





# WoTDT: an Extension of the WoT Thing Description Ontology for Digital Twins in the Construction Domain

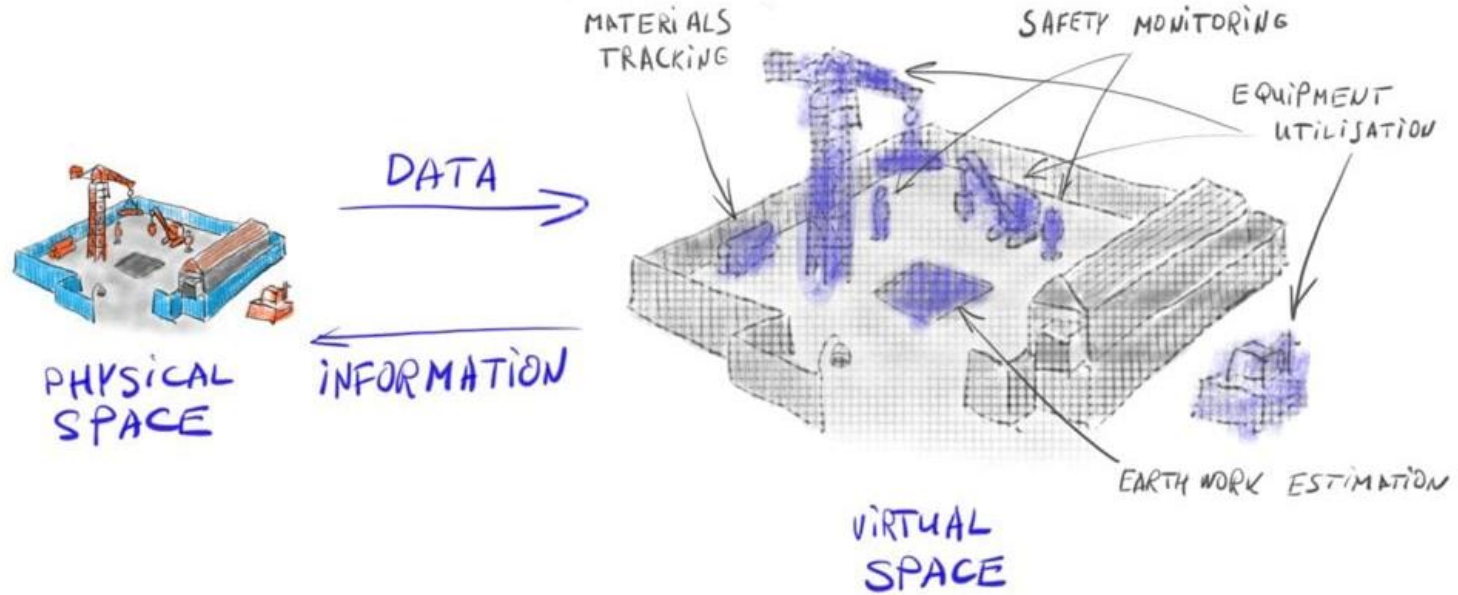
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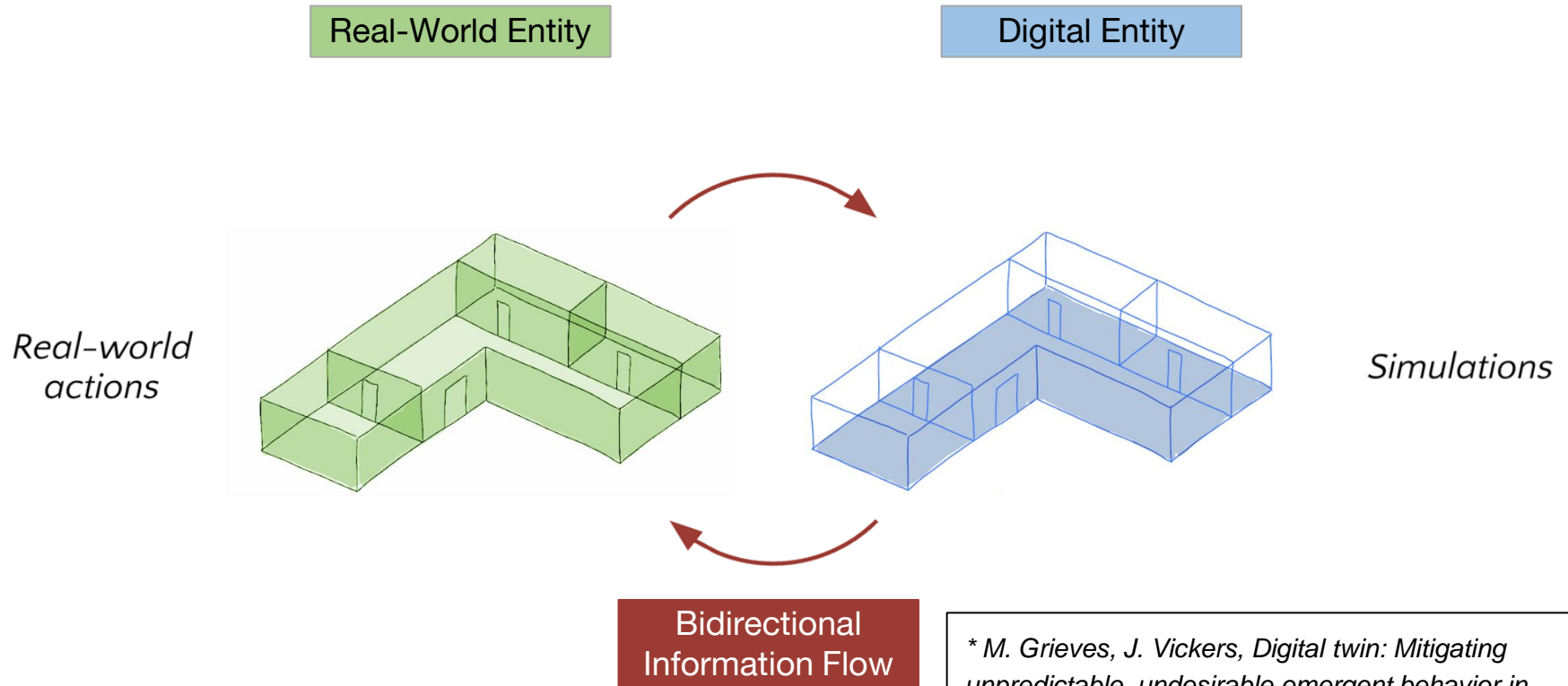
Salvador González-Gerpe, Andrea Cimmino, Socorro Bernardos,  
María Poveda-Villalón, Raúl García-Castro

 [salvador.gonzalez.gerpe@upm.es](mailto:salvador.gonzalez.gerpe@upm.es)

