Immersive Web of Things Applications in Mixed Reality

- M.Sc. **Fady Salama** – Research Associate at ESI TUM
- M.Sc. **Roman Binkert** – Research Associate at ESI TUM

Motivation

Foto: Tim Reckmann via ccnull.de

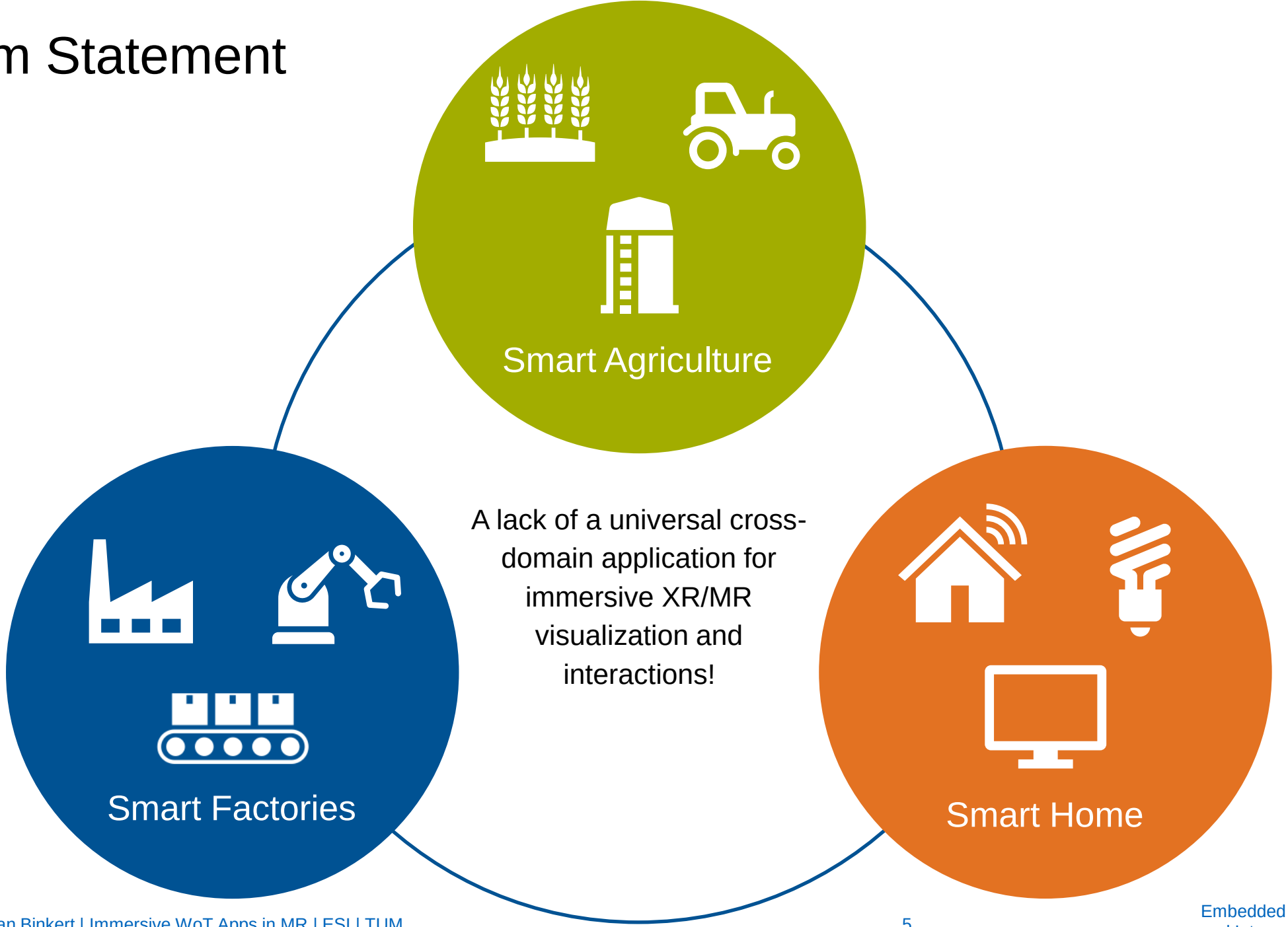
Motivation

Sobalvarro, P. (2018, October 30). The Factory as a Machine. Veo Robotics. Retrieved from https://www.veobot.com/blog/2018/10/30/the-factory-as-a-machine

Motivation

"Innovation in der digitalen Landwirtschaft" by Marco Verch via ccnull.de, CC-BY 2.0

