Automatic generation of consistency constraints for an OWL representation of the FMA

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Context

- Integrate human anatomical knowledge into applications

    - diagnosis of bullet injuries [Virtual Soldier Project]

    - grading tumors (lung, glioma)

    - localization of biological entities (iron metabolism)

    - ⇨ ontologies

- Integrate ontologies of anatomy with other ontologies

    - physiology

    - pathology

    - cellular components

- Perform automatic reasoning

Requirements

- Ontology of anatomy

  - Anatomy = fundamental discipline for medicine

- Representation formalism

  - usable by applications

  - supporting imports

  - supporting reasoning

Available resources

- FMA = reference ontology for anatomical knowledge

    - 75,000 classes + 2.5 millions relations

    - represented in frames

- Previous work on the conversion of the FMA into OWL

    - Golbreich, Zhang and Bodenreider [Web Semantics 2006]

    - Dameron, Rubin and Musen [AMIA 2005]

    - Noy and Rubin [SMI technical report 2007]

Objective

- Guarantee consistency

  - no internal contradiction

    - this is the least that we can expect
    - requires OWL-specific constraints (disjunction...)

  - adequately represents reality

- Generate OWL-specific constraints to improve reasoning

  - complement to the work by Noy and Rubin

  - focus on what is implicit in the FMA-frames ontology

Methods

- Leverage the FMA building principles

  – in the hierarchies and relations

  – in the naming conventions

- 1 building principle -> 1 pattern

  – Check consistency
    - e.g.: direct subclass of "Region of chest wall"
  – Generate additional OWL-specific constraints
    - e.g.: Lung / Left_lung / Right_lung

- Python script for applying pattern

FMA-OWL core architecture

Core architecture

- fma-core.owl = straightforward conversion of the FMA in owl

- 1 owl file / constraint type

  – fma-disjunction.owl

    - imports fma-core.owl

    - import fma-disjunction-lateralization.owl

    - imports fma-disjunction-enumeration.owl ...

  – fma-multipleInheritance.owl

    - imports ...

Taxonomy

Original FMA taxonomy

- Single inheritance

- We reused the method by Noy and Rubin

    - frame classes become OWL classes

    - FMAID are used as rdf:ID (prefixed by fma)

    - class name and synonyms become rdfs:label

File   Edit   Project   Window   Help

protégé

● Classes   ■ Slots   ≡ Forms   ◆ Instances   ▲ Queries   ✎ Script Console

CLASS BROWSER

For Project: ● fma-local

Class Hierarchy

- :SYSTEM-CLASS
- ● Anatomical entity
  - ▼ Physical anatomical entity
    - ▼ Material anatomical entity
      - ▼ Anatomical structure
        - ▶ Body
        - ▶ Cardinal body part
        - ▼ Subdivision of cardinal body part
          - ▶ Subdivision of head
          - ▼ Subdivision of body proper
            - Neck
            - ▶ Subdivision of neck
            - ▶ Trunk
            - ▼ Subdivision of trunk
              - ▶ Thorax
              - ▼ Subdivision of thorax
                - ▶ Chest
                - ▶ Chest wall
                - ▼ Region of chest wall
                  - Thoracic wall
                  - ▶ Anterior chest wall
                  - ▶ Superficial chest wall

CLASS EDITOR

For Class: ⚛ Physical anatomical entity   (instance of Anatomical entity template)

Name

Physical anatomical entity

Role

Concrete ●

Documentation

2.13.01 We include boundary relationship at physical anatomical entity level because non-material physical anatomical entities (surface and line) have boundaries. We will deactivate the "has boundary"

Constraints

Template Slots

Name	Cardinality	Type	Other Facets
constitutional part of	multiple	Class with superclass Mat...	inverse-slot=constitutional part
definition	single	String	
dimension	single	Symbol	allowed-values={3-dimension,2-dimension,1-dimen...
FMAID	required ...	String	
has boundary	single	Boolean	value=false
has dimension	single	Boolean	value=true
Non-English equivalent	multiple	Instance of Concept name	
part	multiple	Class with superclass Ana...	inverse-slot=part of
part of	multiple	Class with superclass Ana...	inverse-slot=part

Definition

t, inferior margin of liver, apex of lung.

Part

Non-English Equiva

◆ KB_AUTO-INSERT(3)_4641
◆ ONARD_Instance_580710

FMAID

Definition

t, inferior margin of liver, apex of lung.

FMAID

61775

Part

Non-English Equiva

◆ KB_AUTO-INSERT(3)_4641
◆ ONARD_Instance_580710

Multiple inheritance

- Left/right and male/female

  - 3 classes (Breast, Areola, Nipple)

- Left/right and enumeration

  - 65 classes (e.g. Left first cervical nerve)

- Upper/lower and enumeration

  - 5 classes (e.g. Upper first molar socket)

