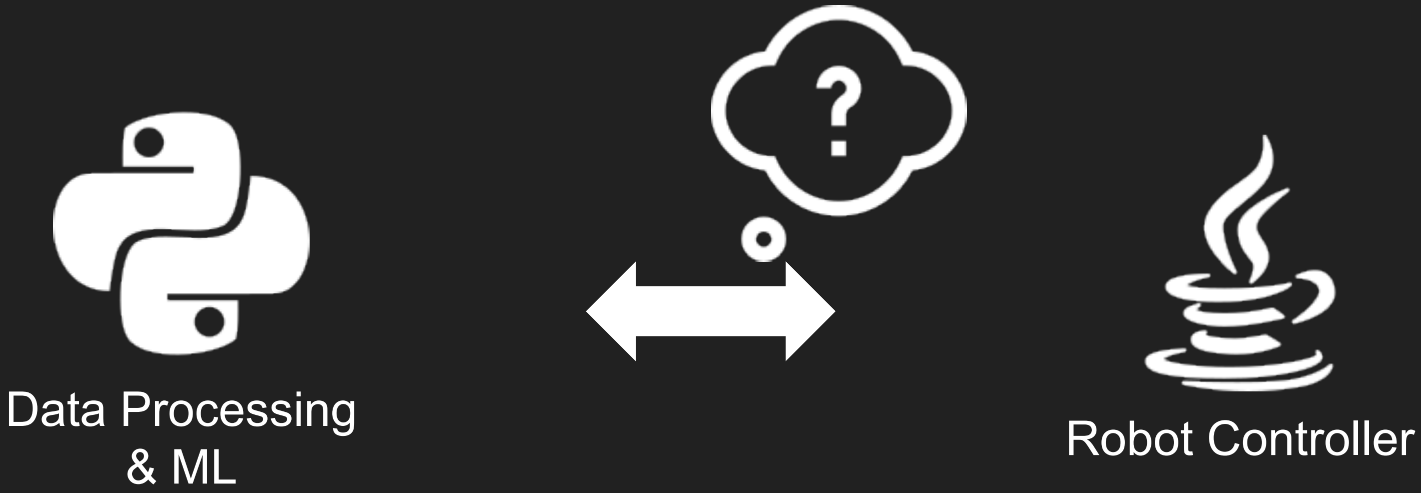
KUKA
ETS
KUKA

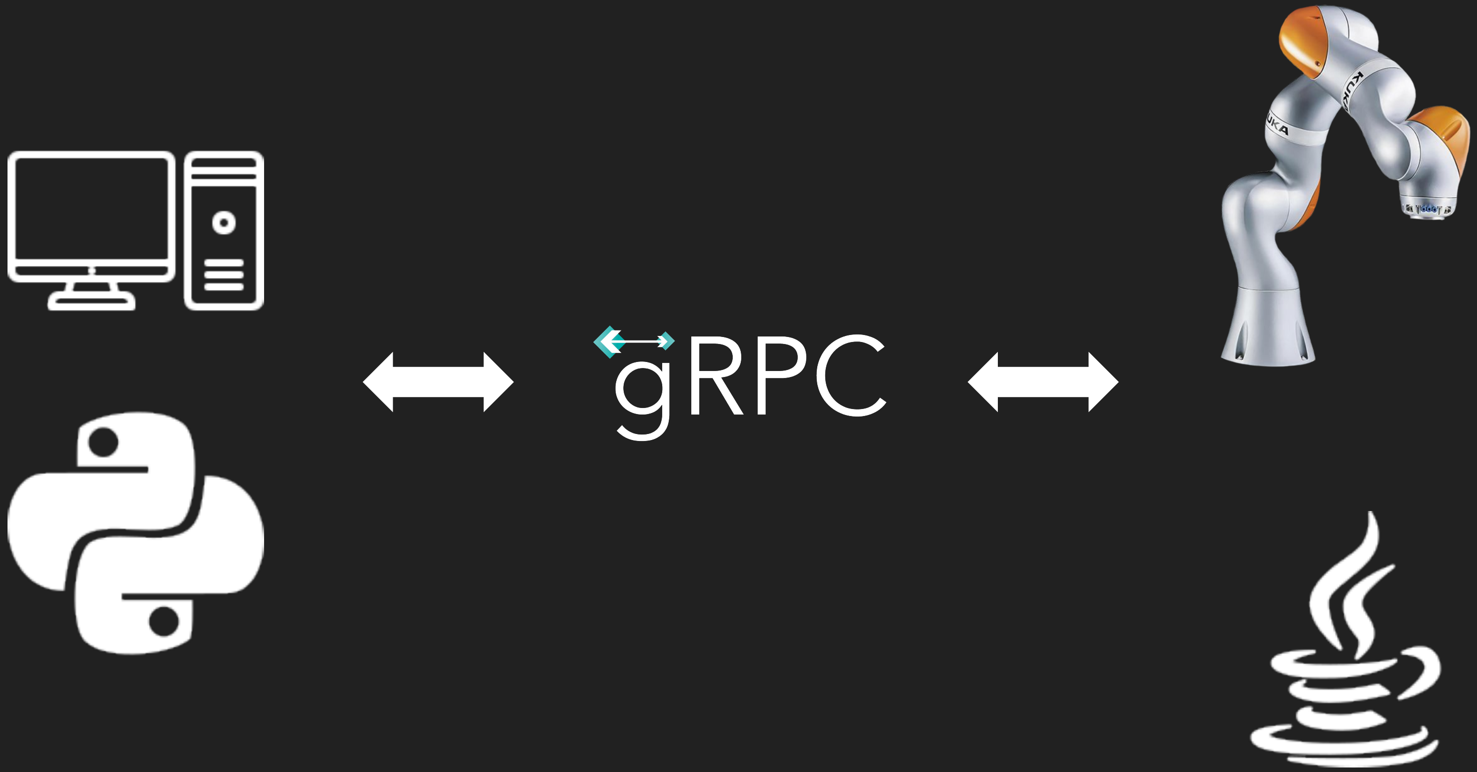

Y
Z
X
P_a
K
ζ
ΔX

