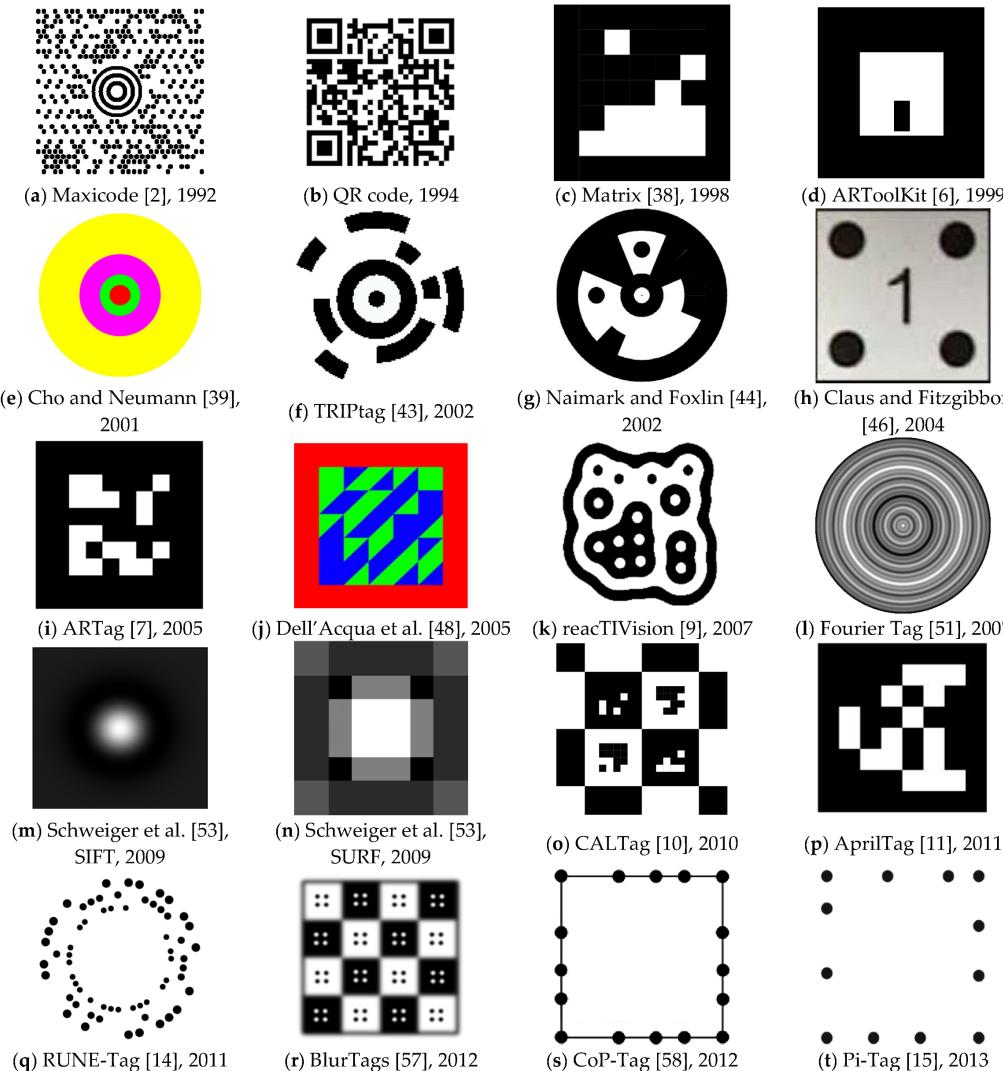


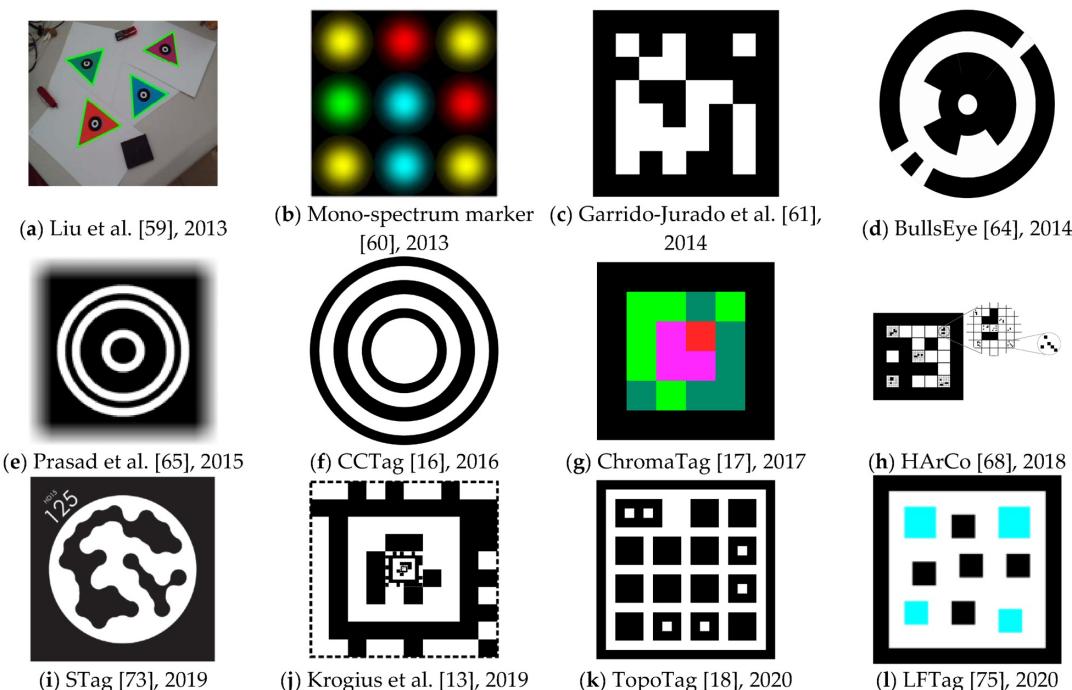
FidMark: A Fiducial Marker Ontology For Semantically Describing Visual Markers

Maxim Van de Wynckel, Isaac Valadez, Beat Signer

Background – Fiducial Marker



Košták, 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**
3. Identification of common **markers types** (and variations)
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