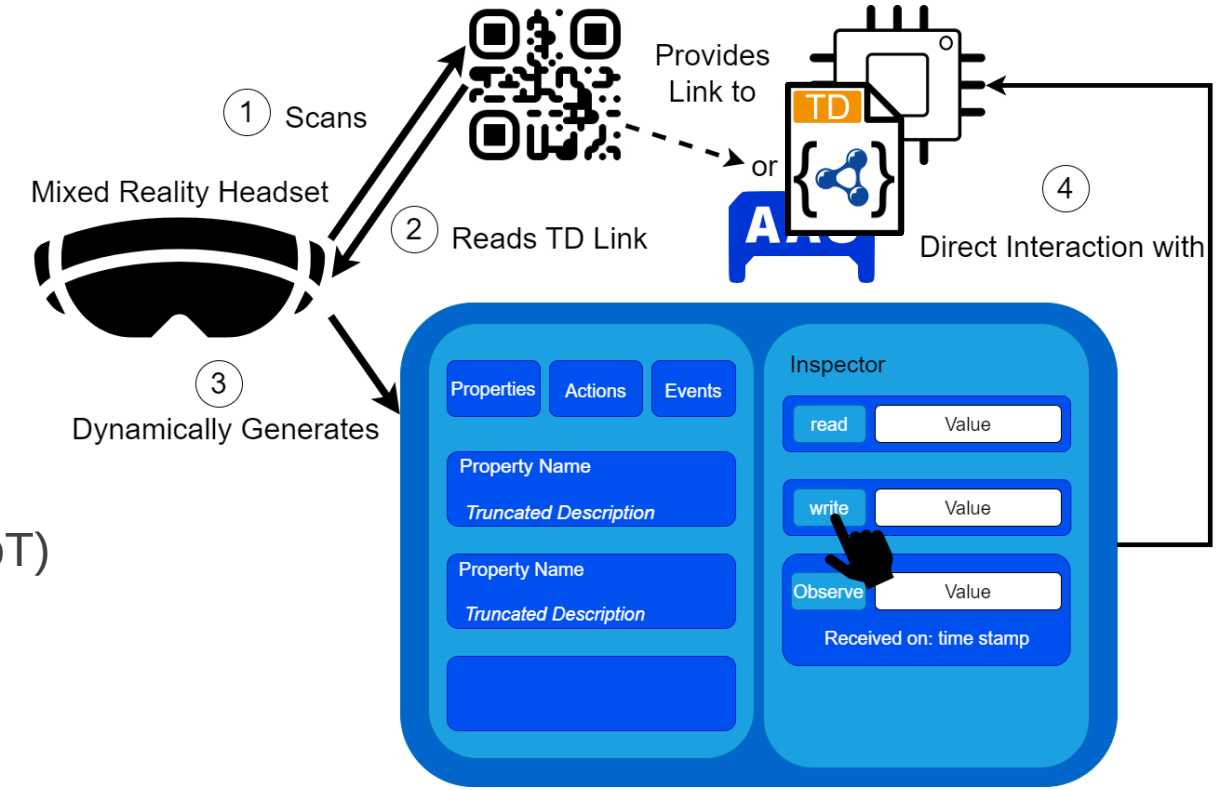
Problem Statement



Idea Approach

XR Application: HoloWoT

- Immersive, seamless, user-centric
- Cross-Platform compatibility
- Dynamic UI generation in runtime
- No intermediaries between XR device and IoT device
- Connectivity established through the Web of Things (WoT)



