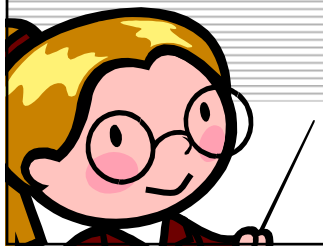
Formalizing the Knowledge related to Shape Acquisition and Processing

Laura Papaleo
Department of Informatics Computer Science
University of Genova
papaleo@disi.unige.it



What we want to do?

- Understand what a context-specific ontology is
- Understand how to
  design a context-specific ontology
- Learn more on an ontology for
  Shape Acquisition (and Processing)
- Understand how to refine an ontology
- Learn by examples and exercises

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What is an Ontology?

- A specific artifact designed with the purpose of expressing the intended meaning of a (shared) vocabulary
- "*An ontology is a specification of a conceptualization*" [Gruber 95]
- An ontology defines concepts and relationships used to describe and represent an *area* of knowledge

What is an ontology?

- Ontologies created for computer applications are written in a formal language that is machine-readable.
- Formalized ontologies are instruments for capturing the meanings of concepts so that they may be used for improved, automated management of information.
- Ontologies may cover very general concepts or (more often) represent specific and restricted domains.
- The selection of concepts and their level of detail will depend on the characteristics of the domains to be covered and the operations needed.

Example: a *bridge* from different points of view

- A map program may use a *simple representation* for *bridges*
- A traffic-planning program needs a *more complex* concept in which bridges have lanes, access ramps, etc.
- A program whose purpose is to aid civil engineers in the design of bridges will require an even more in-depth representation of bridges, their parts, and even the forces that affect them.

The purpose of an ontology influences both its scope and its degree of formal complexity

Ontologies at different levels of abstraction

- *Upper ontologies* (top-level)
  - identify and define general concepts
- *Mid-level ontologies* (general-purpose)
  - reach further toward the domain level in specificity but are still general enough
- *Domain Ontologies*
  - specialized ontologies that cover topical bodies of knowledge.

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An Ontology for Shape Acquisition And Processing

Why ontologies in this context?

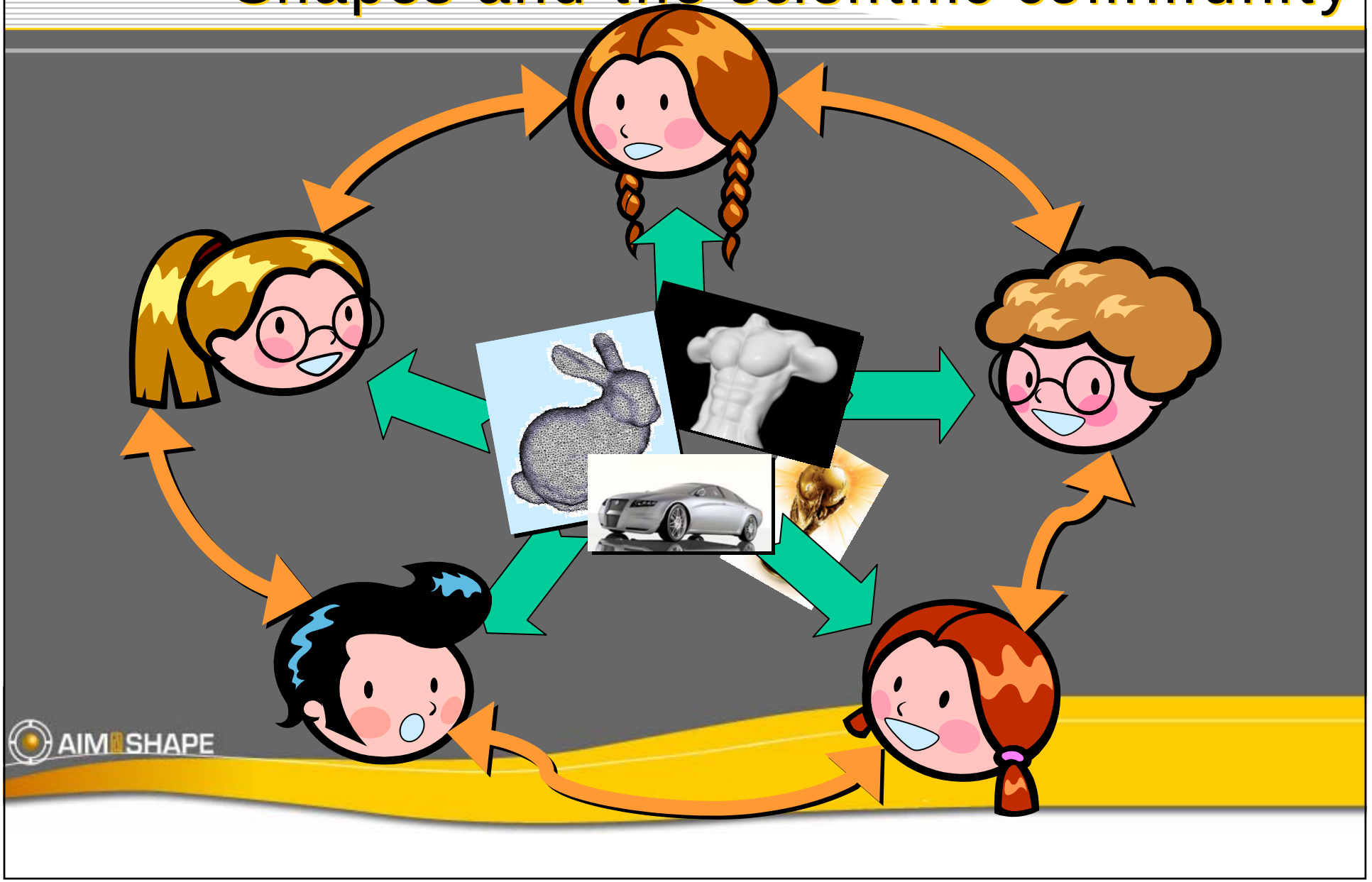
- New Web Technologies are emerging for facilitating the communication and for making easily available a huge amount of information.
  - A problem relevant in the field of **Shape Modelling**

- *Shape Modeling* concerns methods to represent, create, process and analyse digital representations of objects for a variety of applications
  - Cultural Heritage, GIS, Scientific Visualization, Medicine Applications, Virtual Reality and so on…