File   Edit   Project   Window   Help

protégé

Classes   Slots   Forms   Instances   Queri

CLASS BROWSER

For Project: ● fma-local

Class Hierarchy

▼ Subdivision of trunk
  ▶ Thorax
  ▼ Subdivision of thorax
    ▶ Chest
    ▶ Chest wall
    ▶ Region of chest wall
    ▶ Anterior chest
    ▼ Region of anterior chest
      ▶ Pectoral part of chest
      ▶ Inframammary part of chest
      Sternal part of chest
      ▼ Region of pectoral part of chest
        ▼ Breast
          Right breast
          Left breast
          ▼ Female breast
            Right female breast
            Left female breast
          ▼ Male breast
            Right male breast
            Left male breast
        ▶ Region of breast
        Accessory breast
        ▶ Lateral pectoral region
        ▶ Infraclavicular part of chest
        ▶ Pectoral part proper of male
    ▶ Lateral part of chest
    ▶ Right side of chest
    ▶ Left side of chest

Breast

Superclasses

Inframammary part of chest

Sternal part of chest

Region of pectoral part of chest

Breast

  Right breast

  Left breast

  ▼ Female breast

    Right female breast

    Left female breast

  ▼ Male breast

    Right male breast

    Left male breast

Concrete ●

Inherent 3-D Shape

Has Shape   Part   Instances

File   Edit   Project   Window   Help

protégé

● Classes   ■ Slots   ≡ Forms   ◆ Instances   ▲ Queries   ☑ Script Console

CLASS BROWSER

For Project: ● fma-local

Class Hierarchy

▶ ● Parenchymatous organ
▼ ● Nonparenchymatous organ
  ▶ ● Muscle organ
  ▶ ● Ligament organ
  ▶ ● Cartilage organ
  ▶ ● Membrane organ
  ▼ ● Neural tree organ
    ▶ ● Cranial nerve
    ▼ ● Spinal nerve
      ▼ ● Cervical nerve
        ▼ ● First cervical nerve
            ● Right first cervical nerve
            ● Left first cervical nerve
        ▼ ● Second cervical nerve
            ● Right second cervical ner
            ● Left second cervical ner
        ▶ ● Third cervical nerve
        ▶ ● Fourth cervical nerve
        ▶ ● Fifth cervical nerve
        ▶ ● Sixth cervical nerve
        ▶ ● Seventh cervical nerve
        ▶ ● Eighth cervical nerve
      ▶ ● Thoracic nerve
      ▶ ● Lumbar nerve
      ▶ ● Sacral nerve
      ▶ ● Coccygeal nerve
        ● Variant spinal nerve
    ▶ ● Spinal accessory nerve
      ● Peripheral nerve

left first

Superclasses

CLASS EDITOR

● Cervical nerve
  ▼ ● First cervical nerve
      ● Right first cervical nerve
      ● Left first cervical nerve
  ▼ ● Second cervical nerve
      ● Right second cervical ne
      ● Left second cervical ner
  ▶ ● Third cervical nerve
  ▶ ● Fourth cervical nerve
  ▶ ● Fifth cervical nerve
  ▶ ● Sixth cervical nerve
  ▶ ● Seventh cervical nerve
  ▶ ● Eighth cervical nerve

ounded By

emic Part

emic Part Of

es

irst cervical nerve

ous Drainage

Concrete ●

Inherent 3-D Shape

Has Shape   Part   Attributed Continuou

OWL-specific constructs

Disjunction

Two classes are disjoint iff they do not have any instance in common

- By default in the FMA, all siblings are disjoint

File   Edit   Project   Window   Help
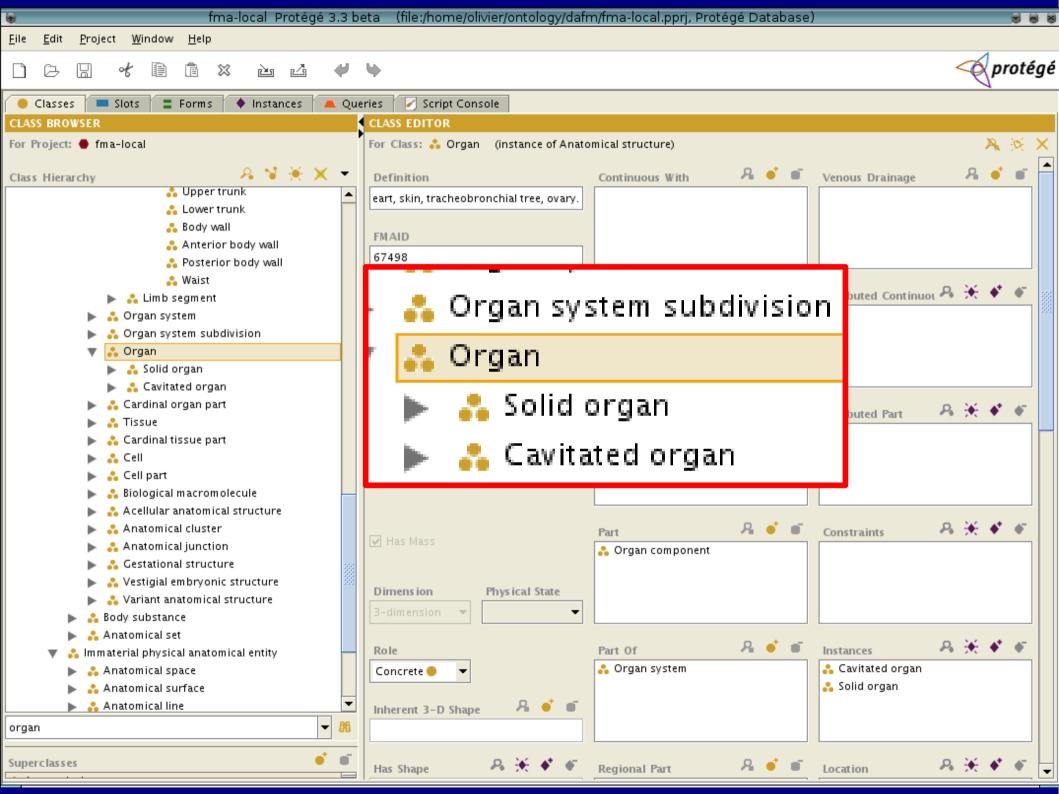
protégé

