

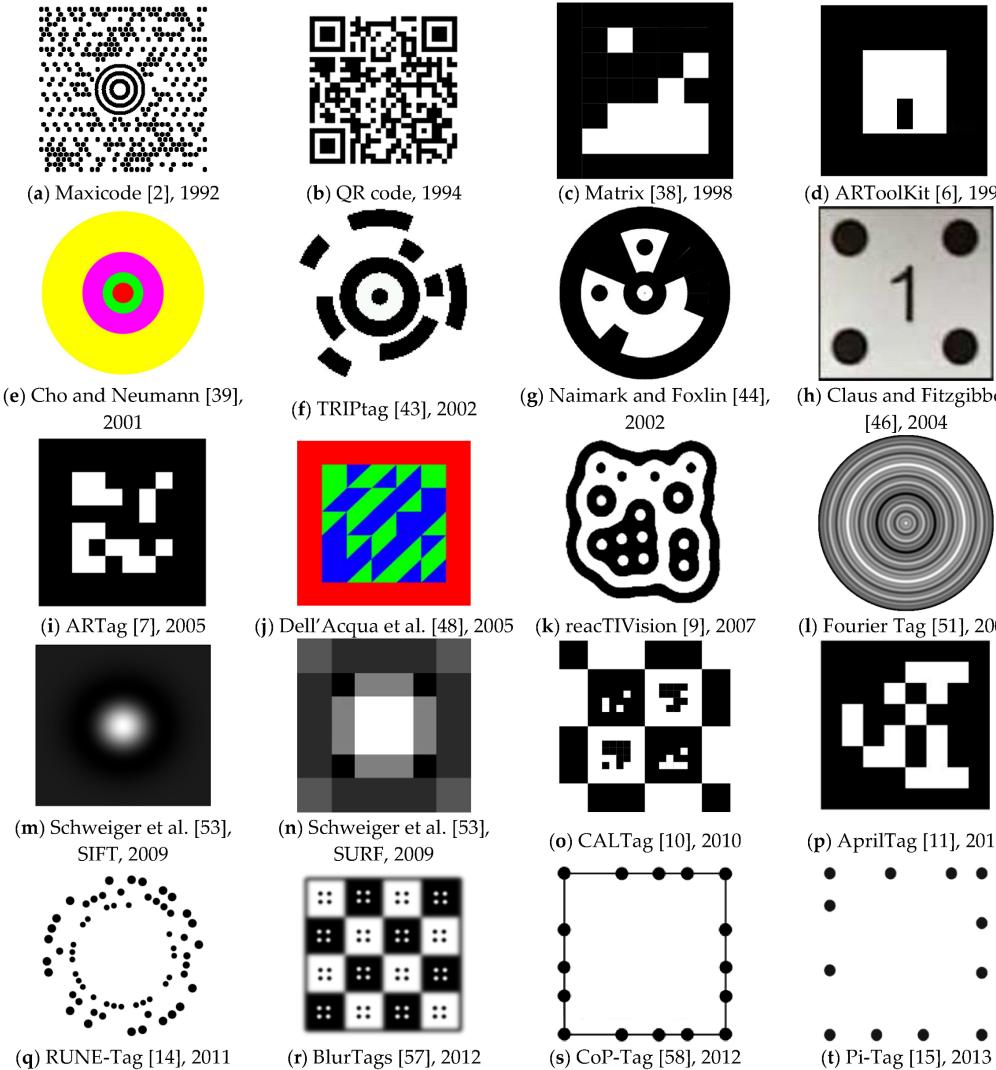


FidMark: A Fiducial Marker Ontology For Semantically Describing Visual Markers

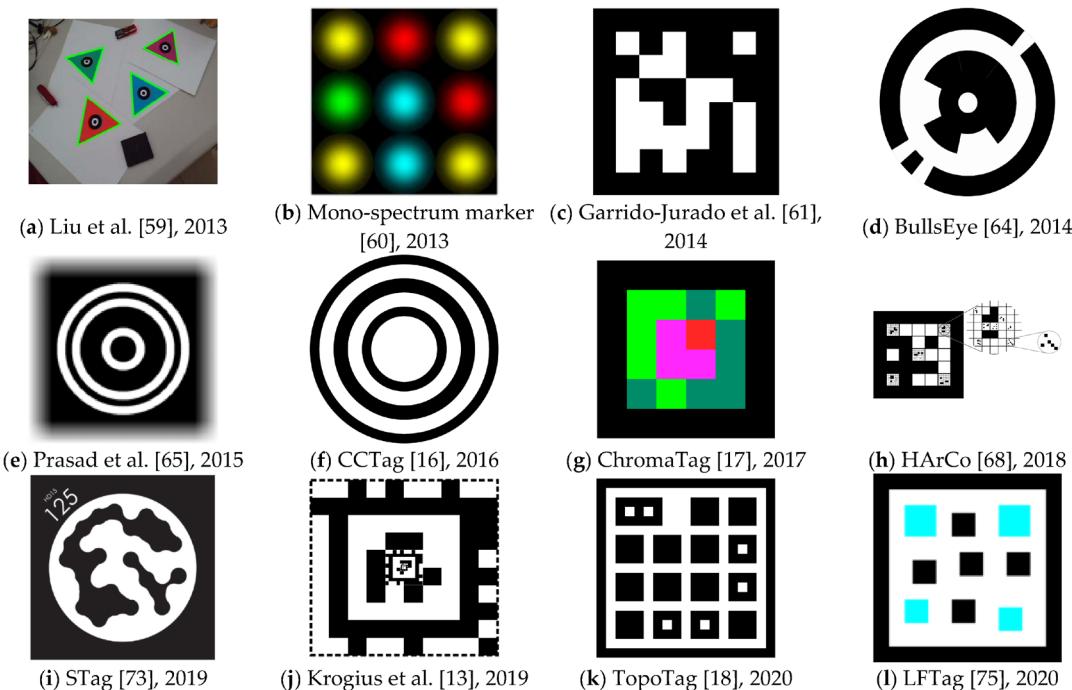
Maxim Van de Wynckel, Isaac Valadez, Beat Signer