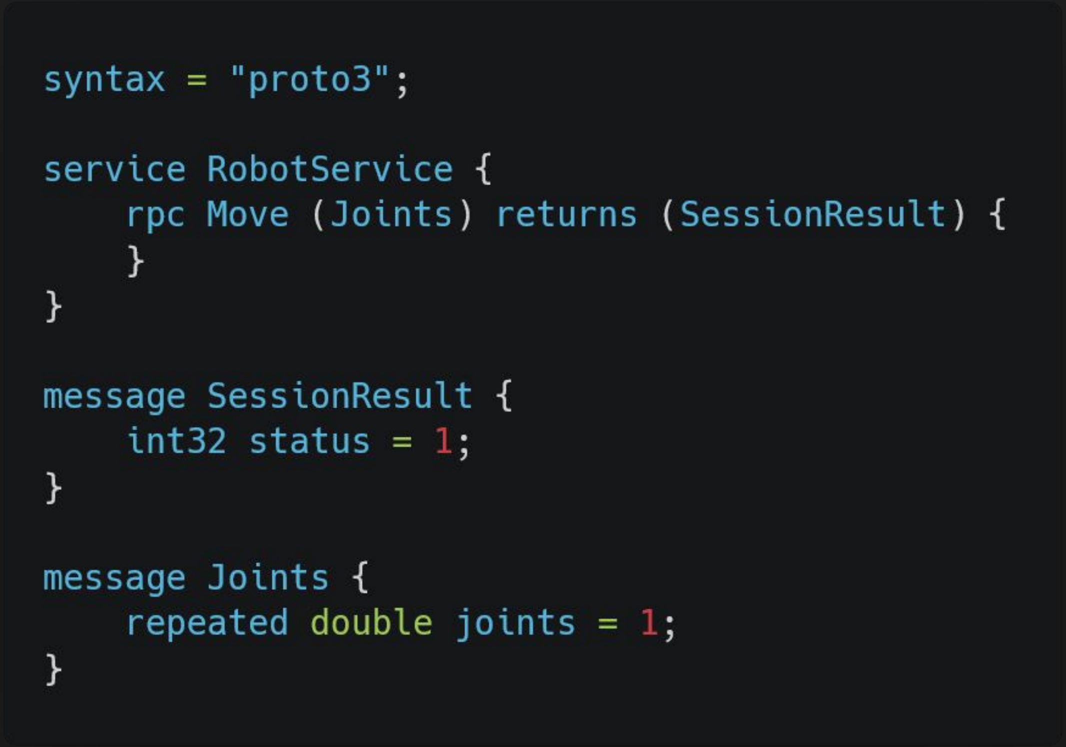

Update Model
Training Data
Predictions
Model

KUKA
KUKA

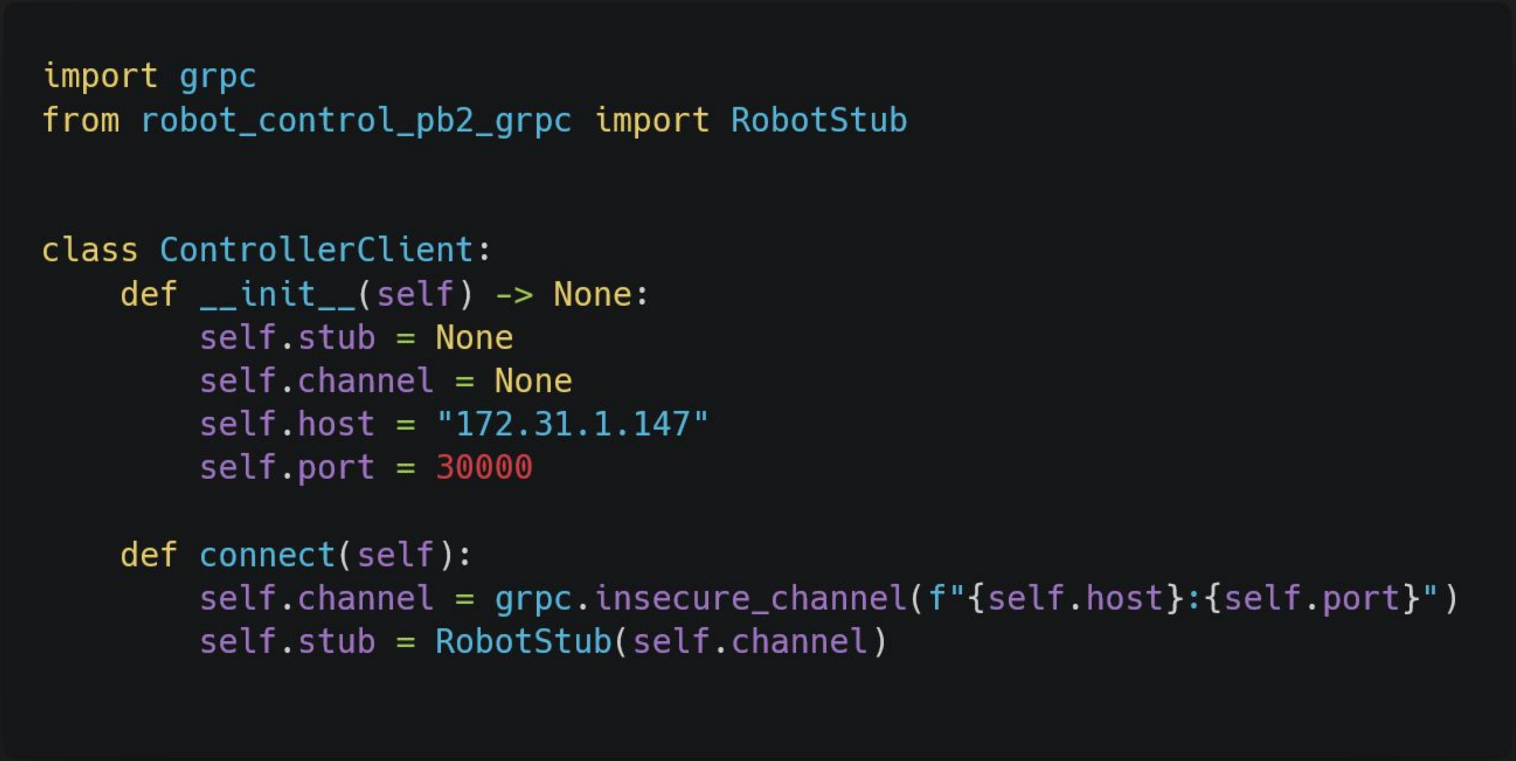
?