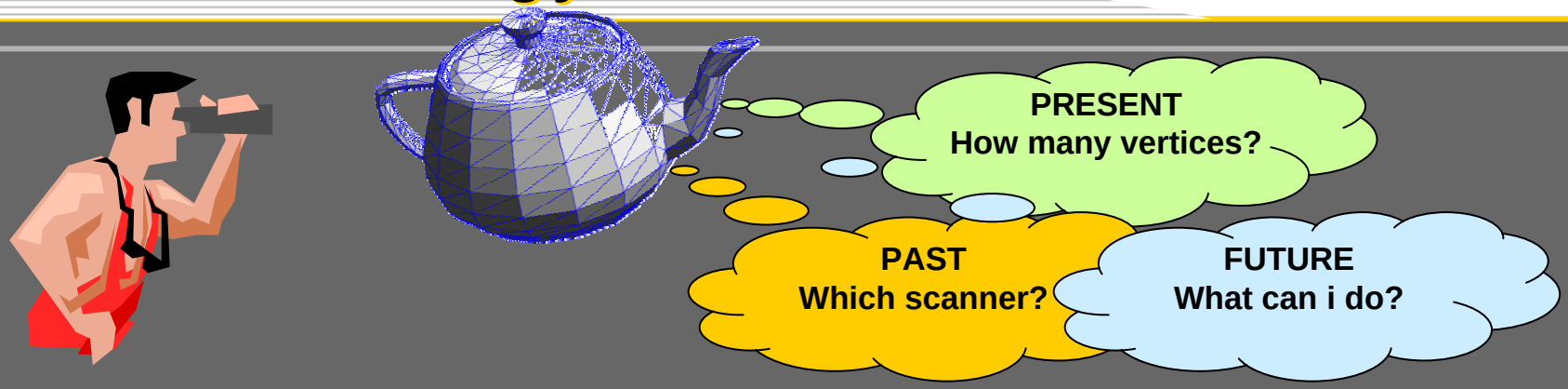
Why ontologies in this context?
A Digital Shape

- Multi-dimensional media characterized by a visual appearance in a space of 2, 3, or more dimensions.
- Examples: pictures, images, 3D models, videos, animations, etc.

Why ontologies in this context?
Shapes and the scientific community



Why ontologies in this context? Ontology-driven annotation of shapes

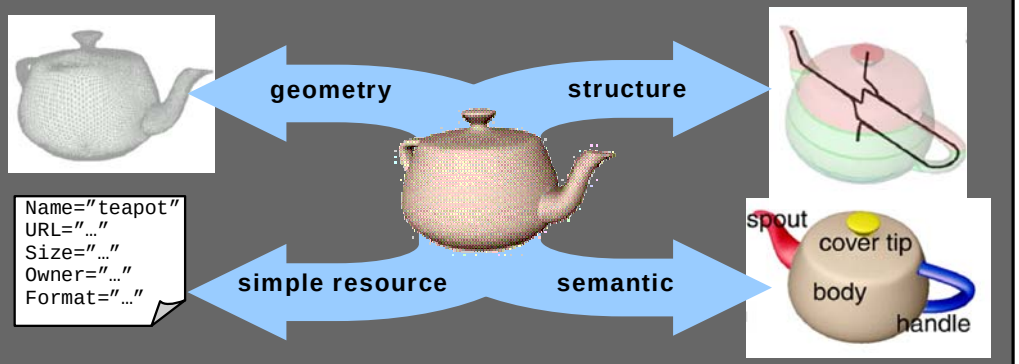


- Due to the intrinsic complexity of shapes, ontology-driven metadata are necessary in order to reach a sufficient level of expressiveness.
- Metadata should provide a thorough characterization of shapes by storing:
  - the information related to its history (its past, e.g. for documentation)
  - the information intrinsically held by the shape itself (its present)
  - the information related to its capabilities and potential uses, (its future, e.g., for acquisition/process planning)

Why ontologies in this context? Ontology-driven annotation of shapes

Able also to represent different levels of sophistication

- **Simple resource**
  (e.g. for cataloguing)
- According to its **geometry**
  (e.g. for rendering),
- According to its **structure**
  (e.g. for matching and similarity),
- According to **what it represents**
  (e.g. for recognition or classification)

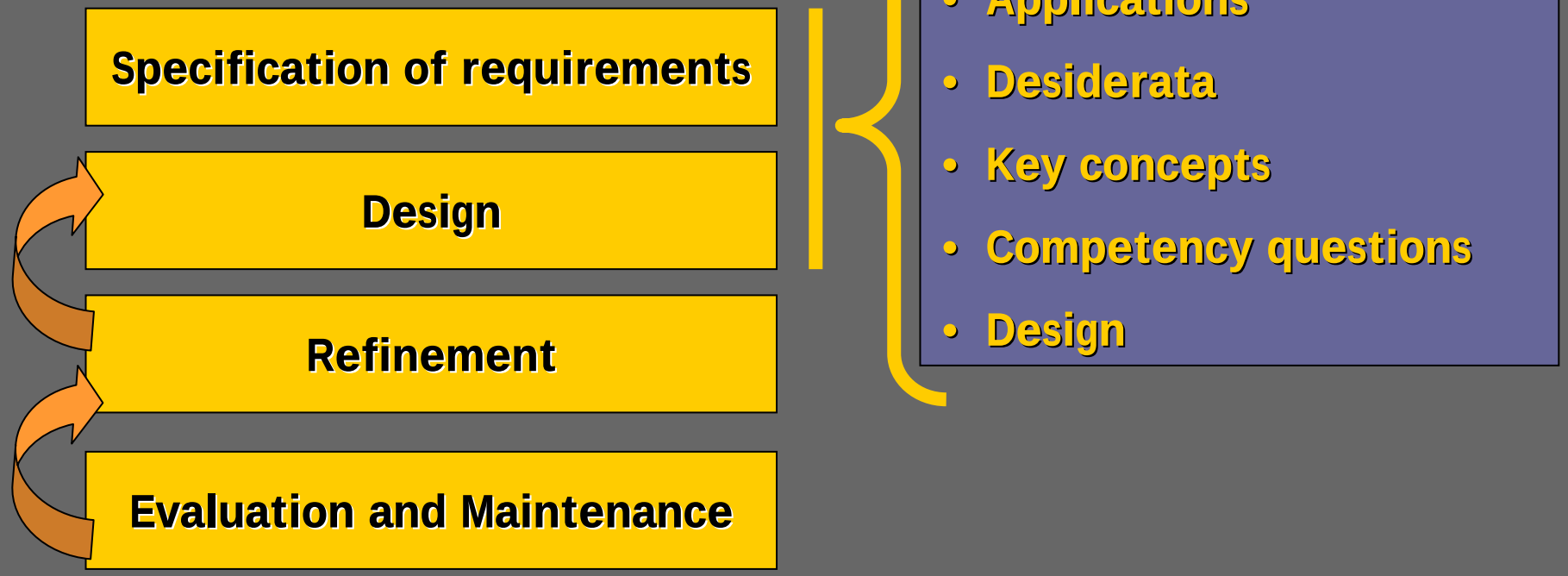


- **Researchers in Shape Modelling are interested in one or more of the characterizations, AND also on the conditions and the tools to pass from one characterization to another.**

