# V4Ann: Representation and Interlinking of Atom-based Annotations of Digital Content

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V4Design

HORIZON 2020

# Outline

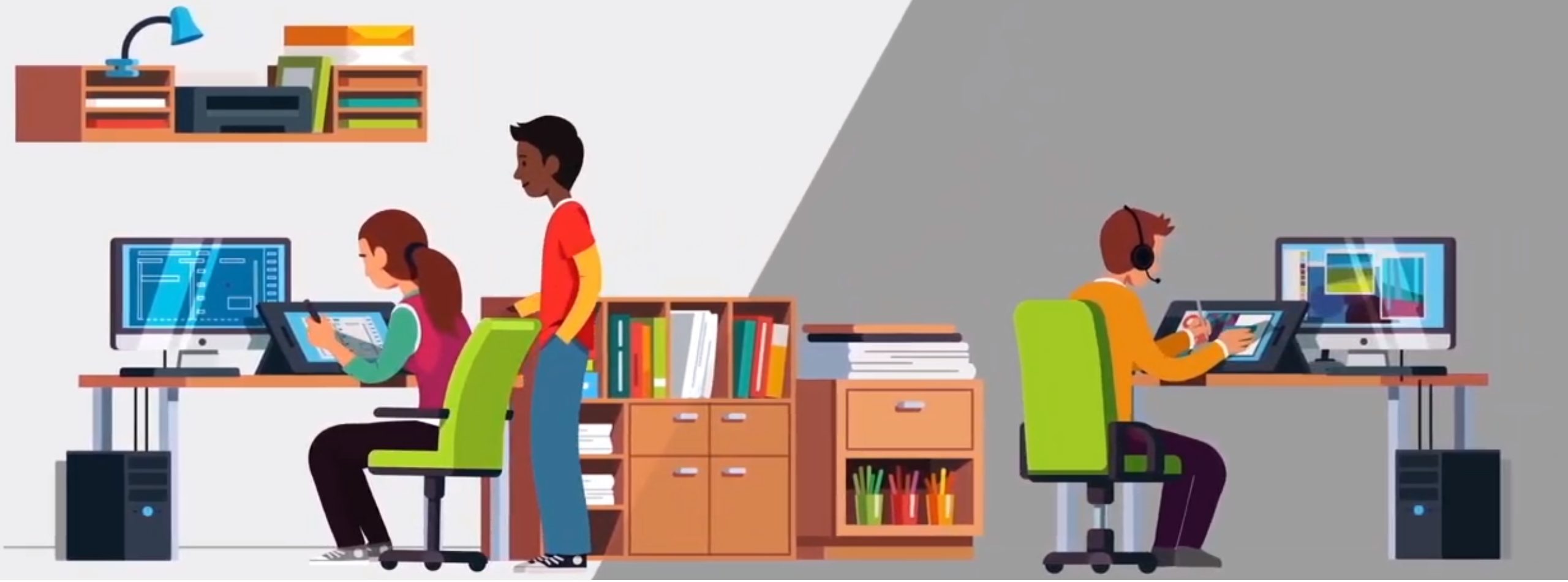
- Overview & Motivation
- Proposed Framework
  - V4Ann Annotation Model
  - Inference and Validation
  - Asset searching
- Evaluation
- Future Directions

# Overview & Motivation

- **High quality content** is nowadays widely available on the web and other sources
  - user-generated content, such as images, videos and text posted by users on social media, wikis and blogs
  - content provided through official publishers and distributors, such as digital libraries, organisations and online museums
- This content remains largely **under-exploited**
  - lack of solutions for its retrieval and integration into the design process
- If leveraged appropriately, could serve as a **valuable source of inspiration**
  - a great source of revenue for the Creative Industries, such as architecture and video game design
  - inspire and support the creation of new content and to produce new assets or to enhance and (re-)use the already existing ones

# Challenge

- Maximise the potential for re-purposing of digital content
- Development of innovative technologies to systematically
  - Analyse
  - Combine
  - Link
  - Foster searchability and reusability of heterogeneous content