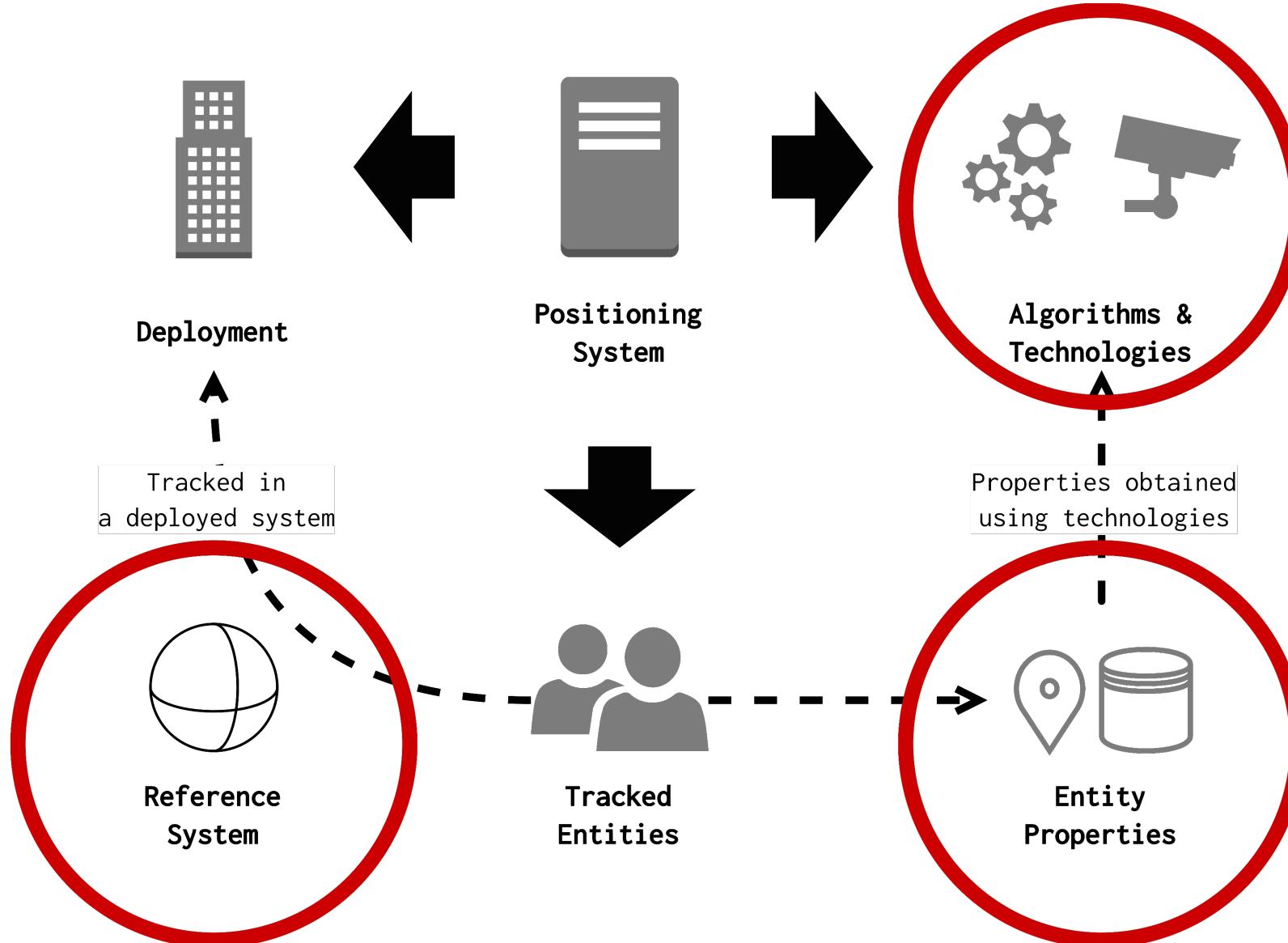
DG4 Enable pose estimation of markers

DG5 Enable relative positioning of objects to markers