Classes | Slots | Forms | Instances | Queries | Script Console

CLASS BROWSER

For Project: ● fma-local

Class Hierarchy

- Upper trunk
- Lower trunk
- Body wall
- Anterior body wall
- Posterior body wall
- Waist
  - ▶ Limb segment
- ▶ Organ system
- ▶ Organ system subdivision
- ▼ Organ
  - ▶ Solid organ
  - ▶ Cavitated organ
- ▶ Cardinal organ part
- ▶ Tissue
- ▶ Cardinal tissue part
- ▶ Cell
- ▶ Cell part
- ▶ Biological macromolecule
- ▶ Acellular anatomical structure
- ▶ Anatomical cluster
- ▶ Anatomical junction
- ▶ Gestational structure
- ▶ Vestigial embryonic structure
- ▶ Variant anatomical structure
- ▶ Body substance
- ▶ Anatomical set
- ▼ Immaterial physical anatomical entity
  - ▶ Anatomical space
  - ▶ Anatomical surface
  - ▶ Anatomical line

organ

Superclasses

CLASS EDITOR

For Class: ● Organ   (instance of Anatomical structure)

Definition

eart, skin, tracheobronchial tree, ovary.

FMAID

67498

● Organ system subdivision	
● Organ	
▶ ● Solid organ	
▶ ● Cavitated organ	

Continuous With

Venous Drainage

...buted Continuo...

...buted Part

Part

● Organ component

Constraints

☑ Has Mass

Dimension   **Physical State**

3-dimension ▼

Role

Concrete ● ▼

Inherent 3-D Shape

Part Of

● Organ system

Instances

● Cavitated organ
● Solid organ

Has Shape   **Regional Part**   **Location**

File   Edit   Project   Window   Help

protégé

● Classes   ■ Slots   ≡ Forms   ◆ Instances   ▲ Queries   ☑ Script Console

CLASS BROWSER

For Project: ● fma-local

Class Hierarchy

- Upper trunk
- Lower trunk
- Body wall
- Anterior body wall
- Posterior body wall
- Waist
  - ▶ Limb segment
  - ▶ Organ system
  - ▶ Organ system subdivision
  - ▼ Organ
    - ▼ Solid organ
      - ▶ Parenchymatous organ
      - ▶ Nonparenchymatous organ
    - ▶ Cavitated organ
  - ▶ Cardinal organ part
  - ▶ Tissue
  - ▶ Cardinal tissue part
  - ▶ Cell
  - ▶ Cell part
  - ▶ Biological macromolecule
  - ▶ Acellular anatomical structure
  - ▶ Anatomical cluster
  - ▶ Anatomical junction
  - ▶ Gestational structure
  - ▶ Vestigial embryonic structure
  - ▶ Variant anatomical structure
  - ▶ Body substance
  - ▶ Anatomical set
  - ▼ Immaterial physical anatomical entity
    - ▶ Anatomical space

organ

Superclasses

CLASS EDITOR

For Class: ● Solid organ   (instance of Organ)

Definition

organ), meninx, superficial fascia, skin.

FMAID

55670

Organ

▼ ● Solid organ

  ▶ ● Parenchymatous organ

  ▶ ● Nonparenchymatous organ

▶ ● Cavitated organ

Dimension   Physical State

3-dimension ▼   Solid ▼

Role

Concrete ● ▼

Inherent 3-D Shape

Systemic Part Of

Develops From

Part

Attributed Part

Has Shape   Part Of   Constraints

File   Edit   Project   Window   Help

protégé

● Classes   ■ Slots   ≡ Forms   ◆ Instances   ▲ Queries   ☑ Script Console

CLASS BROWSER

For Project: ● fma-local

Class Hierarchy

- Upper trunk
- Lower trunk
- Body wall
- Anterior body wall
- Posterior body wall
- Waist
- ▶ Limb segment
- ▶ Organ system
- ▶ Organ system subdivision
- ▼ Organ
  - ▼ Solid organ
    - ▶ Parenchymatous organ
    - ▼ Nonparenchymatous organ
      - ▶ Muscle organ
      - ▶ Ligament organ
      - ▶ Cartilage organ
      - ▶ Membrane organ
      - ▶ Neural tree organ
      - ▶ Fascia organ
      - Skin
      - Tongue
      - Viscerocranial mucosa
  - ▶ Cavitated organ
- ▶ Cardinal organ part
- ▶ Tissue
- ▶ Cardinal tissue part
- ▶ Cell
- ▶ Cell part
- ▶ Biological macromolecule
- ▶ Acellular anatomical structure