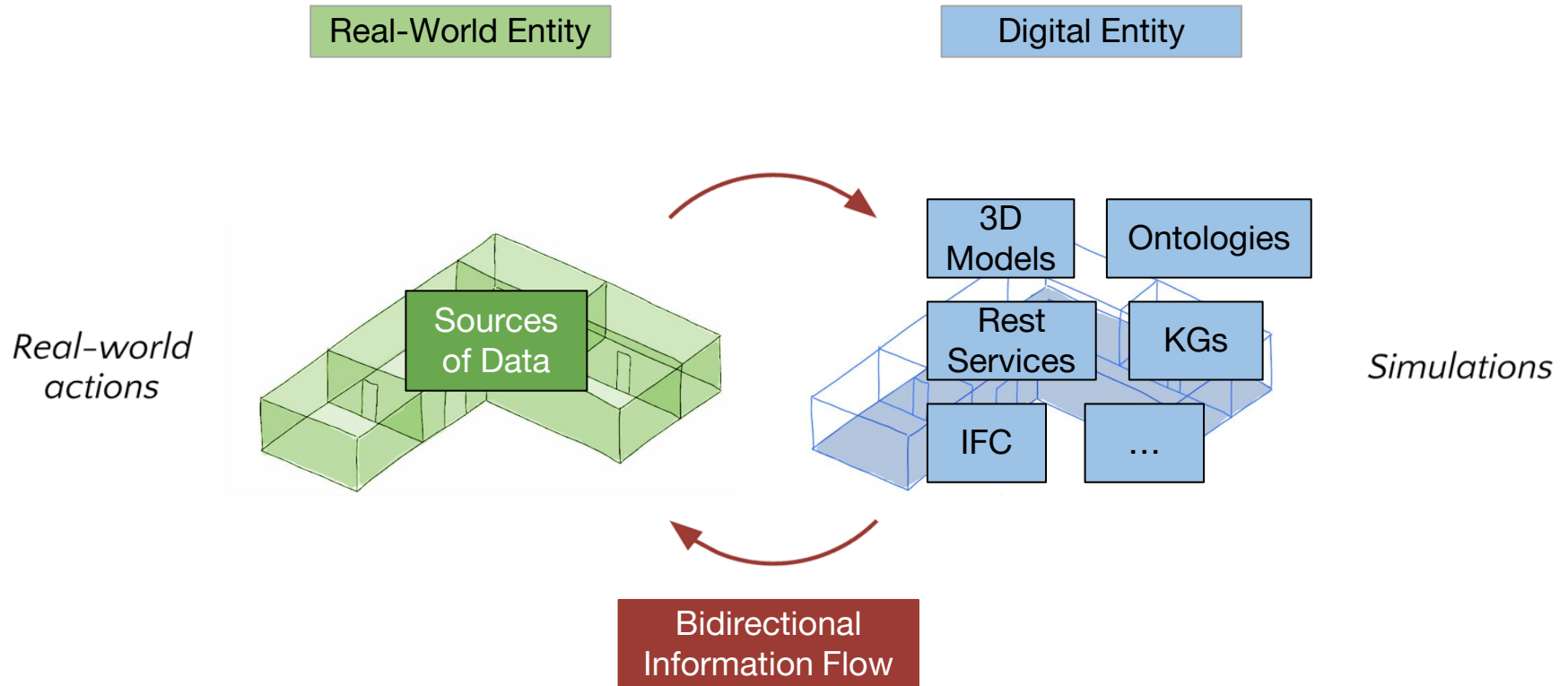
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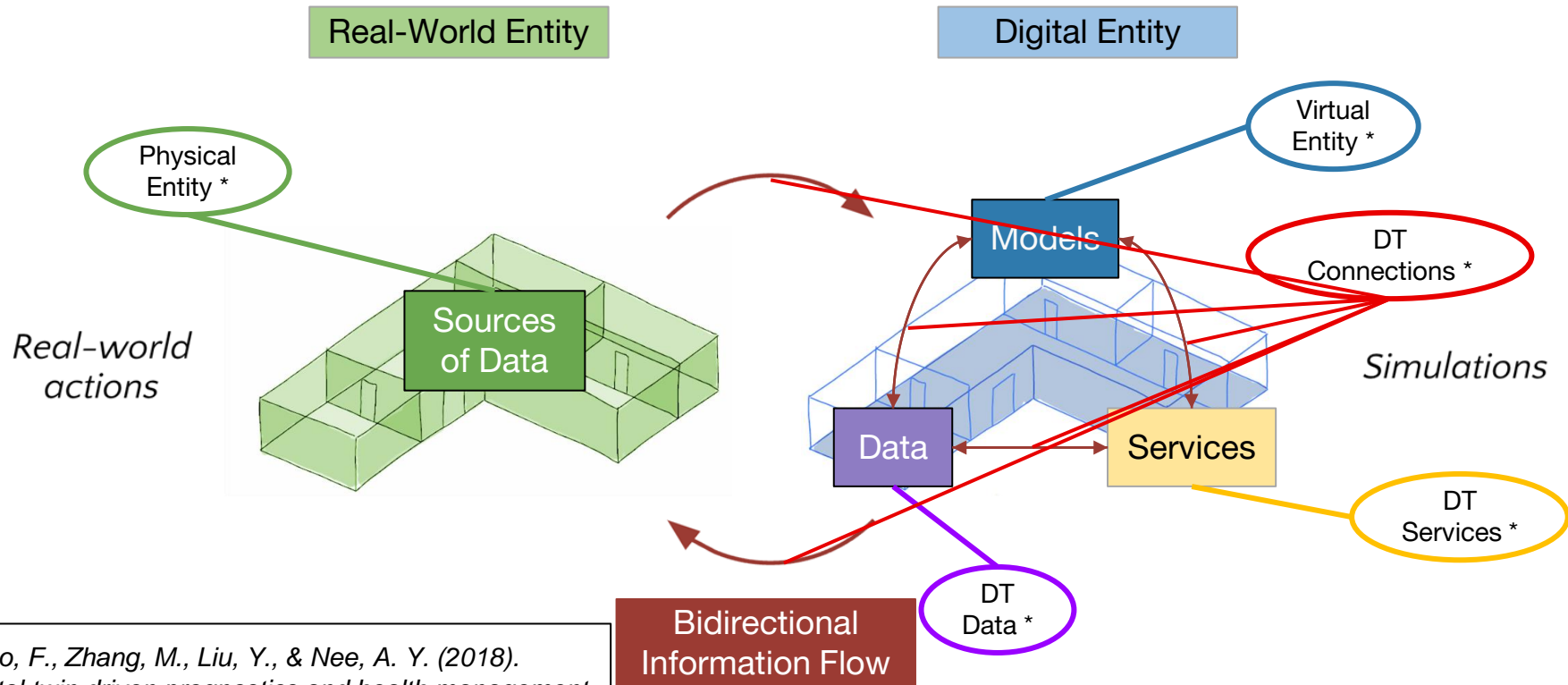




\* M. Grieves, J. Vickers, *Digital twin: Mitigating unpredictable, undesirable emergent behavior in complex systems, Transdisciplinary perspectives on complex systems: New findings and approaches (2017)*

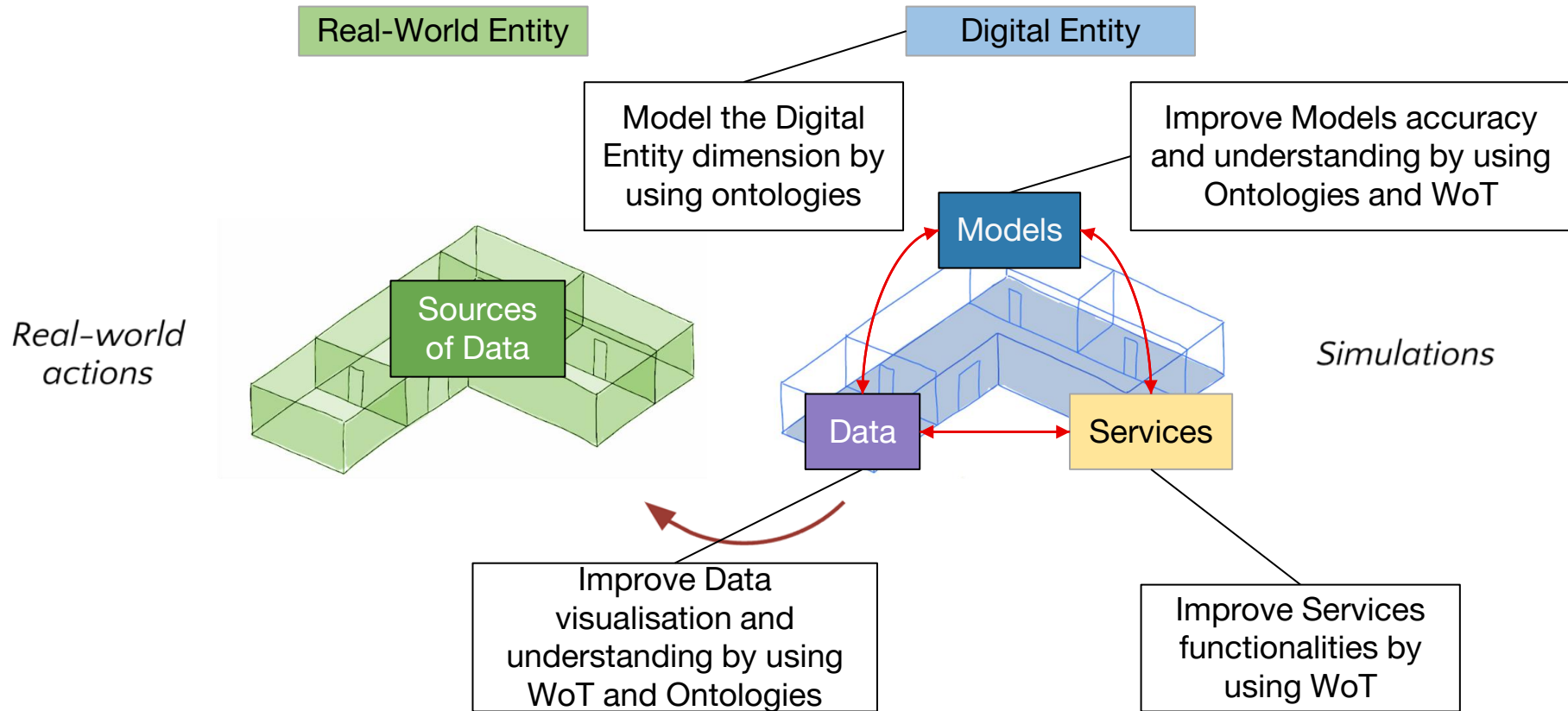


# Digital Twin five-dimensional architecture approach



\* Tao, F., Zhang, M., Liu, Y., & Nee, A. Y. (2018). Digital twin driven prognostics and health management for complex equipment. *Cirp Annals*, 67(1), 169-172.