DG6 Enable markers as engineering reference frames

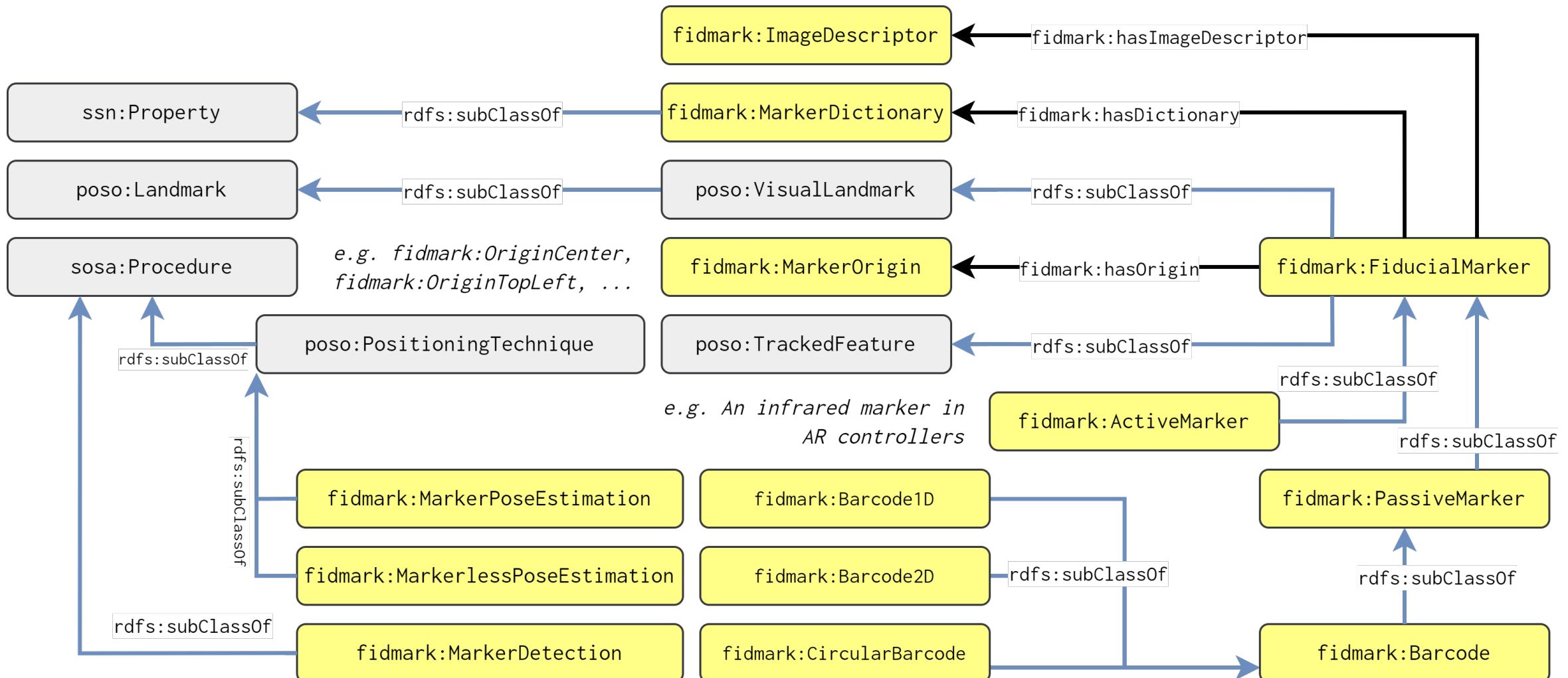
DG7 Facilitate the integration in CV frameworks