organ

Superclasses

▼ Organ

　▼ Solid organ

　　▶ Parenchymatous organ

　　▼ Nonparenchymatous organ

　　　▶ Muscle organ

　　　▶ Ligament organ

　　　▶ Cartilage organ

　　　▶ Membrane organ

　　　▶ Neural tree organ

　　　▶ Fascia organ

　　　Skin

　　　Tongue

　　　Viscerocranial mucosa

　▶ Cavitated organ

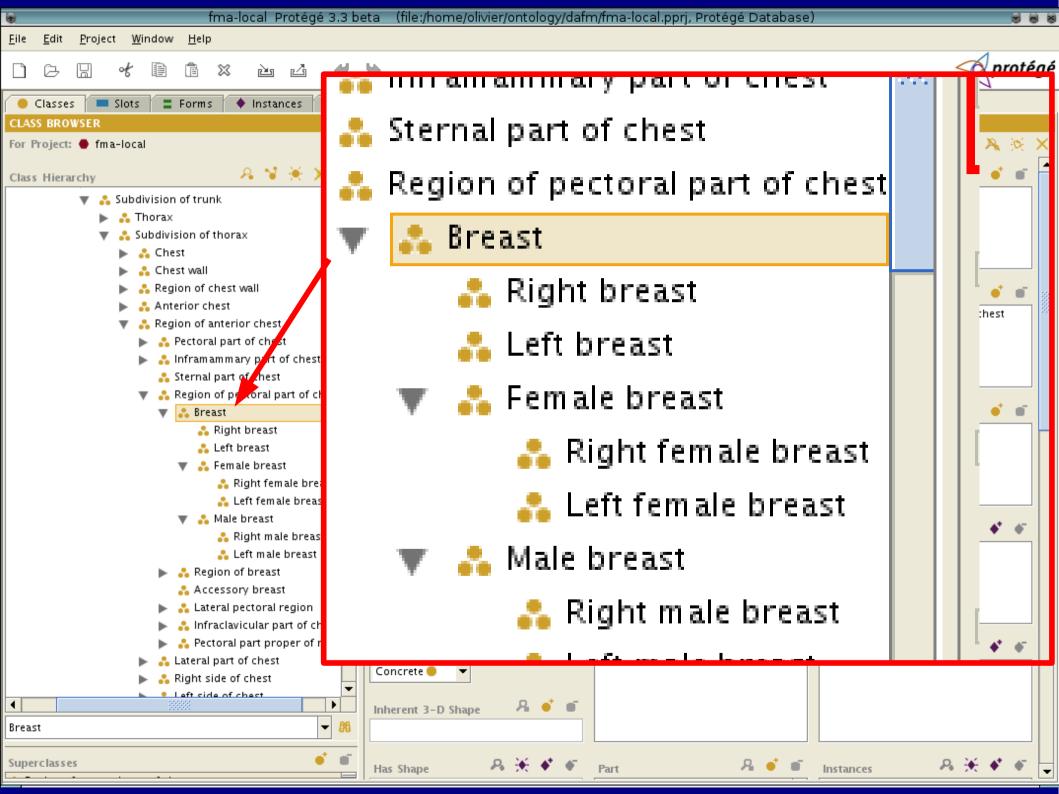Has Shape   Part Of   Attributed Part

Disjunction

Two classes are disjoint iff they do not have any instance in common

- By default in the FMA, all siblings are disjoint

- Sometimes they are not :-(

File   Edit   Project   Window   Help

protégé

Classes   Slots   Forms   Instances

CLASS BROWSER

For Project: ● fma-local

Class Hierarchy

▼ Subdivision of trunk
  ▶ Thorax
  ▼ Subdivision of thorax
    ▶ Chest
    ▶ Chest wall
    ▶ Region of chest wall
    ▶ Anterior chest
    ▼ Region of anterior chest
      ▶ Pectoral part of chest
      ▶ Inframammary part of chest
      Sternal part of chest
      ▼ Region of pectoral part of chest
        ▼ Breast
          Right breast
          Left breast
          ▼ Female breast
            Right female breast
            Left female breast
          ▼ Male breast
            Right male breast
            Left male breast
        ▶ Region of breast
        Accessory breast
        ▶ Lateral pectoral region
        ▶ Infraclavicular part of chest
        ▶ Pectoral part proper of
    ▶ Lateral part of chest
    ▶ Right side of chest
    Left side of chest