# V4Design Project

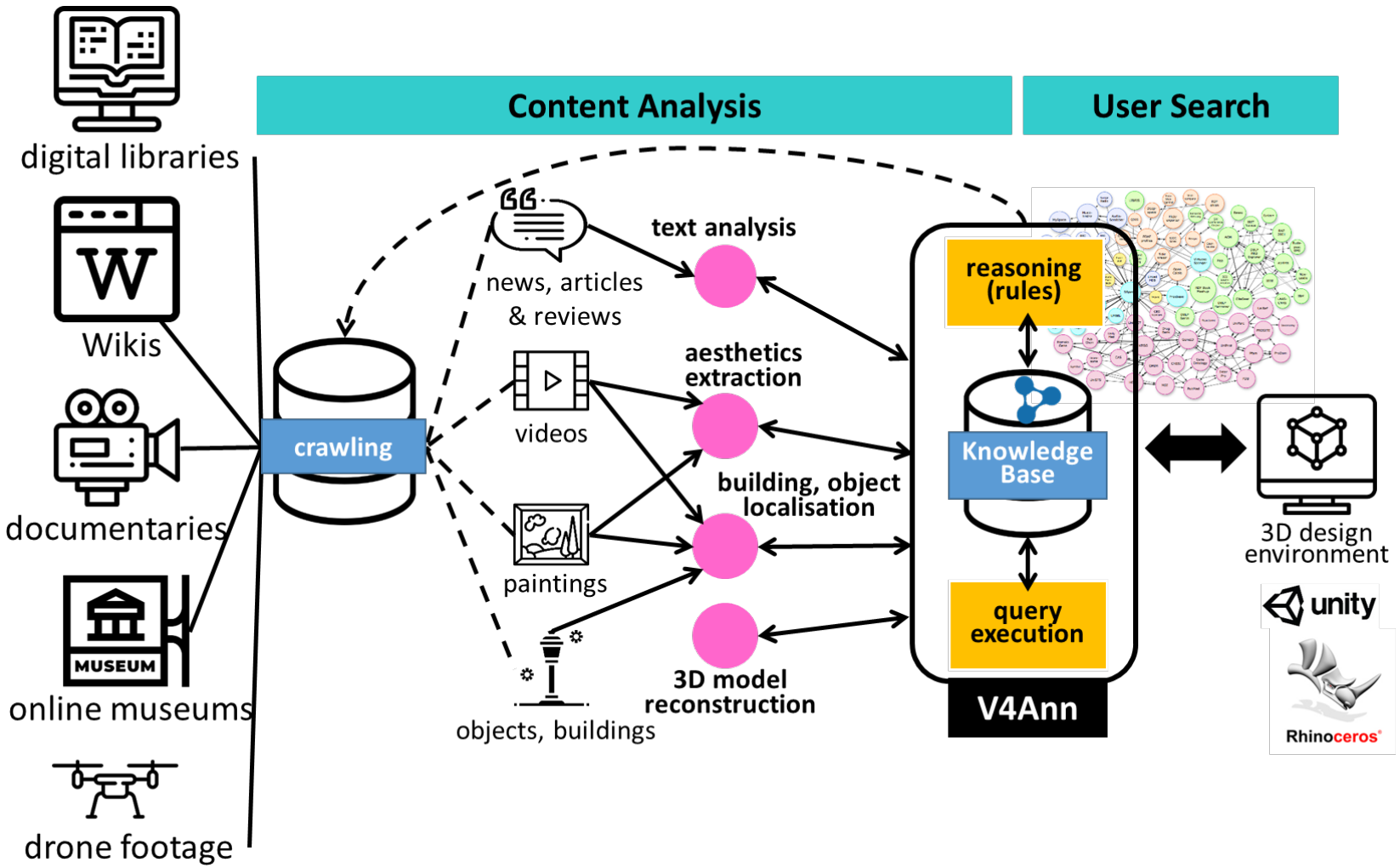
http://www.v4design.eu/

**Visual and textual content re-purposing FOR(4) architecture, Design and video virtual reality games**

# V4Design Concept

- **Vision**
  - Reuse and repurpose high quality content
  - Provide repurposed content to targeted creative industries
    - Architects, VR and video game designers
  - Provide revenues for the data providers and creative industries
- **Key Technologies**
  - Web data mining for crawling visual and textual data
  - Aesthetics extraction and texture proposals
  - Language understanding and text generation
  - 3D reconstruction
  - **Semantic knowledge representation, linking and reasoning**