Data Processing & ML
Robot Controller

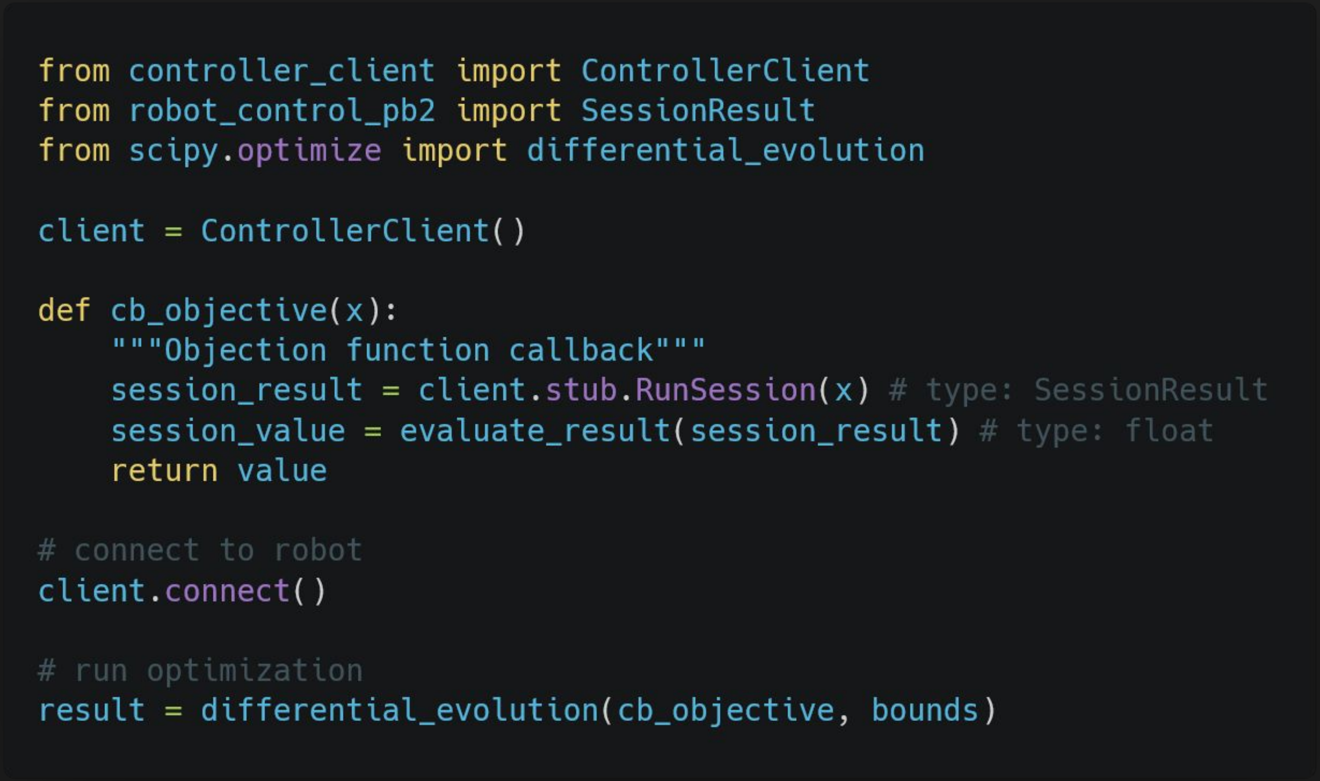

gRPC
KUKA



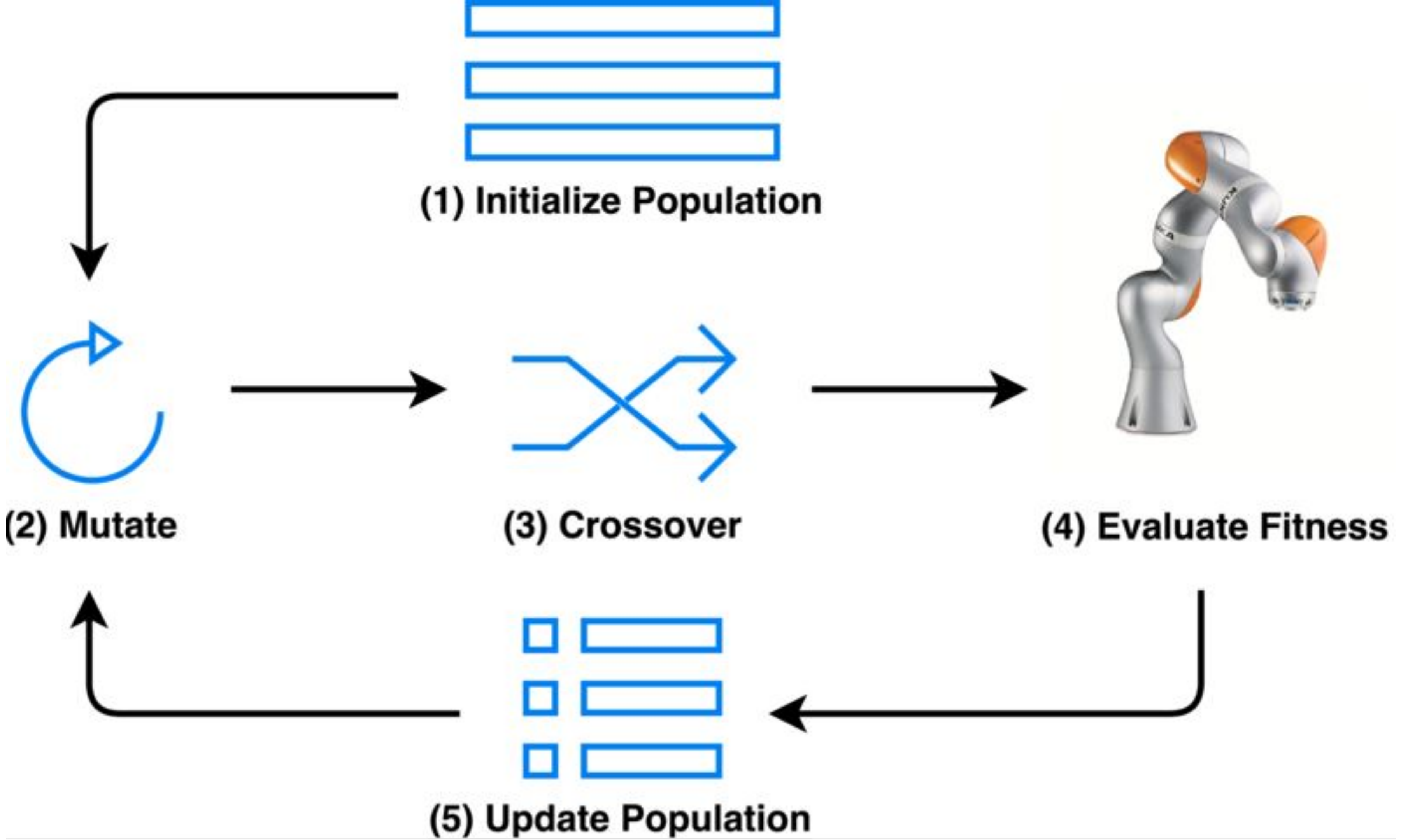
```
syntax = "proto3";

service RobotService {
    rpc Move (Joints) returns (SessionResult) {
    }
}

message SessionResult {
    int32 status = 1;
}

message Joints {
    repeated double joints = 1;
}
```