Ontology development is an iterative process

1. **Kick-off phase:** capturing the ontology
   - Define the requirements specification
   - Build a first draft version in a semi-formal description
2. **Refinement phase:** formal representation
3. **Evaluation phase**
4. **Maintenance and Evolution phase**

The OntoKnowledge Approach

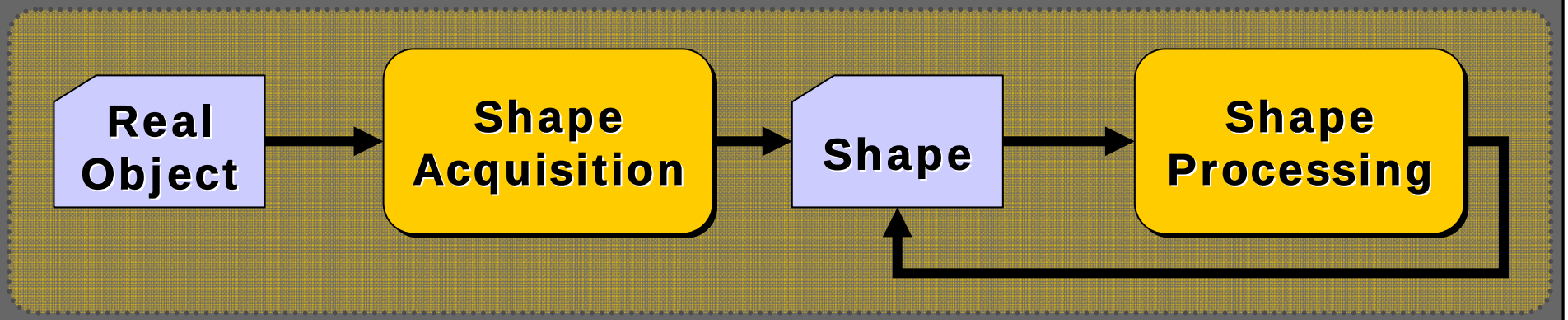


Kick-off phase: Step 1 Brainstorming

- What is the domain the ontology will cover?
- What is the ontology going to be used for?
  - Brainstorming session

- All involved must collectively possess sufficient domain expertise
- Quickly capture potentially relevant terms and phrases of the domain

What we want to model...



- Which knowledge would we like to formalize?
- At which level of detail?

- It depends on the target applications we have in mind and on the specific domain...

Domain and Applications

- The ontology defines and formalizes concepts and relations among them.
  - **Shape models** and **tools** are treated as resources that can be uploaded and downloaded together with their metadata in different repositories.

DOMAIN

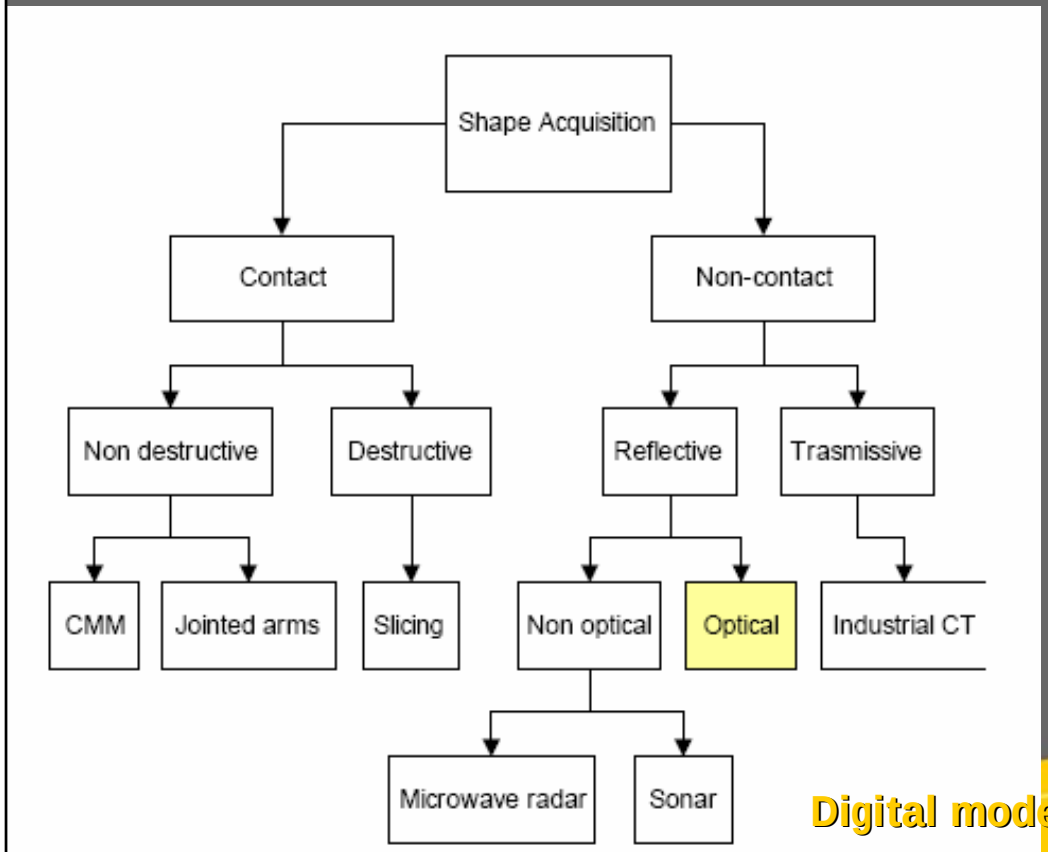
The development, usage and sharing of hardware tools, software tools and shape data by researchers and experts in the field of **acquisition and processing of shapes**.