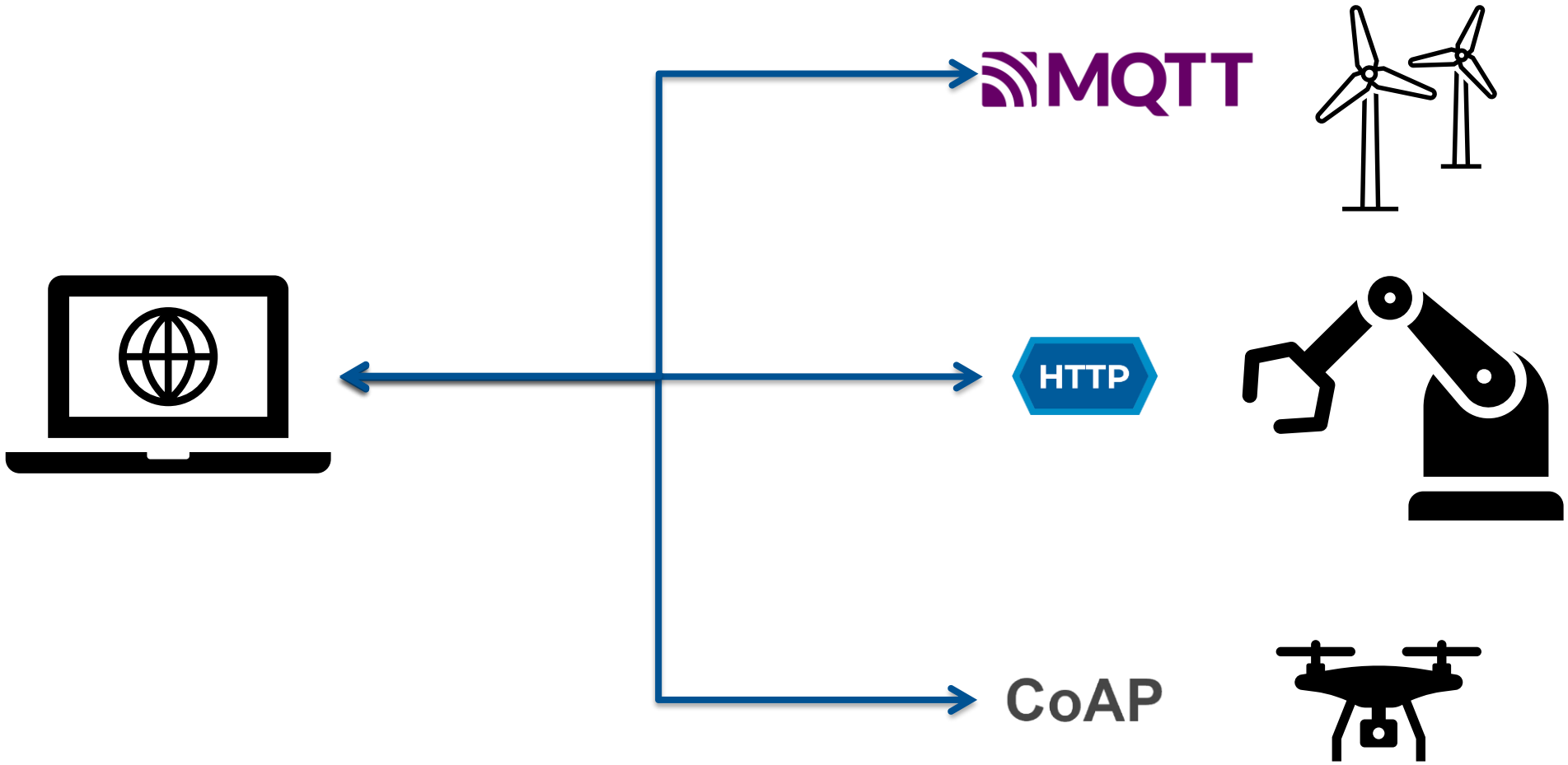
Project Details

Communication

Interaction

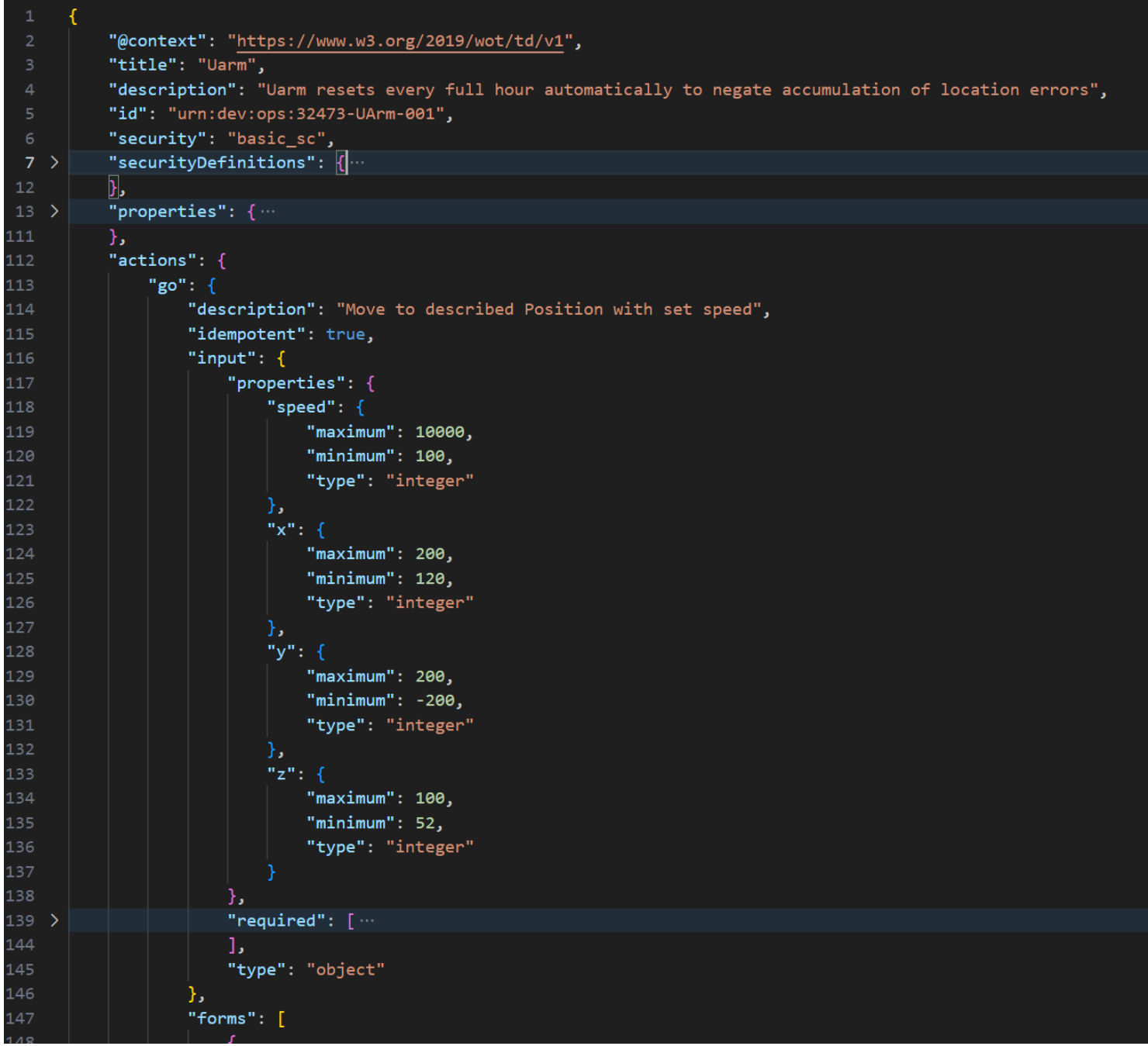
Web of Things

- Goal: Enhance IoT interoperability by applying standardized Web technologies



WoT Thing Description

- Interaction Affordances:
  - Property
  - Action
  - Event
- General Metadata
- Data Schemas



```
{
    "@context": "https://www.w3.org/2019/wot/td/v1",
    "title": "Uarm",
    "description": "Uarm resets every full hour automatically to negate accumulation of location errors",
    "id": "urn:dev:ops:32473-UArm-001",
    "security": "basic_sc",
    "securityDefinitions": {···
    },
    "properties": {···
    },
    "actions": {
        "go": {
            "description": "Move to described Position with set speed",
            "idempotent": true,
            "input": {
                "properties": {
                    "speed": {
                        "maximum": 10000,
                        "minimum": 100,
                        "type": "integer"
                    },
                    "x": {
                        "maximum": 200,
                        "minimum": 120,
                        "type": "integer"
                    },
                    "y": {
                        "maximum": 200,
                        "minimum": -200,
                        "type": "integer"
                    },
                    "z": {
                        "maximum": 100,
                        "minimum": 52,
                        "type": "integer"
                    }
                },
                "required": [···
                ],
                "type": "object"
            },
            "forms": [
```