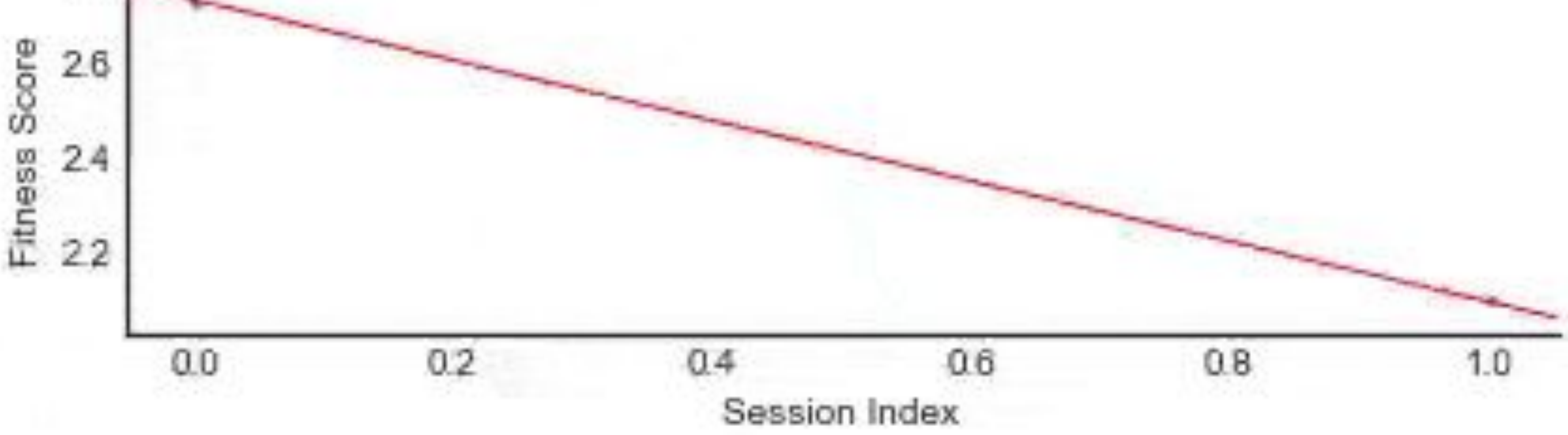


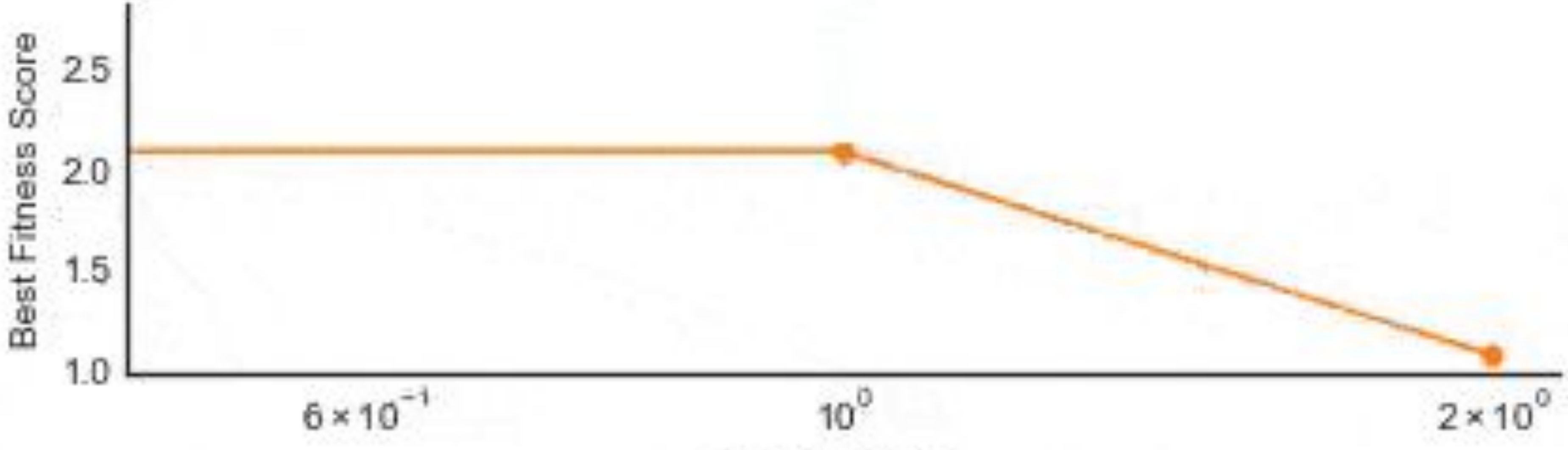
```python
import grpc
from robot_control_pb2_grpc import RobotStub


class ControllerClient:
    def __init__(self) -> None:
        self.stub = None
        self.channel = None
        self.host = "172.31.1.147"
        self.port = 30000

    def connect(self):
        self.channel = grpc.insecure_channel(f"{self.host}:{self.port}")
        self.stub = RobotStub(self.channel)
```

