

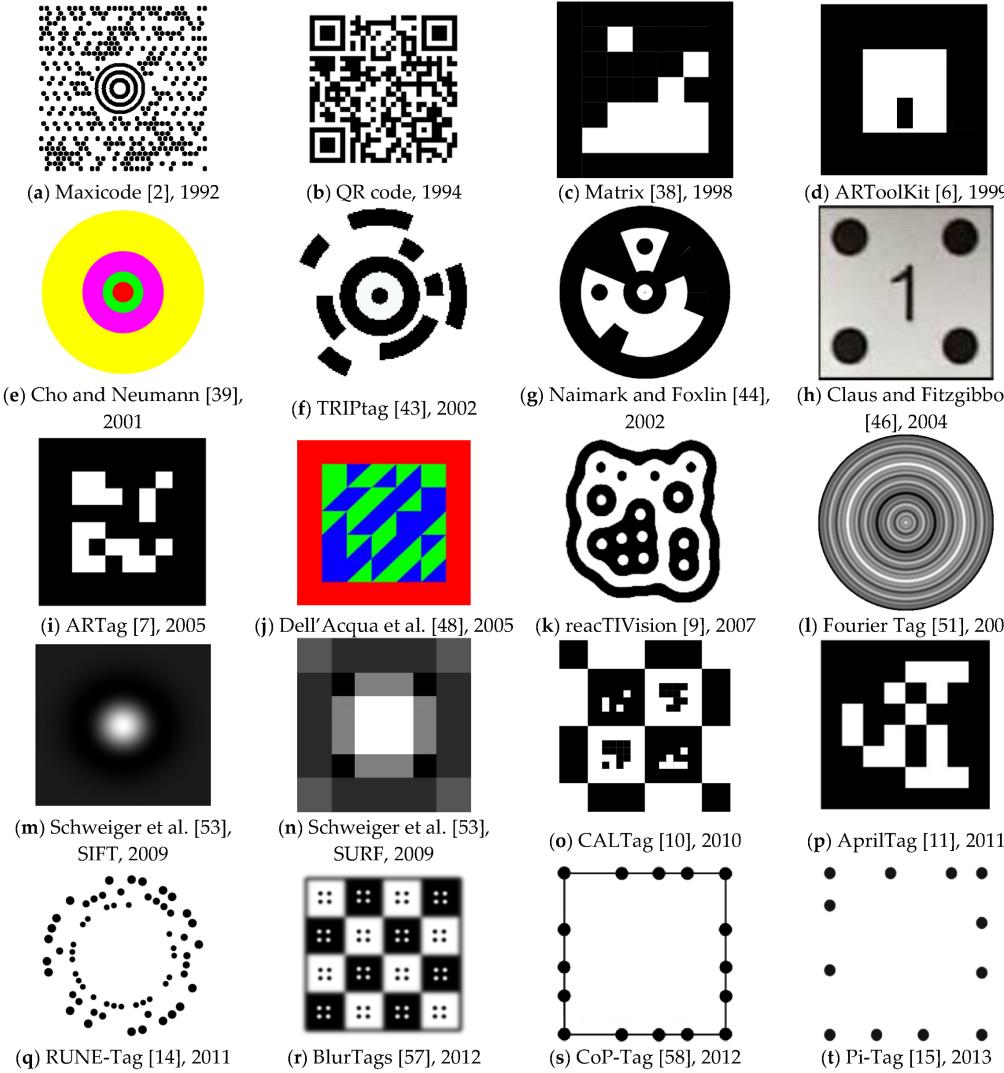


# FidMark: A Fiducial Marker Ontology For Semantically Describing Visual Markers

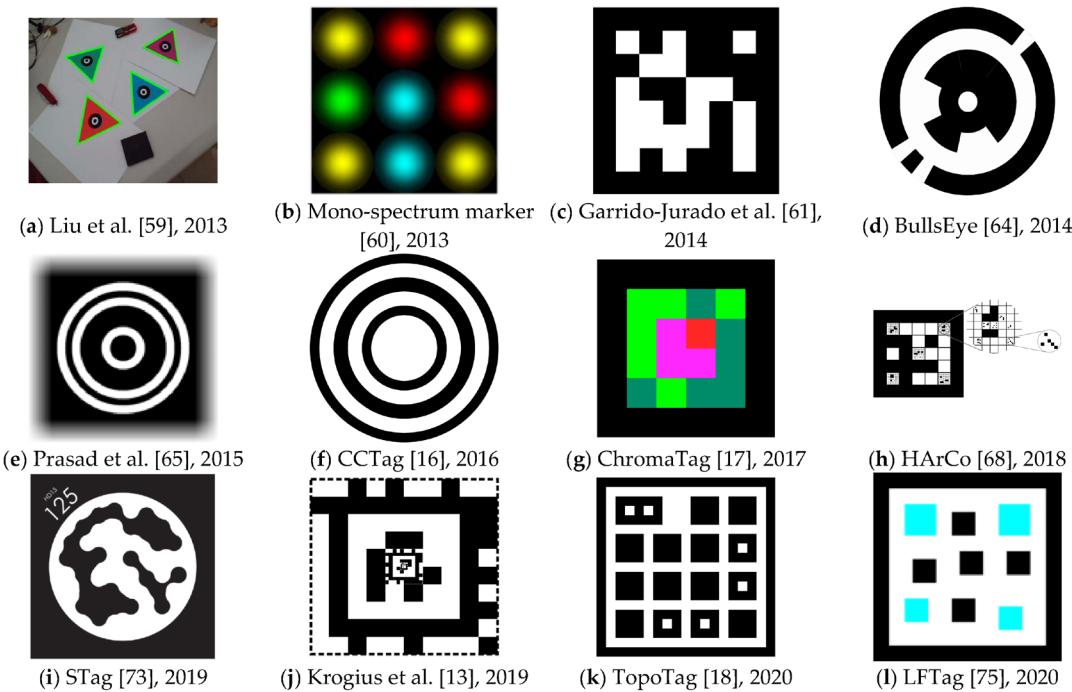
Maxim Van de Wynckel, Isaac Valadez, Beat Signer



# Background – Fiducial Marker



Košťák, M.; Slabý, A. Designing