VIP ANR-09\_COSI\_03

Virtual Imaging Platform

D1.1.1 Final ontologies

(contributors, in alphabetic order)

|  |  |  |
| --- | --- | --- |
| Hugues Benoit-Cattin | CREATIS | yougz@creatis.insa-lyon.fr |
| Patrick Clarysse | CREATIS | clarysse@creatis.insa-lyon.fr |
| Germain Forestier | IRISA (INRIA Rennes) | germain.forestier@inria.fr |
| Denis Friboulet | CREATIS | friboulet@creatis.insa-lyon.fr |
| Bernard Gibaud | IRISA (INRIA Rennes) | Bernard.Gibaud@irisa.fr |
| Tristan Glatard | CREATIS | glatard@creatis.insa-lyon.fr |
| Patrick Hugonnard | CEA-Leti | patrick.hugonnard@cea.fr |
| Carole Lartizien | CREATIS | lartizien@creatis.insa-lyon.fr |
| Hervé Liebgott | CREATIS | liebgott@creatis.insa-lyon.fr |
| Joachim Tabary | CEA-Leti | joachim.tabary@cea.fr |

Abstract

This deliverable describes the different ontologies defined to specify the semantics of the annotations of the object models, simulated data and simulation tools in the Virtual Imaging Platform. It relies on the preliminary models provided at milestones M1.1.1 (basic version of the semantic model) and M1.1.2 (refined version of the ontologies).

This deliverable describes the ontologies’ content as well as how the ontologies were produced. Although the title of this deliverable is “final ontologies” the ontology files listed in this document may be updated in the following of the project, in order to meet potential new needs from the VIP platform’s end-users or to cope with specific implementation constraints.

# 1. Introduction

The VIP ontology is composed of several parts:

* an ontology of object models
* an ontology of simulated data
* an ontology of simulation (including simulation tasks, simulators and major simulation parameters)

All these ontologies have been produced using the same method:

1. Definition of the domain of discourse (entities to be modeled), based on a review of the requirements of the VIP project and based on the expertise available in the consortium
2. Conceptual modeling and design of the ontology according to the OntoSpec methodology [Kassel 2003], and, when relevant, extraction and integration of external ontologies’ subsets.
3. Creation of an OWL implementation of the ontology, taking into account the needs of the semantic processing envisaged in the following of the project.

The following sections refer to the corresponding files (i.e. OntoSpec and OWL files) and document how they were produced.

They also contain information about known current limitations of the ontologies such as entities not yet modeled, known imperfections, etc.

# 2. Ontology of object models (i.e. Medical image simulation object models)

## 2.1. Conceptual models

### 2.1.1. OntoSpec file of basic entities

The basic OntoSpec file is : VIPmodel-V3.3.doc

This file introduces the major entities of the VIP ontology for Medical image simulation object models, namely:

|  |  |  |
| --- | --- | --- |
| Medical image simulation object model | Object model of physical manufactured object | Geometrical phantom object layer part |
| Geometrical phantom object model | Object model of physical biological object | Anatomical object layer part |
| Biological object model | Model layer | Foreign body object layer part |
| Anatomical object model | Values layer | External agent object layer part |
| Object model without foreign body | Object layer | Pathological object layer part |
| Object model with foreign body | Physical parameter values layer | Physical parameter |
| Static object model | External agent values layer | Physical quality of external agent |
| Dynamic object model | Geometrical phantom object layer | External agent concentration |
| Longitudinal follow up object model | Geometrical phantom object | Contrast agent concentration |
| Moving object model | Anatomical object layer | Radiopharmaceutical concentration |
| Object model with external agent | Anatomical object | Radiopharmaceutical radioactivity |
| Object model without external agent | Foreign body object layer | Time point |
| Non pathological object model | External agent object layer | Instant |
| Pathological object model | External agent object | Mathematical distribution |
| Pure virtual object model | Pathological object layer |  |
| Object model of physical object | Pathological object |  |

### 2.1.2. Complementary entities (selected from existing ontologies)

The different entities needed for the project were extracted from several existing resources using a software called vSPARQL, developed by Marianne Shaw et al.  « vSPARQL is an extension of the W3C recommended query language for RDF, SparQL, with additional syntax enabling the creation of application ontologies as views of reference ontologies. » [Shaw 2011]. For each specific need, the resource was identified, the relevant entities were selected and a vSPARQL query was designed in order to extract them. This approach will facilitate future updates / extensions on the ontology.