Breast

Superclasses

Inframammary part of chest

● Sternal part of chest

● Region of pectoral part of chest

▼ ● Breast

   ● Right breast

   ● Left breast

  ▼ ● Female breast

     ● Right female breast

     ● Left female breast

  ▼ ● Male breast

     ● Right male breast

     Left male breast

Concrete ●

Inherent 3-D Shape

Has Shape   Part   Instances

Disjunction patterns

- X / NonX or X / Non-X   (84)
  - Non-nucleated cell

- Left X / Right X   (3736)
  - Left lung

- X left Y / X right Y   (13989)
  - Skin of right breast

- Male X / Female X   (25)
  - Male breast

- X male Y / X female Y   (75)
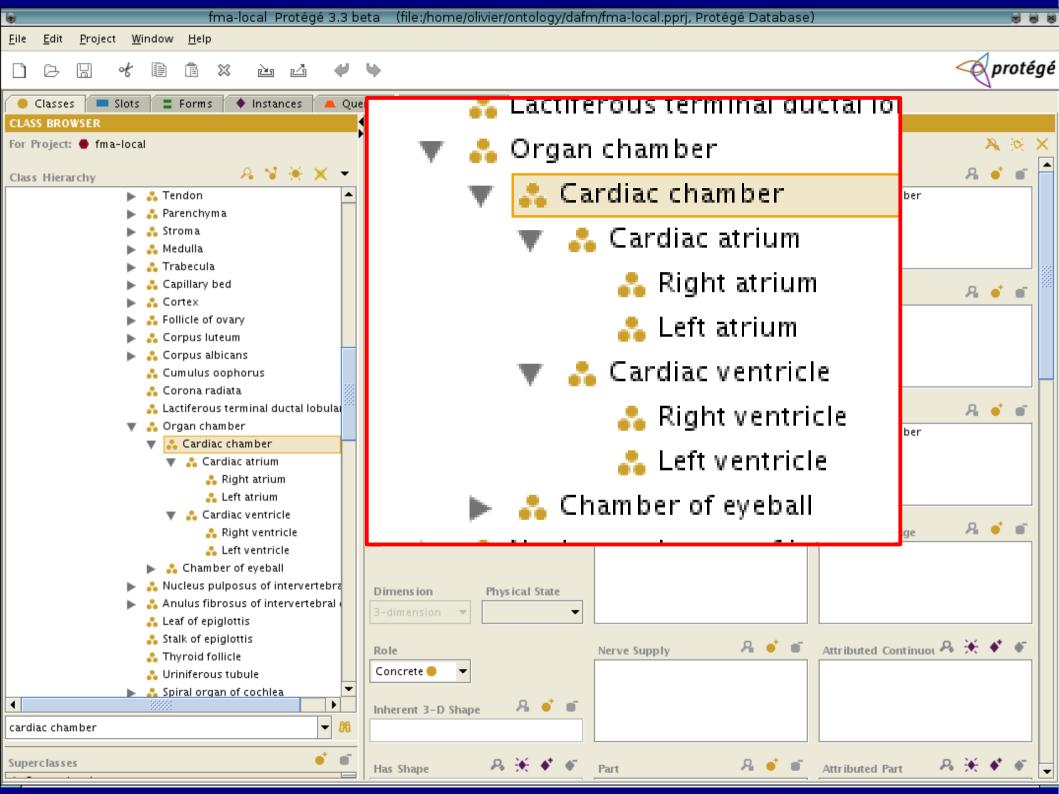 - Right side of male chest

- enumerations   (140)
  - First cervical nerve

- upper / (middle) / lower (99)
  - Upper lobe of lung

File   Edit   Project   OWL   Code   Tools   Window   Help

protégé

Metadata (fma-disjun...zation.owl)   OWLClasses

SUBCLASS EXPLORER

For Project: ● fma-disjunction-lateralization

Asserted Hierarchy

- ▶ Upper hemithorax
- ▶ Lower hemithorax
- ▼ Region of anterior chest
  - ▶ Inframammary part of chest
  - Sternal part of chest
  - ▶ Pectoral part of chest
  - ▼ Region of pectoral part of chest
    - ▶ Pectoral part proper of male chest
    - ▶ Infraclavicular part of chest
    - ▶ Lateral pectoral region
    - ▶ Region of breast
    - Accessory breast
    - ▼ Breast
      - Right breast
      - Left breast
      - ▶ Female breast
      - ▶ Male breast
  - ▶ Lateral part of chest
  - ▶ Right side of chest
  - ▶ Left side of chest
- ▶ Subdivision of back of thorax
- Waist
- Subdivision of pelvis
- Front of trunk
- Back of trunk
- Abdominopelvis
- Anterior body wall
- Posterior body wall
- Thorax
- Abdomen
- Pelvis

CLASS EDI...

For Class:

rdfs:co
rdfs:la

● Breast

- ● Left breast
- ▶ ● Female breast
- ▶ ● Male breast
- ● Lateral part of chest
- ● Right side of chest
- ● Left side of chest
- bdivision of back of thorax
- vision of pelvis
- of trunk
- of trunk
- minopelvis
- ior body wall

● Right breast

● Right breast   Disjoints

◉ Logic View ○ Properties View

Coverage

The subclasses of a class provide an exhaustive decomposition of this class (partition)

- Most of the time, using the union of all the direct subclasses is enough

File   Edit   Project   Window   Help

protégé

Classes   Slots   Forms   Instances   Que

CLASS BROWSER

For Project: ● fma-local

Class Hierarchy

- ▶ Tendon
- ▶ Parenchyma
- ▶ Stroma
- ▶ Medulla
- ▶ Trabecula
- ▶ Capillary bed
- ▶ Cortex
- ▶ Follicle of ovary
- ▶ Corpus luteum
- ▶ Corpus albicans
- Cumulus oophorus
- Corona radiata
- Lactiferous terminal ductal lobular
- ▼ Organ chamber
  - ▼ Cardiac chamber
    - ▼ Cardiac atrium
      - Right atrium
      - Left atrium
    - ▼ Cardiac ventricle
      - Right ventricle
      - Left ventricle
  - ▶ Chamber of eyeball
- ▶ Nucleus pulposus of intervertebra
- ▶ Anulus fibrosus of intervertebral
- Leaf of epiglottis
- Stalk of epiglottis
- Thyroid follicle
- Uriniferous tubule
- ▶ Spiral organ of cochlea

cardiac chamber

Superclasses

▼ Lactiferous terminal ductal lol

▼ Organ chamber

  ▼ Cardiac chamber

    ▼ Cardiac atrium

      Right atrium

      Left atrium

    ▼ Cardiac ventricle

      Right ventricle

      Left ventricle

  ▶ Chamber of eyeball

---

ber

ber

Dimension   **Physical State**

3-dimension ▼

Role

Concrete ●

Inherent 3-D Shape

Has Shape   **Part**

ge

Nerve Supply   **Attributed Continuou**

Attributed Part

Coverage

The subclasses of a class provide an exhaustive decomposition of this class (partition)