# Digital Twin artefacts research background



<https://w3id.org/def/digitaltwin#>

## WoTDT: The WoT Digital Twin Ontology

**Revision:**

0.3.0

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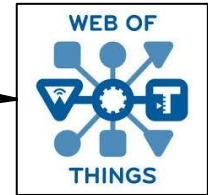


<https://github.com/oeg-upm/WoT-DT-ontology>

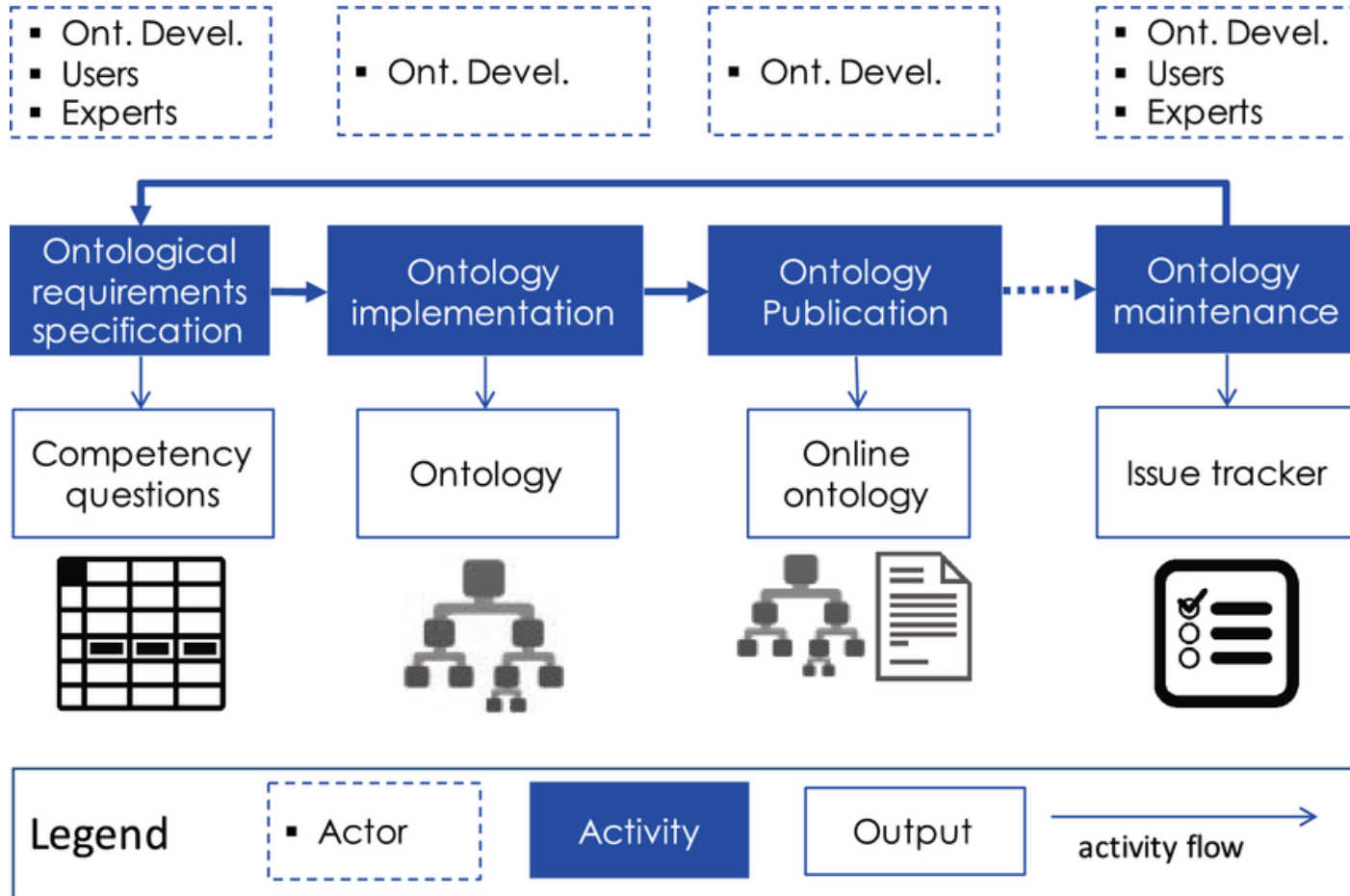
WoTDT ontology has been developed in the COGITO project to **describe the 5 dimensions of a DTw and its features** extending **WoT**.

WoTDT in DTws allows to:

- **Conceptualise** the five-dimensional model architecture and its features
- **Describe** services of different dimensions
- **Discover** services across dimensions
- **Define** the **security** specification of each dimension
- Facilitates data **accessibility** of a specific dimension
- Promotes data **interoperability** in all dimensions
- Provide **direct access** to all DTw functionalities