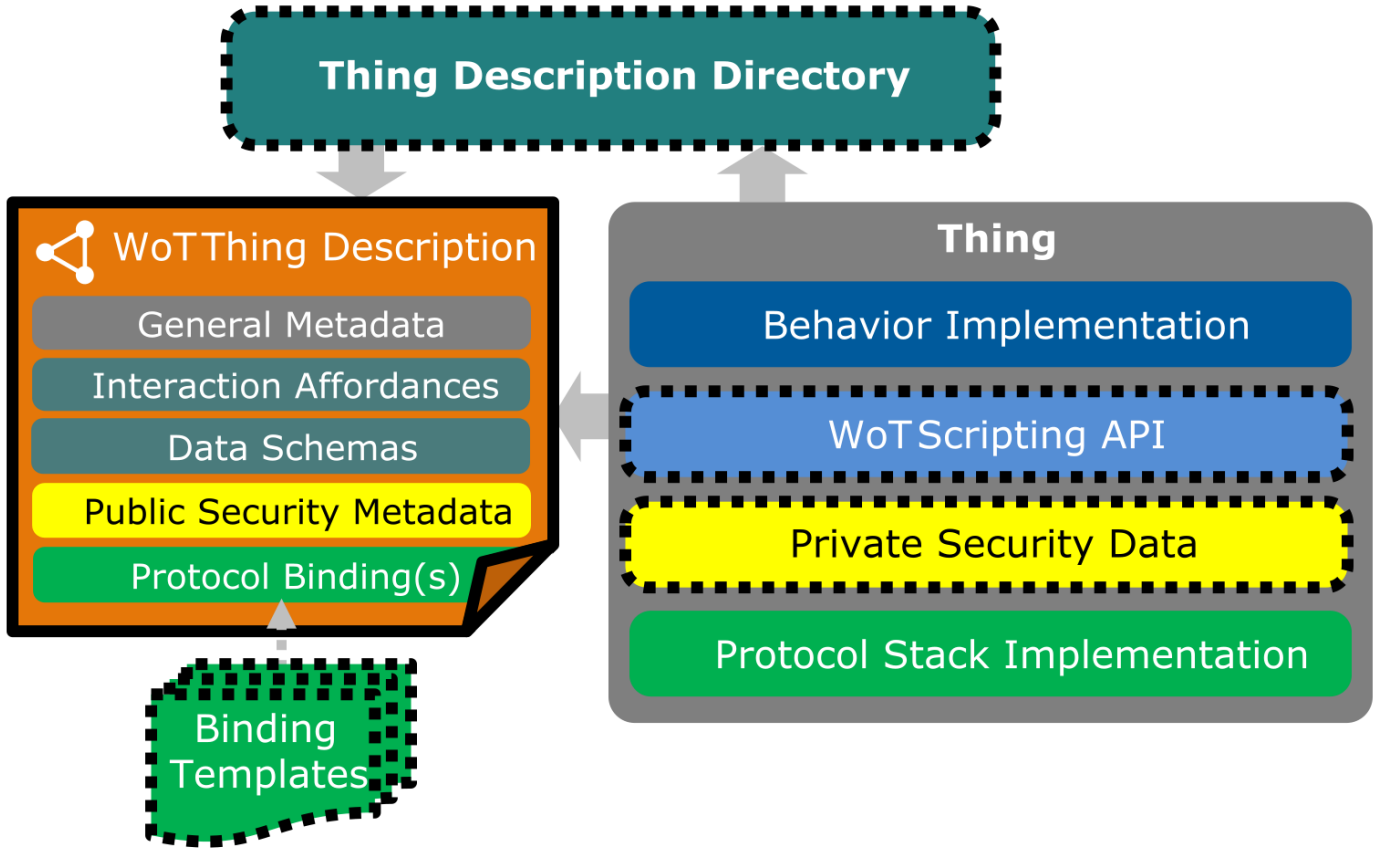
WoT Thing Description

Forms & Protocol Bindings

- Match Interaction Affordance to actual, protocol-specifc request

```
"go": {
    "description": "Move to described Position with set speed",
    "idempotent": true,
    "input": {
        "properties": {
            "speed": {
                "maximum": 10000,
                "minimum": 100,
                "type": "integer"
            },
            "x": {
                "maximum": 200,
                "minimum": 120,
                "type": "integer"
            },
            "y": {
                "maximum": 200,
                "minimum": -200,
                "type": "integer"
            },
            "z": {
                "maximum": 100,
                "minimum": 52,
                "type": "integer"
            }
        },
        "required": [ ···
        ],
        "type": "object"
    },
    "forms": [
        {
            "contentType": "application/json",
            "href": "http://172.16.1.150:8080/uarm/actions/gowithspeed",
            "htv:methodName": "POST",
            "op": "invokeaction"
        },
        {
            "contentType": "application/json",
            "href": "mqtt://dbbroker.local:1883/uarm/actions/gowithspeed",
            "mqv:controlPacketValue": "PUBLISH",
            "op": "invokeaction"
        }
    ]
}
}
}
```