a Simple Fiducial Marker for Localization in Spatial Scenes Using Neural Networks. *Sensors* 2021, *21*, 5407.

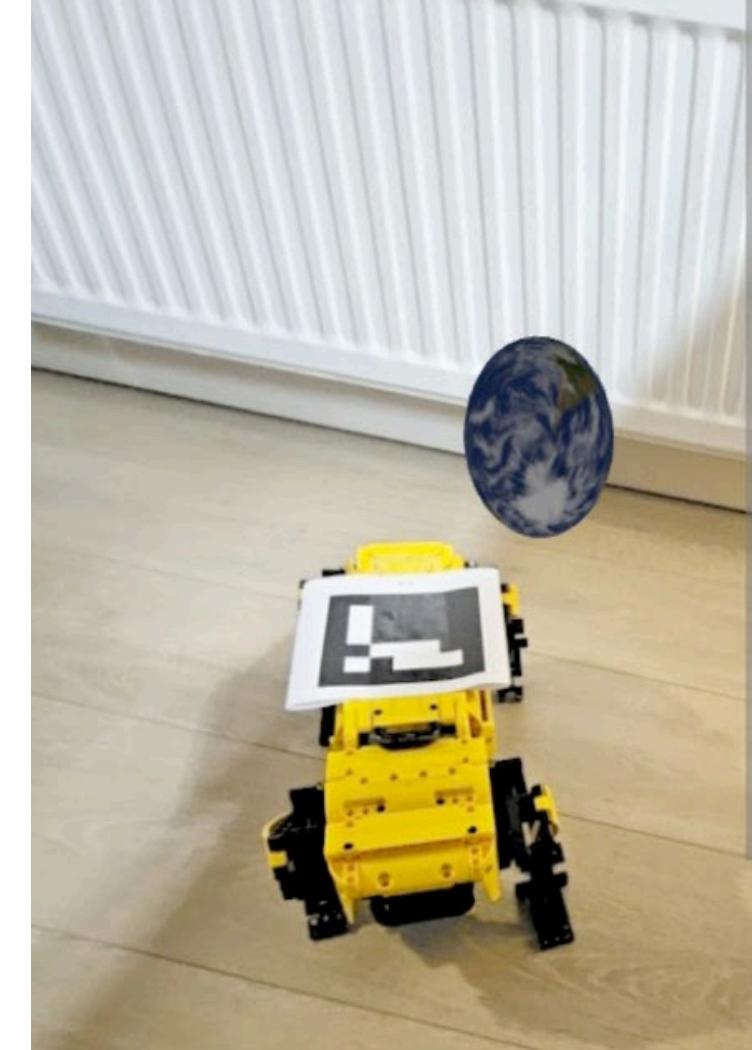




# Problem

How can we define a common reference space between two independent augmented reality frameworks?