# Requirements for WoTDT ontology

Physical Entity

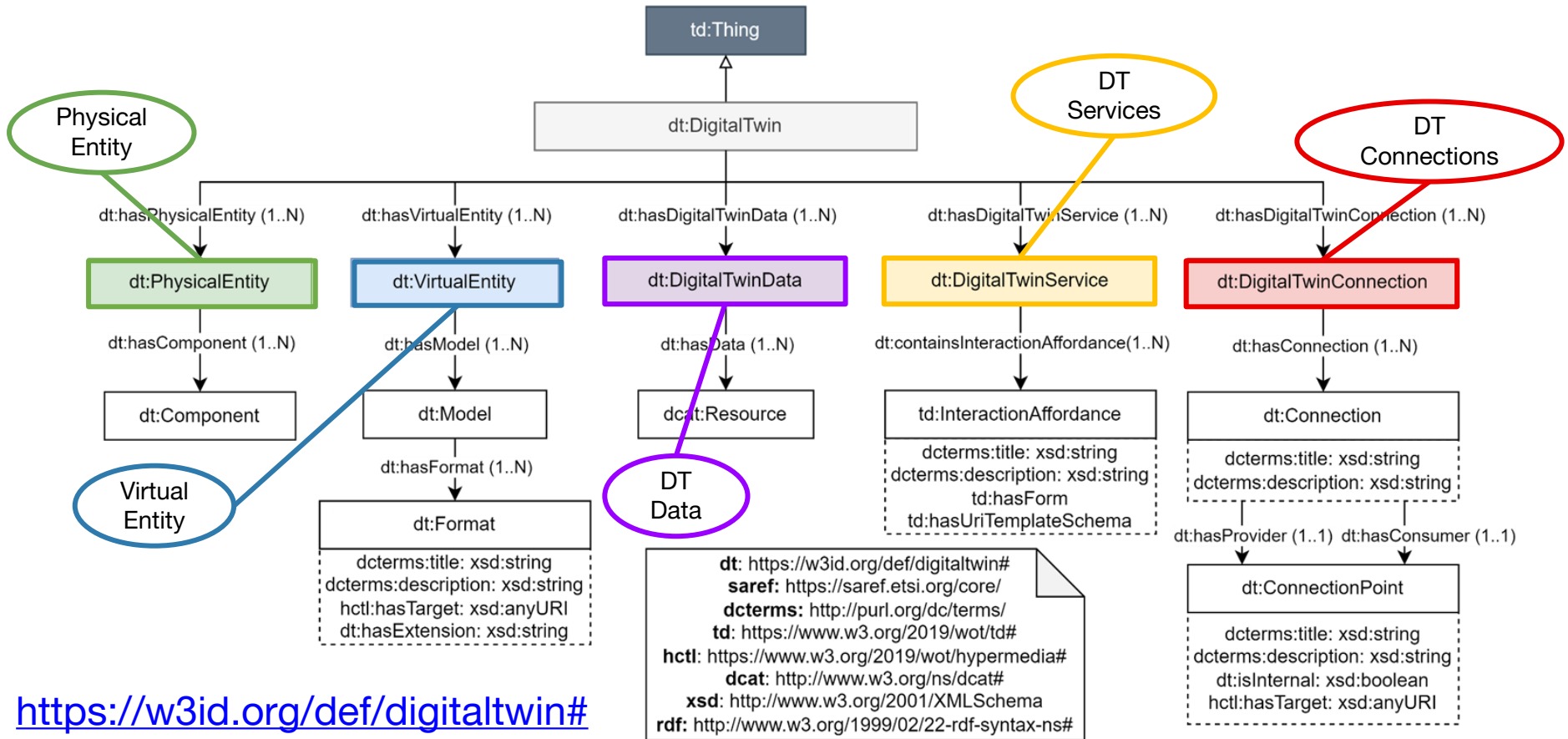
Virtual Entity

DT Data

DT Services

DT Connections

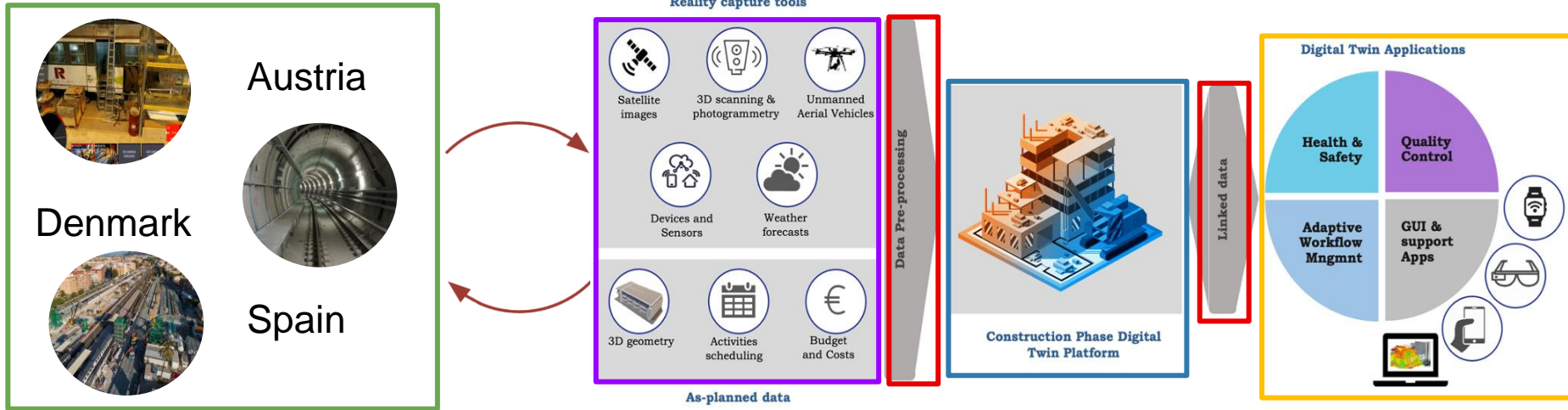
ID	Competency Question / Statement - Possible answer
WOTDT-1	A Digital Twin is a Thing.
WOTDT-2	A Digital Twin contains 5 dimensions.
WOTDT-3	Physical Entity is a dimension that represents the real world asset of the Digital Twin.
WOTDT-4	Virtual Entity is a dimension that represents the different models used in the Digital Twin.
WOTDT-5	Digital Twin Data is a dimension where are stored all the data used in the Digital Twin.
WOTDT-6	Digital Twin Services is a dimension where all the services of the Digital Twin are described.
WOTDT-7	Digital Twin Connection is a dimension where all the connections between other dimensions in the Digital Twin are described.
WOTDT-8	Physical Entity dimension can have components.
WOTDT-9	Which kind of components can be described in the Physical Entity dimension? - The component can be from the physical asset that the Digital Twin is modelling, to the different devices like sensors or actuators that read or act over the specific physical asset.
WOTDT-10	Virtual Entity dimension can have models.
WOTDT-11	Which kind of models can be described in the Virtual Entity dimension? - The models can be from rules, behavioral, physical and geometric models to semantic models like ontologies.
WOTDT-12	Digital Twin Data dimension can have resources that can be used to represent the different type of data stored at the Digital Twin.
WOTDT-13	Digital Twin Service dimension can have Interaction Affordances from the WoT Thing Descriptions ontology to represent the different services used at the Digital Twin.
WOTDT-14	Digital Twin Connection dimension can have different connections.
WOTDT-15	Which type of connections the Digital Twin Connection dimension can describe? - The connections defined in the Digital Twin Connection dimension are described with the different existing elements of other dimensions of the Digital Twin such as models, resources and interaction affordances; and the connections with external Things such as other Digital Twins.