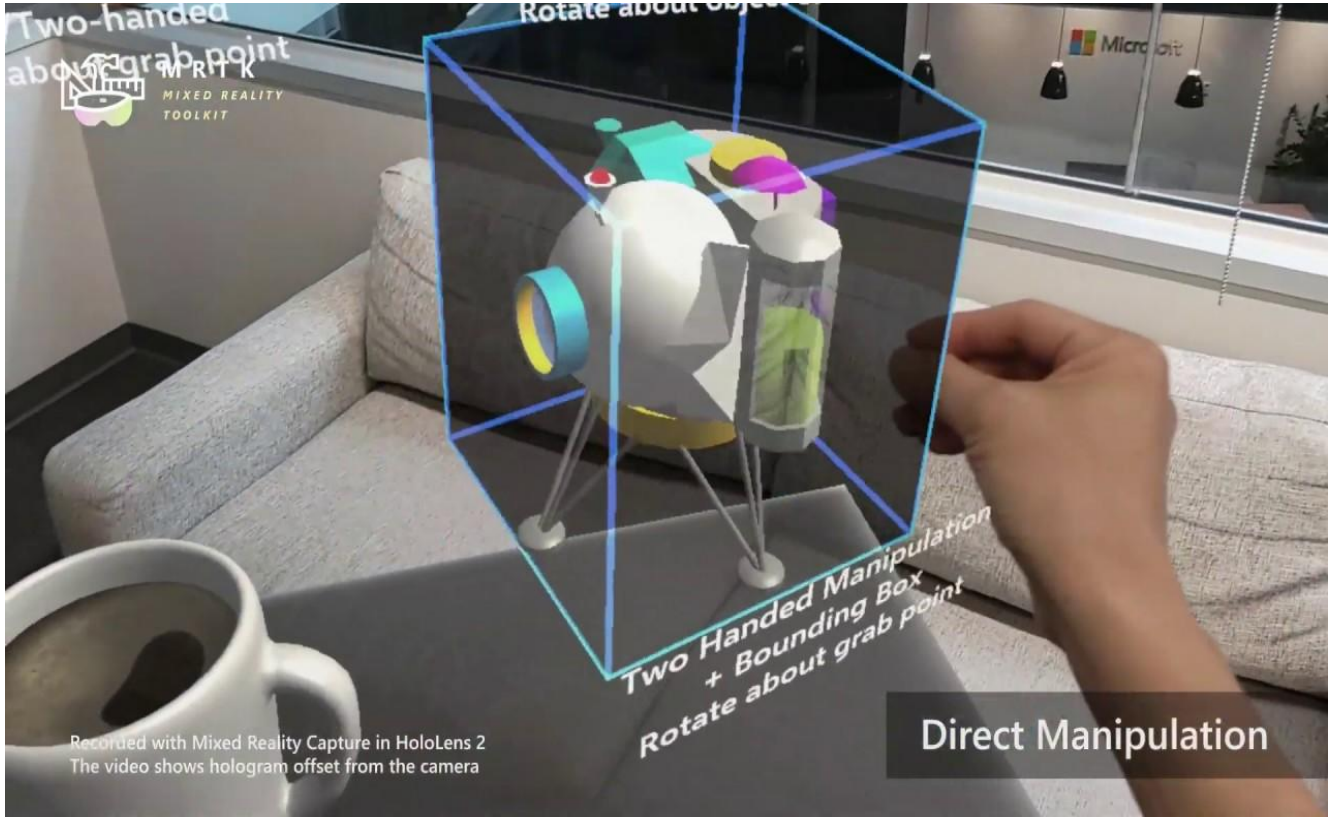
Web of Things: Building Blocks



https://www.w3.org/TR/wot-architecture11/

Microsoft Hololens 2

- AR Headset
- Holographic overlay
- Interaction via gesture, voice, eye tracking
- Mapping of environment

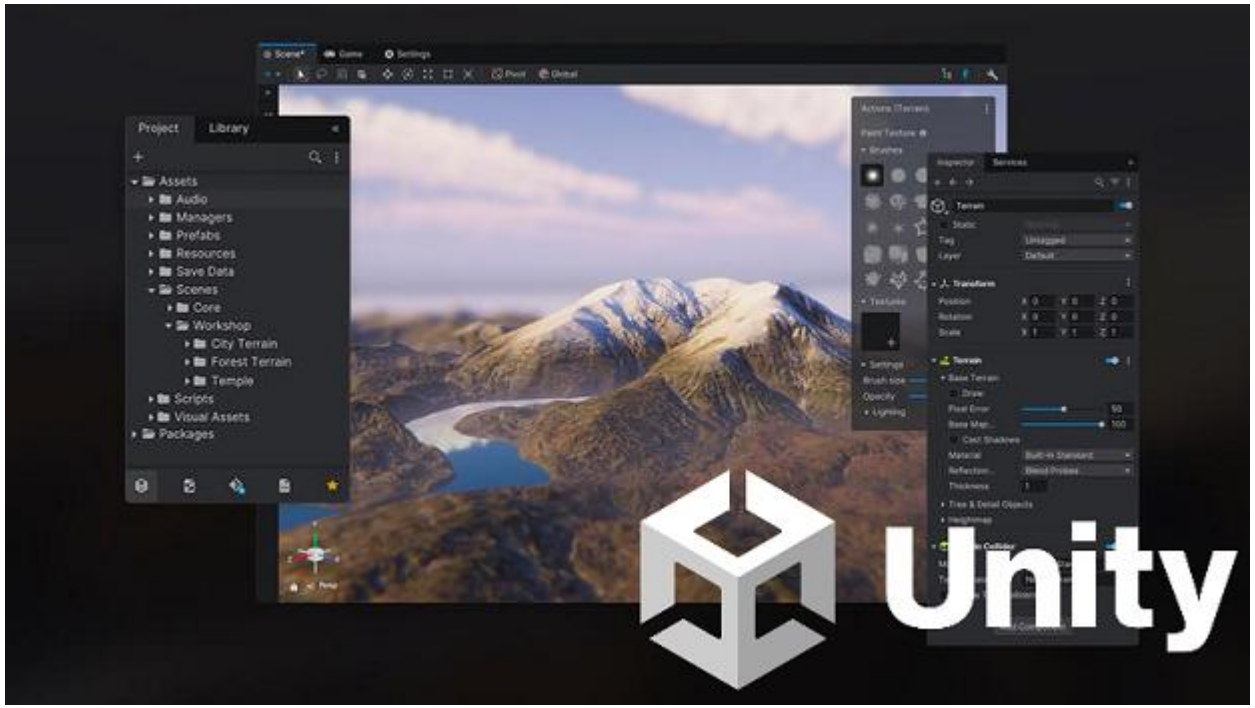


https://learn.microsoft.com/de-de/windows/mixed-reality/develop/unity/galaxy-explorer-update

Hololens Programming

- Unity
  - Cross-platfrom game engine
  - Game Objects in Scenes
  - C# Scripts

- Mixed Reality Toolkit (MRTK)
  - Spatial awareness and holographic anchors
  - Gesture recognition and hand tracking
  - openXR plugin for cross-platform compatibility

