Implementing ETSI NGSI-LD for Semantic Interoperability and Context-Aware Intelligence in Human-Centric Industrial Scenarios - Insights from P2CODE

- Presented By:

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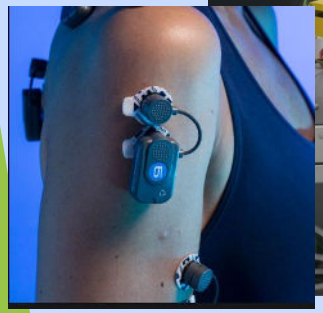
P2CODE Project – AA3 Use cases

- MADE test bed hosts 2 use cases :
  - Use case 1(Healthy Operator): Adaptive Collaborative robotic cells – With Operator fatigue monitoring
  - Use case 2(Human in the loop): Adaptive Production line speed – With Operator Stress Monitoring



Motivation

- Fragmentation of systems (wearables, robots, Assembly stations, analytics)
  - Heterogenous data
  - Variety of industrial protocols
  - Multiple Vendors
  - Non-Industrial wearable sensors
- Need for unified semantic representation
- Need for real-time context awareness

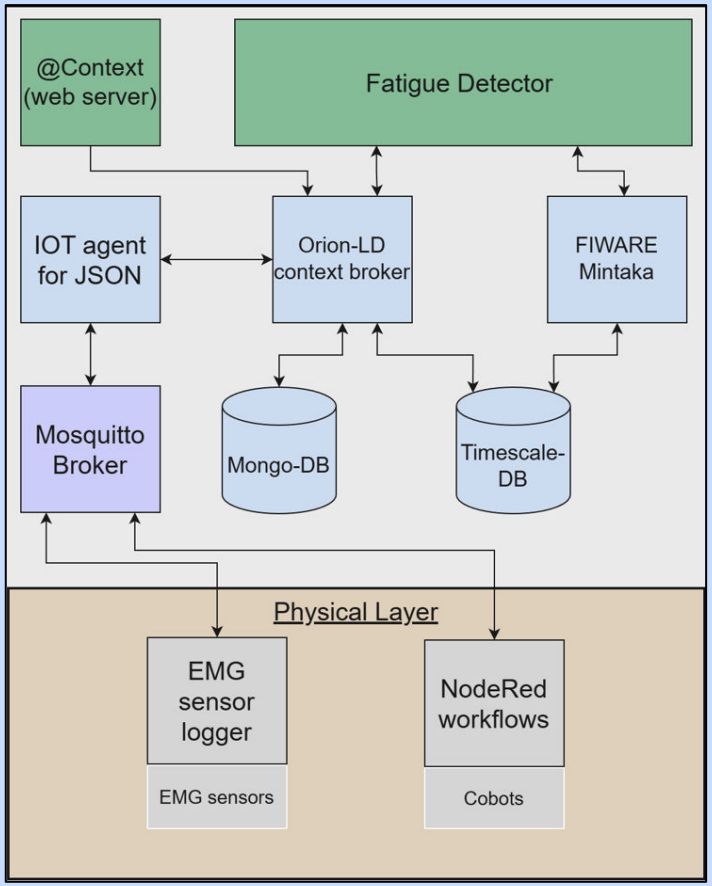
P2CODE as Enabler

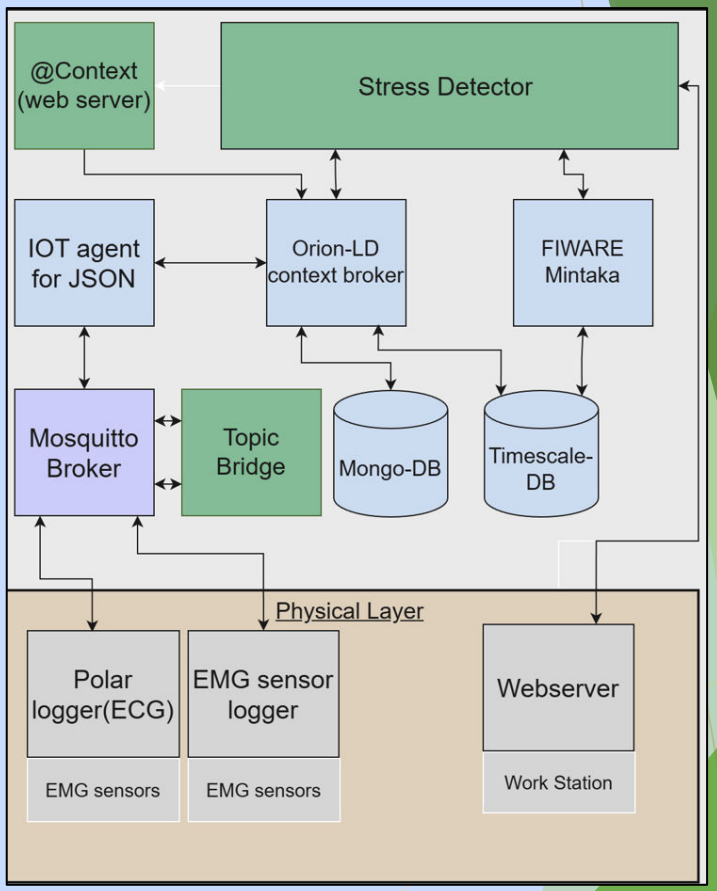
- P2CODE Provides the overarching development and deployment platform.
- NGSI-LD FIWARE components as IoT backbone.
- NGSI-LD enables semantic interoperability and context awareness
- Interoperability challenges across heterogeneous systems

IoT backbone components from P2CODE Platform

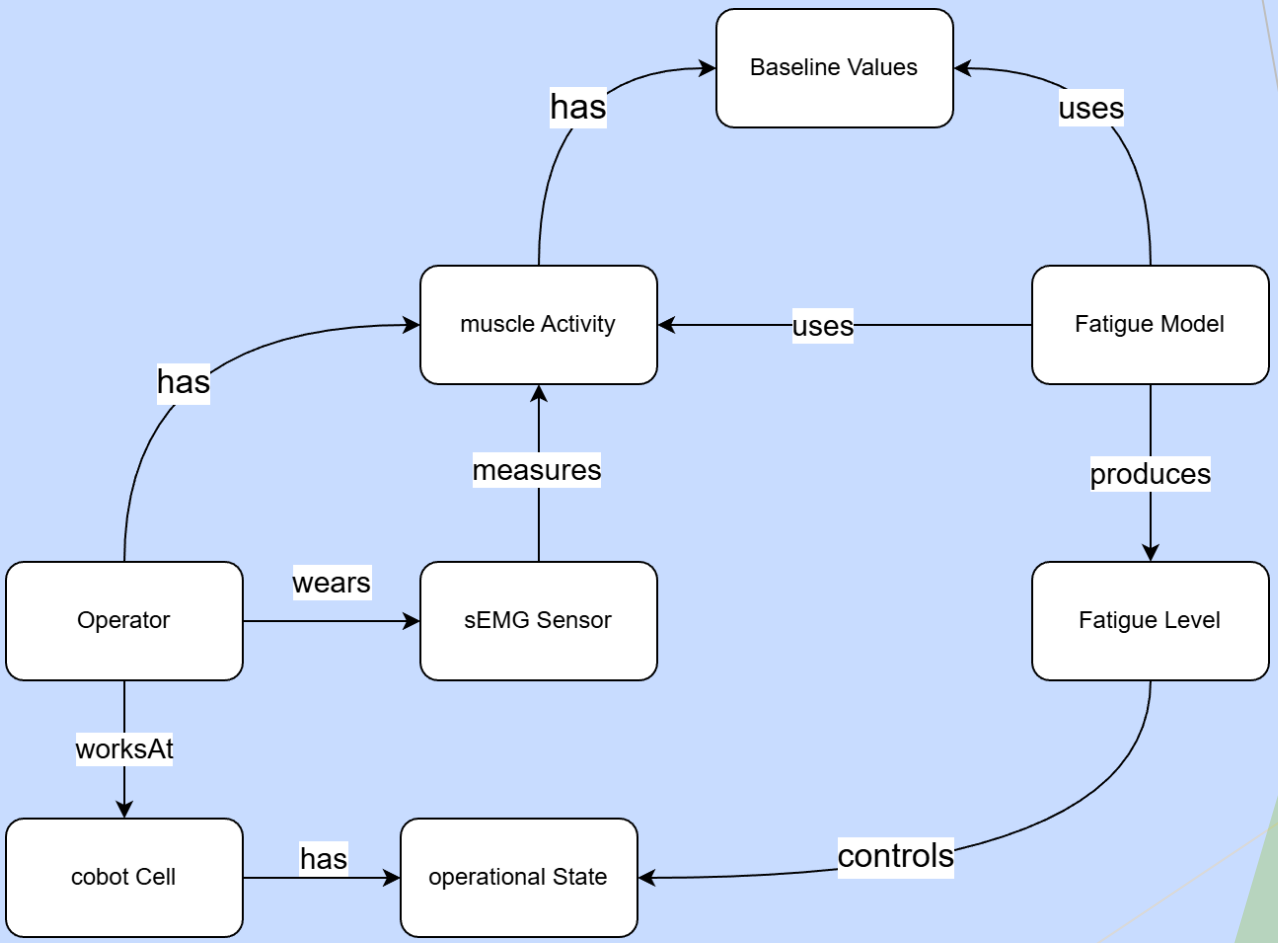
- Context Controller
  - Orion-LD Context Broker
- Context Drivers
  - IoT Agents
  - Mintaka for time-series history