How can we define this common reference space using a wide range of fiducial markers?





# Methodology



1. Identification of **existing ontologies**
2. Identification of **existing frameworks**
  - a) Analysis of terminologies, algorithms and usage
3. Identification of common **markers types** (and variations)
  - a) Analysis of the encoded data and properties of each type
  - b) Analysis of terminologies used by these marker types
4. **Design goals** based on problem statement
5. **Design** of ontology
6. **Validation** of the design goals using SPARQL queries
7. **Integration** testing of the ontology



# Methodology - Design Goals



Central goal: “Interoperable Augmented Reality Applications”

**DG1** Retrieve a list of supported markers

**DG2** Retrieve markers using the identifiable information

**DG3** Describe markers with a non-standard symbology

**DG4** Enable pose estimation of markers

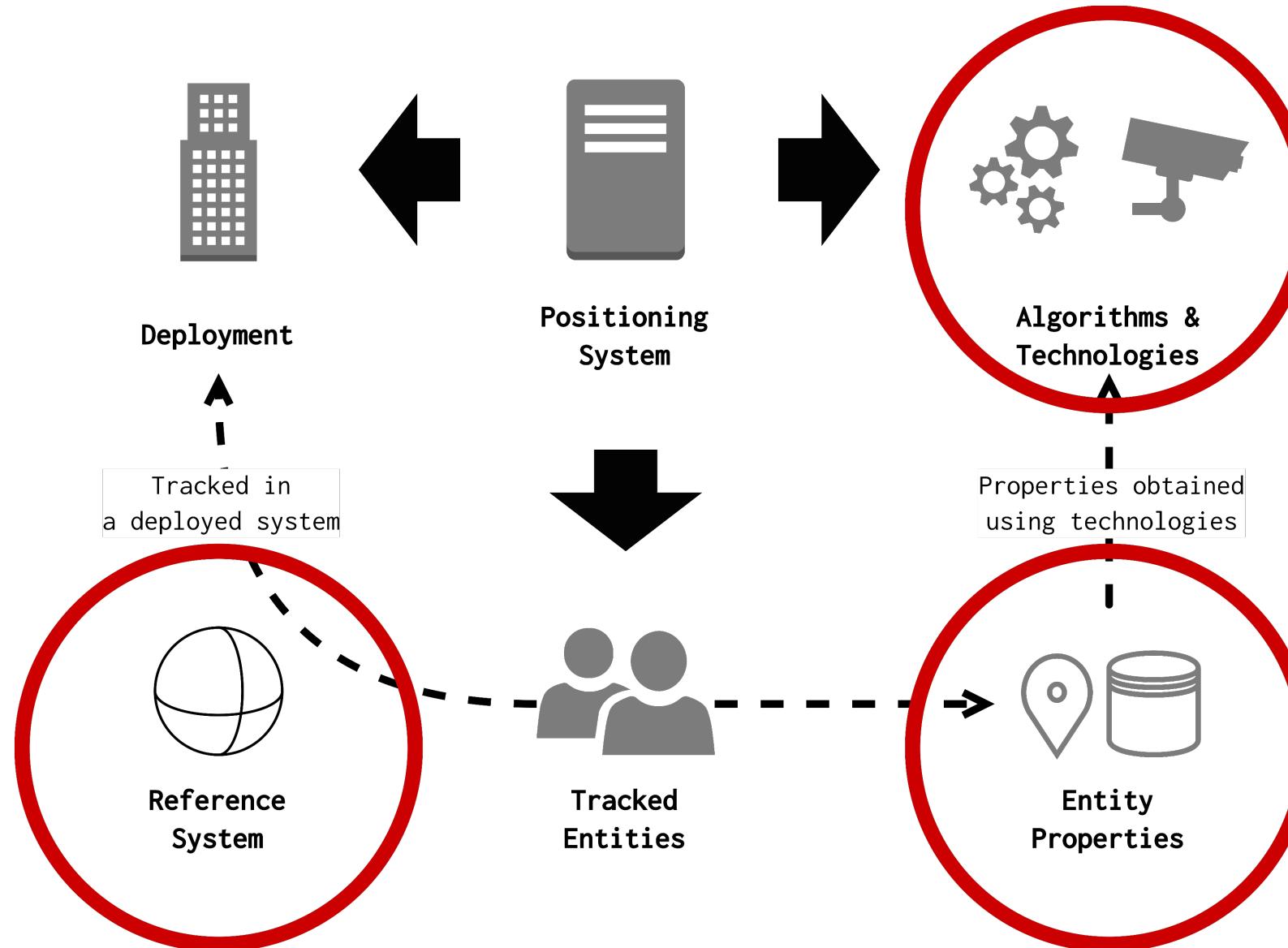
**DG5** Enable relative positioning of objects to markers