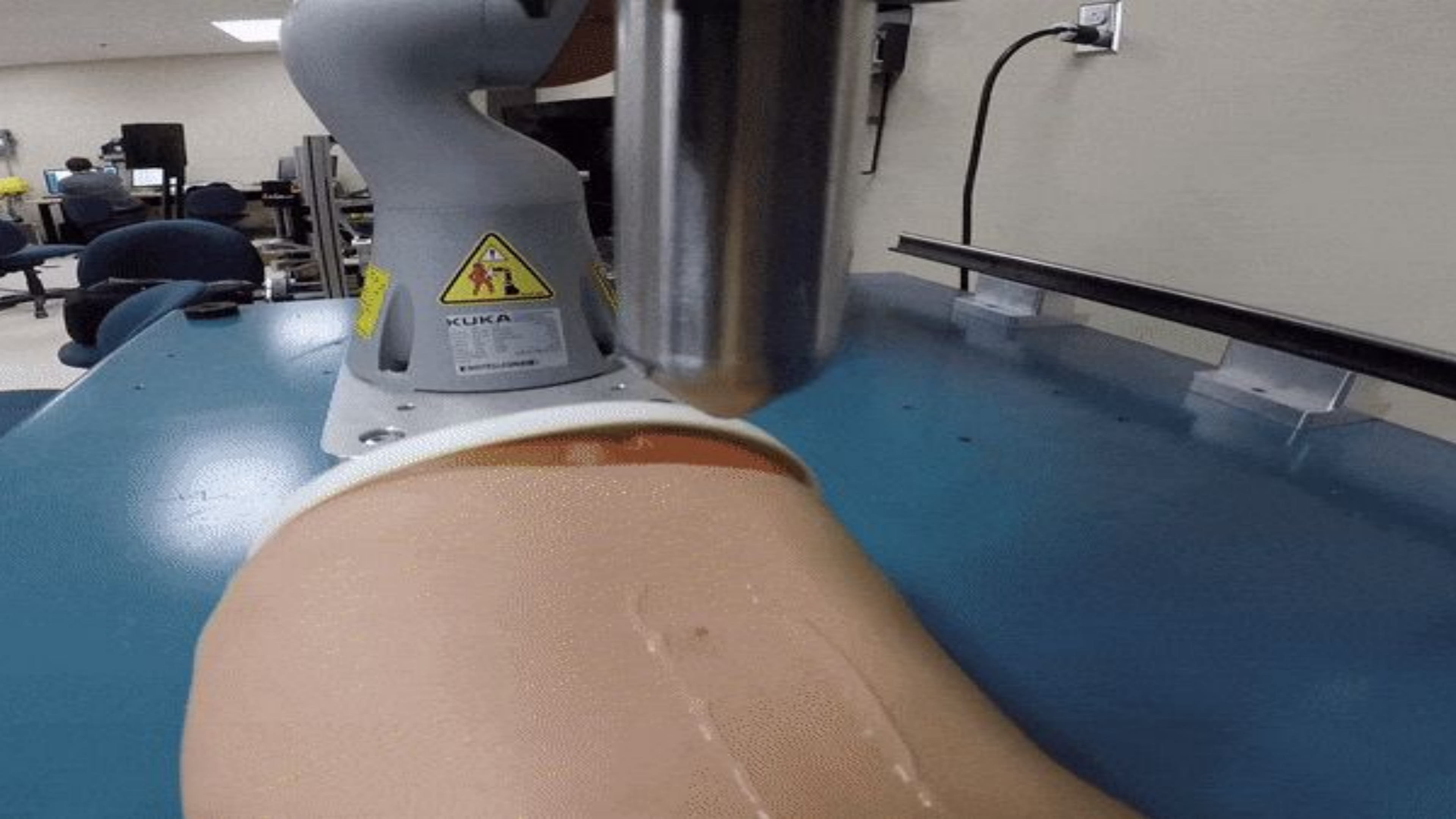


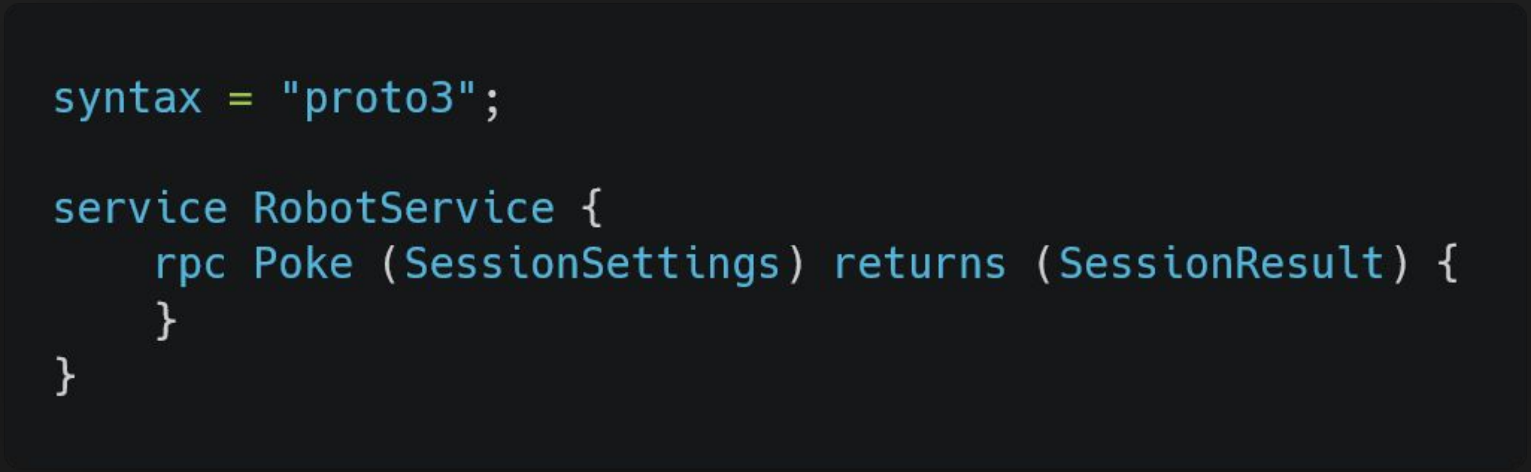
```python
from controller_client import ControllerClient
from robot_control_pb2 import SessionResult
from scipy.optimize import differential_evolution

client = ControllerClient()

def cb_objective(x):
    """Objection function callback"""
    session_result = client.stub.RunSession(x) # type: SessionResult
    session_value = evaluate_result(session_result) # type: float
    return value

# connect to robot
client.connect()