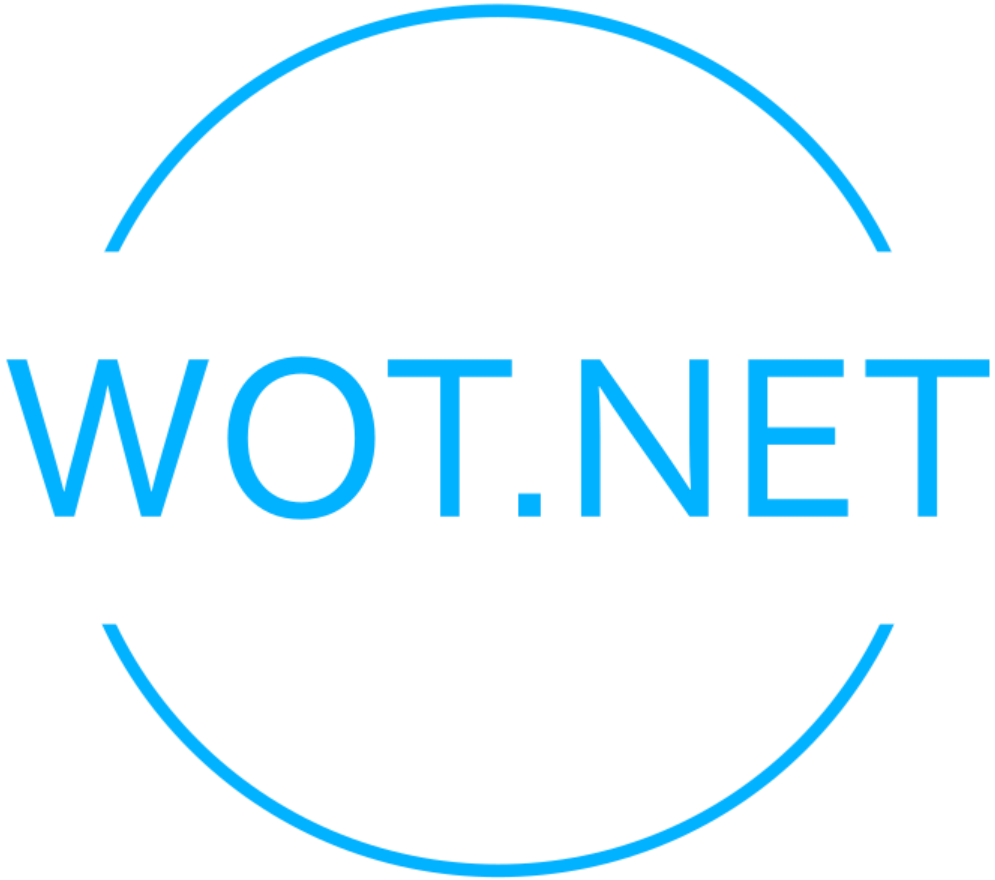


https://dotnet.microsoft.com/en-us/apps/games/unity

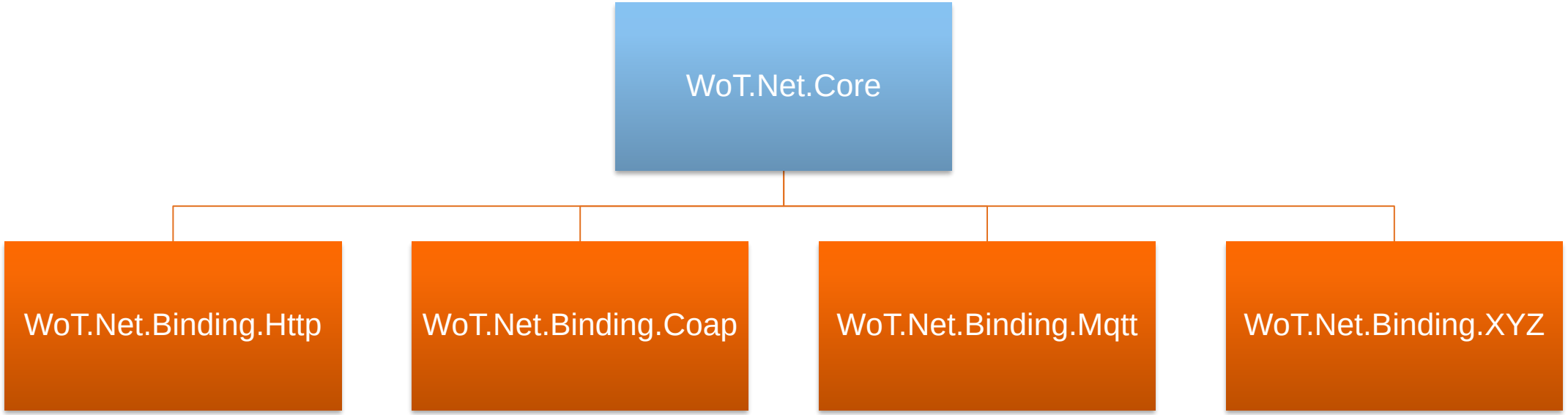
Project Details

Communication: WoT.Net

- Deserialize and parse a Thing Description
- Handle HTTP/S Request
- Handle basic security scheme
- .NET Standard 2.0
- Open-source
- Source Code available in https://github.com/tum-esi/WoT.Net



Project Details



What is currently implemented:

- WoT.Net.Core → https://www.nuget.org/packages/WoT.Net.Core
  - TD Parsing and conversion
  - WoT Interfaces
  - Consumer
- WoT.Binding.Http → https://www.nuget.org/packages/WoT.Net.Binding.Http
  - HTTP/S Client
  - Security

WoT.Net.Core

Documentation:
https://tum-esi.github.io/WoT.Net/api/WoT.Core.html

JSON Schema Types	C#
“null”	null
“boolean”	bool
“integer”	integer
“number”	double
“string”	string
“array”	List<T>
“object”	Dictionary<string,T>