**DG6** Enable markers as engineering reference frames

**DG7** Facilitate the integration in CV frameworks

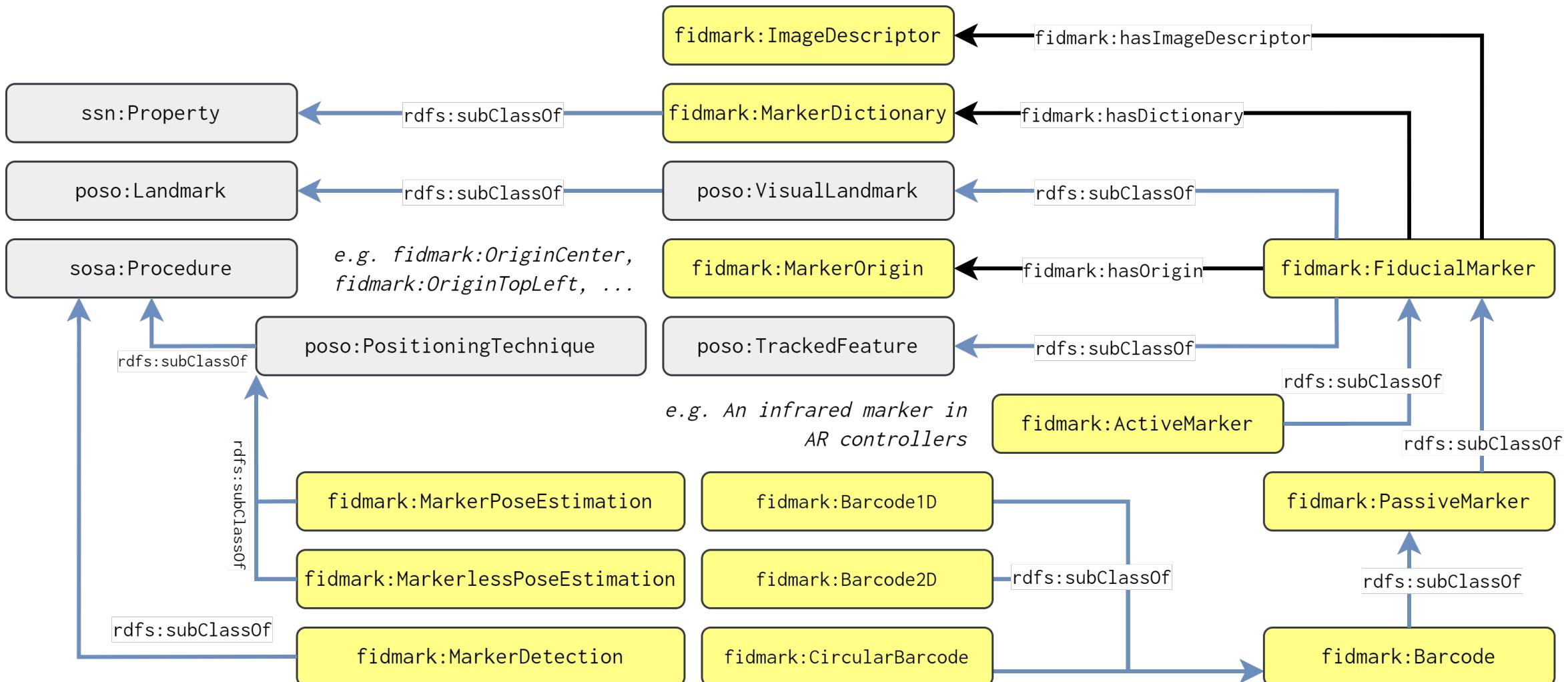


# Ontology Design



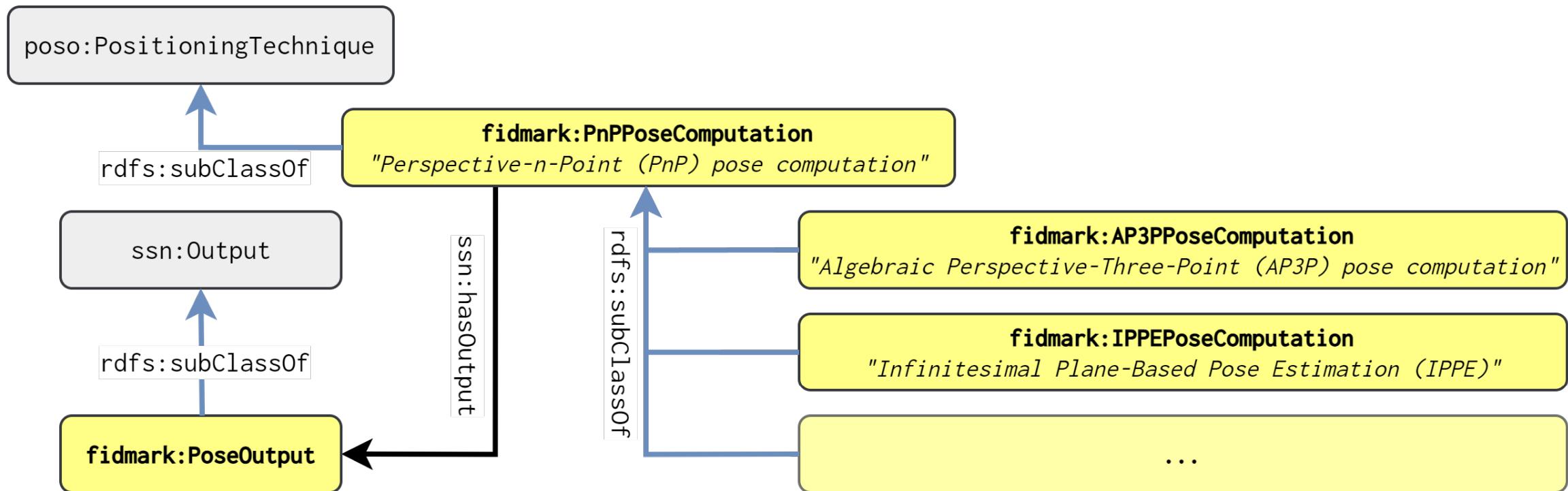
Maxim Van de Wynckel and Beat Signer. 2022. POSO: A Generic Positioning System Ontology. In The Semantic Web - ISWC 2022: 21st International Semantic Web Conference, Virtual Event, October 23-27, 2022, Proceedings. Springer-Verlag, Berlin, Heidelberg, 231–247.

# Ontology Design





# Ontology Design





# Validation



- OOPS! Validator (OntOlogy Pitfall Scanner)
- Examples and generated data for SPARQL
- SPARQL queries for design goals
- Demonstrator Web application



# Validation – Example



```
:marker-1 a fidmark:ArUco ;
    fidmark:markerIdentifier 10 ;
    fidmark:hasOrigin fidmark:CenterOrigin ;
    fidmark:hasDictionary fidmark:DICT_MIP_36h12 ;
    fidmark:hasWidth [ a qudt:QuantityValue ;
        qudt:unit unit:MilliM ; qudt:numericValue "200"^^xsd:double ] ;
    fidmark:hasHeight [ a qudt:QuantityValue ;
        qudt:unit unit:MilliM ; qudt:numericValue "200"^^xsd:double ] .

:earth a sosa:FeatureOfInterest ;
    poso:hasPosition [ a poso:RelativePosition ;
        poso:isRelativeTo :marker-1 ;
        poso:xAxisValue [ ... ] ; poso:yAxisValue [ ... ] ;
        poso:zAxisValue [ a qudt:QuantityValue ;
            qudt:unit unit:CentiM ; qudt:numericValue "10"^^xsd:double ] ] ;
    omg:hasGeometry [ a omg:Geometry;
        fog:asGltf ".../earth.gltf"^^xsd:anyURI ] .
```