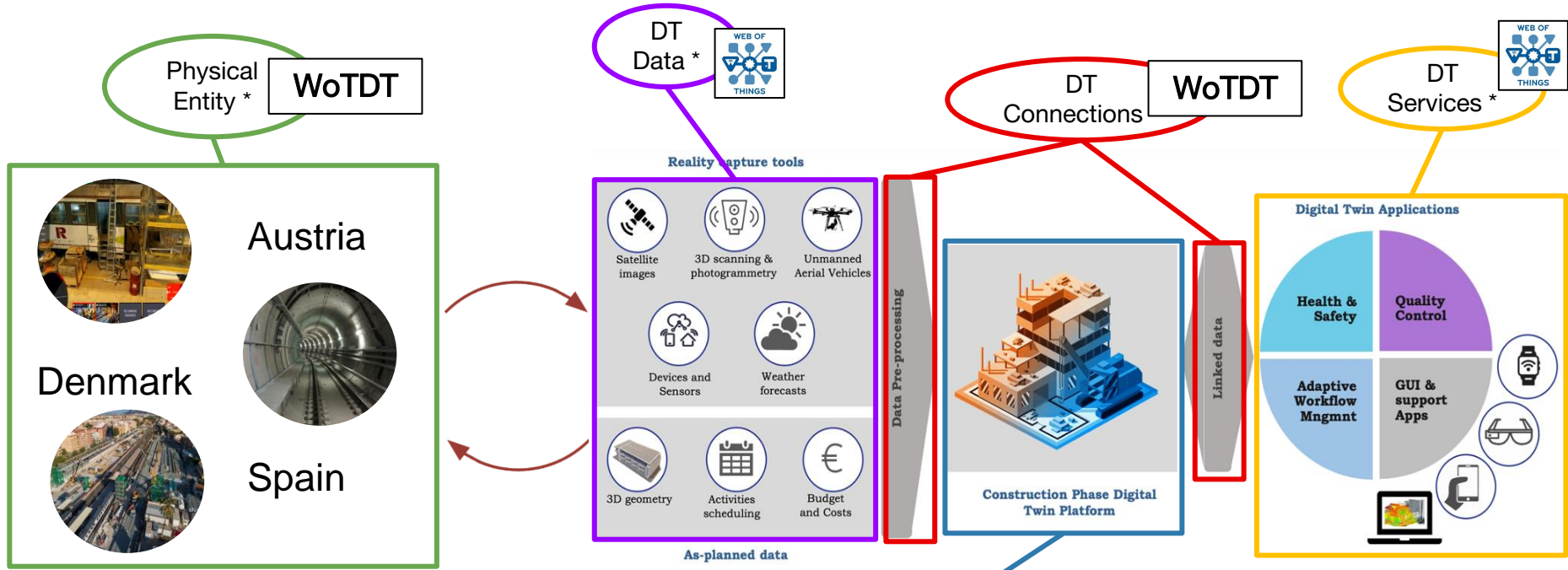


<https://w3id.org/def/digitaltwin#>

## Real-World Entity

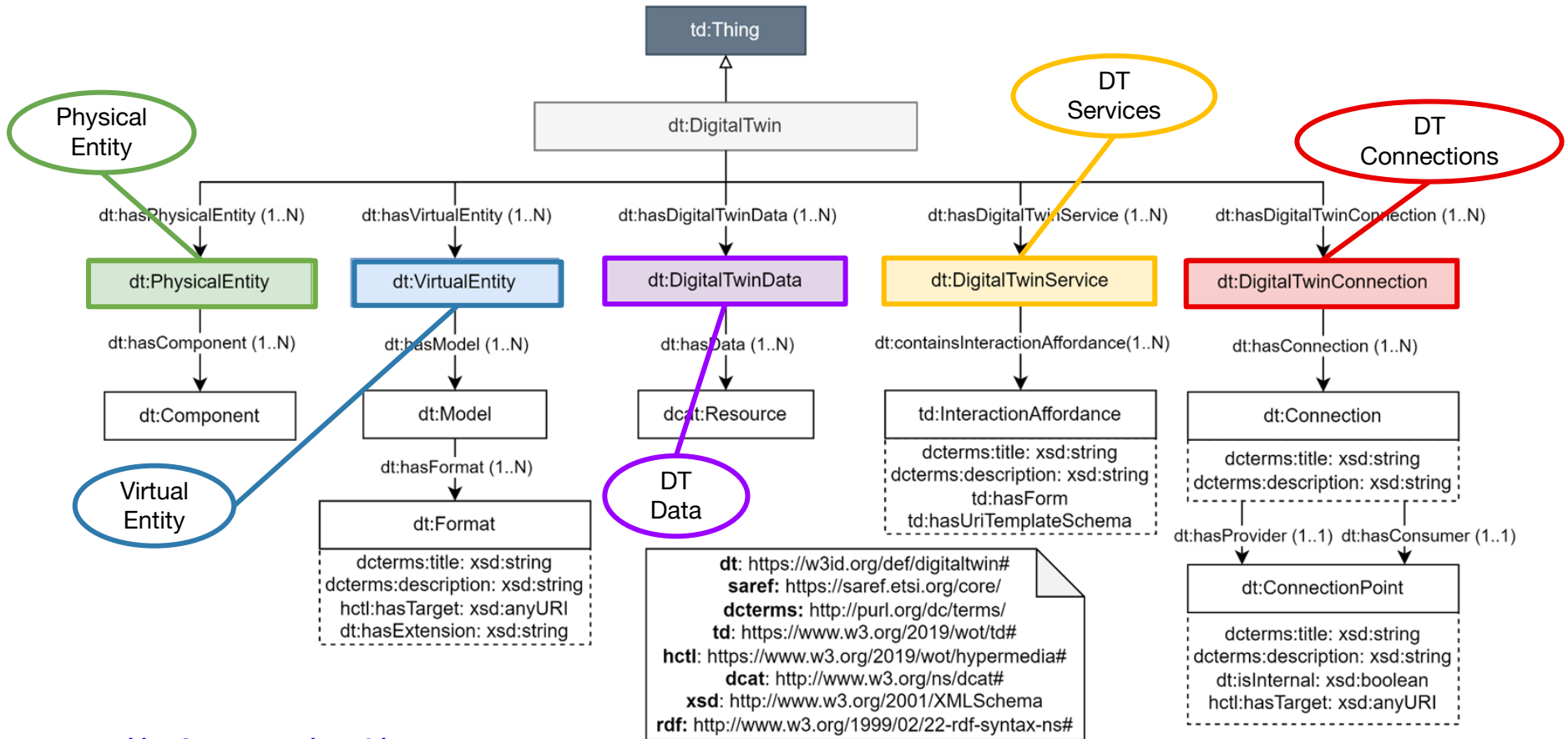
## Digital Entity





\* Tao, F., Zhang, M., Liu, Y., & Nee, A. Y. (2018). Digital twin driven prognostics and health management for complex equipment. *Cirp Annals*, 67(1), 169-172.



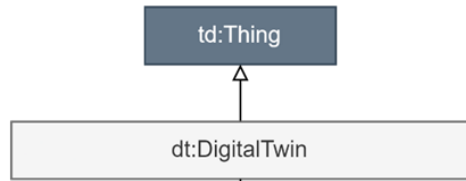
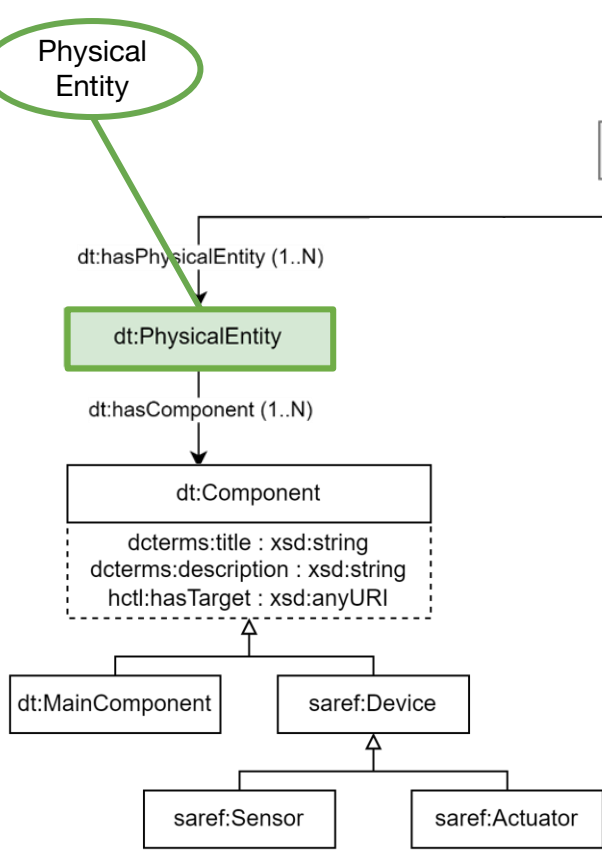


<https://w3id.org/def/digitaltwin#>

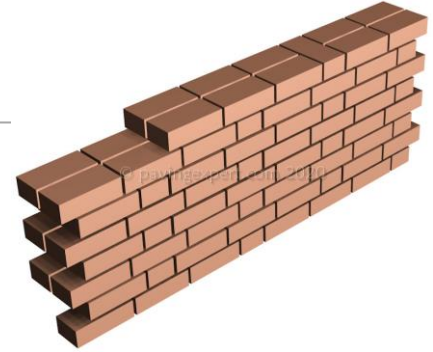
```
{
  "@context": [
    # Ontology URIs
    "https://www.w3.org/2019/wot/td/v1",
    "https://raw.githubusercontent.com/Salva5297/SemanticDT_TD/main/context/dt.td.context.jsonld",
    "https://w3c.github.io/wot-discovery/context/discovery-core.jsonld",
    # Namespaces for data
    {
      "element": "https://data.cogito.iot.linkeddata.es/resources/element/",
      "sdt": "https://data.cogito.iot.linkeddata.es/resources/sdt/",
      "dt_ve": "https://data.cogito.iot.linkeddata.es/resources/ve/",
      "dt_dd": "https://data.cogito.iot.linkeddata.es/resources/dd/",
      ...
    },
  ],
  ...
}
```