# Overview of V4Design Platform



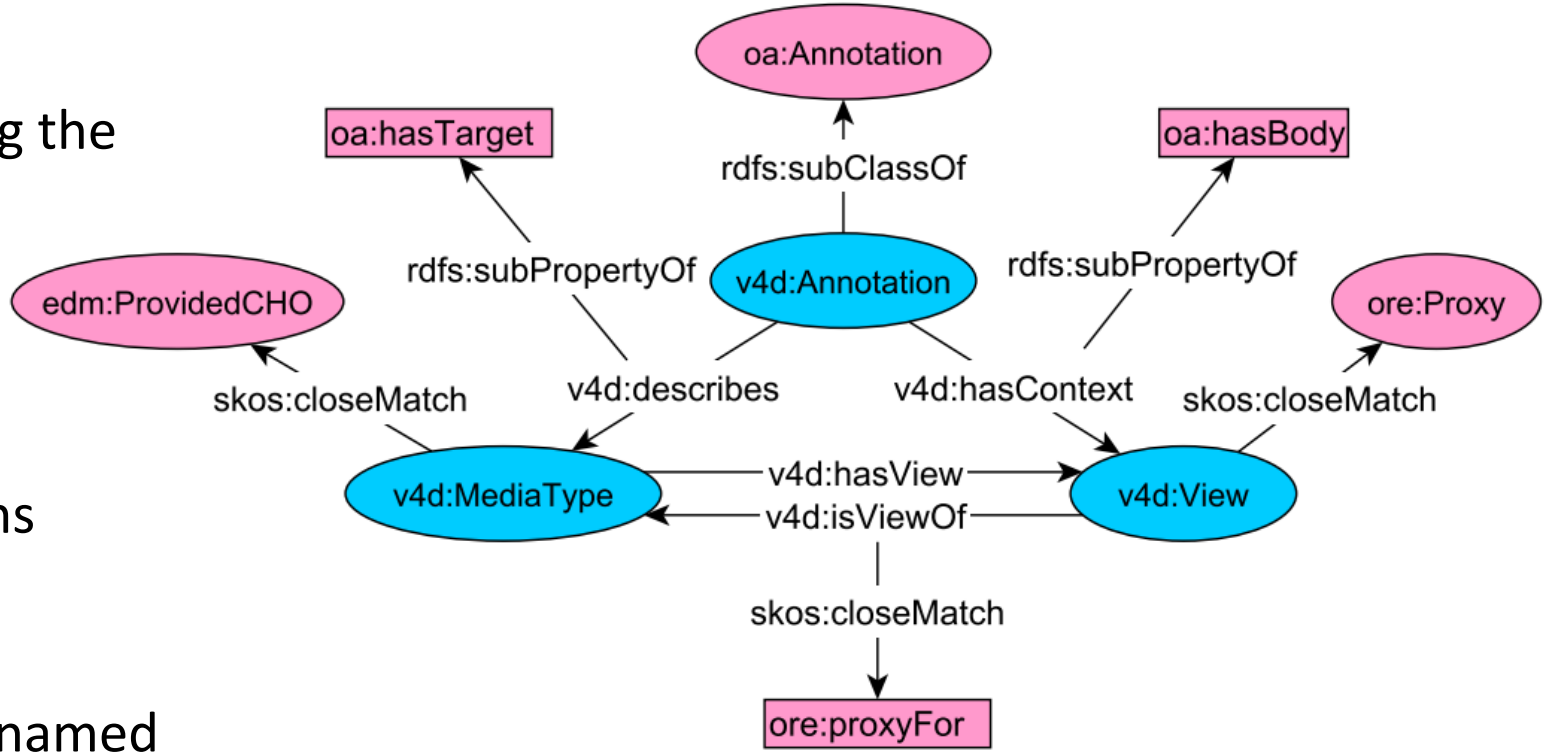
# V4Ann Role in V4Design

- Semantic middleware, capturing, interlinking and serving analysis results to multimedia analysis services
  - Annotation propagation and linking: efficient and interoperable way to represent, exchange and further link metadata, both structurally and semantically
- Semantic atom-based query infrastructure to retrieve generated assets
  - Context-aware retrieval: practical and efficient retrieval mechanisms on top of the multimodal annotations
- How?
  - Web Annotation Data Model (WADM), Building Topology Ontology (BOT)
  - Domain-specific ontologies (Europeana Data Model)
  - SPIN / SHACL inference and validation rules

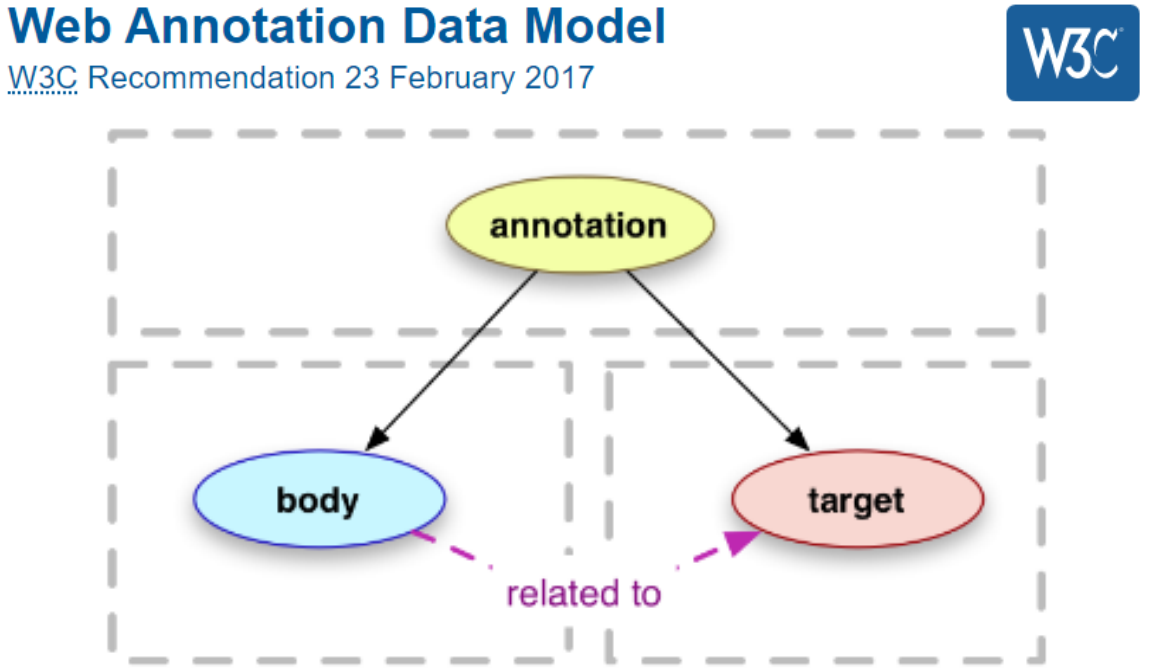
# V4Ann Annotation Model

# Key Concepts

- Annotations
  - resource containers, implementing the annotation pattern of WADM
- Media types
  - image, video, text, 3D model
- Views
  - container for attaching annotations (atoms) to media types
- Atoms
  - aesthetics, object/building types, named entities/relations, image/video frames used for 3D reconstruction



