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Authenticating Engineering Objects for Digital Preservation

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Authentication of Engineering Objects is Complex

- Engineering objects are complex.
- Authentication will be message-based.
- Authentication of the engineering object will require extensive reasoning about the engineering object and its supporting context.
- The supporting context will cover many domains.
- The mode of reasoning may be non-monotonic (tentative) requiring retraction of inferences.
- Procedural code for reasoning will become brittle over time (especially for non-monotonic reasoning).

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An Experiment to Authenticate Part Shape

- Goal: Create a shape fingerprint based on extensive reasoning over the part’s electronic representation.
- Generate and store the fingerprint as metadata to authenticate the part when it is first archived.
- Re-authenticate the part when it is retrieved from the archive.
- The finger print will be a list of shape features.
- The finger print will augment other authenticating instruments such as a statistical fingerprint of the point space of the geometric representation.
- Allow non-monotonic reasoning to search for shape features.

Tools Used

- Pro-Engineer CAD system to create the original geometry and convert to STEP AP203.
- Specialized C++ tool to read AP203 STEP file and infer new authenticating knowledge about the part shape that is not in the AP203 file (e.g. convexity of surfaces and surface area).
- A language to create knowledge representation for shape facts and action semantics (if-then semantics).
- Translator from STEP to above KR language.
- Logistica reasoning engine and reasoning programs.
- Translator from KR language to reasoning engine.
- Translator from reasoning engine to OWL.

Results

- Project was completed in approximately four months with a 3-person technical team of veteran AI programmers.
- An authenticating shape fingerprint was generated for a simple prismatic part and converted to OWL.
- The OWL archival file was sent to the San Diego Super Computing Center (SDSC) for storage in the NARA prototype Electronic Records Archives (ERA).
- The OWL archival file was retrieved from the ERA and re-authenticated using the Logistica reasoner.

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Results

- The Kansas City Plant was able to represent the action semantics in a LISP-like neutral form (not a standard format).
- The action semantics were then dynamically read into the Logistica reasoner.
- The action semantics are not hard-coded into the reasoner; instead the neutral form is read in and applied dynamically. Additonal rules can be written outside of the reasoner and they can then be applied without changing any code in the reasoner.
- The reasoner then applied the action semantics to the geometry and topology of the part to deduce the features of form.
- The KCP neutral format could be replaced by a standardized format in the future.

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Issues and Discussion

- The programming of reasoning engines requires specialized knowledge and different way of thinking about programming.
- The KCP estimates that the logic-based programming techniques used in Logistica are 10-30 times more productive than a procedural language such as C++.
- The KCP recognizes that the complexity of authenticating engineering data may signal a warning of the complexity of authenticating business data.
- The KCP was only able to move horn-clause type representations into OWL, not action semantics.

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Issues and Discussion Continued

- KCP could not have completed the project in the time that it did without the use of non-monotonic logic techniques and a programming tool inherently based on non-monotonic logic.
- The action-semantics that could not be translated to OWL were left in the Logistica reasoner.
- Long-term archiving was declared incomplete because only partial knowledge was stored in OWL.
- Additional work needs to be done to move action semantics out of proprietary systems and into a neutral KR encoding.

Looking to the Future

- Partnerships are important – no single partner has sufficient knowledge or skill.
- Logic-based programs need to be optimized and possibly run on high-performance computers.
- Complexity of authentication of engineering objects needs to be used as a possible guide in characterizing the complexity of authentication in a broader range of subject domains.
- Additional research needs to be done to characterize the nature of the authentication process – does it require significant “tentative” reasoning?

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Looking to the Future - Continued

- The KCP recognizes the importance of the work of the W3C in developing the Semantic Web.
- The KCP wishes to see added importance given to logic-based representation of facts as well as action semantics.
- The KCP hopes that the Semantic Web will ignite new research and development of commercial tools for the creation of logic-based systems.
- The KCP will continue to study and encourage the further development of OWL.
- Partnerships are important – no single person or institution has sufficient knowledge or skill.