Basic Architecture of applications





Information Model – UC1 example



Information Model – P2CODE

Baseline entity


```
{
    "id": "urn:ngsi-ld:baseline:EMG01",
    "type": "baseline",
    "medianFrequency": [
        106,
        101,
        102,
        103,
        104,
        105
    ],
    "meanFrequency": [
        100,
        101,
        102,
        103,
        104,
        105
    ],
    "meanPowerFrequency": [
        100,
        101,
        102,
        103,
        104,
        105
    ],
    "zeroCrossingFrequency": [
        100,
        101,
        102,
        103,
        104,
        105
    ]
}
```


sEMG sensor entity


```
{
    "id": "urn:ngsi-ld:sEMG:EMG1000",
    "type": "sEMG",
    "timeStamp": {
        "type": "Property",
        "value": "2025-11-11T17:35:40.821632",
        "observedAt": "2025-11-11T16:35:40.050Z"
    },
    "data": {
        "type": "Property",
        "value": [
            0.01698101,
            0.008487401,
            0.012340299,
            0.015463838,
            0.013988255,
            0.004421186
        ],
        "observedAt": "2025-11-11T16:35:40.050Z"
    },
    "index": {
        "type": "Property",
        "value": 5296,
        "observedAt": "2025-11-11T16:35:40.050Z"
    },
    "feasibility": {
        "type": "Property",
        "value": [
            true,
            true,
            true,
            true,
            true,
            true
        ],
        "observedAt": "2025-11-11T16:35:40.050Z"
    }
}
```


Fatigue state


```
{
    "id": "urn:ngsi-ld:EmgFrequencyDomainFeatures:001",
    "type": "EmgFrequencyDomainFeatures",
    "trialName": "test1",
    "medianFrequencyState": [
        0.599209275,
        0.603771272,
        0.609060649,
        0.591383793,
        0.614548592,
        0.6209736
    ],
    "meanFrequencyState": [
        0.6,
        0.606,
        0.612,
        0.618,
        0.624,
        0.63
    ],
    "meanPowerFrequencyState": [
        0.464379277,
        0.468419936,
        0.472753652,
        0.469654434,
        0.479194551,
        0.487670828
    ],
    "zeroCrossingFrequencyState": [
        0.209205021,
        0.220043573,
        0.215189873,
        0.211934156,
        0.199616123,
        0.209500838
    ]
}
```

Wearable Sensor Integration

- Supports diverse industrial protocols – OPCUA, MQTT, ROS2, etc.
- IoT Driver converts sensor inputs to NGSI-LD
- Simplified sensor registration
  - Two POST requests and your sensor is connected and publishing data to the databases

Fatigue/Stress Model Integration

- Uses FIWARE APIs to consume the physiological data from the databases
- Subscriptions to specific NGSI entities trigger adaptive responses
  - If cobotState entity changes its value, an automatic MQTT message is sent to the cobot cell to change the operating state.

Lessons Learned

✓ What worked well:

- Multi vendor physiological sensor integration with production machinery.
- Real Time high frequency data collection(1000Hz+) and processing
- Interoperability – Linked Data entities
- Lower development effort
- Semi industrial Implementation

⚠ Challenges and Future perspectives:

- GDPR and Privacy concerns In context of Physiological data processing and storage.
- Full scale Industrial Implementation
- Contribution Sensors – EEG, Eye trackers, EDA etc.
- Human Digital Twin - NGSI-LD Information Model

Thank You

- Questions?
- Contact information

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