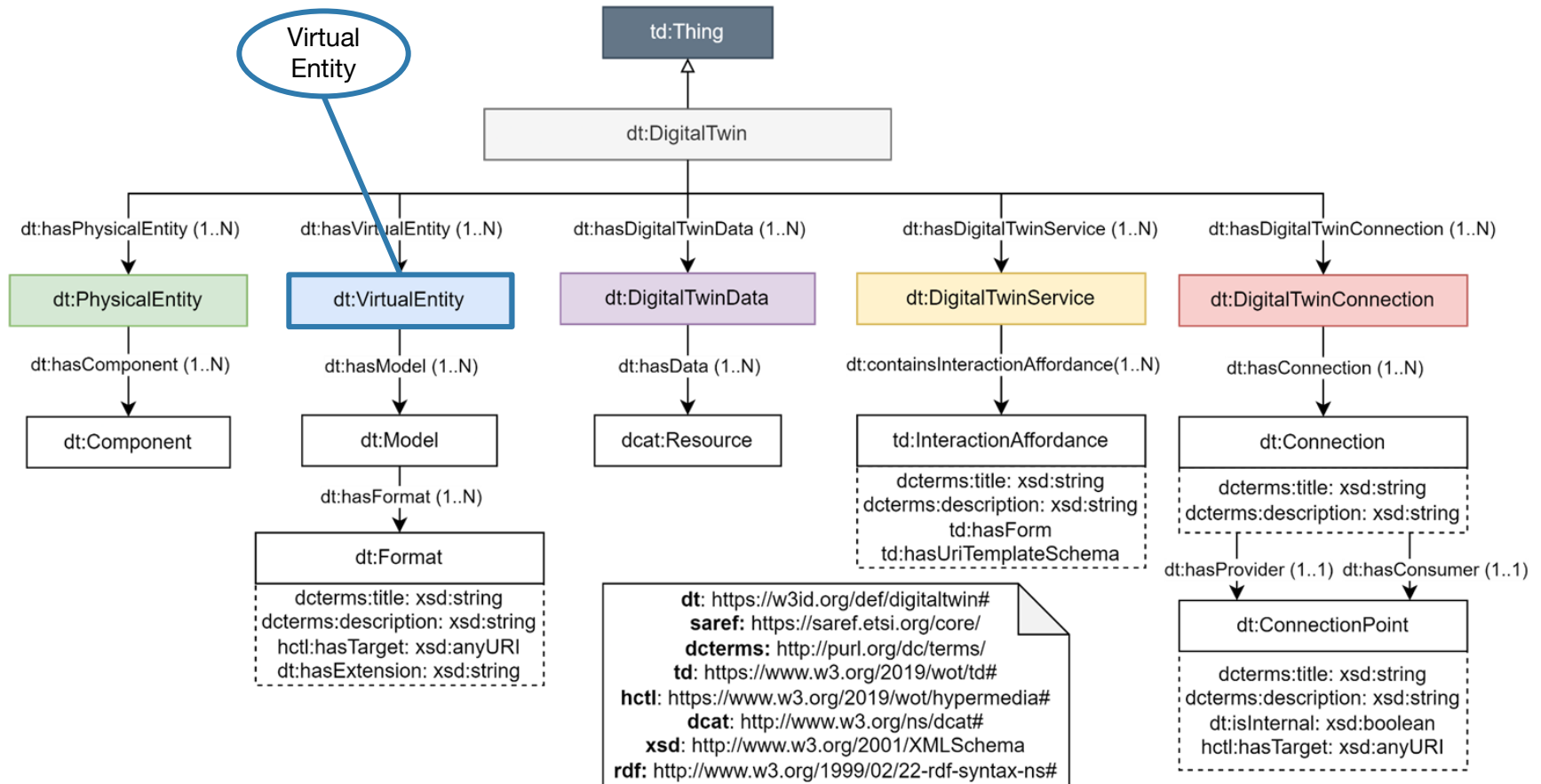
Physical Entity

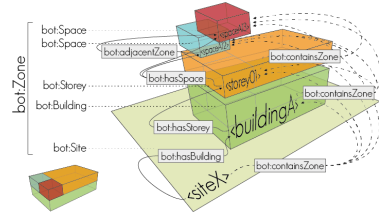
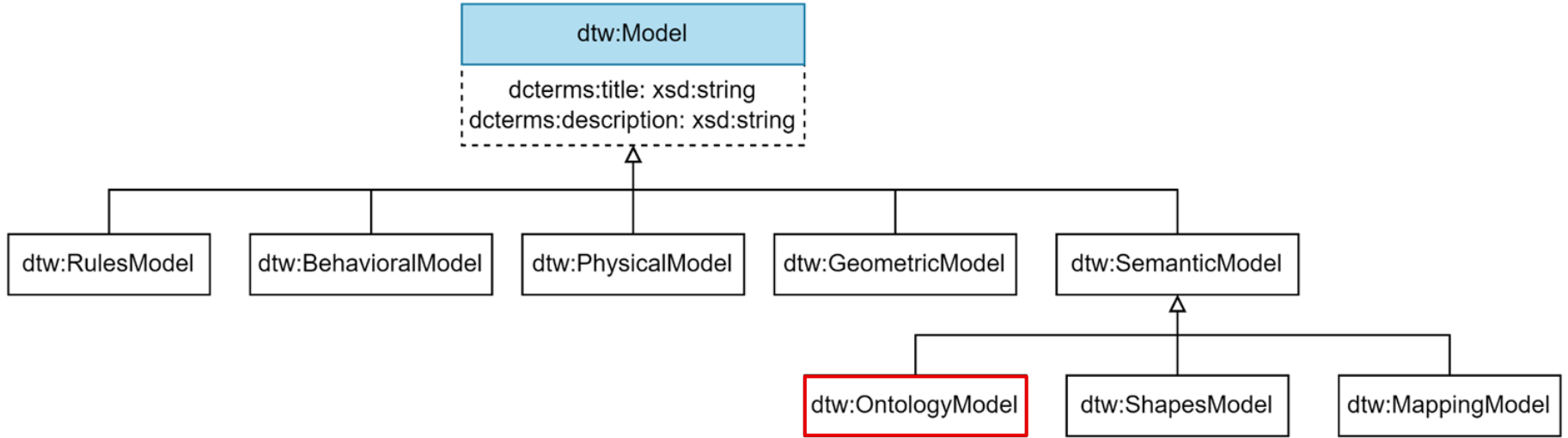


```
{  
  "@context": [...],  
  "id": "sdt:01U2O",  
  "@type": "DigitalTwin",  
  "title": "Element 10486",  
  "physical_entity": {  
    "id": "dt_pe:fb12b",  
    "component": {  
      "id": "component:7d6e5",  
      "title": "Basic Wall...",  
      "description": "A vertical...",  
      "href": "..."  
    }  
  }  
  ...  
}
```







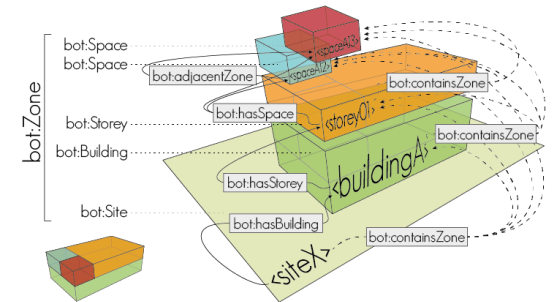


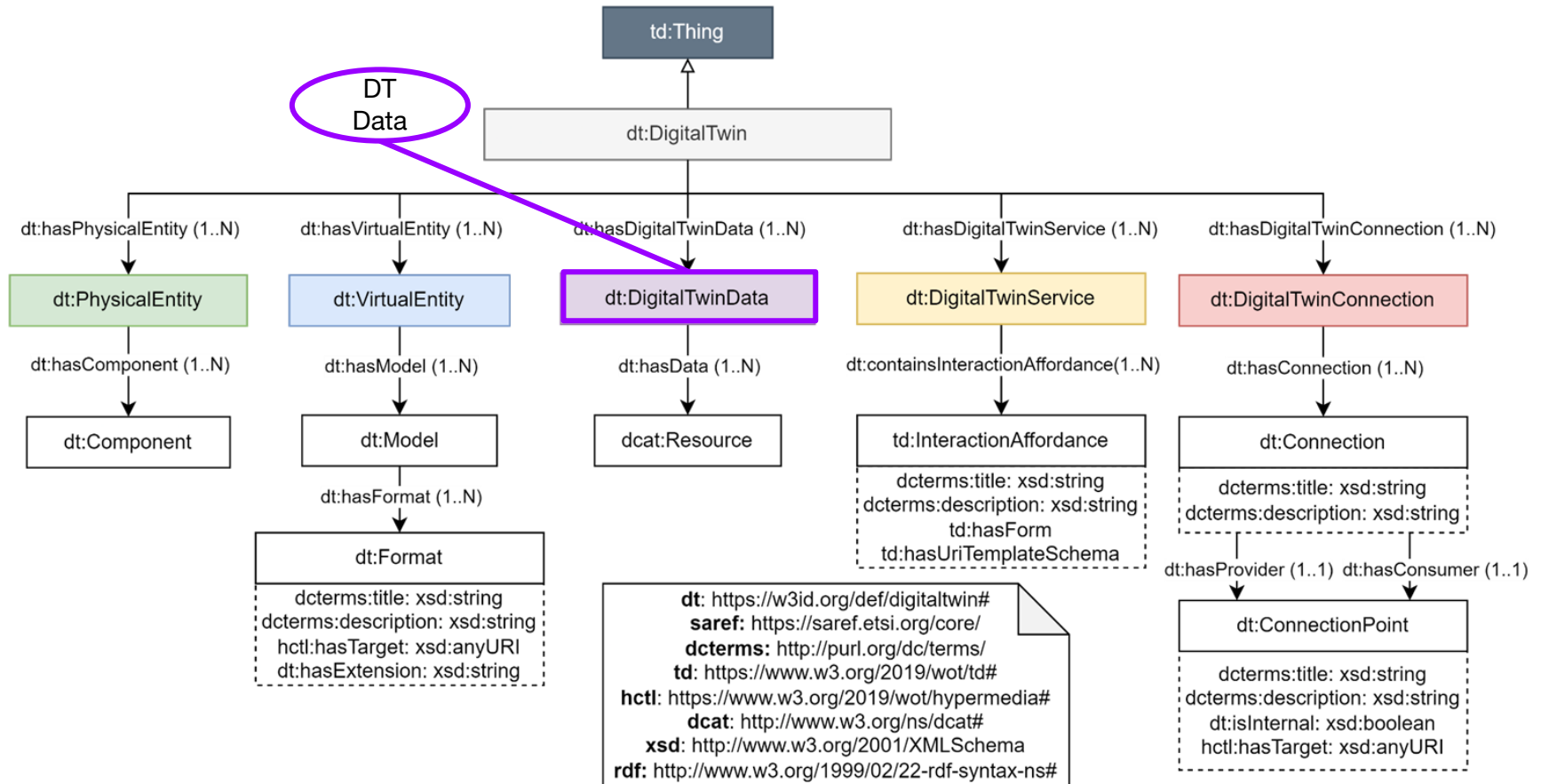
```
"virtual_entity": [  
  {  
    "id": "dt_ve:fb237",  
    "type": "Virtual Entity",  
    "title": "Virtual Entity",  
    "description": "Virtual Entity of DTw 01U2O from project 308736f9-f533-4b4b-9a49-14b5363690db",  
    "models": [  
      {  
        "type": "Ontology_Model",  
        "title": "Building Element Ontology",  
        "description": "The Building Element Ontology provides an ontology based on the IfcBuildingElement subtree in the IFC specification, containing a taxonomy of classes that allow to define common building elements.",  
        "formats": [  
          {  
            "id": "format:fea24",  
            "type": "Format",  
            "title": "JSON-LD",  
            "description": "JSON-LD format.",  
            "href": "https://pi.pauwel.be/voc/buildingelement/ontology.json",  
            "extension": "json"  
          },  
          {  
            "id": "format:ca7ea",  
            "type": "Format",  
            "title": "RDF/XML",  
            "description": "RDF/XML Format.",  
            "href": "https://pi.pauwel.be/voc/buildingelement/ontology.xml",  
            "extension": "xml"  
          }  
        ]  
      }  
    ]  
  }  
]
```