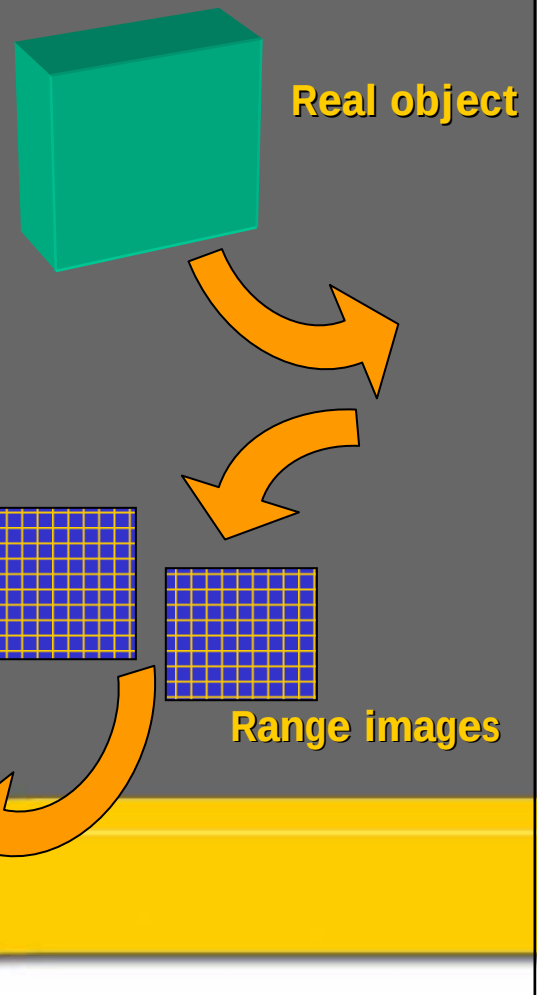
Applications

- Acquisition Planning
- Data validation
- Benchmarking
- Testing
- Data enhancement

Shape Acquisition:
From Real Objects to Digital Shapes

- There exist many different types of acquisition devices

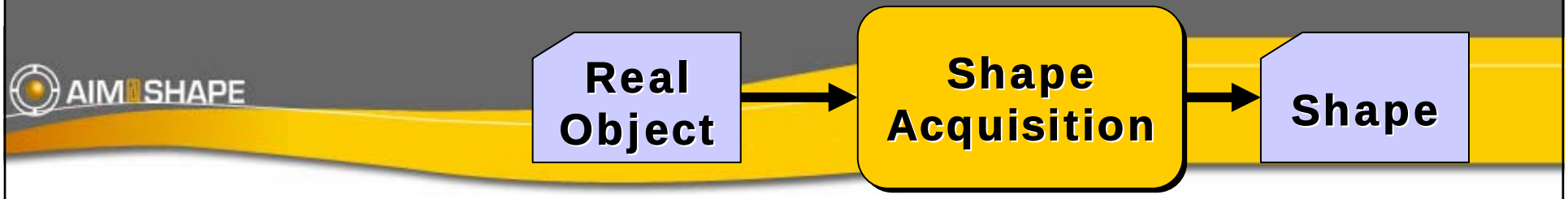




Acquisition: From Real Objects to digital shapes

- What we would like to maintain?

- Given a real object with different properties (which one?) we should be able to model and maintain the information associated to the acquisition session

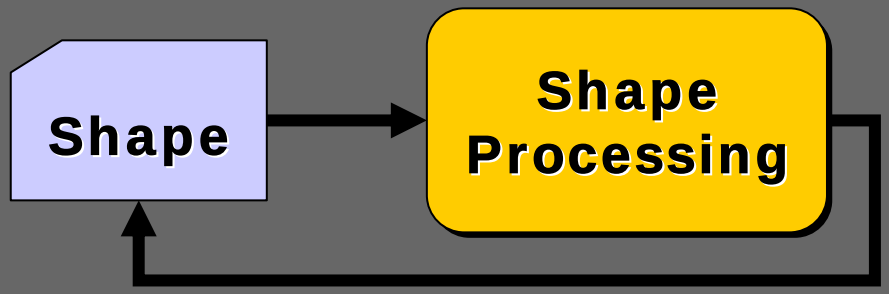


Shape Processing:
From Digital shapes to Digital shapes

- Once you have a digital shape you would like (or you need) to modify it in order to
  - Analyze it (Describe it in terms of “significant parts”)
  - Structure it (Describe it in terms of “structural parts”)
  - Improve it (Remeshing, fill the holes…)
- Wide field of applications…
- Can we describe it in a general sense?
  - At least from our “ontology point of view”…

Shape Processing:
From Digital shapes to Digital shapes

- What we would like to maintain?



- In processing a shape it can be interesting to maintain all the information regarding
  - the tool/algorithm used…
  - The parameters
  - The initial and final shape and the relative properties
  - And so on…

Key entities

Shape Acquisition

Scanning device
Object Size
Object Material
Object Fragility

Shape Processing

Filling holes
Sharp features
Recovery actions
Smoothing

Transversal Entities

Points
Mesh
Algorithm
Parameters
Complexity

Points cloud
Process
Input/output
Performance
Accuracy

Shape Acquisition and Processing Ontology Design

- A huge set of *confused* (not organized) concepts!

We need to understand

- which concepts will become an entity in the ontology
- which one will become a property and
- which one will disappear

- This was done looking also at the competency questions we have identified…

CQs: some examples

Questions regarding Shape Data and Real Objects

- Which are the **Real Objects** owned by “UU”?
- Who is the *owner* of the **Real Object** "Black Tire"?

Questions regarding the Acquisition phase

- What are the **Acquisition Systems** able to scan a **Real Object** which is *light absorbent*?
- What **tricks** have been performed in order to scan the **Real Object** "Frog”?
- Has the **real object** “PisaCathedral” been scanned *indoor*?
- Under which *LightingConditions* the **real object** “FROG” has been scanned?
- Who is the *owner* of “XYZ” **Acquisition System**?

Questions regarding tools using Shape Data

- What *parameters* were used to segment this **image** with the “SWA” **tool**?