Background – Fiducial Marker

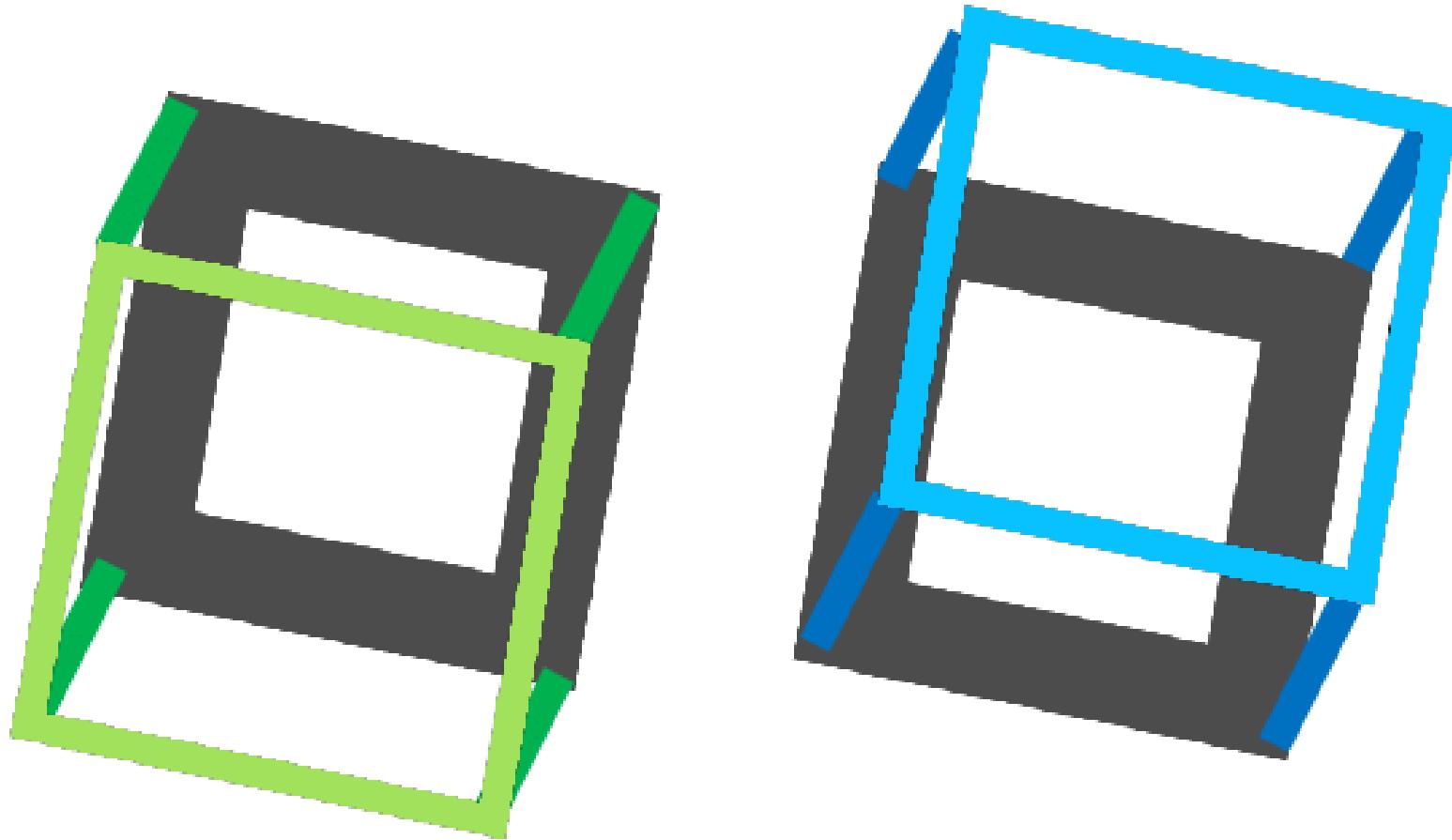


Košťák, M.; Slabý, A. Designing a Simple Fiducial Marker for Localization in Spatial Scenes Using Neural Networks. *Sensors* 2021, 21, 5407.