Virtual Entity Metadata

Formats

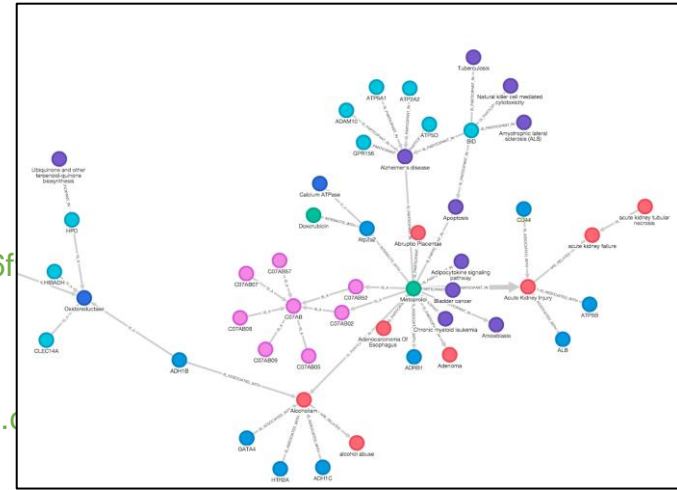
Models

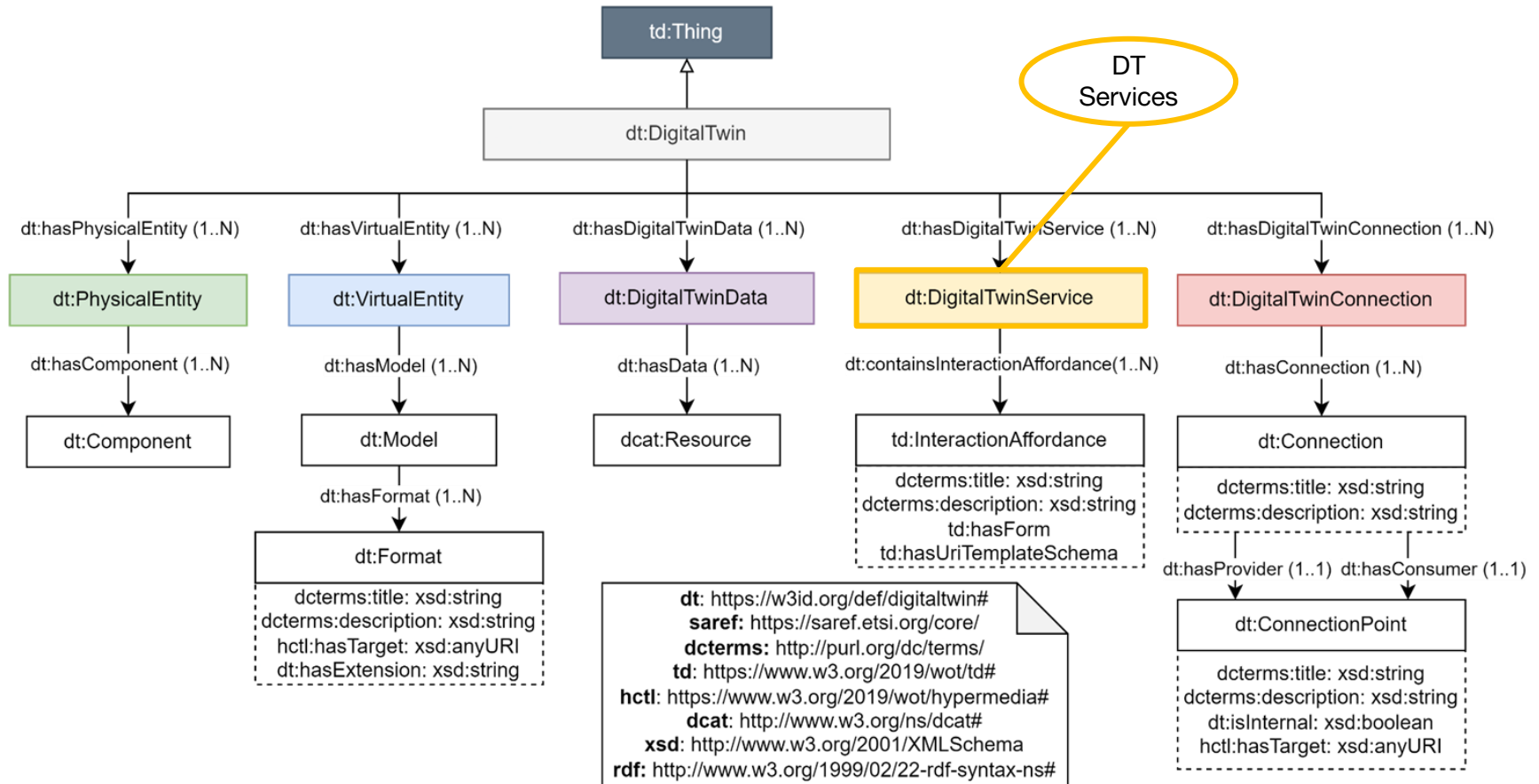




# WoTDT Digital Twin Data Example

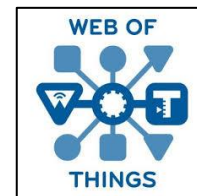
```
"dt_data": { ← dt:DigitalTwinData
  "id": "dt_dd:f5336c"
  "data": [ ← dcat:Resource
    {
      "type": "dcat:Dataset",
      "title": "Knowledge Graph",
      "description": "Knowledge Graph of SDT 01U20 from project 308736f",
      "distribution:abae0": {
        "type": "dcat:Distribution",
        "dcat:accessURL":
          "https://triplestore.cogito.iot.linkeddata.es/resource?uri=https:%2F%2Fdata.cogito.iot.linkeddata.es%2F308736f9-f533-4b4b-9a49-14b5363690db&role=context",
        "dcat:mediaType": "application/sparql-results+json",
        "dcat:downloadURL": "https://triplestore.cogito.iot.linkeddata.es/repositories/cogito-triplestore/statements?infer=false&context=%3Chttps%3A%2F%2Fdata.cogito.iot.linkeddata.es%2F308736f9-f533-4b4b-9a49-14b5363690db%3E&location=&Accept=text%2Fturtle",
        "data_service:f1526": {
          "type": "dcat:DataService",
          "dcat:endpointURL": "https://triplestore.cogito.iot.linkeddata.es/repositories/cogito-triplestore",
          "dcat:endpointDescription": "SPARQL endpoint of the Triplestore where the Knowledge Graph is stored."
        }
      }
    }
  ],
  ...
}
```