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Shape Acquisition

Identification of key concepts…

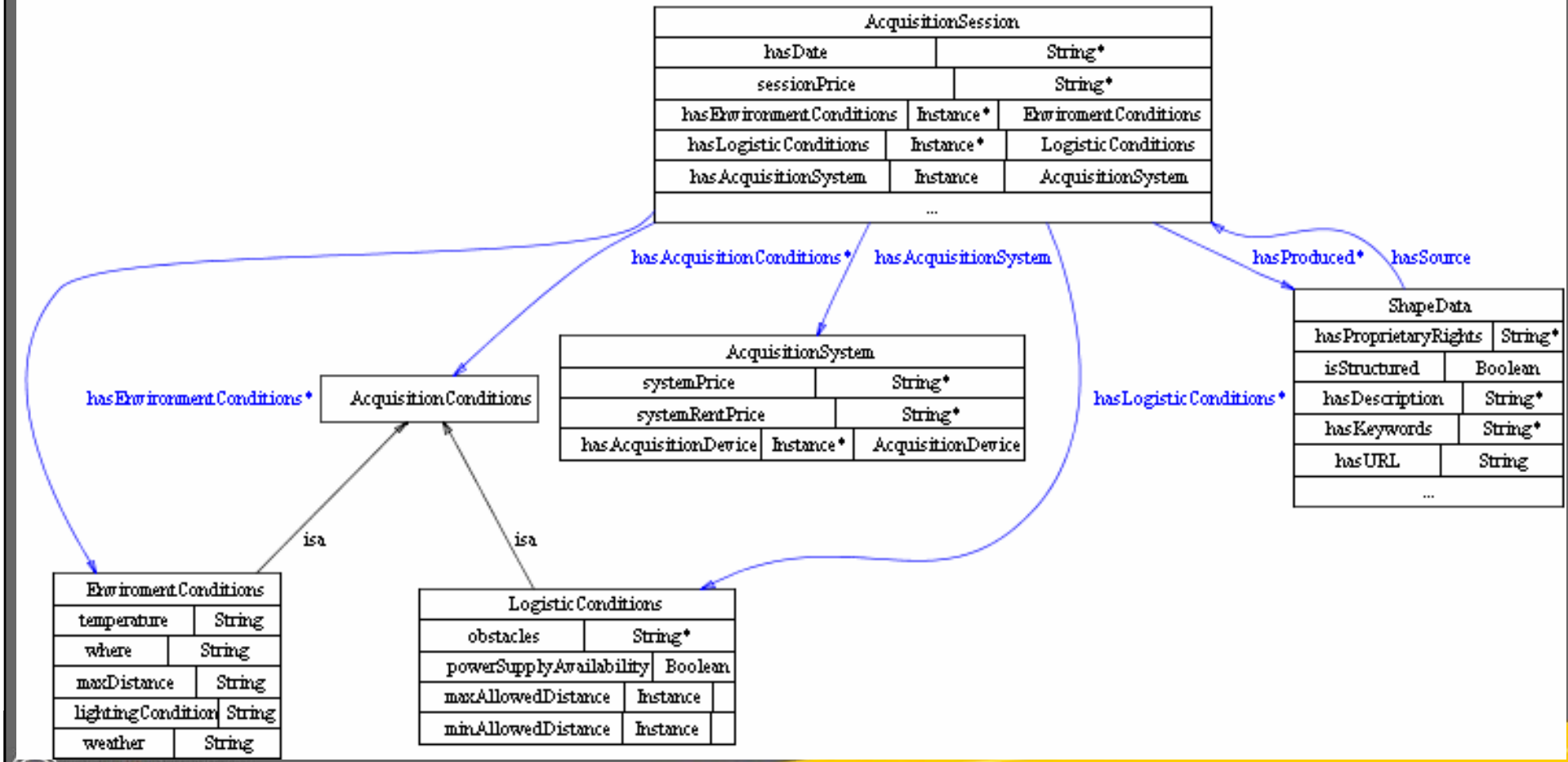
- The acquisition process basically deals with an acquisition session which takes place considering a particular real object and producing a digital shape on the basis of certain conditions.

- Acquisition System
- Acquisition Device
- Acquisition Session
- Real Object
- Shape
- Institution
- Person
- Environment
- Logistic…

Modeling and Initial schema

- the *AcquisitionSession* has been modeled as an entity, and it is related
  - to an *AcquisitionSystem* (which is made up by one or more *AcquisitionDevices* - e.g. scanners) and
  - to the *AcquisitionConditions* in which the acquisition is performed (environment, logistic)
- It produces a ShapeData (*hasOutput*)
- It acquires a Real Object (*hasInput*)
- It can also has used some tricks for the acquisition (*hasTrick*)

The AcquisitionSession



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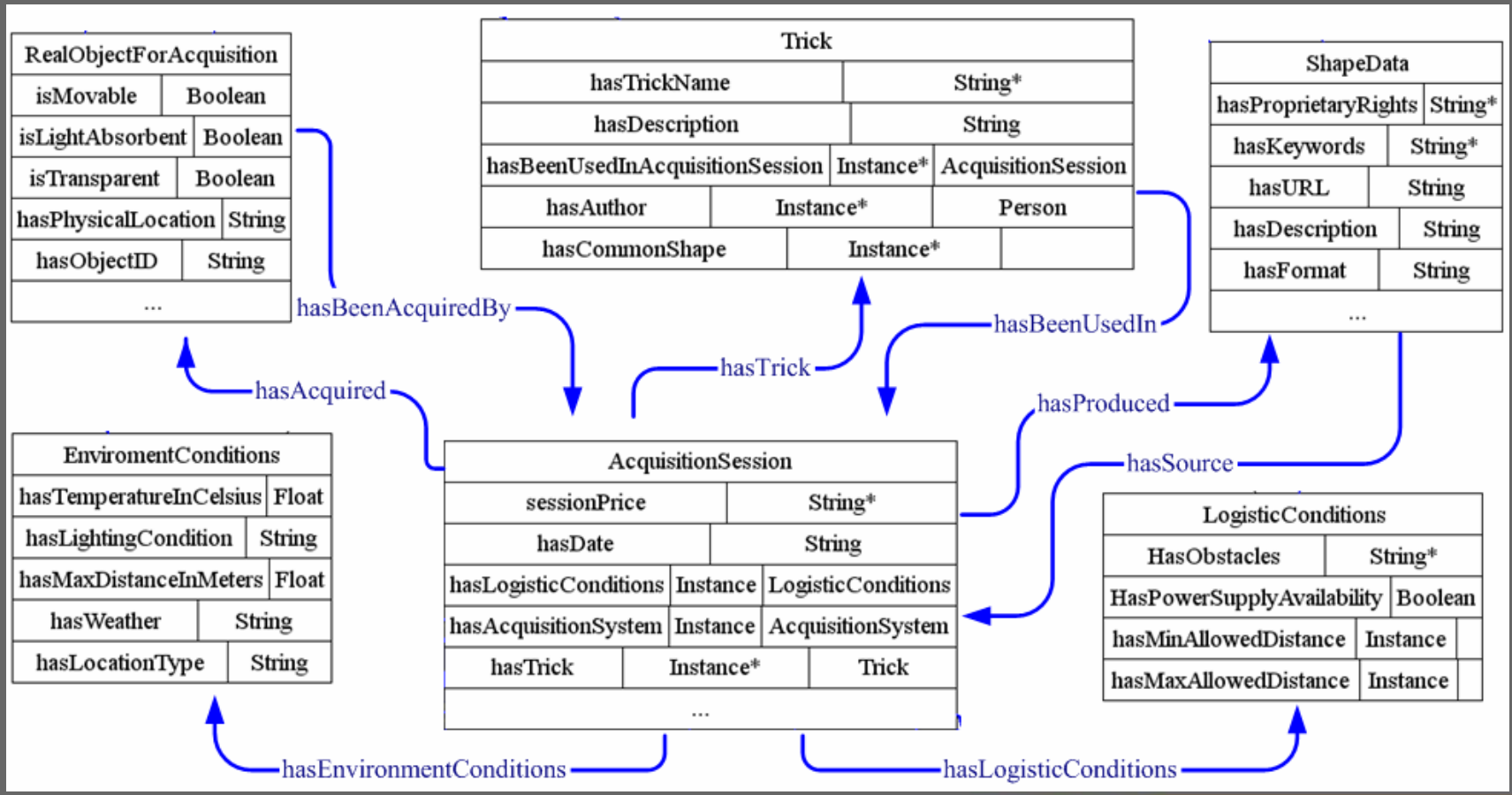