Ontology Design

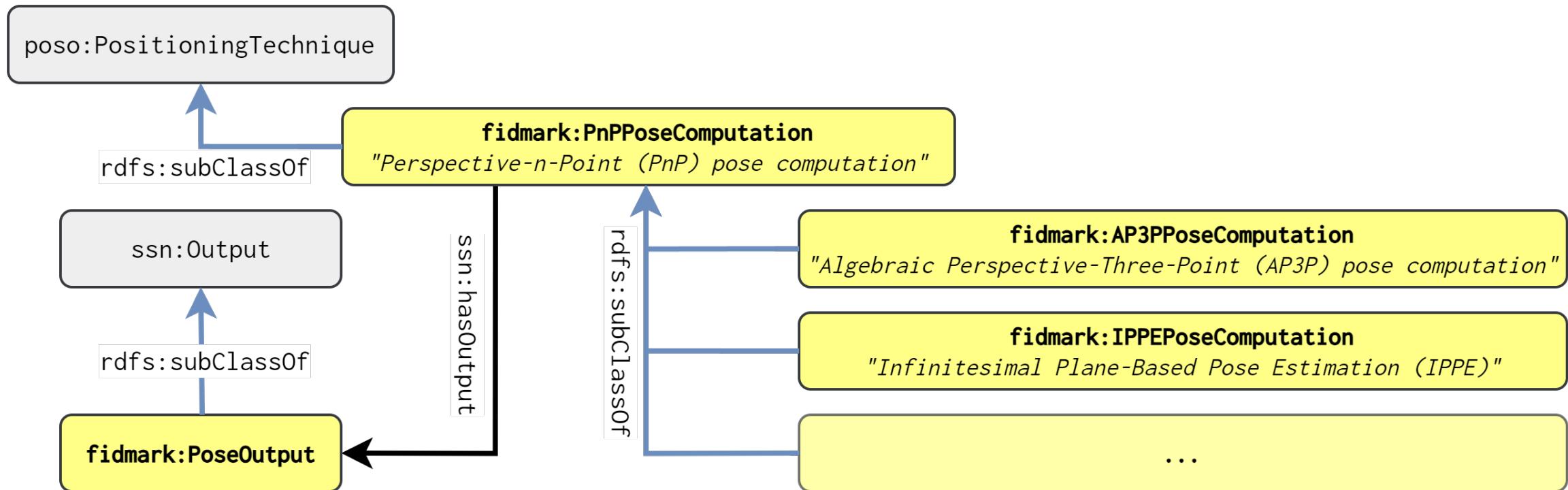


Maxim Van de Wynckel and Beat Signer. 2022. POSO: A Generic Positioning System Ontology. In The Semantic Web - ISWC 2022: 21st International Semantic Web Conference, Virtual Event, October 23–27, 2022, Proceedings. Springer-Verlag, Berlin, Heidelberg, 231–247.