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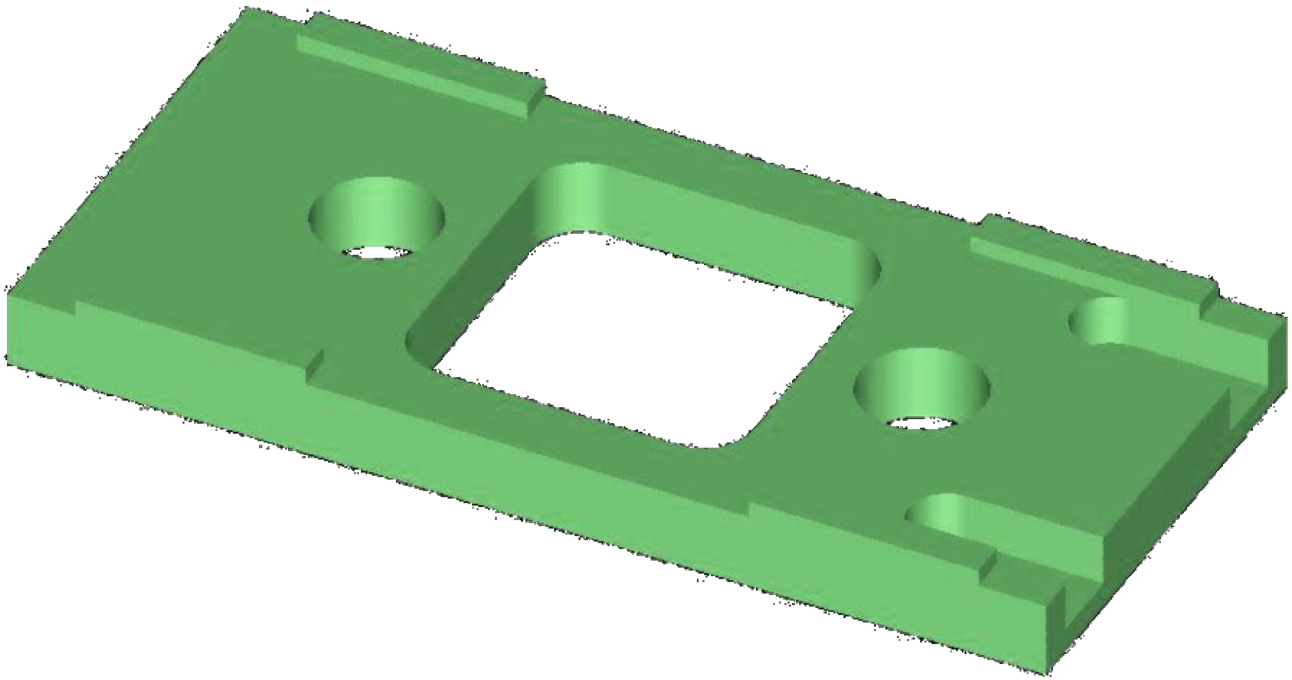
Acknowledgement of Partnerships

- **Thanks to our NARA partners for encouraging our research in the authentication of engineering objects and connecting us with the SDSC.**
- **Thanks to the AI team at KCP and Artificial Intelligence Inc. that designed and wrote the authentication reasoning programs.**
- **Thanks to our PDES Incorporated partners for assistance and encouragement.**
- **Thanks to TopQuadrant for their assistance in pushing us towards OWL and linking us to W3C.**

The Mechanical Part that was the Subject of the Experiment



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Deduced Features

- **($cutout 2)**
  ($thru-round-hole-0 4)
  ($closed-pocket 0)
  ($blind-round-hole-0 0)
  ($rectangular-cutout 0)
  ($closed-rectangular-pocket 0)
  ($boss 4)
  ($rectangular-boss 4)
  ($open-pocket 2))

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Same Meaning for Topology and Geometry but Many Formats

ISO 10303 STEP

```
#190=CYLINDRICAL_SURFACE
#191=EDGE
#192=EDGE
#194=EDGE
#195=EDGE
#196=EDGE_LOOP(#191,#192,#194,#195)
#197=FACE_OUTER_BOUND(“,#196,.F.)
#198=ADVANCED_FACE(“,(#197),#190,.F.)
```

Data Format

↔

Logistica

```
(Face Face-3
  :area 112.916
  :convexity Smooth
  :surface Plane-0
  :loops (unordered
    (Loop (Edge-18)
    (Loop (Edge-16)))
```

Reasoner Format

↔

OWL

```
<owl:class rdf:ID=“face”>
<owl:equivalentClass>
<owl:unionOf rdf:parseType=“Collection”
<owl:intersectionOf rdf:parseType=“Collection”
<owl:restriction>
<owl:onProperty rdf:resource=“name”/>
<owl:hasValue rdf:resource=“face-8”/>
</owl:restriction>
<owl:onProperty rdf:resource=“convexity”/>
<owl:hasValue rdf:resource=“smooth”/>
</owl:restriction>
```