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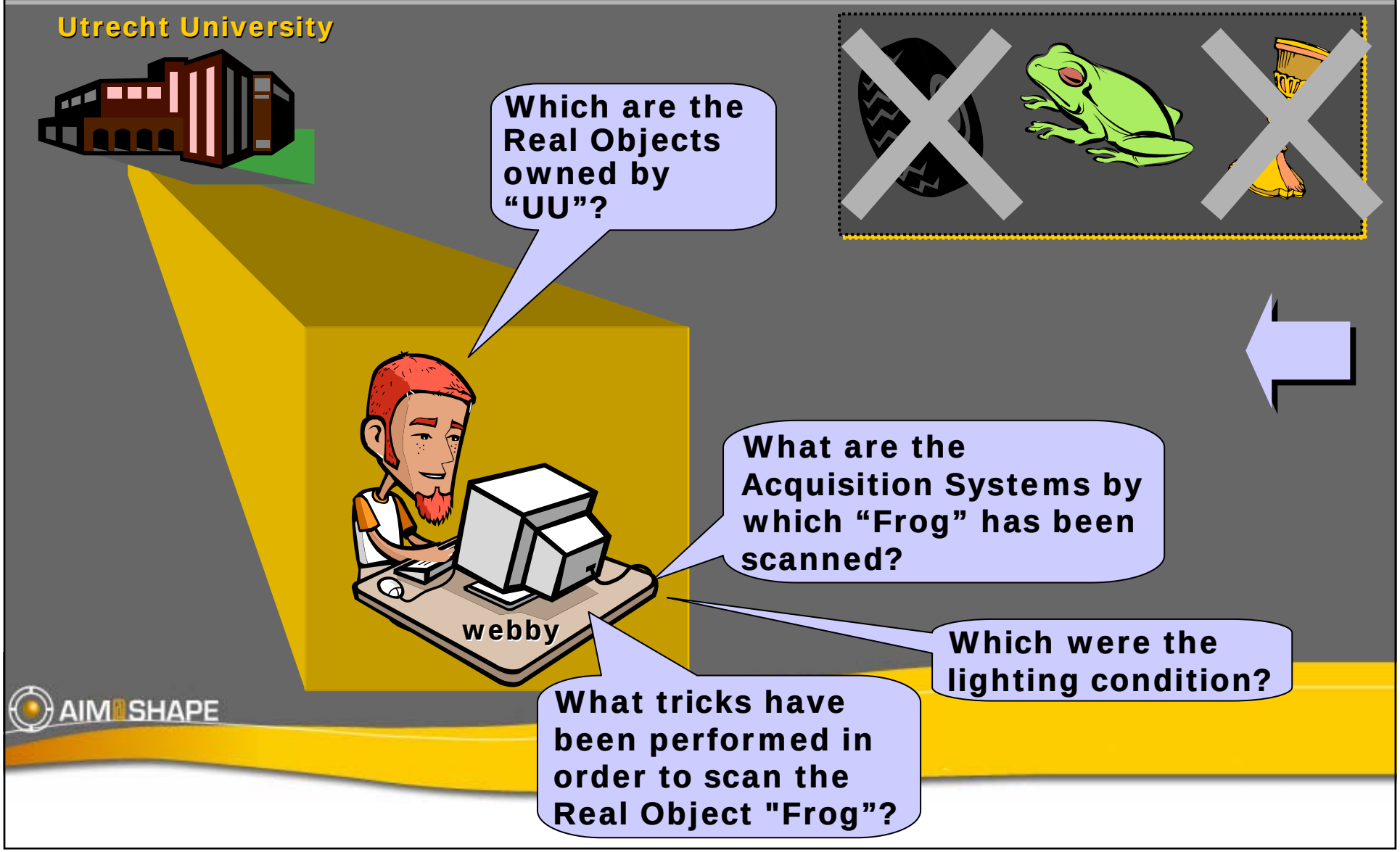
One Usage Scenario (*Webby and the Acquisition Planning*)



