An Advanced Digital Twin Approach for Iconographic Heritage Modeling and Processing

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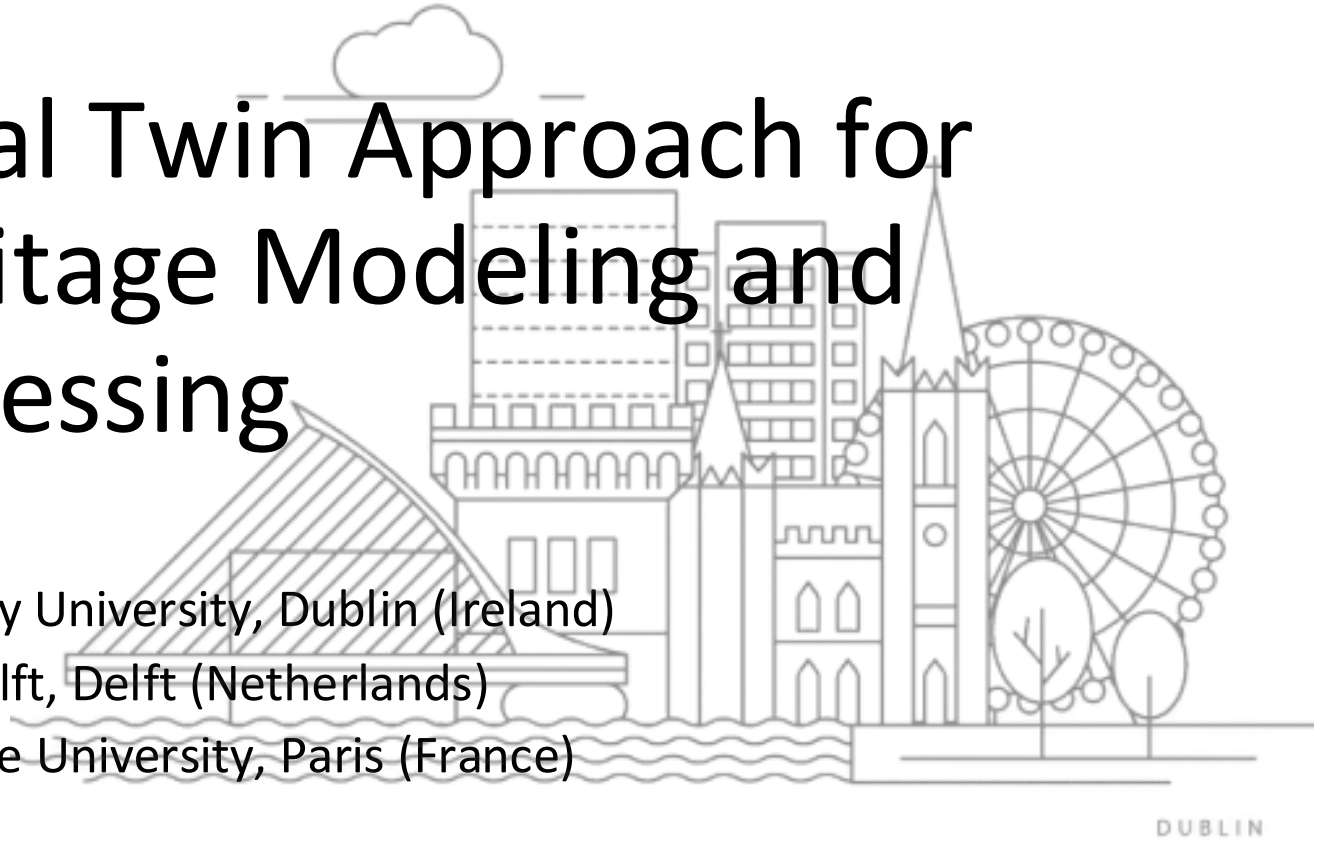

Motivation & Context

From Digital Replicas to Semantic Understanding

Anthony van Dyck (1599 - 1641), Self-portrait, 1616 – 1617,
Oil on panel (Rubenshuis)

Problem

- Digital Twins in Cultural Heritage often stop at visual replication - high-fidelity 3D scans or images that capture form, not meaning.

Research question

- Can artworks be modelled as semantic, narrative entities rather than static digital objects?

Goal

- Introduce Digital Cultural Heritage Twins built with the Narrative Knowledge Representation Language (NKRL) - to capture what artworks mean, not only what they look like.

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Van der Stighelen, K., Janssens, K., van der Snickt, G., et al. (2014). Young Anthony Van Dyck revisited: a multidisciplinary approach to a portrait once attributed to peter paul rubens. *Art matters: international journal for technical art history*

Theoretical Background
From Replicas to Semantic Cultural Heritage Twins

1 Digital Twin (today's CH)

A 3D scan or photogrammetric model

"High-fidelity replica: visual + geometric data"

2 Semantic Twin (adding meaning)

[E22 Man-Made Object : "Self-Portrait"]
| P108 was produced by
▼
[E12 Production]
| P14 carried out by
▼
[E39 Actor : "Anthony van Dyck"]

[E12 Production]
| P4 has time-span
▼
[E52 Time-Span : 1616–1617]

Why useful, but limited

- Current methods (e.g., CIDOC CRM) capture *what happened* in a structured, machine-readable way.
- But it stays **binary**: each arrow is only a two-entity link.
- It doesn't capture, in a single structure, all the *roles, temporal relations, intentions,* or *semantic nuances* (e.g., that the artist *revised* his work multiple times).