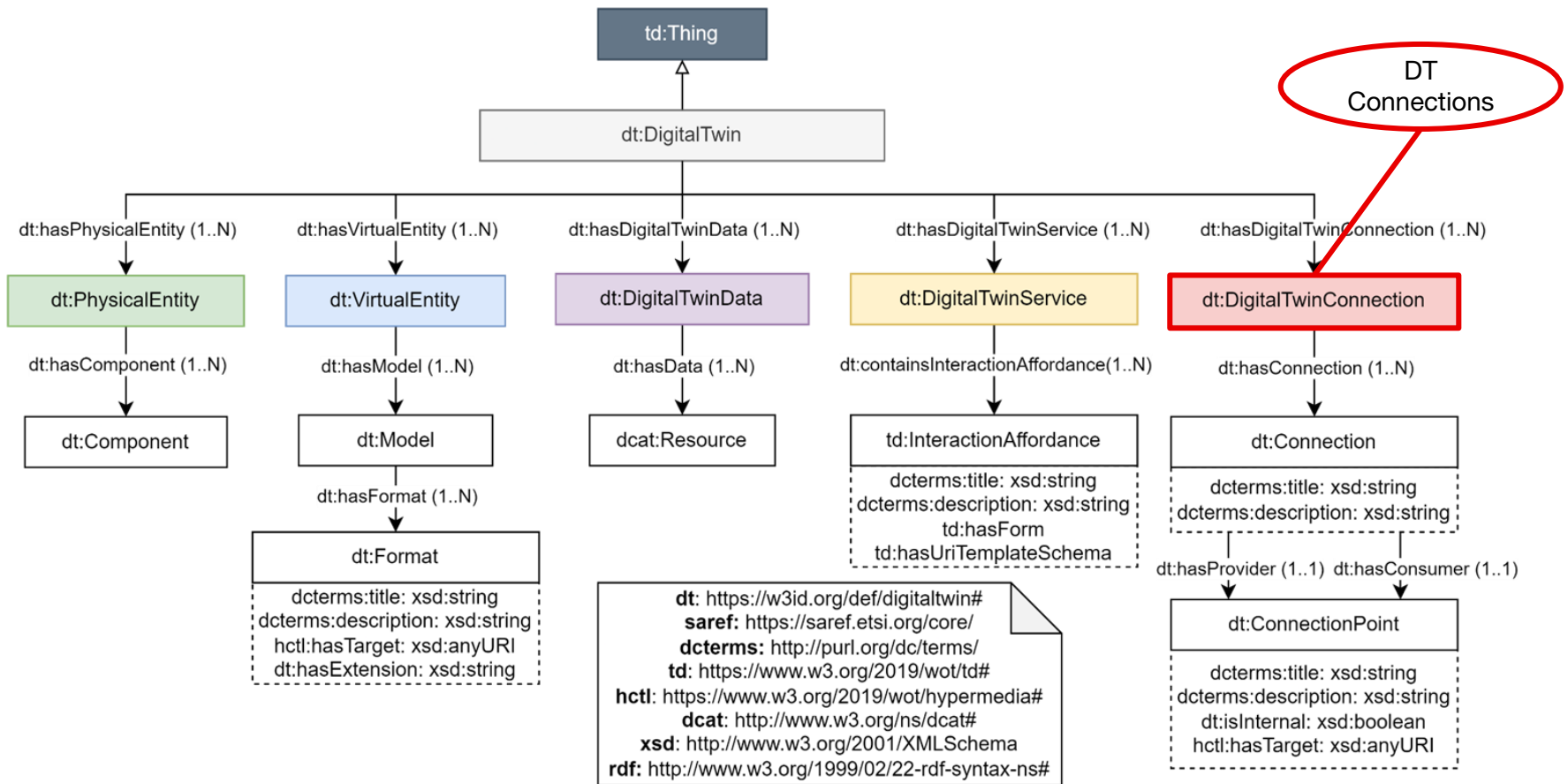




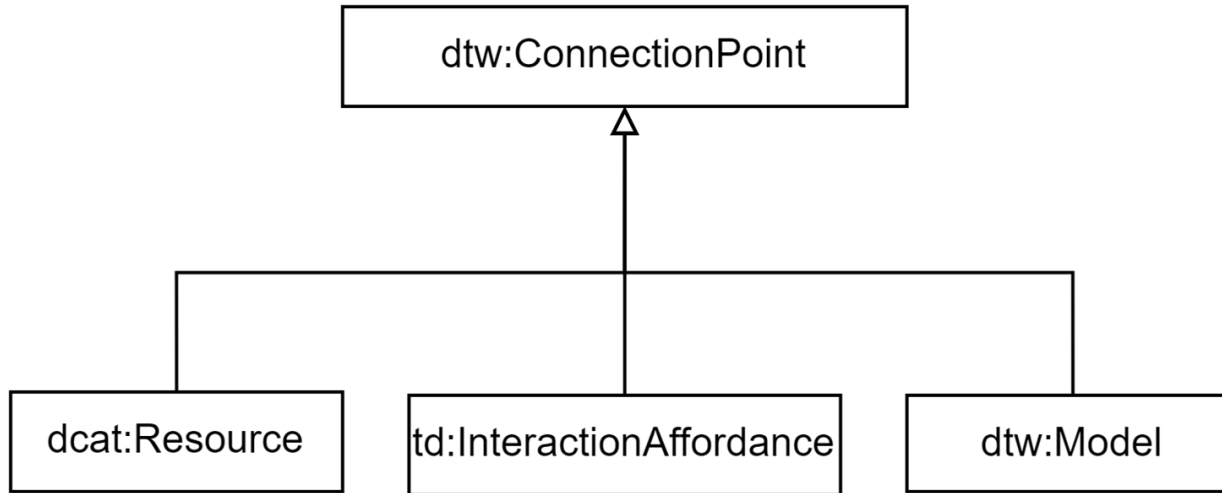
```
"dt_services": [  
  "id": "dt_ss:075c1"  
  "properties": {  
    "validate_rdf": {  
      "forms": [{  
        "href": "https://data.cogito.iot.linkeddata.es/validation/api/validate_rdf/data",  
        "type": "text/turtle"  
      }]  
    }  
  },  
  "actions": {  
    "register_shacl_model": {  
      "forms": [{  
        "href": "https://data.cogito.iot.linkeddata.es/validation/api/rdf_shacl/ma  
        "type": "application/octet-stream"  
      }]  
    }  
  },  
  "events": {}  
],
```

td:InteractionAffordance

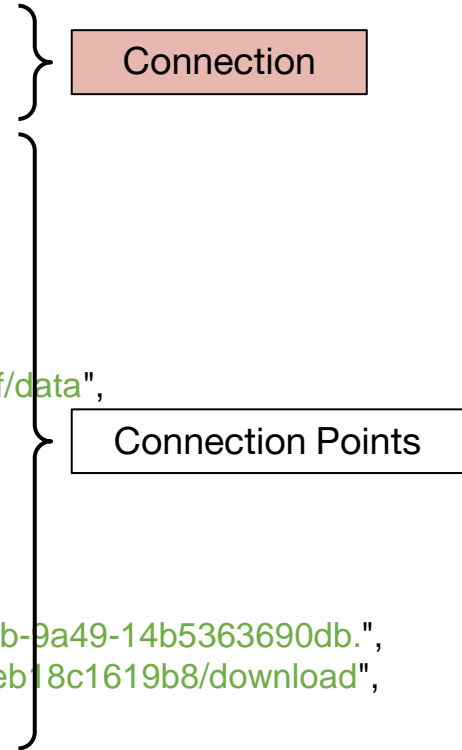




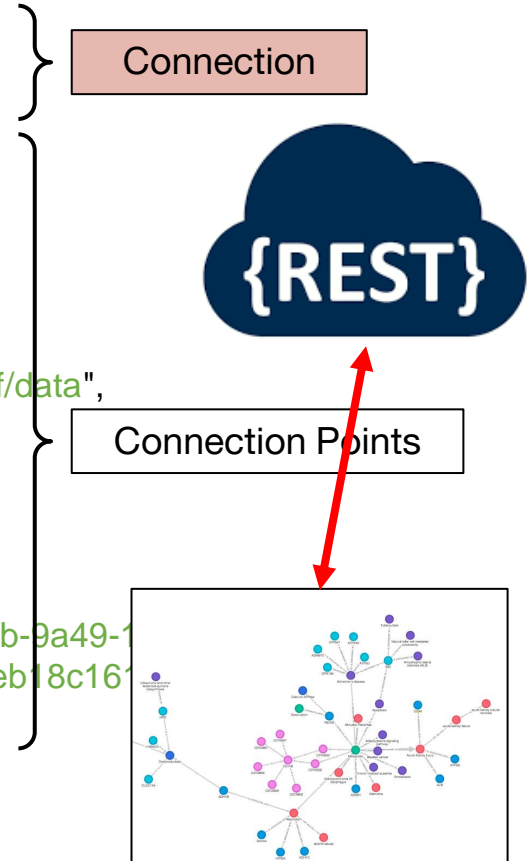




```
"dt_cn": [  
  "id": "dt_cn:38cca",  
  "connection": {  
    "id": "connection:190d0",  
    "type": "Connection",  
    "title": "Materialization connection.",  
    "consumer": {  
      "type": "DTw_Service",  
      "title": "Helio",  
      "description": "Materialization service used to generate RDF data.",  
      "href": "https://data.cogito.iot.linkeddata.es/validation/api/project_to_rdf/data",  
      "internal": "true"  
    },  
    "provider": {  
      "type": "dcat:Dataset",  
      "title": "IFC File",  
      "description": "IFC File of SDT 01U2O from project 308736f9-f533-4b4b-9a49-14b5363690db.",  
      "href": "https://dtp.cogito-project.com/file/508bfae6-dada-46d1-8d40-beb18c1619b8/download",  
      "internal": "false"  
    }  
  },  
  ...  
]
```



```
"dt_cn": [  
  "id": "dt_cn:38cca",  
  "connection": {  
    "id": "connection:190d0",  
    "type": "Connection",  
    "title": "Materialization connection.",  
    "consumer": {  
      "type": "DTw_Service",  
      "title": "Helio",  
      "description": "Materialization service used to generate RDF data.",  
      "href": "https://data.cogito.iot.linkeddata.es/validation/api/project_to_rdf/data",  
      "internal": "true"  
    },  
    "provider": {  
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      "description": "IFC File of SDT 01U2O from project 308736f9-f533-4b4b-9a49-1",  
      "href": "https://dtp.cogito-project.com/file/508bfae6-dada-46d1-8d40-beb18c16",  
      "internal": "false"  
    }  
  },  
  ...  
]
```



- **WoTDT ontology** is developed as an **extension of TD ontology** to describe the **five-dimensional architecture** approach of DTws.
- Thanks to **WoT**, this ontology enables a more **precise comprehension** of the DTws and provides **direct access** to all the **system functionalities**.
- Despite **being initially designed for the construction domain**, the ontology is **flexible enough** to incorporate new classes and subclasses to the different dimensions, to **cover other domains**.
- In future research, **WoTDT** can be **useful for the aggregation of DTws**, where **different DTws can be defined**, and use this definition to perform the **aggregation process**.



# Many Thanks!

**Salvador González-Gerpe**, Andrea Cimmino, Socorro Bernardos  
María Poveda-Villalón, Raúl García-Castro

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