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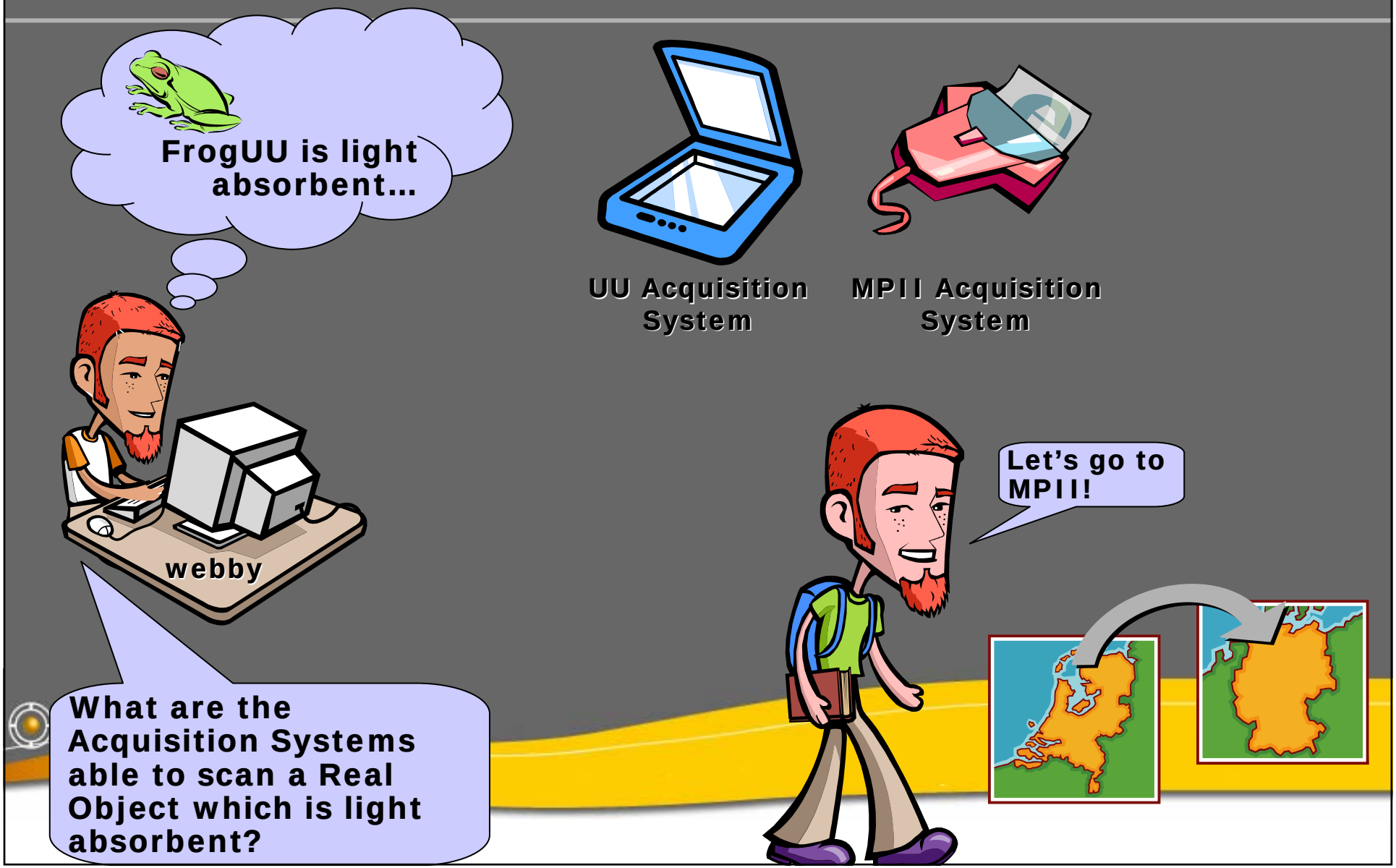

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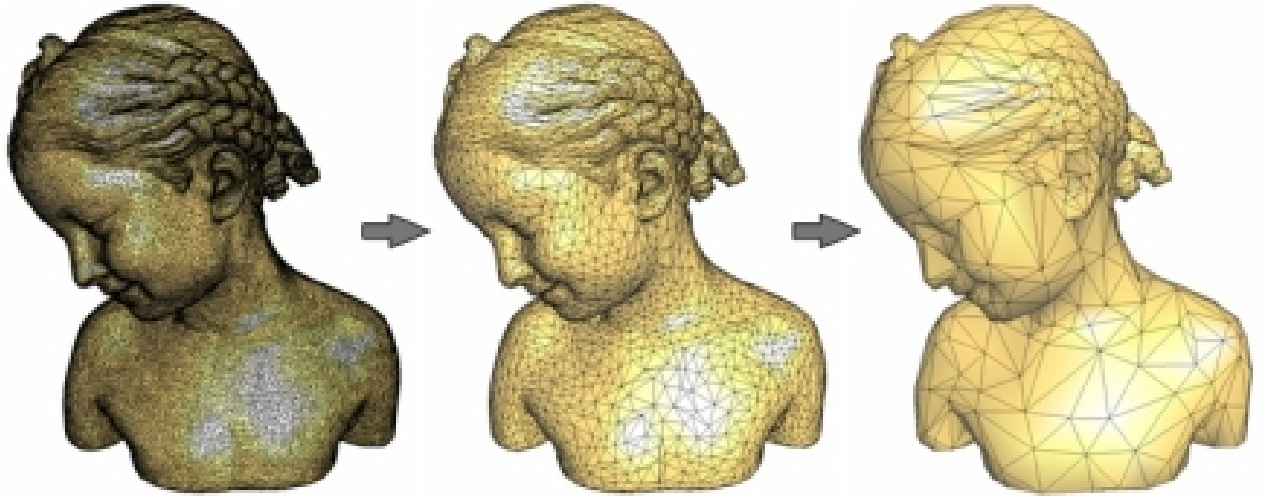


The *History* of a Shape

Shape Repository at www.aimatshape.net

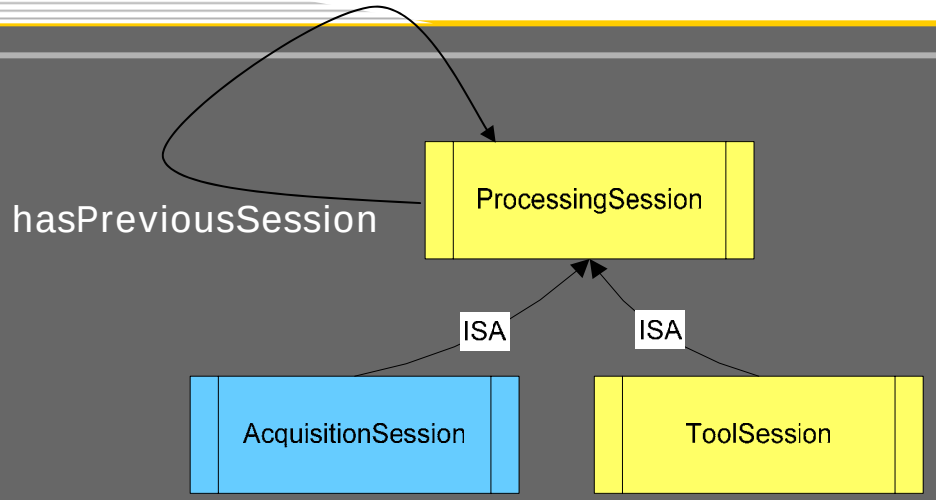
History of a Shape

- Given a shape (in the repository) one can be interested in searching it and understand how it has been produced
- What is the **history** of a shape?

  - The history of a shape X is basically the set of operations (with all the details) that have been performed in order to obtain X.
  - These operations can be related to the acquisition of a real object or the processing of different shapes.