# Validation – SPARQL queries



*Get the position and orientation of a detected marker  
(i.e. an ArUco marker with ID 19)*

```
SELECT ?position ?orientation WHERE {  
    ?markerType rdfs:subClassOf* fidmark:ArUco .  
    ?marker a ?markerType .  
    ?marker fidmark:identifier 19 .  
    ?marker poso:hasPosition ?position .  
    ?marker poso:hasOrientation ?orientation .  
}
```



# Validation – SPARQL queries



*Get all virtual objects placed relative to a QR-code marker with the data 0x001122334455*

```
SELECT ?object WHERE {  
    ?object a sosa:FeatureOfInterest .  
    ?object omg:hasGeometry ?geometry .  
    ?object poso:hasPosition ?position .  
    ?position poso:isRelativeTo ?marker .  
    ?marker a fidmark:QRCode .  
    ?marker fidmark:markerData "001122334455"^^xsd:hexBinary .  
}
```



# Validation – SPARQL queries



*Find all dictionaries and the count of markers that can be identified in this dictionary for the marker type "TopoTag". Ensure that at least 150 markers can be identified.*

```
SELECT ?dictionary ?size WHERE {
    ?dictionary a fidmark:MarkerDictionary .
    ?dictionary fidmark:supportedMarker fidmark:TopoTag .
    ?dictionary fidmark:dictionarySize ?size .
    FILTER(?size >= 150)
}
```



# Demonstrator



Camera



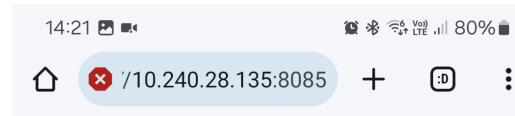
AR



text/turtle



Objects



Semantic Description

```
1 @prefix : <http://example.org/>.
2 @prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>.
3 @prefix sosa: <http://www.w3.org/ns/sosa#>.
4 @prefix ogc: <http://www.opengis.net/def/crs/OGC/1.3/CRS_OGC>.
5 @prefix dcmi: <http://purl.org/dc/terms/>.
6 @prefix xsd: <http://www.w3.org/2001/XMLSchema#>.
7 @prefix qudt: <http://qudt.org/schema/qudt#>.
8 @prefix unit: <http://qudt.org/vocab/unit#>.
9 @prefix poso: <http://purl.org/poso/>.
10 @prefix fidmark: <http://purl.org/fidmark/>.
11 @prefix example: <http://example.org/>.
12 @prefix omg: <https://w3id.org/omg#>.
13 @prefix fog: <https://w3id.org/fog#>.
14 .
15 example:marker-1 a fidmark:ArUco, sosa:hasFeatureOfInterest .
16 dcmi:created "2023-12-05T13:20:24".
17 fidmark:markerIdentifier 10;
18 fidmark:hasDictionary fidmark:DICT_MIP_36h12;
19 fidmark:hasHeight [
20   a qudt:QuantityValue;
21   qudt:unit unit:MilliM;
22   qudt:numericValue "150"^^xsd:double
23 ];
24 fidmark:hasWidth [
25   a qudt:QuantityValue;
26   qudt:unit unit:MilliM;
27   qudt:numericValue "150"^^xsd:double
28 ];
29 fidmark:DICT_MIP_36h12 a fidmark:Marker .
30 example:earth a sosa:FeatureOfInterest .
31 dcmi:created "2023-12-05T13:20:24".
```



Objects

Markers

[http://example.org/marker-1](http://example.org(marker-1)  
ID=10, DICT=[http://purl.org/fidmark/DICT\\_MIP\\_36h12](http://purl.org/fidmark/DICT_MIP_36h12)

[http://example.org/marker-2](http://example.org(marker-2)  
ID=94, DICT=[http://purl.org/fidmark/DICT\\_ARUCO\\_ORI...](http://purl.org/fidmark/DICT_ARUCO_ORI...)