Problem





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

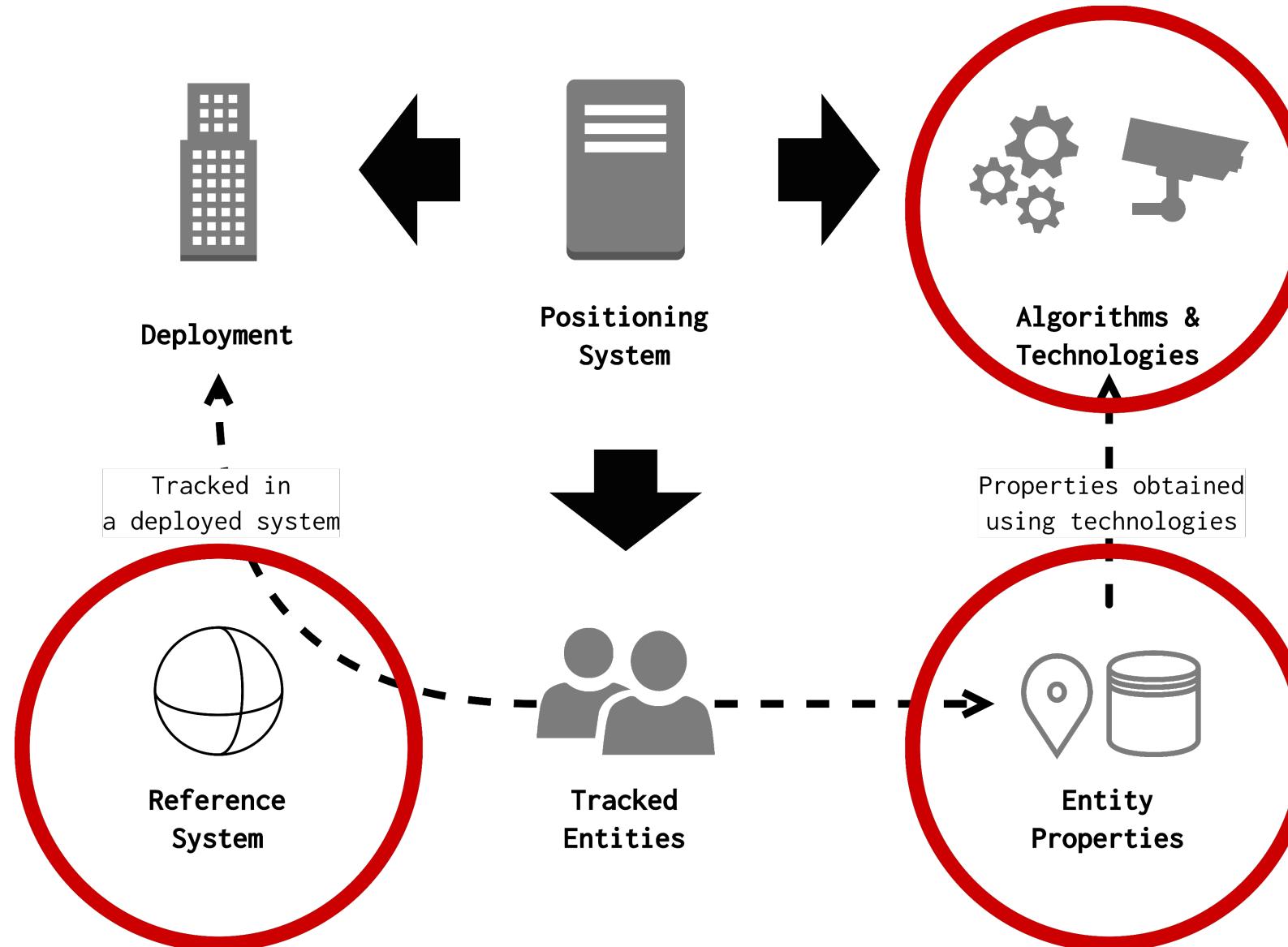


Central goal: “Interoperable Augmented Reality Applications”