#### 2.1.2.1. Biological objects

A number of entities in relation to anatomy were extracted from FMA (the Foundational Model of Anatomy, OWL, version 3.0 [FMA 2009]). We started by listing the anatomical terms used in the description of the models (specifications, publications, etc.). These terms were matched with the anatomical terms of the FMA (the entities subsumed by the ‘Material\_Anatomical\_Entity’) using a fuzzy string comparison using the Lucene library developed by the Apache Foundation. A manual step consisted in checking and completing this matching. Then, a vSPARQL query was designed to extract the identified entities along with the entities present in the paths from the entities to the root entity in FMA : ‘Material\_Anatomical\_Entity’.

Sample of vSPARQL query for the concept fma:Adipose\_tissue :

PREFIX rdfs:<http://www.w3.org/2000/01/rdf-schema#>

PREFIX fma:<http://sig.biostr.washington.edu/fma3.0#>

CONSTRUCT {?x ?y ?z.}

FROM NAMED <extracted\_ontology> [

CONSTRUCT {fma:Adipose\_tissue rdfs:subClassOf ?super . fma:Adipose\_tissue fma:FMAID ?fmaid . fma:Adipose\_tissue fma:definition ?definition . fma:Adipose\_tissue rdfs:comment ?comment . fma:Adipose\_tissue rdfs:label ?label }

FROM <http://sig.biostr.washington.edu/fma3.0>

WHERE {fma:Adipose\_tissue rdfs:subClassOf ?super . fma:Adipose\_tissue fma:FMAID ?fmaid . fma:Adipose\_tissue fma:definition ?definition . OPTIONAL{fma:Adipose\_tissue rdfs:comment ?comment}. fma:Adipose\_tissue rdfs:label ?label . FILTER(!isBlank(?super)).}

UNION

CONSTRUCT {?super rdfs:subClassOf ?next . ?super fma:FMAID ?fmaid . ?super fma:definition ?definition . ?super rdfs:comment ?comment. ?super rdfs:label ?label}

FROM <http://sig.biostr.washington.edu/fma3.0>

FROM NAMED <extracted\_ontology>

WHERE { GRAPH <extracted\_ontology> {?next2 rdfs:subClassOf ?super} .

?super rdfs:subClassOf ?next . ?super fma:FMAID ?fmaid . ?super fma:definition ?definition. OPTIONAL {?super rdfs:comment ?comment }. ?super rdfs:label ?label

FILTER(!isBlank(?next)).

}

] WHERE {GRAPH <extracted\_ontology> {?x ?y ?z }.}

Note: A script was developed in order to automate the conception of this query according to a list of terms to extract. The list of FMA terms used in those queries is provided in ANNEX 1.

#### 2.1.2.2. Contrast agents

The entities were extracted from the RadLex resource [RadLex 2009]. All the entities present in RadLex regarding contrast agents seemed interesting. So, we designed a query to extract all the entities below the entity contrast-agent in the RadLex resource.

vSPARQL query with "RID11582"@en being the entity contrast-agent :

PREFIX radlex: <http://bioontology.org/projects/ontologies/radlex/radlexOwl#>

PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>

PREFIX owl: <http://www.w3.org/2002/07/owl#>

PREFIX xmls: <http://www.w3.org/2001/XMLSchema#>

CONSTRUCT {?x ?y ?z}

FROM NAMED <extracted\_ontology> [

CONSTRUCT {?const rdfs:label "RID11582"@en. ?sub rdfs:subClassOf ?const. ?const radlex:Preferred\_name ?prefname. ?const radlex:Definition ?def }