# Annotation resources




- `LocalisationAnnotation`, `TextualAnnotation`, `AestheticsAnnotation` and `3DModelAnnotation`
- Extends `oa:Annotation` concept
  - `hasContext` ⊑ `oa:hasBody`
  - `describes` ⊑ `oa:hasTarget`
- V4Ann annotation has a context that describes a media type using views

$$\texttt{Annotation} \sqsubseteq \texttt{oa:Annotation} \sqcap \exists \texttt{describes.MediaType} \sqcap \forall \texttt{hasContext.View}$$

# Media types

- Four media types
  - Video
  - Text
  - Image
    - Mask ⊑ Image
    - Texture ⊑ Image
  - 3DModel
- Intuitively, each media type resource represents a single multimedia asset for which a set of annotation atoms needs to be captured.

# Views and Atoms

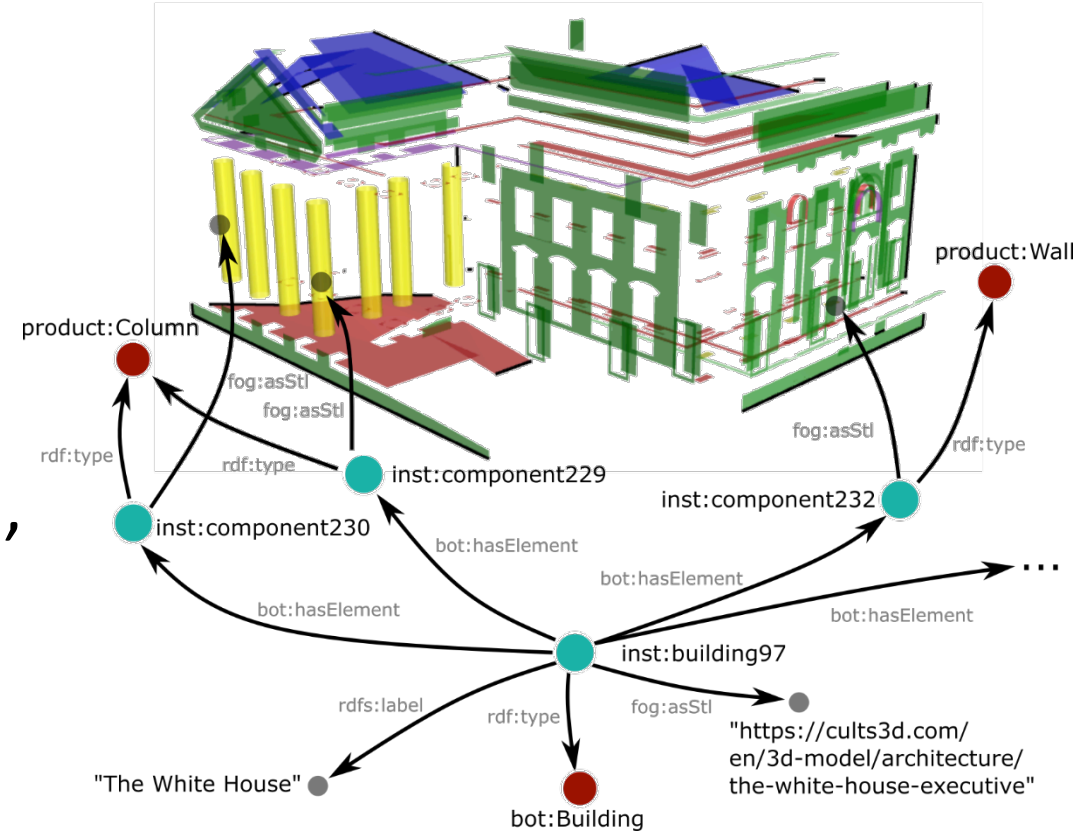
- Encapsulate the annotation data (for media types)
  - Annotation are derived from content analysis (text analysis, visual analysis, etc.)
- **Aesthetics**: categorisation of the aesthetics of paintings and images that contain architecture objects and buildings
  - Style: e.g. impressionism, cubism and expressionism
  - Creator: mainly for paintings (schema.org)
  - Emotion: e.g. fear

$$\mathtt{AestheticsAnnotation} \sqsubseteq \mathtt{oa{:}Annotation} \sqcap \exists \mathtt{describes}.\{\mathtt{Image} \sqcup \mathtt{Video}\} \sqcap \forall \mathtt{hasContext}.\mathtt{AestheticsView}$$

$$\mathtt{AestheticsView} \sqsubseteq \forall \mathtt{creator}.\mathtt{Creator} \sqcap \forall \mathtt{style}.\mathtt{Style}$$