Knowledge Format

COMMON SEMANTICS

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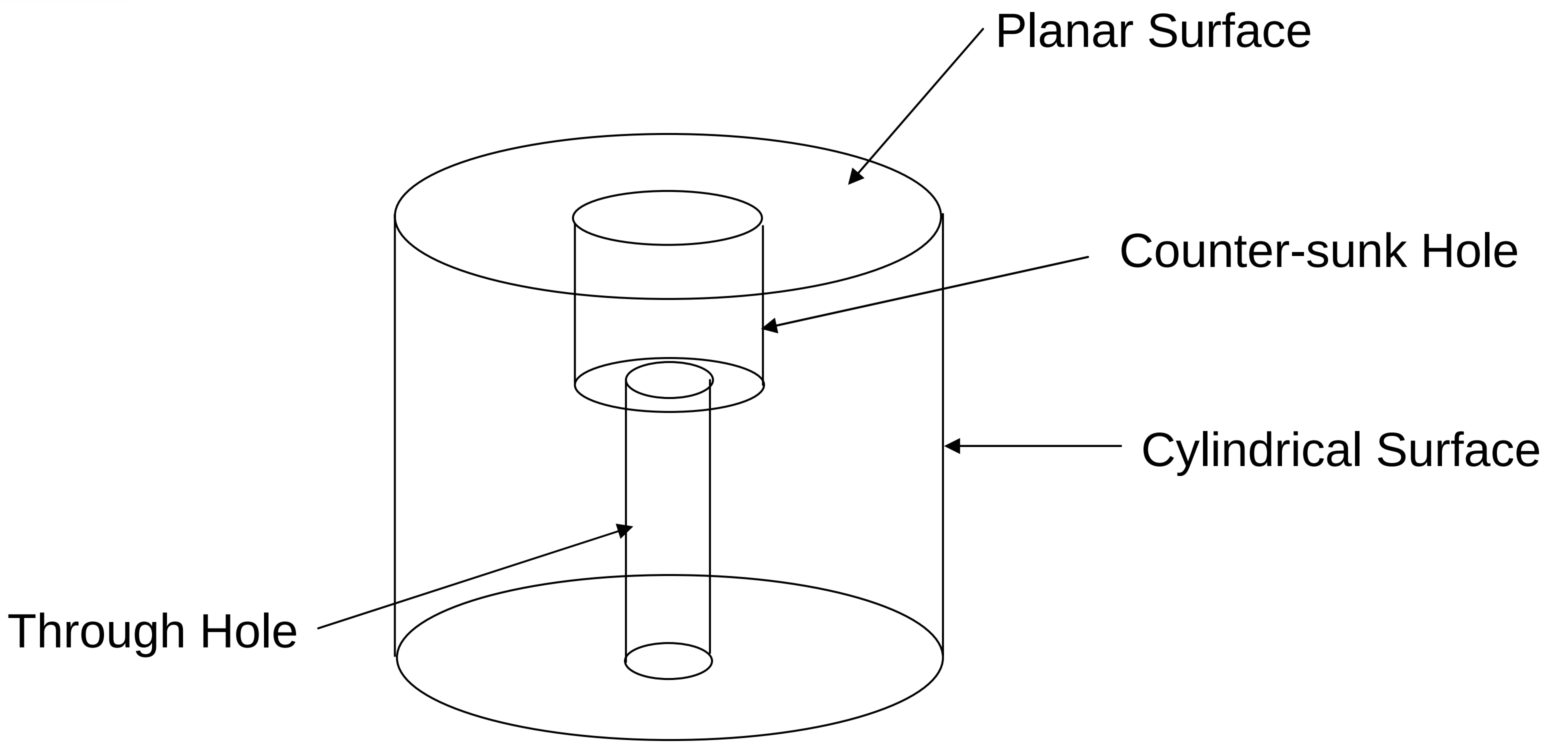
Features of Shape