FROM <http://orchestria.u-strasbg.fr/~forestier/onto/radlex\_owl.owl>

WHERE {?const rdfs:label "RID11582"@en. ?sub rdfs:subClassOf ?const . ?const radlex:Preferred\_name ?prefname. OPTIONAL {?const radlex:Definition ?def}}

UNION

CONSTRUCT {?next rdfs:subClassOf ?sub . ?sub rdfs:label ?label . ?sub radlex:Preferred\_name ?prefname. ?sub radlex:Definition ?def. ?next rdfs:label ?label2 . ?next radlex:Preferred\_name ?prefname2. ?next radlex:Definition ?def2}

FROM <http://orchestria.u-strasbg.fr/~forestier/onto/radlex\_owl.owl>

FROM NAMED <extracted\_ontology>

WHERE {

GRAPH <extracted\_ontology> {?sub rdfs:subClassOf ?super.} .

?next rdfs:subClassOf ?sub . ?sub rdfs:label ?label . ?sub radlex:Preferred\_name ?prefname. OPTIONAL {?sub radlex:Definition ?def} .

?next rdfs:label ?label2 . ?next radlex:Preferred\_name ?prefname2. OPTIONAL {?next radlex:Definition ?def2} .

}

]

WHERE {GRAPH <extracted\_ontology> {?x ?y ?z }}

#### 2.1.2.3. Foreign body objects

We used the same approach used for the contrast agents and extracted all foreign bodies from RadLex. The query is similar, the only difference is the root concept: "RID5425"@en:foreign-body

#### 2.1.2.4. Radiopharmaceuticals

We used the same approach used for contrast agents and extracted all the radiopharmaceuticals from RadLex. The query is similar, the only difference is the root concept : "RID11692"@en:radiopharmaceutical

#### 2.1.2.5. Pathological anatomical object qualities

The entities were extracted from PATO [PATO 2011], using a vSPARQL query and a list of term identified manually and with discussion with experts.

vSPARQL sample query for the concept "curled" :

PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>

PREFIX owl: <http://www.w3.org/2002/07/owl#>

PREFIX fma: <http://sig.biostr.washington.edu/fma3.0#>

PREFIX xmls: <http://www.w3.org/2001/XMLSchema#>

PREFIX oboInOwl: <http://www.geneontology.org/formats/oboInOwl#>

CONSTRUCT {?x ?y ?z}

FROM NAMED <extracted\_ontology> [

CONSTRUCT {?const rdfs:label "curled"@en. ?const fma:definition ?stringdef. }

FROM <http://orchestria.u-strasbg.fr/~forestier/onto/pato.owl>

WHERE {?const rdfs:label "curled"@en. ?const oboInOwl:hasDefinition ?def. ?def rdfs:label ?stringdef.}

]

WHERE {GRAPH <extracted\_ontology> {?x ?y ?z }}

Note: A script was developed in order to automate the conception of this query according to a list of terms to extract. The list of PATO terms used in those queries is provided in ANNEX 2.

#### 2.1.2.6. Pathological objects

The entities were extracted from MPATH [MPATH 2011], using a vSPARQL query. All the entities bellow "pathological anatomical entity" were extracted.

vSPARQL sample query :

PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>

PREFIX owl: <http://www.w3.org/2002/07/owl#>

PREFIX xmls: <http://www.w3.org/2001/XMLSchema#>

CONSTRUCT {?x ?y ?z}

FROM NAMED <extracted\_ontology> [

CONSTRUCT {?const rdfs:label "pathological anatomical entity"@en. ?sub rdfs:subClassOf ?const. }

FROM <http://orchestria.u-strasbg.fr/~forestier/onto/mpath.owl>

WHERE {?const rdfs:label "pathological anatomical entity"@en. ?sub rdfs:subClassOf ?const .}

UNION

CONSTRUCT {?next rdfs:subClassOf ?sub . ?sub rdfs:label ?label . ?next rdfs:label ?label2 .}

FROM <http://orchestria.u-strasbg.fr/~forestier/onto/mpath.owl>

FROM NAMED <extracted\_ontology>

WHERE {

GRAPH <extracted\_ontology> {?sub rdfs:subClassOf ?super.} .