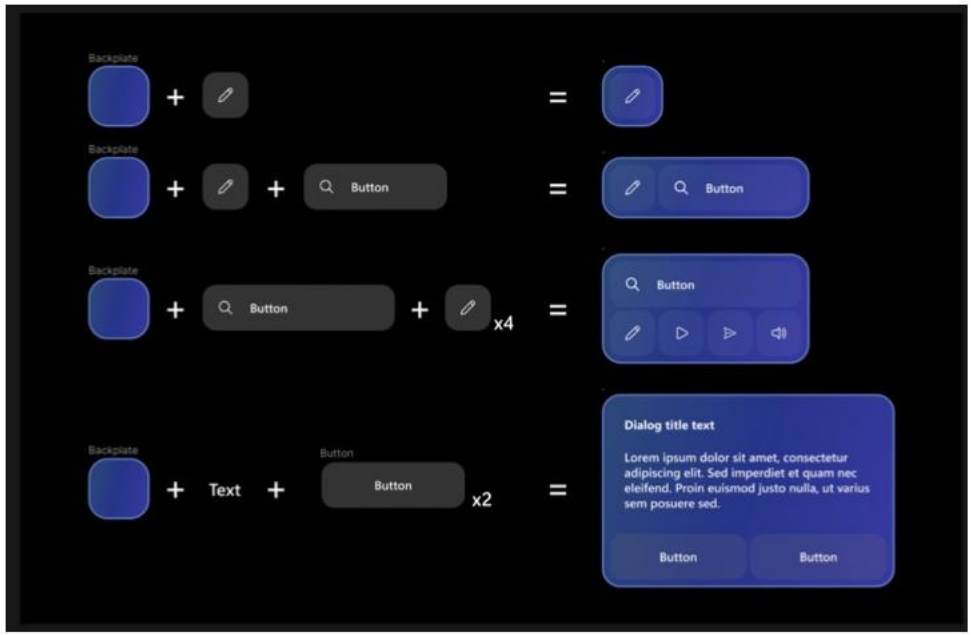
WoT.Net.Binding.Http

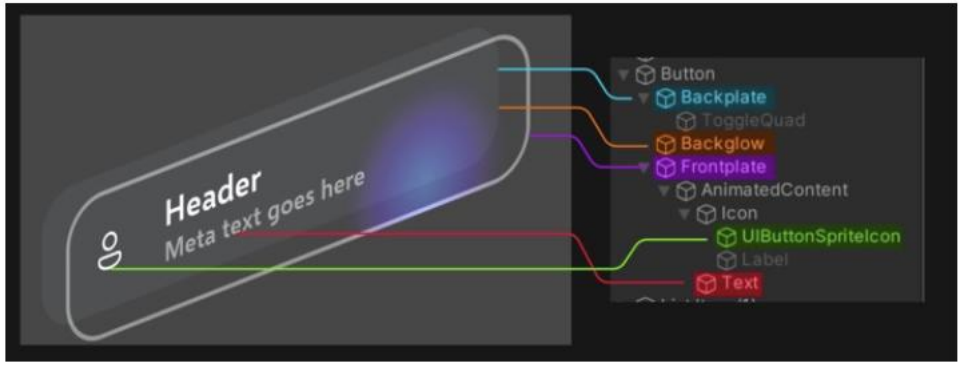
Documentation:
https://tum-esi.github.io/WoT.Net/api/WoT.Binding.Http.html

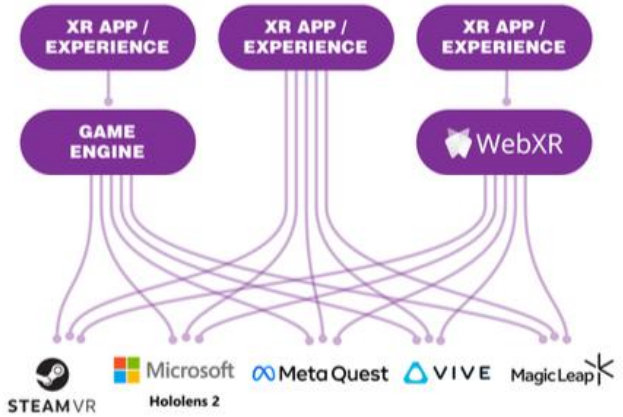
Project Details

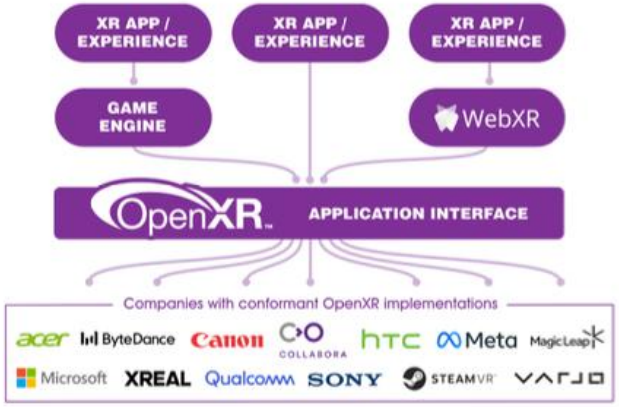
Interaction: XR Application

- Developed in Unity, C#
- Device and platform agnostic (OpenXR)
- Microsoft Mixed Reality Tool Kit 3 (MRTK3)
- Canvas Based UI elements
- QR Code Detection and Tracking
- Interaction specific prefabs









UI Prefabs


Read
Value
Successfully read on:


Read
Enum1
Successfully read on: Timestamp


Read
Value
Successfully read on:


Write


Write
Slider value
Min
Max


Write
Enter text...