# run optimization
result = differential_evolution(cb_objective, bounds)
```


(1) Initialize Population
(2) Mutate
(3) Crossover
(4) Evaluate Fitness
(5) Update Population


Fitness Score
2.6
2.4
2.2
0.0
0.2
0.4
0.6
0.8
1.0
Session Index


Best Fitness Score
2.5
2.0
1.5
1.0
6×10^{-1}
10^{0}
2×10^{0}

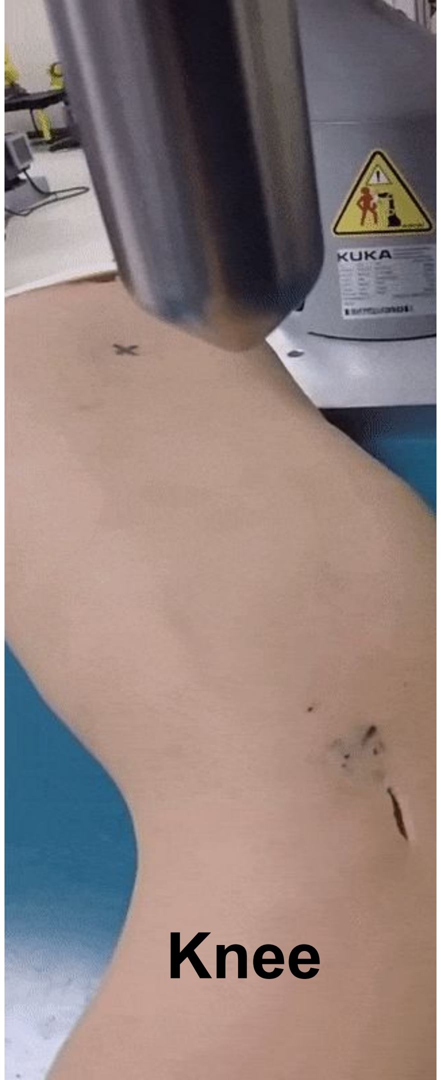

KUKA



```protobuf
syntax = "proto3";

service RobotService {
    rpc Poke (SessionSettings) returns (SessionResult) {
    }
}
```