- Most of the time, using the union of all the direct subclasses is enough

- But sometimes this is sub-optimal (but still logically valid)

fma-coverage Protégé 3.3 beta   (file:/home/olivier/projects/fma2owl/fma-coverage.pprj, OWL / RDF Files)

File   Edit   Project   OWL   Code   Tools   Window   Help

protégé

● Metadata (fma-coverage.owl)   ● OWLClasses   ■ Properties   ◆ Individuals   ≡ Forms

SUBCLASS EXPLORER

For Project: ● fma-coverage

Asserted Hierarchy

- ▶ ● Biological macromolecule
- ▼ ● Subdivision of cardinal body part
  - ▼ ● Subdivision of body proper
    - ▼ ● Subdivision of trunk
      - ● Waist
      - ▶ ● Thorax
      - ▶ ● Perineum
      - ▶ ● Pelvis
      - ● Abdomen
      - ● Upper trunk
      - ● Lower trunk
      - ▶ ● Subdivision of perineum
      - ▶ ● Subdivision of abdomen
      - ▼ ● Subdivision of thorax
        - ▼ ● Region of anterior ches
          - ▶ ● Left side of chest
          - ▶ ● Right side of chest
          - ▼ ● Region of pectoral
            - ▼ ● Breast
              - ● Left breast
              - ● Right breast
              - ▼ ● Female brea
                - ● Right fe
                - ● Left fem
              - ▼ ● Male breast
                - ● Left mal
                - ● Right m
            - ▶ ● Region of breas
            - ▶ ● Lateral pectoral
            - ▶ ● Infraclavicular p
            - ▶ ● Pectoral part pr

breast

CLASS EDITOR

For Class: ● Breast - Internal name: fma:fma9601   (instance of owl:Class) ☐ Inferred View

Annotations

Property	Value	Lang
▬ rdfs:comment		
▬ rdfs:label	Breast	en

Asserted Conditions

─────────────────────────────────── NECESSARY & SUFFICIENT
Ⓤ Female breast **or** Male breast   ≡

─────────────────────────────────── NECESSARY & SUFFICIENT
Ⓤ Right breast **or** Right breast   ≡

─────────────────────────────────── NECESSARY
● Region of pectoral part of chest   ⊑

Disjoints

◉ Logic View ○ Properties View

Coverage patterns

- **Left / right**

  – Breast

- **Male / female**

  – Breast

- **Enumeration**

  – Internal intercostal muscle (1 - 11)

- **Upper / (middle) / lower**

  – Lobe of lung

- **X / Non-X**

  – Cell (nucleated vs Non-nucleated)

We reused the multiple inheritance patterns

Consistency checking

Consistency

check that among the direct XXX parts of an anatomical entity, none is a superclass of the other

- part: 118

- constitutional part: 26

- regional part: 86

- systemic part: 34

Consistency

- If we consider the regional parts of "Body", we find :

    - "Head",

    - "Body proper",

    - "Upper limb", "Left upper limb", "Right upper limb",

    - "Lower limb", "Left lower limb", "Right lower limb".

Consistency

- If we consider that this represents one exhaustive decomposition of the body into regional parts, it makes sense to specify that there has to be one left lower limb and one rigt lower limb and one left upper limb... But then, "Upper limb" and "Lower limb" are not necessary (but still correct).

- Now, if we consider that these are the only possible elements of this partition, we only need "Head", "Body proper", "Upper limb" and "Lower limb"... and the left/right upper/lower limbs are again not necessary (but admittedly again still correct).

Consistency

check that among the direct XXX parts of an anatomical entity, none is a part (possibly indirect) of the other