- 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

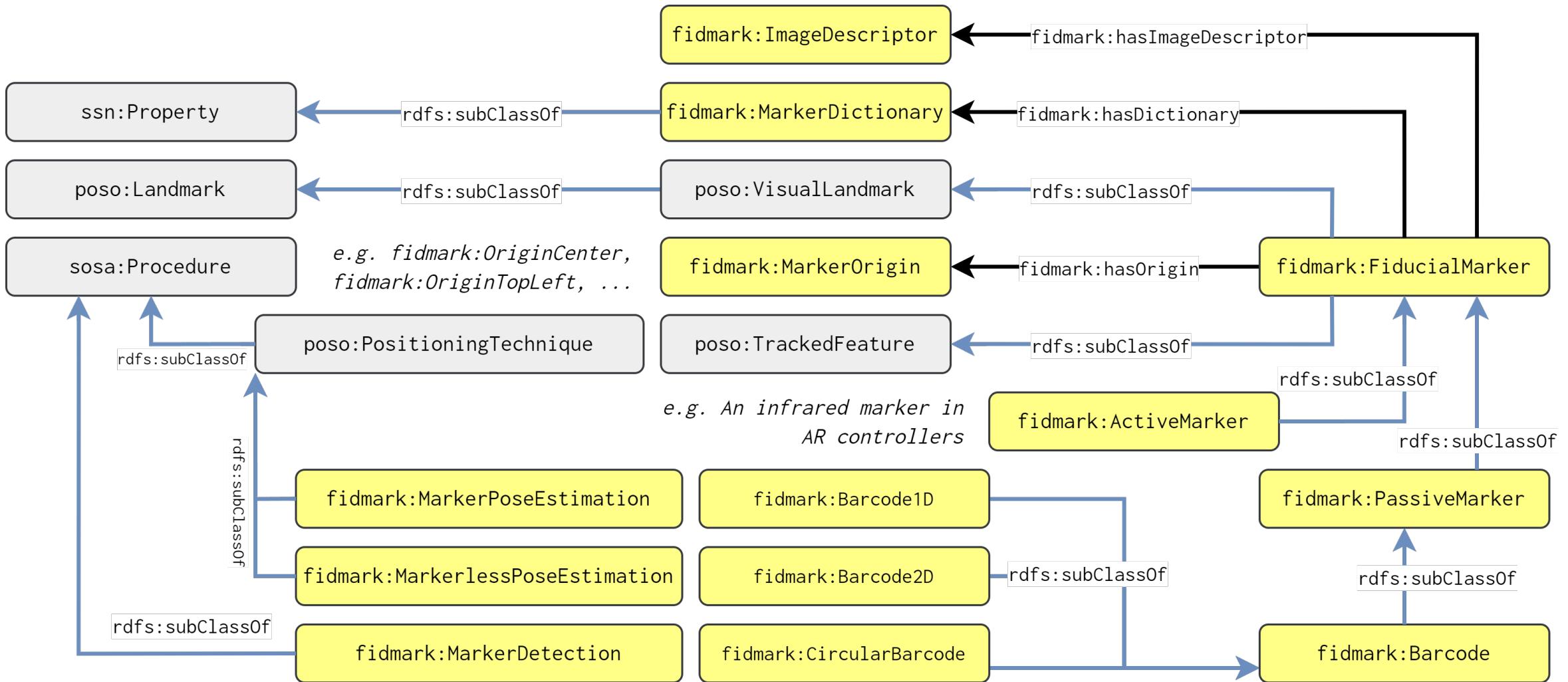


Ontology Design



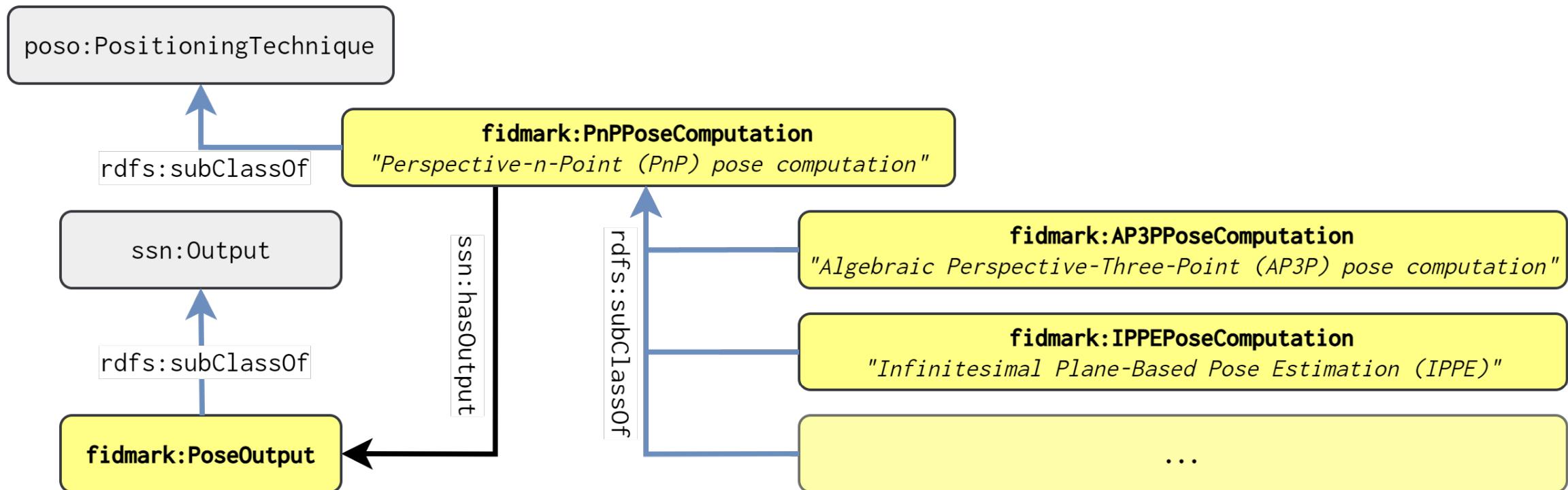
Maxim Van de Wynckel and Beat Signer. 2022. POSO: A Generic Positioning System Ontology. In The Semantic Web - ISWC 2022: 21st International Semantic Web Conference, Virtual Event, October 23–27, 2022, Proceedings. Springer-Verlag, Berlin, Heidelberg, 231–247.