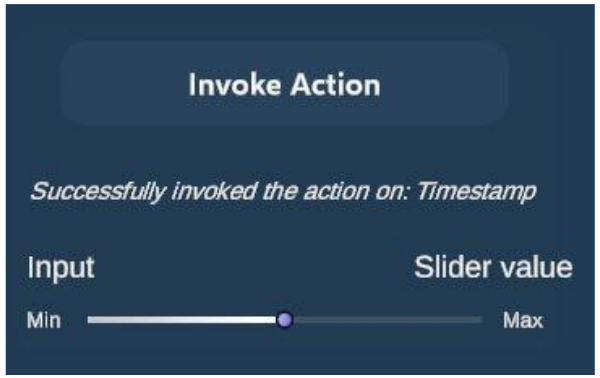

Write
Enum1


Observe
Observable 1
Received on: Timestamp


Observe
Value
Received on: Timestamp


Invoke Action
Successfully invoked the action on: Timestamp


Invoke Action
Successfully invoked the action on: Timestamp
Input
Enum1


Invoke Action
Successfully invoked the action on: Timestamp
Input
Slider value
Min
Max

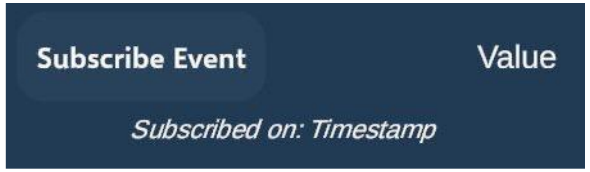

Invoke Action
Successfully invoked the action on: Timestamp
Input
Enter text...


Subscribe Event
Output 1
Subscribed on: Timestamp


Subscribe Event
Subscribed on: Timestamp

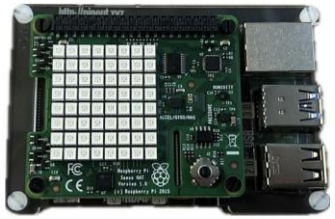

Invoke Action
Successfully invoked the action on: Timestamp
Input


Invoke Action
Successfully invoked the action on: Timestamp
Output
Output Value


Subscribe Event
Value
Subscribed on: Timestamp


Invoke Action
Successfully invoked the action on: Timestamp
Output
Array item 1

Application Flow



Application Flow

Demo Video: Please see the video on the WoT CG YouTube

HoloWoT 2.0 – Bring Mashup to Mixed Reality

How could we design an accessible, scalable, low-code IoT orchestration framework using the Web of Things (WoT) standard?

Approach – UI Improvements

Separation of concerns!

Approach – UI Improvements

Sticky Scrollable Panel

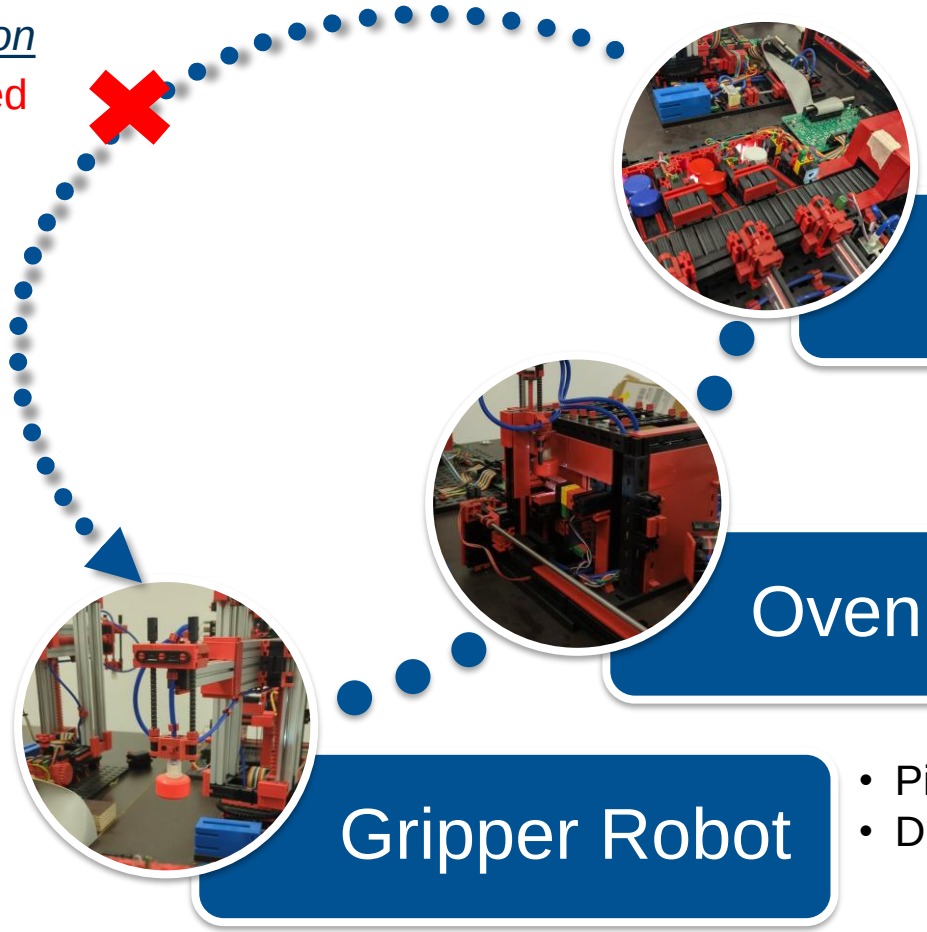
Nested Data Structures

Selecting an Input

Approach – Mashup Creation

Trigger Condition

If product **is** Red



Sorting Line

Sort Product into red/blue/white

Oven

Start Baking + *Input* (e.g. 5 sec)

Gripper Robot

- Pick Object from Red Position
- Drop Object at …

- Pick Object from Warehouse
- Drop Object at Oven

Approach – Mashup Creation

Demo Video: Please see the video on the WoT CG YouTube

Thank you for your attention

Contact Details:

Fady Salama
Research Associate

Associate Professorship of Embedded Systems and Internet of Things
School of Computation, Information and Technology
Technical University of Munich

E-Mail:
- fady.salama@tum.de
- roman.binkert@tum.de

Homepage

Email:
Fady Salama

Email:
Roman Binkert