# Views and Atoms

- **Object and Building Localisation:**
  Building and interior objects localization, e.g. include tables, vases, as well as statues, buildings, etc.
  - Masks: outline of the object
  - Tags: computer vision labelling
  - Frames

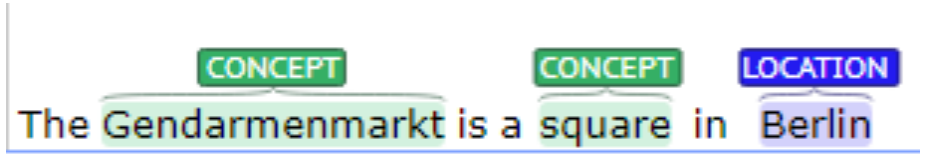



$$\mathtt{LocalisationAnnotation} \sqsubseteq \mathtt{oa{:}Annotation} \sqcap \exists \mathtt{describes}.\{\mathtt{Image} \sqcup \mathtt{Video}\} \sqcap \forall \mathtt{hasContext}.\mathtt{LocalisationView}$$

$$\mathtt{LocalisationView} \sqsubseteq \exists \mathtt{hasTag}.\mathtt{Tag} \sqcap \forall \mathtt{hasFrame}.\mathtt{integer}$$

# Views and Atoms

- **Text Analysis:** annotation enrichment with entities and concepts extracted from titles, captions, descriptions, etc.
  - Already disambiguated: WordNet, BabelNet or Dbpedia




$$\texttt{TextAnnotation} \sqsubseteq \texttt{oa:Annotation} \sqcap \exists \texttt{describes}.\{\texttt{Image} \sqcup \texttt{Video}\} \sqcap \forall \texttt{hasContext}.\texttt{TextView}$$

$$\texttt{TextView} \sqsubseteq \exists \texttt{hasTag}.\texttt{Tag}$$

# Views and Atoms

- **3D reconstruction:** Converts input videos / images into 3D point clouds and meshes
  - 3D-related properties (e.g. number of points )
  - Source of 3D reconstruction (very important for annotation propagation and linking!)

$$\texttt{3DModelAnnotation} \sqsubseteq \texttt{oa:Annotation} \sqcap \exists \texttt{describes.3DModel} \sqcap \forall \texttt{hasContext.3DModelView}$$

$$\texttt{3DModelView} \sqsubseteq \exists \texttt{hasSource}.\{\texttt{Images} \sqcup \texttt{Video}\}$$

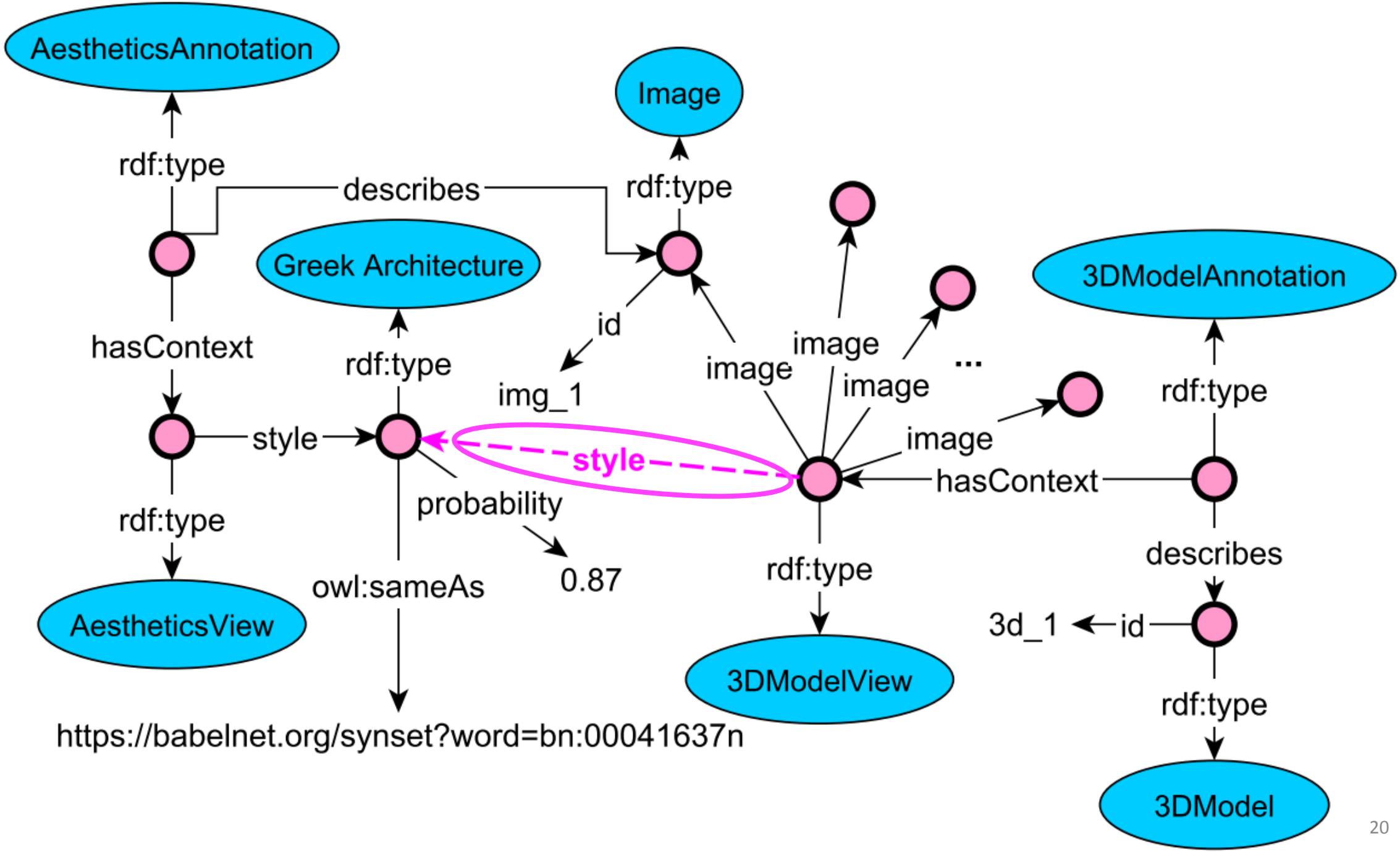
AestheticsAnnotation
rdf:type
describes
Image
rdf:type
Greek Architecture
hasContext
rdf:type
id
img_1
image
image
image
...
3DModelAnnotation
rdf:type
style
probability
rdf:type
owl:sameAs
0.87
AestheticsView
image
hasContext
rdf:type
describes
3d_1
id
3DModelView
rdf:type
3DModel
https://babelnet.org/synset?word=bn:00041637n