Virtual Objects

<http://example.org/earth>  
GLTF=<https://raw.githubusercontent.com/microsoft/mi...>

<http://example.org/jupiter>  
GLTF=<https://raw.githubusercontent.com/microsoft/mi...>

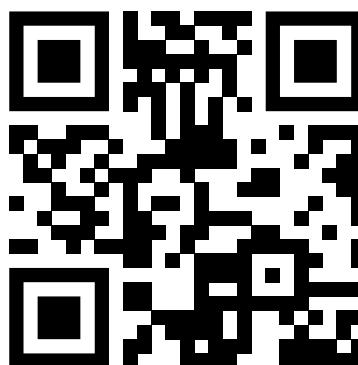




# Conclusions and Future Work



- Fiducial marker ontology with a focus on Augmented Reality and Pose estimation
- Extensible ontology with support for future marker types and dictionaries
- Expanding the dictionaries
- Demonstrator application & TypeScript library



<https://purl.org/fidmark/>  
<https://fidmark.openhps.org/>



<https://github.com/OpenHPS/FidMark/>



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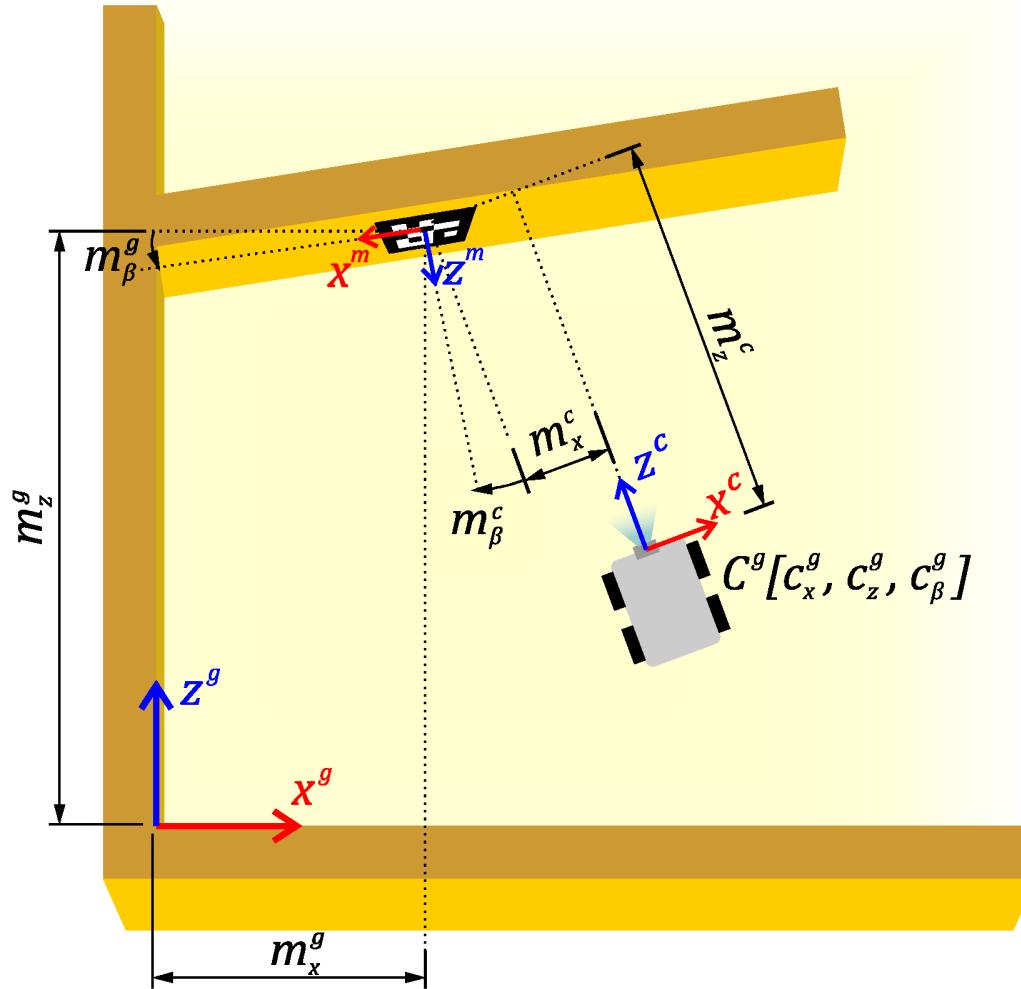


# Demonstrator





# Background – Pose Estimation



Adámek R, Brablc M, Vávra P, Dobossy B, Formánek M, Radil F. Analytical Models for Pose Estimate Variance of Planar Fiducial Markers for Mobile Robot Localisation. *Sensors*. 2023; 23(12):5746.