Theoretical Background
From Replicas to Semantic Cultural Heritage Twins

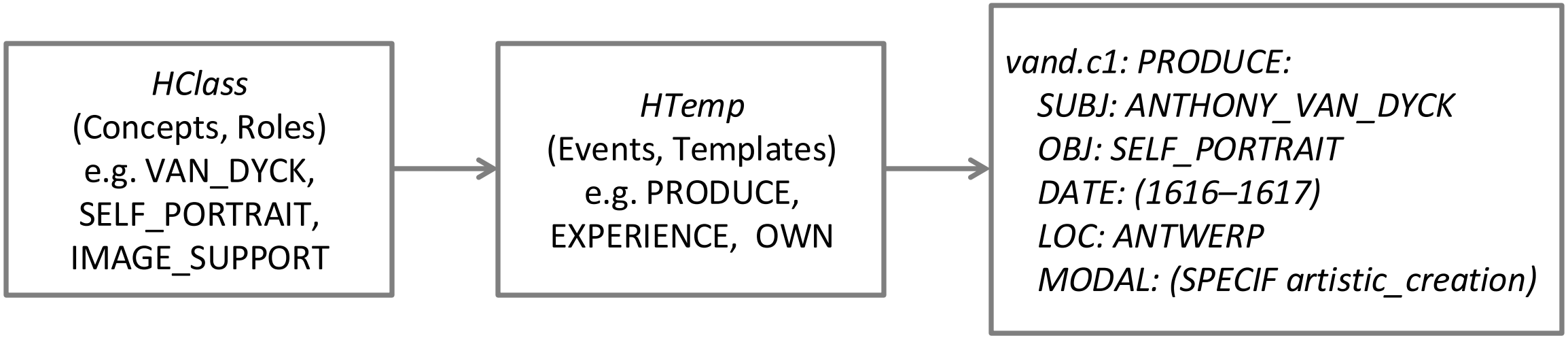
3 Cultural Heritage Twin (NKRL)

Our proposed Cultural Heritage Twins use NKRL, an *augmented n-ary knowledge representation* that models *who-does-what-to-whom*, *when*, *why*, and *how*, enabling machine-actionable narratives.

```
vand.c1: PRODUCE:
   SUBJ: ANTHONY_VAN_DYCK
   OBJ: SELF_PORTRAIT
   DATE: (1616–1617)
   LOC: ANTWERP
   MODAL: (SPECIF artistic_creation)
```

NKRL element	Meaning
vand.c1	Identifier of this particular predicative occurrence(the painting event).
PRODUCE	Predicate describing the type of event — an act of creating something.
SUBJ: ANTHONY_VAN_DYCK	The agent (actor) who performs the action.
OBJ: SELF_PORTRAIT	The object affected or produced by the event.
DATE: (1616–1617)	Temporal component directly embedded in the same event structure.
LOC: ANTWERP	Optional spatial information.
MODAL: (SPECIF artistic_creation)	Qualifier expressing the nature or modality of the event — here, an intentional artistic act.

Building Digital Cultural Heritage Twins with NKRL



- Static knowledge: "what exists" (people, objects, materials, attributes)
- Clarifies that this is your vocabulary layer

- Dynamic templates — "what happens" (actions, events, situations)
- Highlights that this layer defines event structures.

- Integrated semantic model: "*who does what*, *when*, *where*, and *why*"
- Shows that this is the final, computable narrative output.

Modelling the Semantic Evolution of Van Dyck's Self-Portrait (1616–1617)

Objective: Model the *semantic* + *temporal evolution* of the painting's *pentimenti*.

Method: Each phase encoded as an NKRL event template (EXPERIENCE, OWN) linked by **CAUSE/COORD** relations.

Result: A **Digital Cultural Heritage Twin** that formalises both *physical transformation* and *iconographic meaning*.

[PHASE 1] —(CAUSE)→ [PHASE 2] —(COORD)→ [PHASE 3]

Phase 1 (Fig. b):
Open hair, simple collar, no hat.

Phase 2 (Fig. c):
Fuller face, larger collar.

Phase 3 (Fig. c):
Adds hat, refined collar, lighter face.

```
vand.p1: EXPERIENCE:
   SUBJ: (image_support SELF_PORTRAIT)
   OBJ: MODIFICATION_1
   MODAL: (SPECIF pentimenti_ PHASE_1)
vand.p2: (CAUSE vand.p2 vand.p1)
vand.p3: (COORD vand.p3 vand.p2)
```

Contributions, Implications & Future Work

Contributions

- **Conceptual innovation**: Defined the Digital Cultural Heritage Twin - artworks modelled as semantic, narrative entities, not static replicas.
- **Technical advance**: Showed that NKRL augmented n-ary formalism overcomes the limits of binary ontologies (CIDOC CRM, RDF).
- **Applied result**: Created a machine-actionable model of Van Dyck's pentimenti, linking material data with semantic interpretation.
- **Interoperability**: Aligns with ECCCH and Linked Open Data frameworks, offering a semantic layer compatible with CH infrastructures.

Future directions

- Develop **AI-assisted natural language → NKRL translation** to automate event modelling.
- Extend modelling to **other heritage domains**: sculpture, architecture, manuscripts.
- Integrate NKRL with **semantic web platforms** for large-scale CH reasoning.
- Explore **user-facing interfaces** for curators and visitors - semantic querying & narrative visualisation.

Thank You

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closing.1: BEHAVE:
SUBJ: PRESENTER_
OBJ: (SPECIF gratitude_)
BENF: AUDIENCE_
CONTEXT: (SPECIF SUMAC_25 DUBLIN_ 2025-10-27)