# Inference and Validation

# Implicit Relations

- Additional inferences are derived by combining native OWL 2 RL reasoning and custom rules
  - SPARQL-based CONSTRUCT graph patterns are used that identify the valid inferences that can be made on the annotation graphs.
- **Example: atom propagation**
  - Propagate / interlink atoms among view-based annotation provided that they are somehow connected
  - For example, the aesthetics atoms extracted from video frames can be used to annotate the 3D models that have been reconstructed using those frames

```
CONSTRUCT {
   ?view :style ?atom .
} WHERE {
   ?a1 a :AestheticsAnnotation;
      :describes ?img; :hasContext [:style ?atom] .
   ?a2 a :3DModelAnnotation; :hasContext ?view .
   ?view :image ?img .
}
```


AestheticsAnnotation
Image
rdf:type
describes
rdf:type
Greek Architecture
id
hasContext
rdf:type
image
image
...
3DModelAnnotation
img_1
image
rdf:type
style
style
image
hasContext
rdf:type
probability
rdf:type
describes
owl:sameAs
0.87
AestheticsView
3DModelView
3d_1
id
rdf:type
3DModel
https://babelnet.org/synset?word=bn:00041637n

# Validation and Consistency Checking

- Consistency, structural and syntactic quality of the metadata

A. Native ontology consistency checking (e.g. OWL 2 DL reasoning)
   - TBox consistency (e.g. class disjointness)

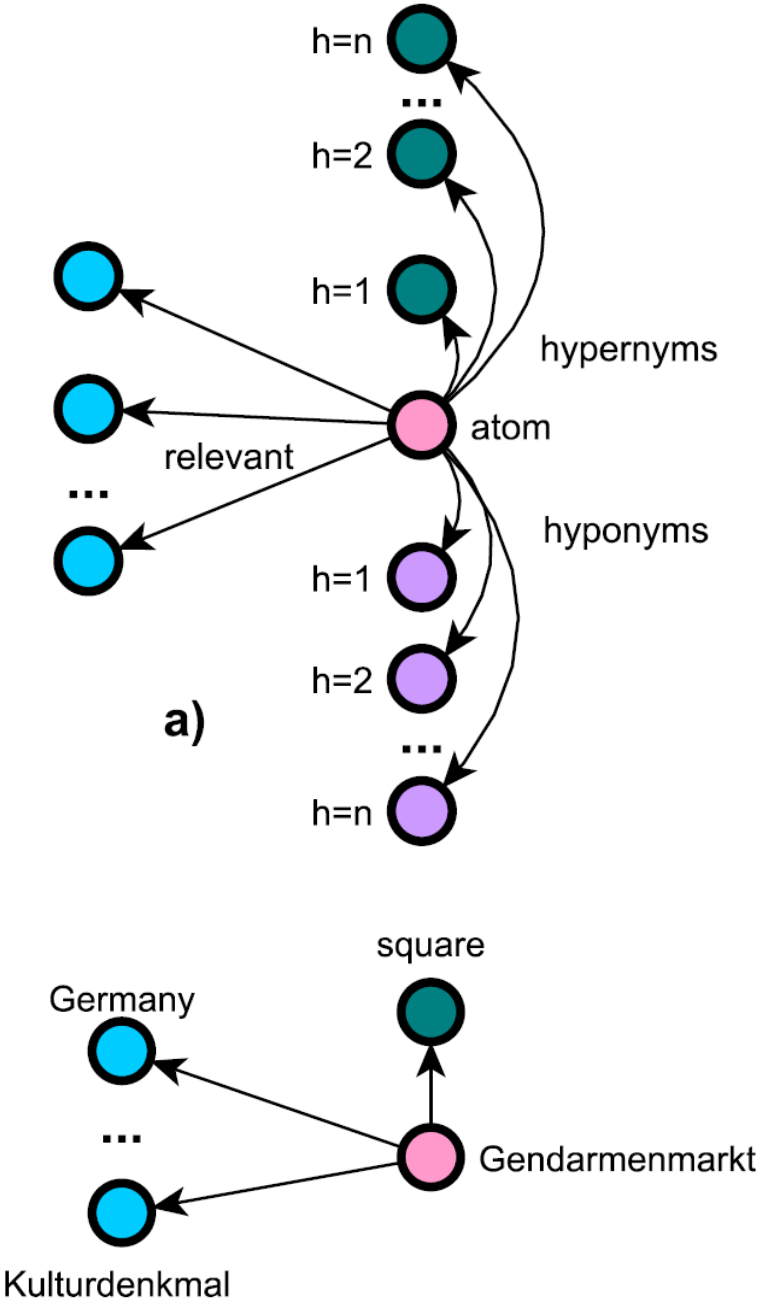
B. Custom SHACL validation rules
   - constraint violations, e.g. missing values and cardinality violations
     - e.g. that all 3D model views should include references to the atoms (images) used for the 3D reconstruction.

```
v4d:3DModelView
    rdf:type sh:NodeShape ;
    sh:property [
        rdf:type sh:PropertyShape ; sh:path v4d:image ;
        sh:class v4d:MediaType ; sh:minCount 1 ;
        sh:name "one or more images" ; sh:nodeKind sh:IRI ;
    ] .
```