?next rdfs:subClassOf ?sub . ?sub rdfs:label ?label.

?next rdfs:label ?label2 .

}

]

WHERE {GRAPH <extracted\_ontology> {?x ?y ?z }}

### 2.1.3. Important limitations

The more salient limitations of this ontology with regards to the general needs met in medical image simulation are documented in this section.

*1. Representation of dynamic processes*

Dynamic processes are modeled using explicit time samples. These time samples can be taken at two complementary granularity levels, namely: (1) at *time point* level, in order to model longitudinal follow-up of physiological processes (i.e. time scale of months or years, mimicking physiological evolution taking place *between* successive imaging procedures); (2) at *instant* level, in order to model fast changing physiological processes, usually explored *during* an imaging acquisition (e.g. US series, dynamic CT or dynamic PET). Model layers are related to time points and instants by means of the relation *refers to*.

Both entities are modeled as *Time intervals*, following a general approach documented in [Allen 1983], and used as a philosophical basis in DOLCE as well. Instants are proper parts of Time points.

Note that no axioms are defined to enforce Dynamic object models (or their parts, i.e. their Model layers) to refer to Time points or Instants.

*2. Absence of reference to Perdurants in characterising dynamic processes.*

At this stage, Medical image simulation object models are focusing on the morphological characteristics of objects, in relation with their physical qualities that actually play an important role in image simulation. Their variations, as stressed above, are made explicit at various time samples. However, Medical image simulation object models do not refer to Perdurants : so there is currently no way to make the semantics of those changes explicit (e.g. respiratory movement, heart beating, nor their abnormalities (e.g. heart arrhythmia).

*3. Limited number of anatomical structures.*

So far, we extracted only a limited set of entities from FMA. It will certainly be necessary to recursively retrieve entities related by “part-whole” relationships, in order to get a more complete set. However, there are several such relationships in FMA, e.g. constitutional-part (/constitutional-part-of), regional-part (/regional-part-of), so this choice must be done with care in order to prevent getting a huge unmanageable set of entities.

## 2.2. OWL implementation

The OWL files are listed below :

NeuroLOG Core ontologies

* action-on-program-software-owl-lite.owl
* action-owl-lite.owl
* agentive-owl-lite.owl
* artefact-owl-lite.owl
* capacity-owl-lite.owl
* collection-owl-lite.owl
* computer-language-expression-owl-lite.owl
* computer-language-owl-lite.owl
* discourse-message-act-owl-lite.owl
* file-owl-lite.owl
* *human-owl-lite.owl*
* iec-owl-lite.owl
* language-owl-lite.owl
* library-software-platform-owl-lite.owl
* linguistic-expression-owl-lite.owl
* number-owl-lite.owl
* participant-role-owl-lite.owl
* particular-owl-lite.owl
* *physical-quality-owl-lite.owl*
* state-owl-lite.owl
* temporal-quality-owl-lite.owl

NeuroLOG domain ontologies

* dataset-owl-lite.owl
* dataset-processing-owl-lite.owl
* medical-image-expression-owl-lite.owl
* medical-image-file-owl-lite.owl
* medical-image-format-owl-lite.owl
* mr-protocol-owl-lite.owl

VIP domain ontologies

* vip-biological-object.owl
* vip-contrast-agent.owl
* vip-foreign-body-object.owl
* vip-model.owl
* vip-pathological-anatomical-object-quality.owl
* vip-pathological-object.owl
* vip-radiopharmaceutical.owl

Note: files noted in italics are not used, yet

*Important limitations*

The modularity of the ontologies has to be improved.

Actually one may be surprised to find in the ontology file vip-model.owl some axioms characterizing specific contrast agents (e.g. reticuloendothelial-contrast-agent), such as :

<owl:Class rdf:about="&vip-constrast-agent;reticuloendothelial-contrast-agent">

<rdfs:subClassOf rdf:resource="&mr-protocol-owl-lite;contrast-agent"/>

</owl:Class>

since the other properties of this entity are provided in ontology file contrast-agent.owl.