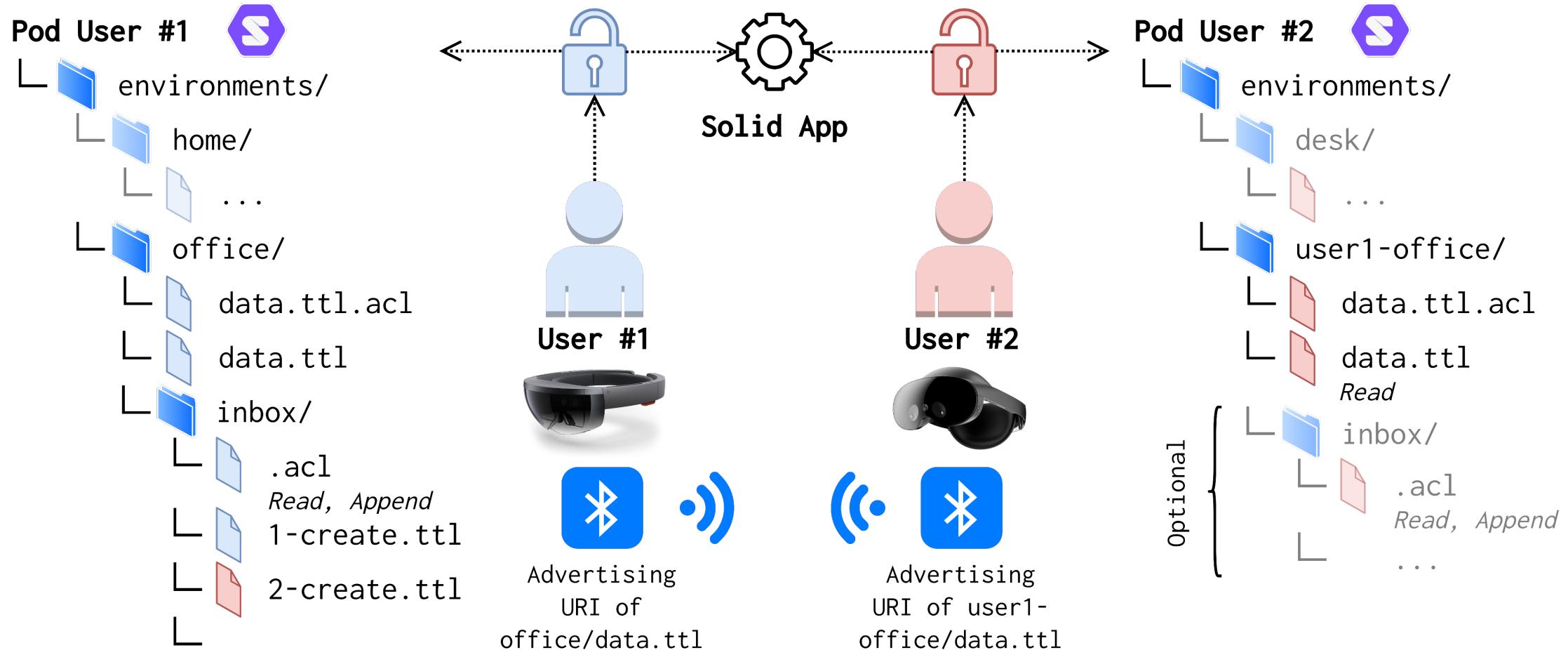
# Validation – SPARQL queries



*Select all square fiducial marker types*

```
SELECT ?markerType WHERE {
    ?markerType rdfs:subClassOf* fidmark:FiducialMarker .
    ?markerType fidmark:shape "Square"@en .
}
```

# Solid Symposium 2 - 3 May, 2024



```
<> a seas:Room ; rdfs:label "Our Lab"@en ;
    ldp:inbox <./inbox/> ;
    vcard:address [ ... ] .

:table_marker a fidmark:AruCo ;
    poso:hasPosition [ poso:isRelativeTo <> ] ;
    fidmark:hasDictionary fidmark:DICT_ARUCO_ORIGINAL ;
    fidmark:markerIdentifier 94 ;
    fidmark:hasOrigin fidmark:OriginCenter ;
    fidmark:hasHeight [ a qudt:QuantityValue ;
        qudt:unit unit:MilliM ; qudt:numericValue "80"^^xsd:double
    ] ;
    fidmark:hasWidth [ a qudt:QuantityValue ;
        qudt:unit unit:MilliM ; qudt:numericValue "80"^^xsd:double
    ] .
```