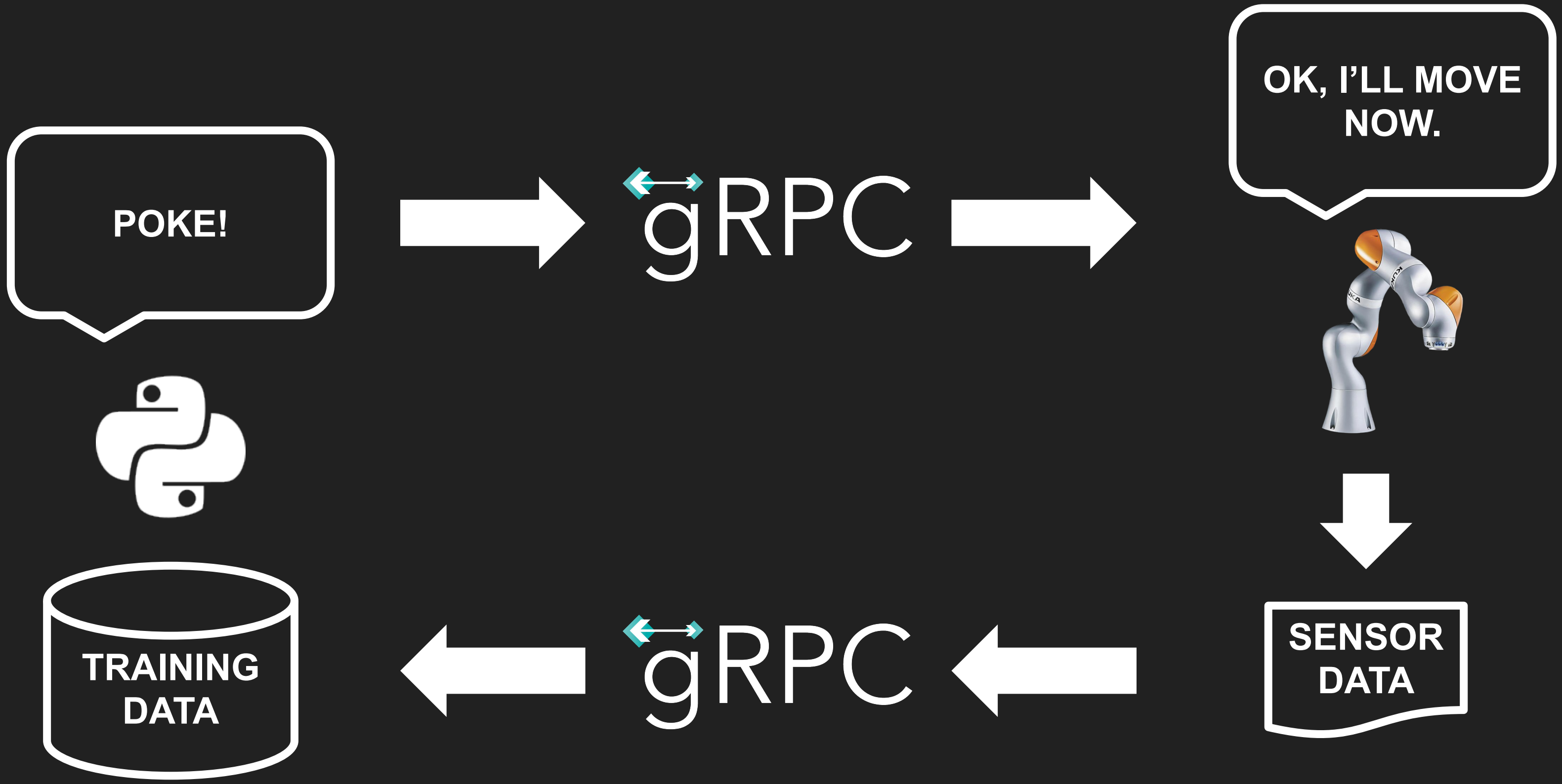
What was involved in the contact event?