History of a shape

- ProcessingSession as an entity
  - Acquisition and Tool as sub-entities



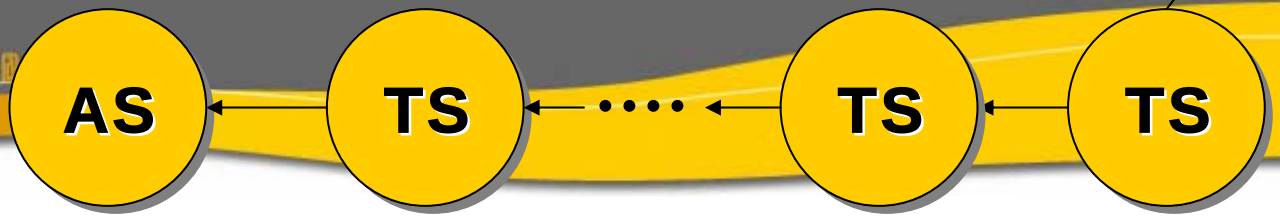
- Properties
  - *hasInput* (ShapeData or RealObject)
  - *hasOutput* (ShapeData)
  - *hasPreviousSession*, which links a *ProcessingSession* to the previous one.
    - The transitive closure of this property, called *hasHistory*, is the relation which produce the history of a given shape.

Second Usage Scenario (*Webby and the history of a shape*)

- Webby wants to learn more on acquisition and surface meshes
- He searches for all the surface meshes with a given characteristic (let's say "no self-intersections"…)
- He browses the results and chooses the shape "bimbaConNastrino.ply"

Which is the History of this shape?

hasOutput



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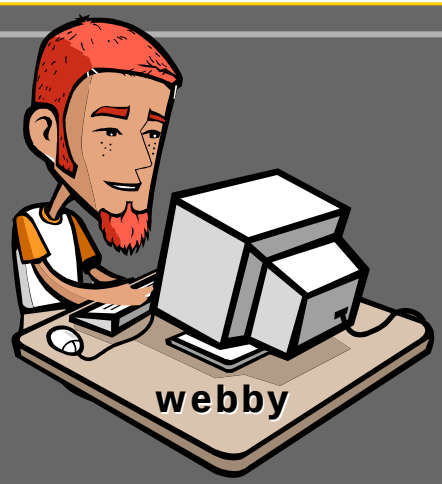
Tasks and Tools for Shape Processing

Third usage scenario (*Webby and the difference among shapes*)



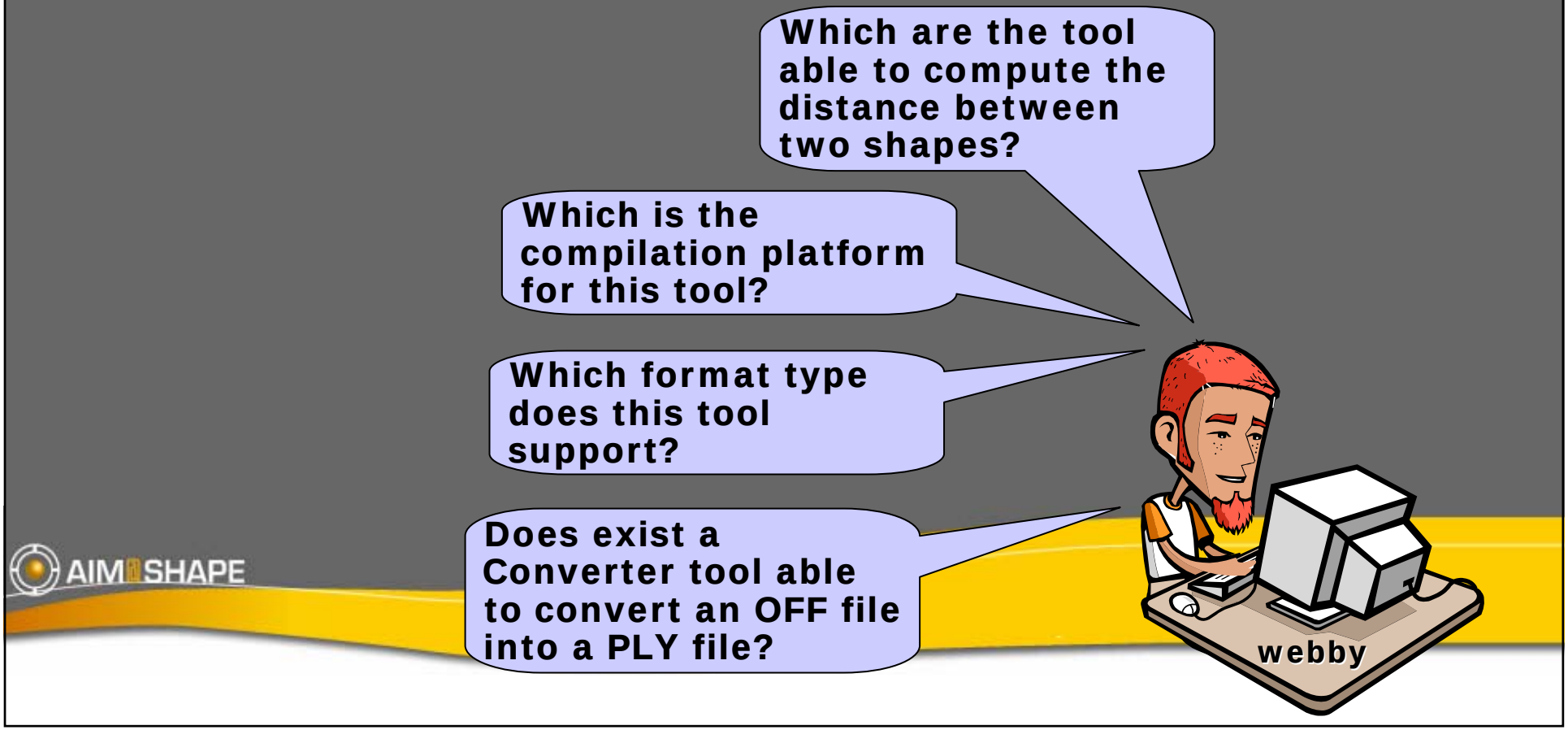
FROG at MPII

FROG at UU

- Webby wants to measure the quality of its scanning result wrt to the one at UU.
- He searches for a tool able to compute the distance between two shapes.
- Browsing the results he chooses the “Metro” tool
  - it can run on Linux.
  - But is able to load only “PLY” files.
- Webby searches for a converter from OFF to PLY.
- He browses the results and chooses the “Off2Ply”

Third usage scenario (*Webby and the difference among shapes*)

- Guided by the Competency Questions we could propose a draft of schema...



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Thanks!