- ex: Areola has among its parts "Skin of areola", "Sebaceous gland" and "Areolar gland". It turns out that "Sebaceous gland" and "Areolar gland" are already parts of "Skin of areola"
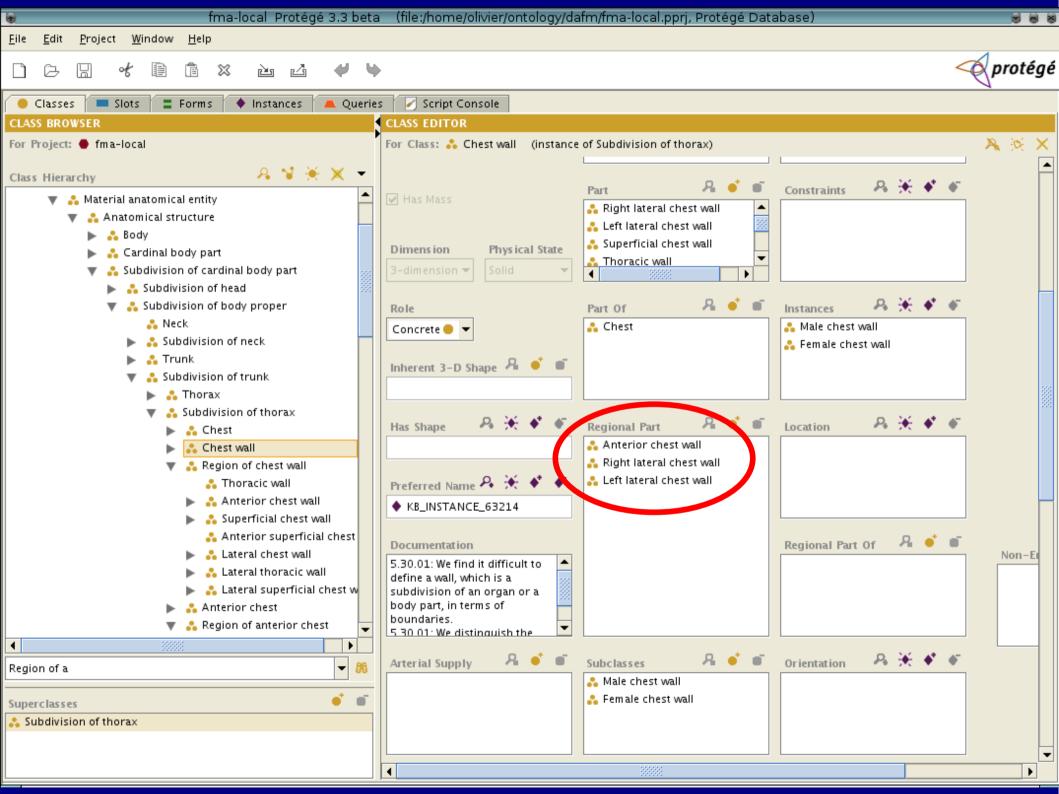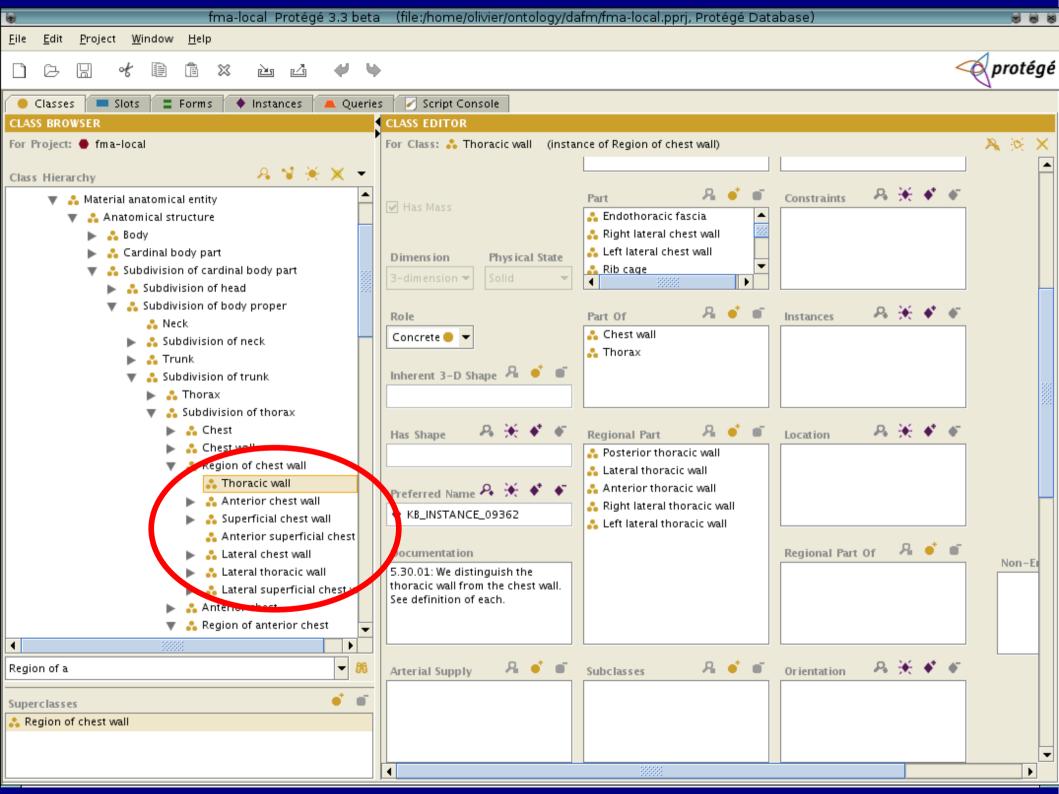
File   Edit   Project   Window   Help

protégé

● Classes   ■ Slots   ≡ Forms   ◆ Instances   ▲ Queries   ✎ Script Console

CLASS BROWSER

For Project: ● fma-local

Class Hierarchy

▶ ▲ Pectoral part of chest
▶ ▲ Inframammary part of chest
▲ Sternal part of chest
▼ ▲ Region of pectoral part of chest
  ▶ ▲ Breast
  ▼ ▲ Region of breast
    ▶ ▲ Nipple
    ▶ ▲ Areola
    ▶ ▲ Breast proper
    ▶ ▲ Quadrant of breast
    ▶ ▲ Superior region of breast
    ▶ ▲ Medial region of breast
    ▶ ▲ Lateral region of breast
    ▶ ▲ Central region of breast
    ▶ ▲ Subareolar region of brea
    ▲ Accessory breast
  ▶ ▲ Lateral pectoral region
  ▶ ▲ Infraclavicular part of chest
  ▶ ▲ Pectoral part proper of male
  ▶ ▲ Lateral part of chest
  ▶ ▲ Right side of chest
  ▶ ▲ Left side of chest
▲ Back of thorax
▶ ▲ Subdivision of back of thorax
▶ ▲ Hemithorax

areola

Superclasses
▲ Region of breast

CLASS EDITOR

For Class: ▲ Areola   (instance of Region of breast)