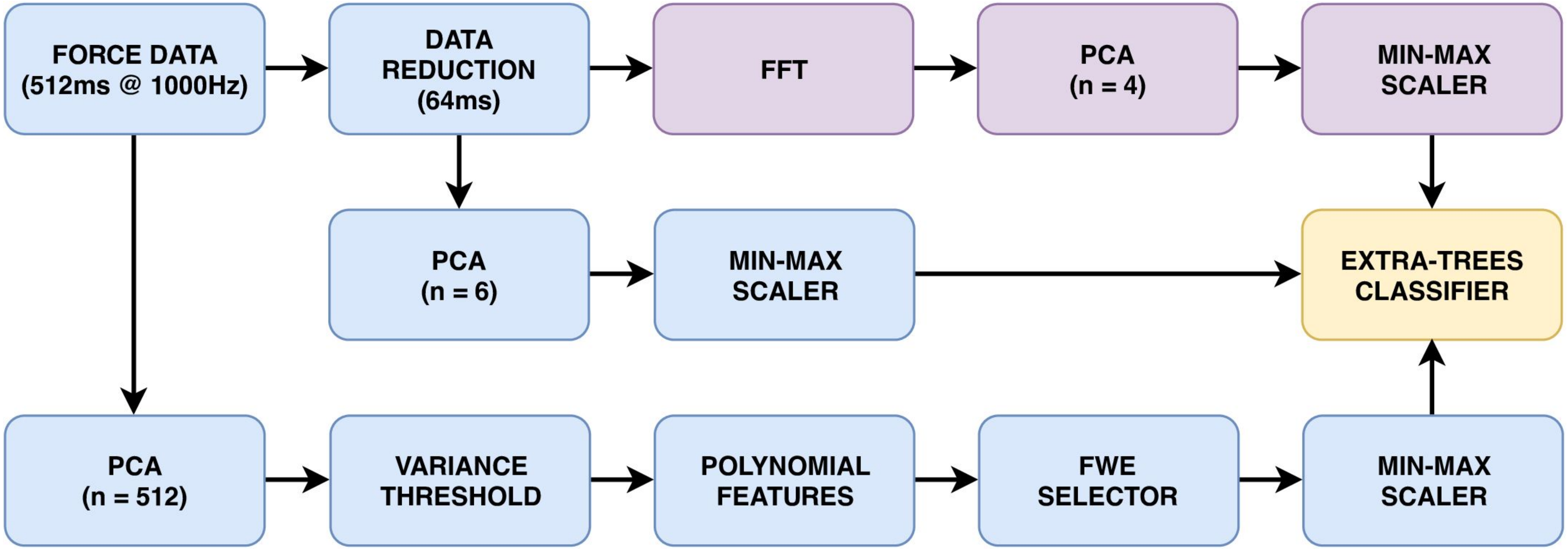
KUKA
Thigh


KUKA
Knee

Calf

KUKA
Ankle

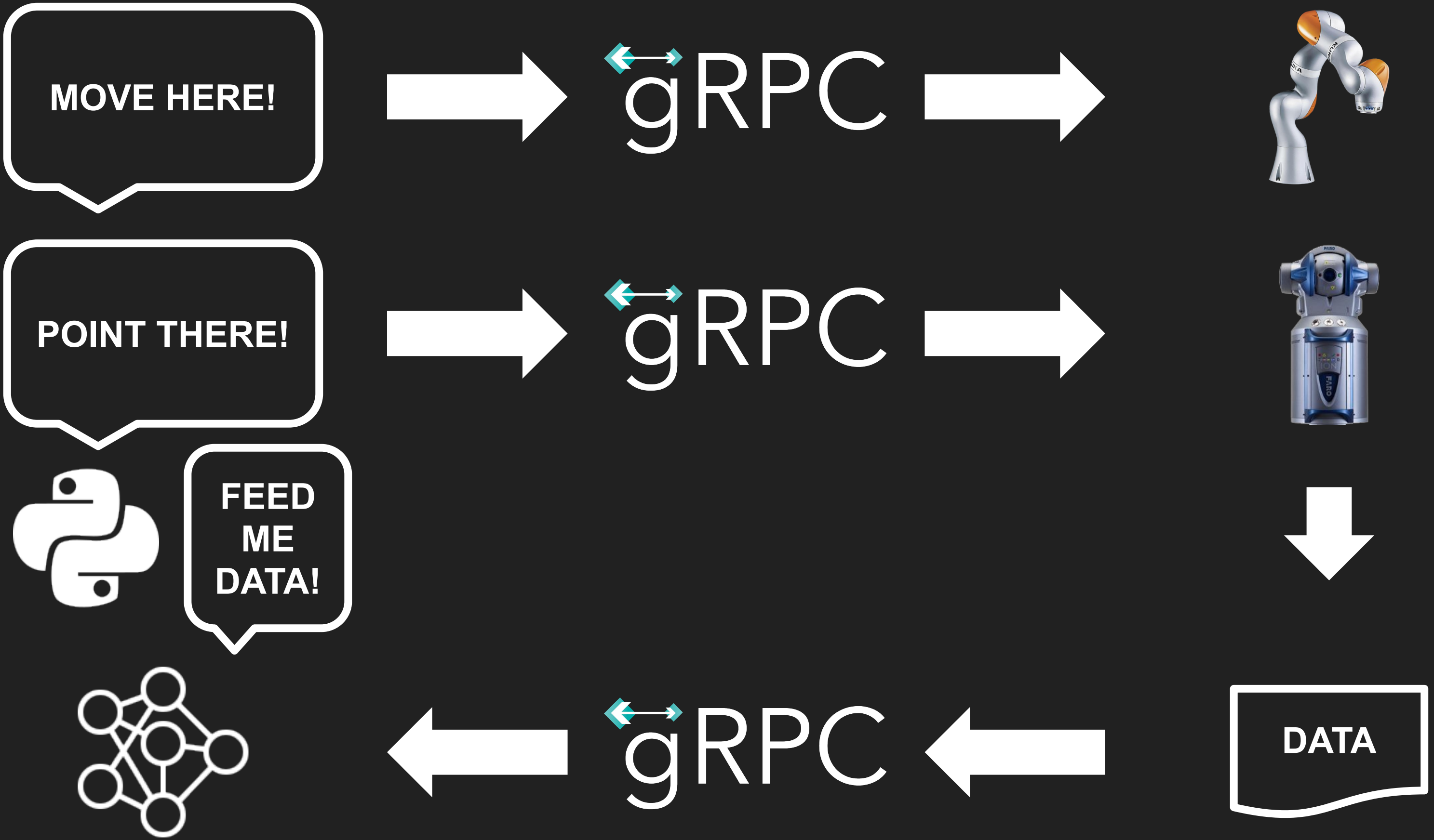

POKE!
gRPC
OK, I'LL MOVE NOW.
SENSOR DATA
gRPC
TRAINING DATA


FORCE DATA (512ms @ 1000Hz)
DATA REDUCTION (64ms)
FFT
PCA (n = 4)
MIN-MAX SCALER
PCA (n = 6)
MIN-MAX SCALER
EXTRA-TREES CLASSIFIER
PCA (n = 512)
VARIANCE THRESHOLD
POLYNOMIAL FEATURES
FWE SELECTOR
MIN-MAX SCALER

```python
import pandas as pd
from sklearn.decomposition import PCA
from sklearn.ensemble import ExtraTreesClassifier
from sklearn.feature_selection import SelectFwe, VarianceThreshold
from sklearn.pipeline import make_pipeline, make_union
from sklearn.preprocessing import MinMaxScaler, PolynomialFeatures

df = pd.read_csv("training-data.csv")
x, y = split_features_labels(df)

pipeline = make_pipeline(
    make_union(
        make_pipeline(
            Reducer(64), FFT(), PCA(n_components=4), MinMaxScaler(),
        ),
        make_pipeline(
            Reducer(64), PCA(n_components=6), MinMaxScaler(),
        ),
        make_pipeline(
            PCA(), VarianceThreshold(), PolynomialFeatures(),
            SelectFwe(), MinMaxScaler(),
        ),
    ),
    ExtraTreesClassifier(),
)
pipeline.fit(x, y)
```

FARO

KUKA
KUKA


MOVE HERE!
gRPC
POINT THERE!
gRPC
FEED ME DATA!
gRPC
DATA

Thank You!

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