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

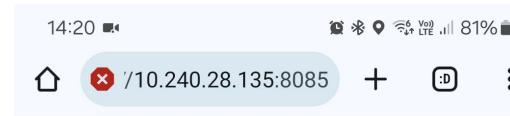


Find all dictionaries and the count of markers that can be identified in this dictionary for the marker type “TopoTag”. Ensure that at least 150 markers can be identified.

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



Demonstrator



Camera



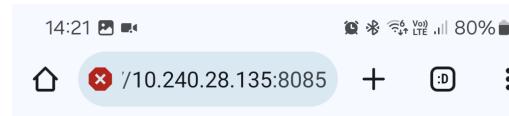
AR



text/turtle

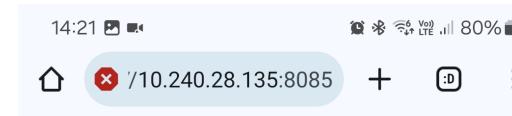


Objects



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/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".
```



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/microsoft-glTF-samples/1.0.0/ARU...>

<http://example.org/jupiter>
GLTF=<https://raw.githubusercontent.com/microsoft/microsoft-glTF-samples/1.0.0/ARU...>

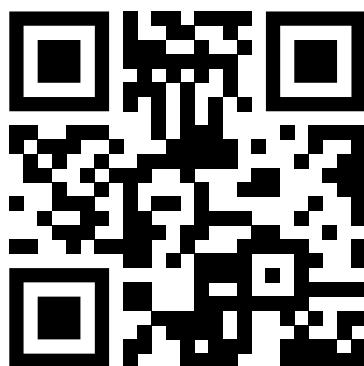




Conclusions and Future Work



- 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



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



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

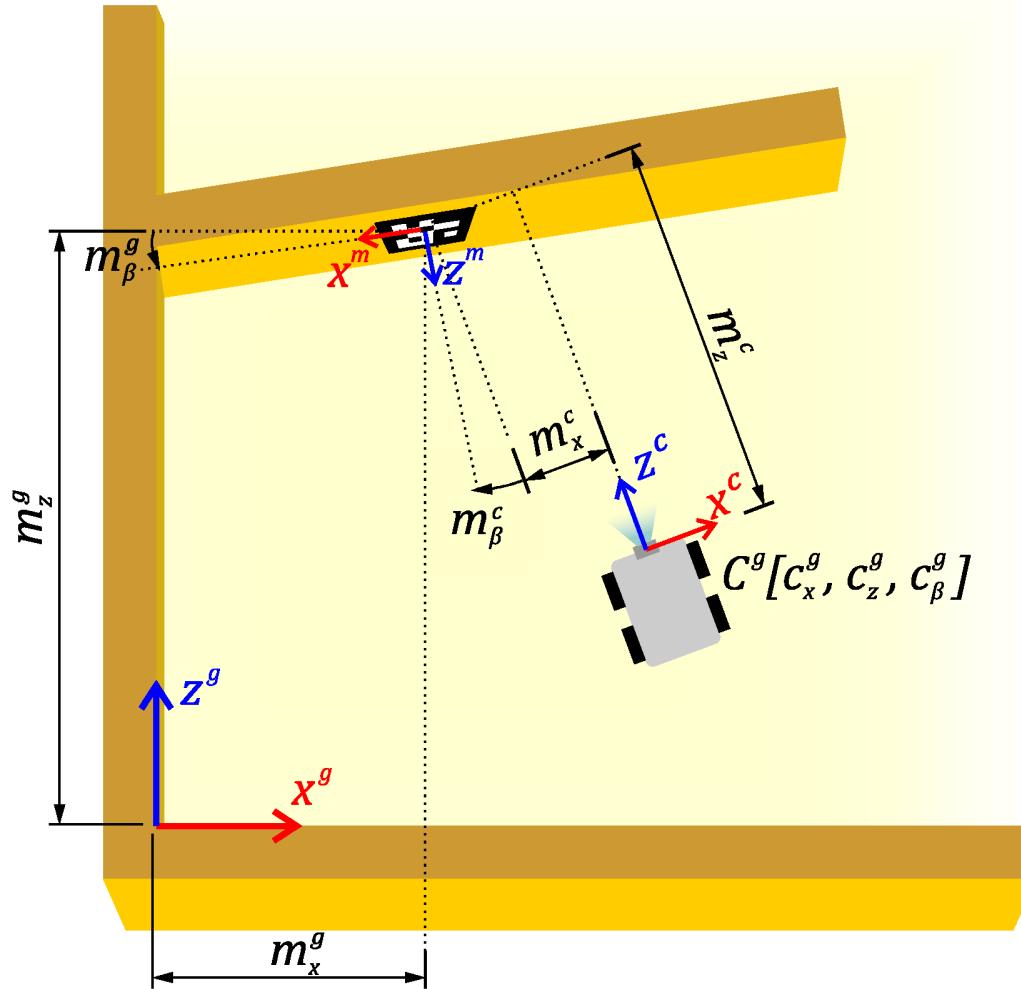


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Background – Pose Estimation



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.

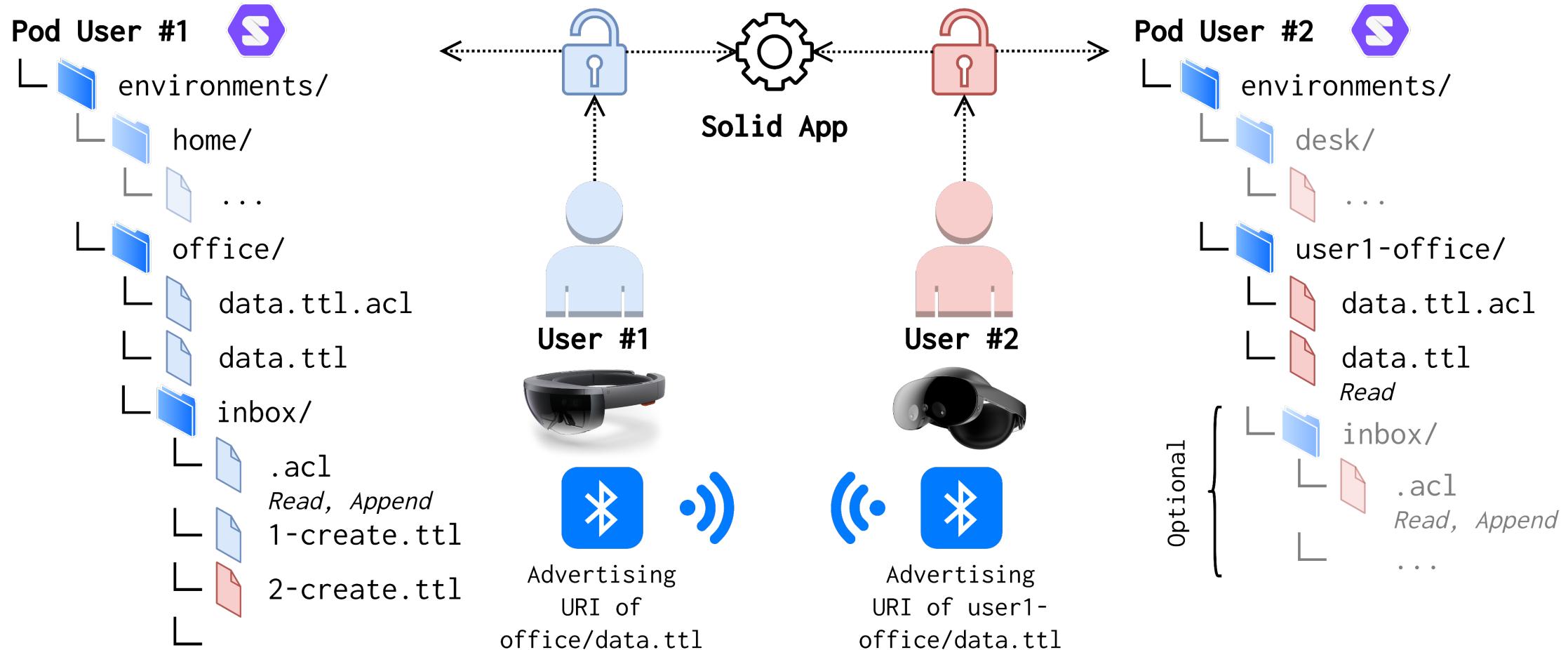
Validation – SPARQL queries



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
    ] .
```