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 .
}
```

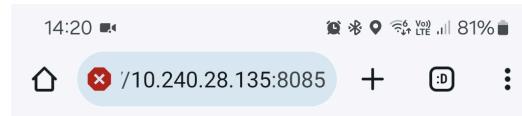
Validation – SPARQL queries



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

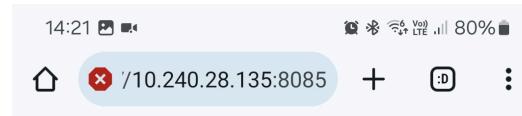


Camera



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/CRS84>.  
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:  
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".
```

AR text/turtle Objects

☰ ⌂ <



Objects

Markers

[http://example.org/marker-1](http://example.org(marker-1)
ID=10, DICT=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...

Virtual Objects

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

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

AR text/turtle Objects

☰ ⌂ <

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
- Demonstrator application & TypeScript library
- Future work will add new marker types and SHACL shapes for each of these types



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

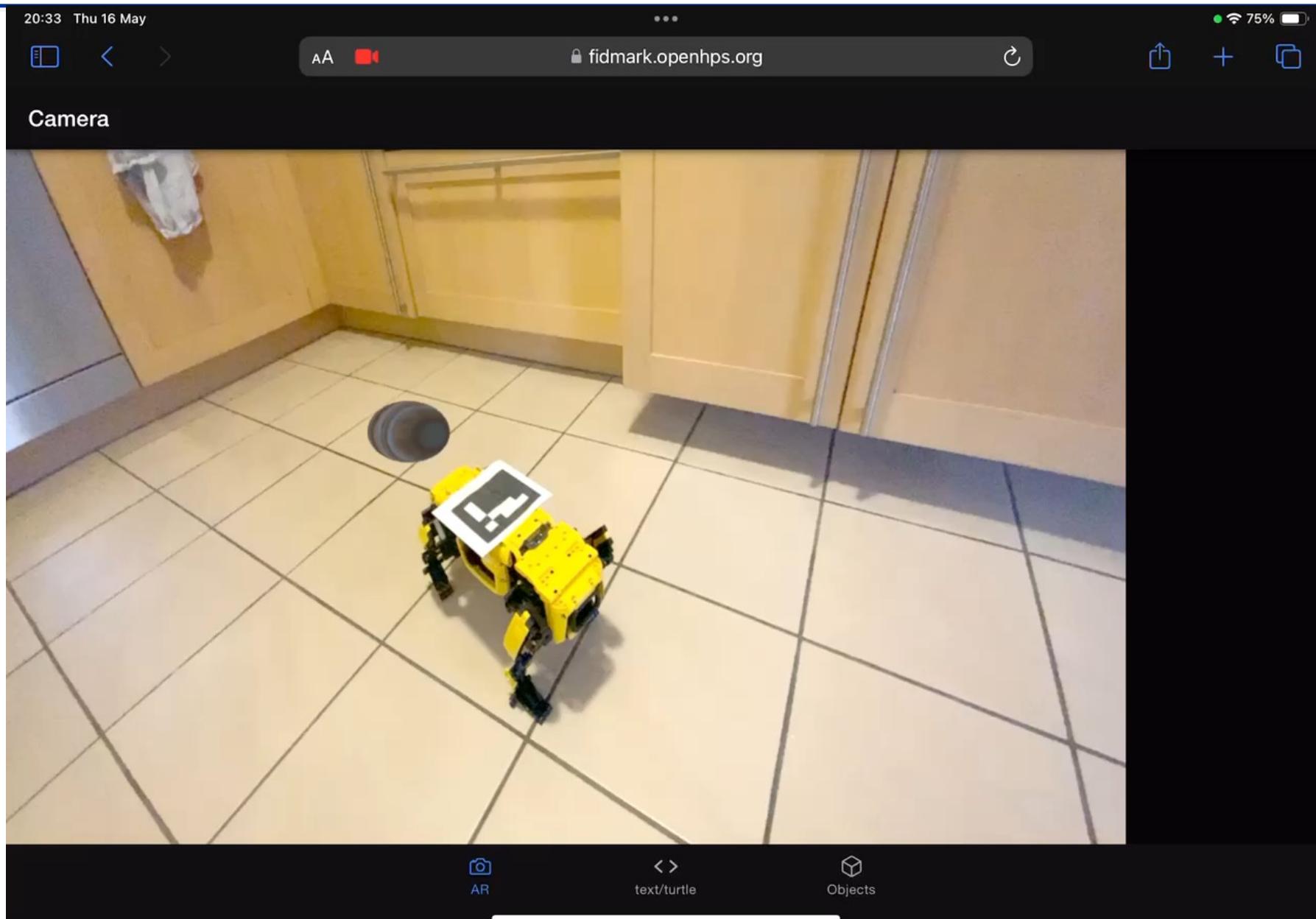


<https://github.com/OpenHPS/FidMark/>

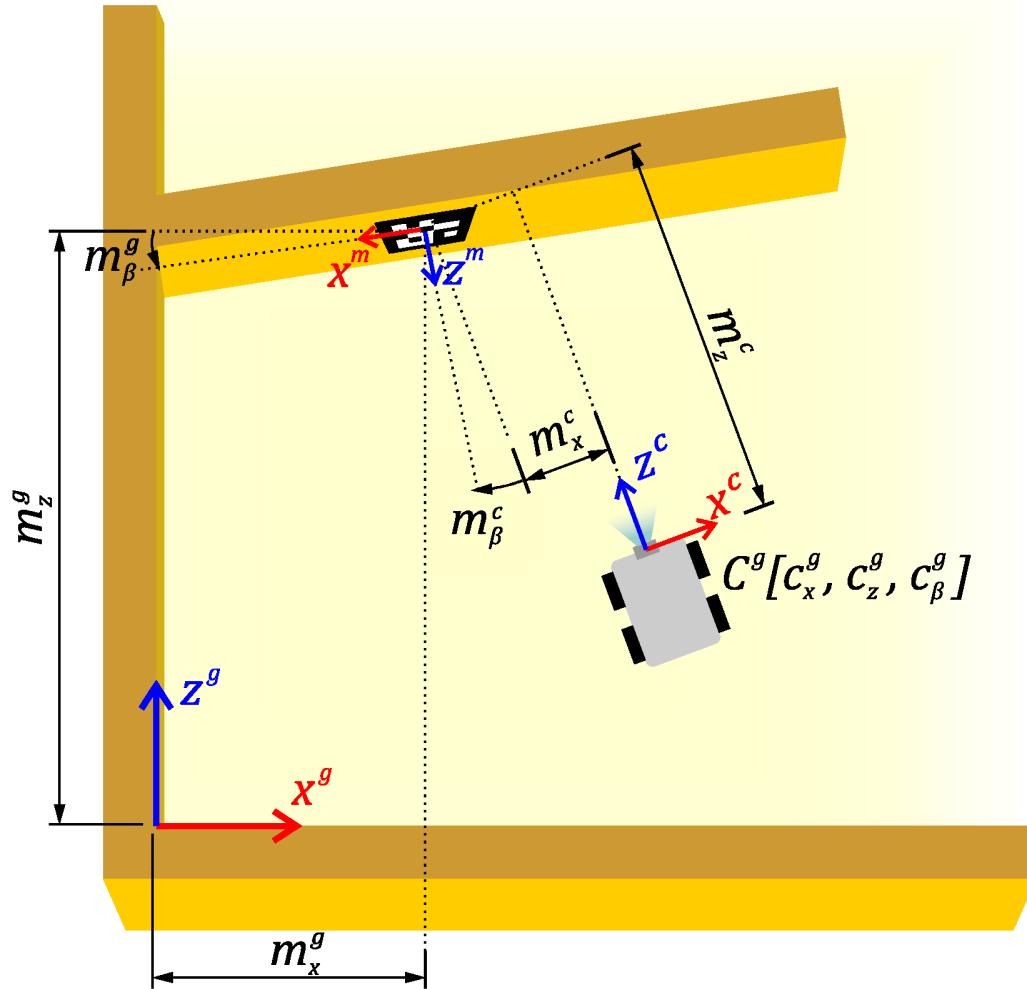
FidMark: A Fiducial Marker Ontology For Semantically Describing Visual Markers