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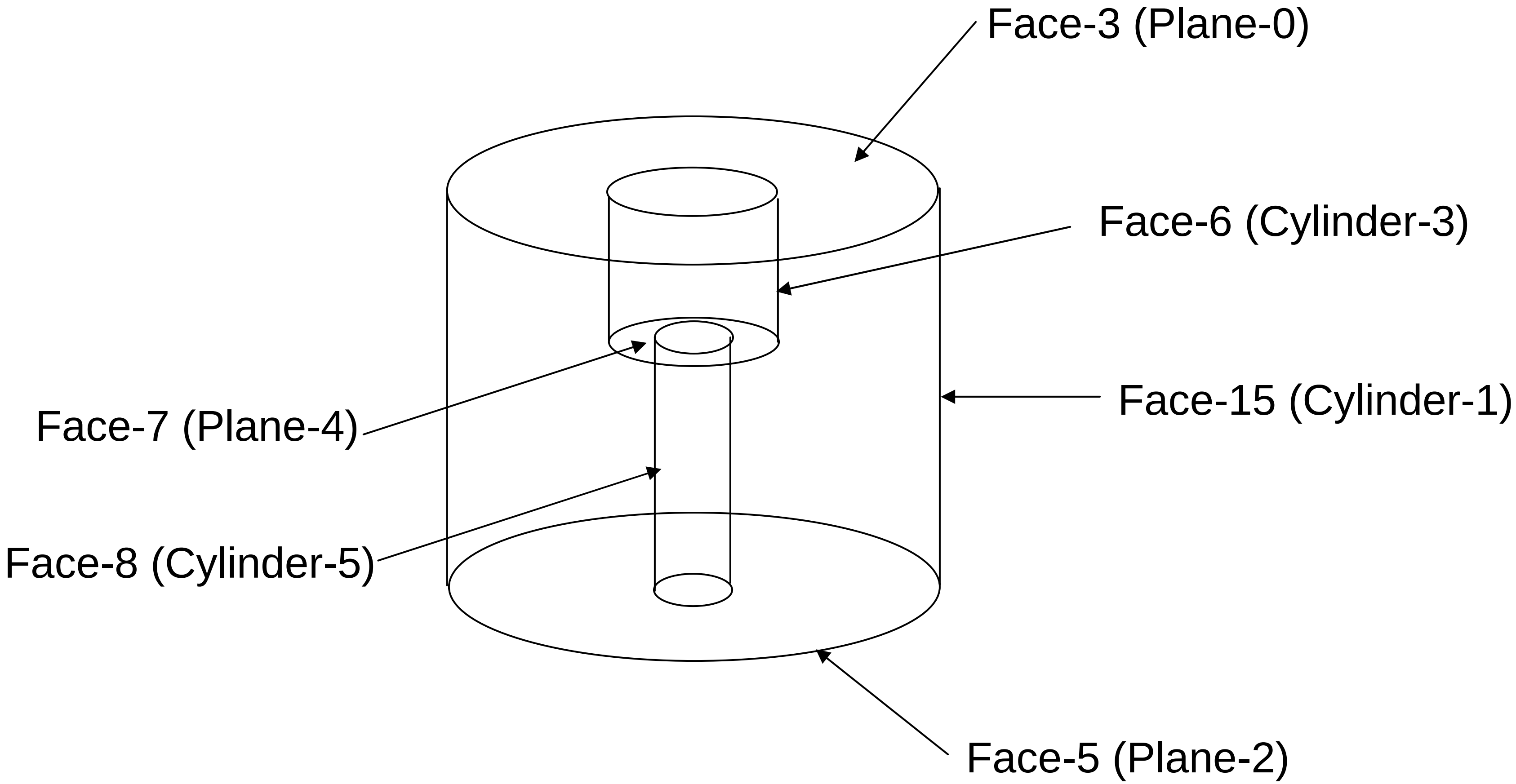
Part Topology and Geometry



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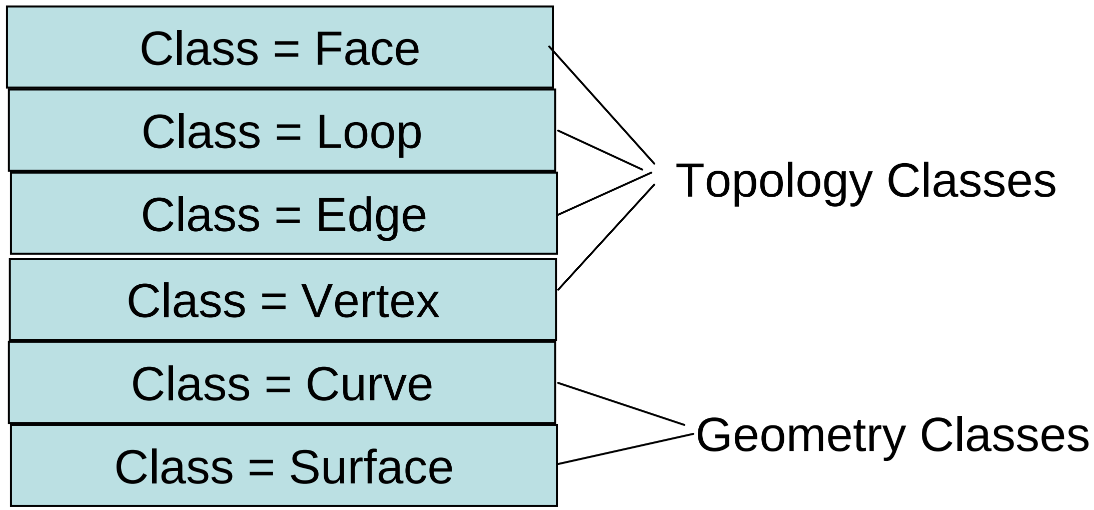
OWL Mapping: A Collection of Six Classes



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OWL Mapping: Class Defined by Extension