Has Mass

Dimension   Physical State
3-dimension ▼   Solid ▼

Role
Concrete ● ▼

Inherent 3-D Shape

Has Shape

Preferred Name
◆ fm-live_12915

Documentation

Arterial Supply

Lymphatic Drainage
▲ Lymphatic tree of subareolar part o
▲ Lymphatic tree of areola

Nerve Supply

Part
▲ Skin of areola
▲ Areolar gland
▲ Sebaceous gland of areola
▲ Sweat gland of areola

Part Of
▲ Female breast
▲ Breast

Regional Part

Attributed Part
◆ fm-live_12918
◆ fm-live_12919
◆ fm-live_12924
◆ fm-live_12925

Constraints

Instances
▲ Right areola
▲ Left areola
▲ Male areola
▲ Female areola

Location

Non-English Equiv
◆ su_incus_38303
◆ KB_AUTO-INSERT(3)_4604

File   Edit   Project   Window   Help

protégé

Classes | Slots | Forms | Instances | Queries | Script Console

CLASS BROWSER

For Project: ● fma-local

Class Hierarchy

▶ ☙ Organ segment
▼ ☙ Zone of organ
    ▶ ☙ Zone of eyeball
    ▶ ☙ Zone of nerve
    ▼ ☙ Zone of skin
        ▶ ☙ Zone of skin of head
        ▶ ☙ Zone of skin of neck
        ▼ ☙ Zone of skin of trunk
            ▼ ☙ Zone of skin of thorax
                ☙ Skin of chest
                ▼ ☙ Zone of skin of chest
                    ☙ Skin of anterior chest
                    ▼ ☙ Zone of skin of anterior c
                        ▶ ☙ Skin of pectoral part o
                        ▼ ☙ Zone of skin of pecto
                            ▶ ☙ Skin of infraclavic
                            ▶ ☙ Skin of breast
                            ▼ ☙ Skin of subdivisio
                                ▶ ☙ Skin of breast
                                ▶ ☙ Skin of areola
                                ▶ ☙ Skin of nipple
                                ▶ ☙ Skin of quadra
                            ▶ ☙ Skin of inframamn
                    ☙ Skin of sternal part of
                    ▶ ☙ Skin of lateral pectora

skin of areola

Superclasses

☙ Skin of subdivision of breast

CLASS EDITOR

For Class: ☙ Skin of areola   (instance of Skin of subdivision of breast)

☑ Has Mass

☙ Cutaneous lymphatic tree of areola

Dimension   **Physical State**

3-dimension ▼

Role   **Member Of**   **Attributed Continuc**

Concrete ● ▼

Inherent 3-D Shape

Has Shape   **Nerve Supply**   **Attributed Part**

                                                ◆ fm-live_12245
                                                ◆ fm-live_12463

Preferred Name

◆ KB_INSTANCE_63202

Documentation   **Part**   **Constraints**

                        ☙ Sebaceous gland of areola

                        ☙ Areolar gland
                        ☙ Areolar tubercle

Arterial Supply   **Part Of**   **Instances**

                        ☙ Areola   ☙ Skin of right areola
                        ☙ Skin of breast   ☙ Skin of left areola

Attaches To   **Receives Input From** **Location**

Consistency (cont.)

- For the subclasses of "Subdivision of thorax":

  - part: 24 inconsistencies (8 classes)

- For the subclasses of "Subdivision of trunk":

  - part: 42 inconsistencies (13 classes)

  - constitutional part: 4 inconsistencies (1 class)

  - regional part: 8 inconsistencies (1 class)

Consistency

check that the parts of X and the subclasses of "Part of X" (if it exists) are consistent

- ex: "Region of chest wall" and the regional parts of "Chest wall"
- Procedure:
  - all the parts of X are subclasses of "Part of X"
  - all the subclasses of "Part of X" are actually parts of X

Consistency

check that the parts of X and the subclasses of "Part of X" (if it exists) are consistent

- part: 24 inconsistencies
- regional parts: 11008 inconsistancies

Synthesis

Discussion

- Patterns "manually" generated

  - coverage for Vertebra

- Auxiliary classes (Part_of_X, Region_of_Y, ...):

  - exist in FMA-frames so should also exist in FMA-OWL

  - should only be defined

- FMA complex class/metaclass architecture

- Closure

Conclusion

- **Consistency checking**
  - is needed (the bigger your onto, the more you need it)
  - should be automated
    - detect current mistakes
    - avoid new mistakes during updates
  - ... toward semi-automatic correction?
- **Generating the OWL-specific part of the FMA**
  - automatic + ad hoc