# Context-based Asset Retrieval

# Local Context

- Enriched, pre-constructed semantic signature of this atom
  - conceptual and lexical relations from existing semantic networks and datasets, such as WordNet, BabelNet and ConceptNet
- The retrieval mechanism aims to match incoming local contexts of query atoms (keywords) against local contexts of annotation atoms




Generic local context of atom: relevant atoms are extracted from ConceptNet and BabelNet properties, hypernyms stem from WordNet and IS-A BebelNet relationships, hyponyms stem from WordNet; b) example local context for "Gendarmenmarkt".

# Atom Similarity (*AH* Metric)

- Similarity of two atoms taking into account their local context
  - Term similarity function S(A, B) $\in [0, 1]$
  - Set *F* of local context filters
- Filters ( $A \overset{f}{\sim} B$ )
  - **exact**: The two atoms should have either the same URI, or they should be equivalent concepts
  - **plugin:** The atom B should belong to the set of hypernyms of A or to the set of relevant concepts of A
  - **subsume:** The atom B should belong to the set of the hyponyms of A
- The atom A matches the atom B, with respect to a filter set F, if and only if there is at least one filter f ∈ F

$$A \overset{F}{\sim} B \Leftrightarrow \exists f \in F : A \overset{f}{\sim} B$$

# *S* Function

- Heuristic function that takes into account the information capture in local contexts

$$
\begin{aligned}
&r_1\text{: if } A = B \vee A \equiv B, \text{ then } S(A,B) = 1.\\
&r_2\text{: if } B \in hy_A \vee B \in r_A, \text{ then } S(A,B) = a.\\
&r_3\text{: if } B \in ho_A, \text{ then } S(A,B) = b.\\
&r_4\text{: } S(A,B) = 0.
\end{aligned}
$$

- a and b (a > b) are defined manually based on domain knowledge regarding the quality of multimedia analysis that produces the atoms (e.g. aesthetics extraction)
- The empirical dentition of these values (currently a = 0.7 and b = 0.3) aims to promote plugin matches (r2) over subsumed (r3).

# Evaluation

# Digital Content

"description": "Our drone shows you the Bauhaus University in Weimar, Thuringia."

- DeutscheWelle (DW) and Europeana are two key content providers
  - DW provides their documentary and movie archives.
  - Europeana provides their large archive of paintings, pictures of contemporary artwork and related critics.
- The generated V4Ann annotation graphs contain the atoms that have been extracted from the analysis components, along with interconnections among the annotation resources.

| #annotations | #atoms | avg. local context size |
|---|---|---|
| 17245 | 154610 | 17 per atom |

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# User-centred Evaluation

NUROGAMES

Rhinoceros

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1. Collect qualitative feedback on the results, as well as on non-functional aspects, such as query response time
2. (and most important) to generate an annotation dataset and assess the performance of V4Ann

- A list of relevant resources has been provided, such as square names, monuments, building types, etc., in order to help them conduct relevant queries.
- Users filled in a five-point scale questionnaire (1-completely agree, 5-completely disagree).