Maxim Van de Wynckel, Isaac Valadez, Beat Signer

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.

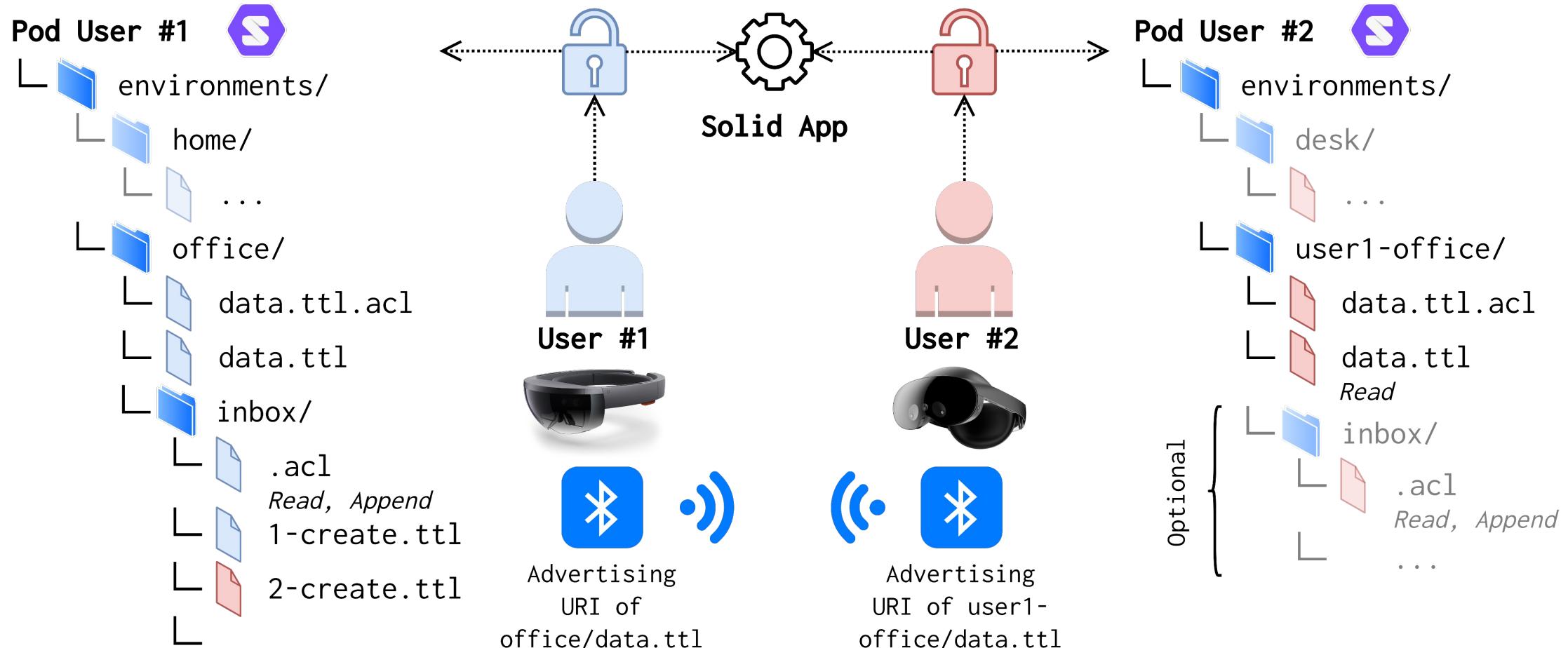
Validation – SPARQL queries



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
    ] .
```