# User-centred Evaluation

- Quality of atoms: The quality and relevance of local contexts depends on the performance of content analysis, e.g. visual and textual analysis. Visual analysis provides, in principle, better results than text analysis
- Retrieval results: The system achieves good top-ranked accuracy, however the complete set of the results contain quite a lot irrelevant entries
- Response time: The response time of the system was positively assessed. The average response time was 4.1 seconds, which includes query analysis, building of local context and search algorithm execution

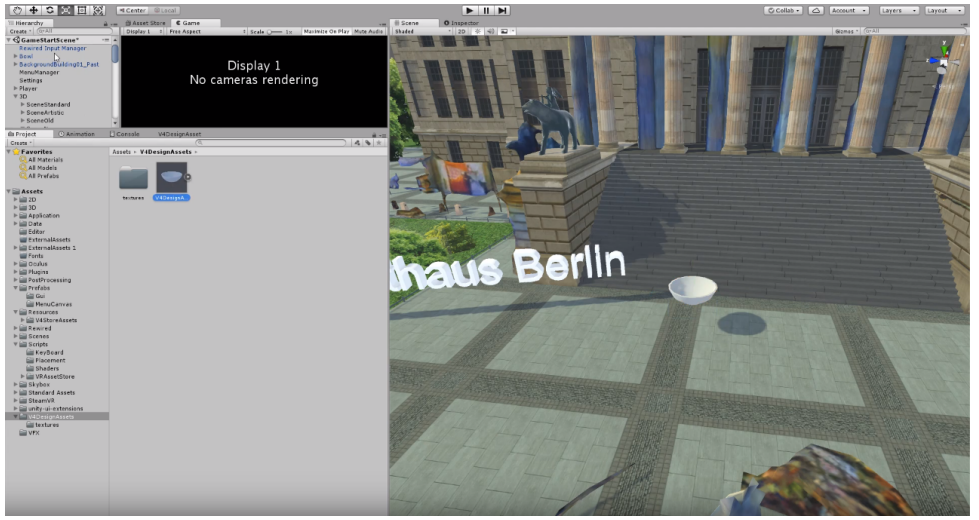
# System Evaluation

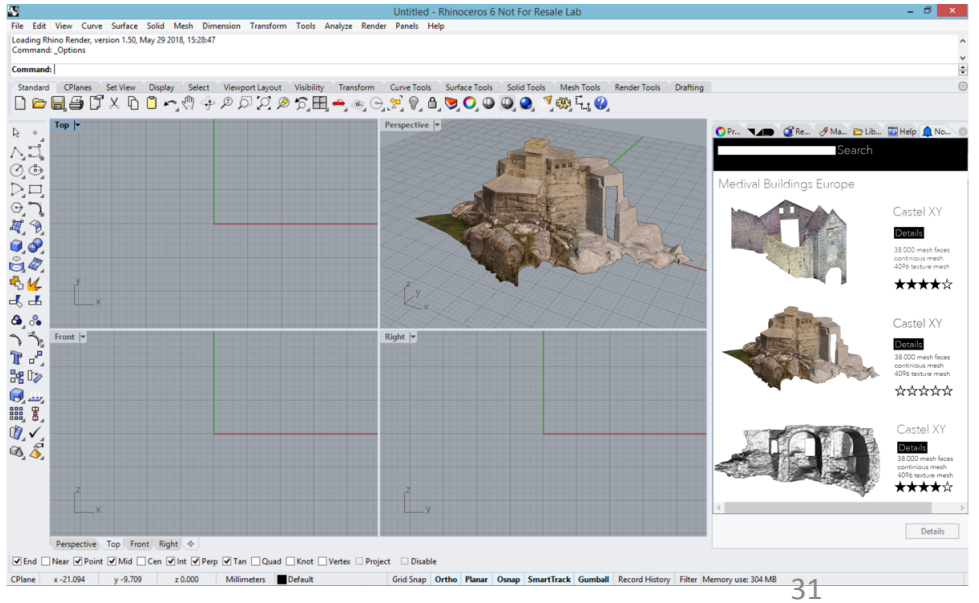
- As expected, the stricter the filter is, the more accurate results we obtain (high precision) with low, however, recall
- A higher h value leads to more generic local contexts that affect precision
  - For example, the third-level WordNet hypernym of “tower” is “unit”, which is too generic
- The more specific the label/atom is, the more room for additional context exists

| | $h = 1$ | | $h = 3$ | |
|---|---|---|---|---|
| | **Recall** | **Precision** | **Recall** | **Precision** |
| exact | 0.59 | **0.77** | 0.44 | 0.51 |
| plugin | 0.67 | 0.69 | 0.52 | 0.48 |
| subsume | **0.73** | 0.61 | 0.59 | 0.42 |

# Conclusion

- Ontology-based framework for representing, linking and enriching results of multimedia analysis on digital content
- Reuses existing standards and schemata, building the atom-based annotations graphs on top of standard ontologies, controlled vocabularies and patterns
  - WADM pattern
- We evaluated the framework using actual multimedia content and atoms provided by the V4Design modules
- V4Ann is accessible through Rhinoceros 3D and Unity plugins developed in the V4Design project.



# Future Directions

- Implement context-aware algorithms to improve the classification accuracy of incoming atoms
  - For example, if the wrong style for a painting is provided by aesthetics, this will affect precision, since V4Ann does not aim at improving the classification of incoming atoms
- Extend the context-aware retrieval algorithm with more sophisticated similarity metrics and functions

# Thank you!

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