This kind of problem occurs for the entities that are located in the subClassOf tree just below an entity of the vip-model.owl ontology. This issue (which concerns also foreign bodies and radiopharmaceuticals) has to be fixed in next releases of the OWL files.

# 3. Ontology of Simulated data

## 3.1. Conceptual models

### 3.1.1. OntoSpec file of basic entities

The basic OntoSpec file is : VIPsimulated-Data-V1.0.doc

This file introduces the major entities of the VIP ontology for Simulated data, namely:

|  |  |  |
| --- | --- | --- |
| Simulated data | US simulated data | PET simulated image |
| Static simulated data | CT sinogram | US simulated image |
| Dynamic simulated data | PET sinogram | US simulated polar image |
| Sinogram | PET list-mode data | US simulated cartesian image |
| List-mode data | CT projection image | US pressure field image |
| Projection image | US raw signal |  |
| Signal | US post-beamforming signal |  |
| MR simulated data | MR k-space signal |  |
| CT simulated data | MR simulated image |  |
| PET simulated data | CT simulated image |  |

### 3.1.2. Complementary entities (selected from existing ontologies)

*to be filled (if any)*

### 3.1.3. Important limitations

The more salient limitations of this ontology with regards to the general needs met in medical image simulation are documented in this section.

*to be filled (if any)*

## 3.2. OWL implementation

The OWL files are listed below :

NeuroLOG Core ontologies

* action-on-program-software-owl-lite.owl
* action-owl-lite.owl
* agentive-owl-lite.owl
* artefact-owl-lite.owl
* capacity-owl-lite.owl
* collection-owl-lite.owl
* computer-language-expression-owl-lite.owl
* computer-language-owl-lite.owl
* discourse-message-act-owl-lite.owl
* file-owl-lite.owl
* *human-owl-lite.owl*
* iec-owl-lite.owl
* language-owl-lite.owl
* library-software-platform-owl-lite.owl
* linguistic-expression-owl-lite.owl
* number-owl-lite.owl
* participant-role-owl-lite.owl
* particular-owl-lite.owl
* *physical-quality-owl-lite.owl*
* state-owl-lite.owl
* temporal-quality-owl-lite.owl

NeuroLOG domain ontologies

* dataset-owl-lite.owl
* medical-image-expression-owl-lite.owl
* medical-image-file-owl-lite.owl
* medical-image-format-owl-lite.owl
* mr-protocol-owl-lite.owl

VIP domain ontologies

* none

Note: files noted in italics are not used, yet

*Important limitations*

To be completed

# 4. Ontology of simulation (simulation tasks and simulation tools)

## 4.1. Conceptual models

### 4.1.1. OntoSpec file of basic entities

The basic OntoSpec file is : VIP-simulation-V1.0.doc

This file introduces the major entities of the VIP ontology for Simulated tasks and tools, namely:

|  |  |
| --- | --- |
| Medical image simulation | US Medical image simulator |
| MR simulation | Simulator component |
| CT simulation | Pre-processing simulator component |
| PET simulation | Core simulation simulator component |
| US simulation | Post-processing simulator component |
| Simulator | Parameters generation simulator component |
| Medical image simulator | Object preparation simulator component |
| MR Medical image simulator | Final parameters assembling simulator component |
| CT Medical image simulator | Image reconstruction simulator component |
| PET Medical image simulator |  |

### 4.1.2. Complementary entities (selected from existing ontologies)

*to be filled (if any)*

### 4.1.3. Important limitations

Only a limited set of entities were defined so far. Needs in relation with the assisted composition of new simulation workflows may require the definition of more categories of simulator components (work in progress by Nadia Cerezo).

Besides, new entities will have to be defined concerning salient simulation parameters that one may want to use to select and retrieve simulations that were previously made in the VIP platform (work in progress concerning the definition of needs concerning queries).

## 4.2. OWL implementation

The OWL files are listed below :

NeuroLOG Core ontologies

* action-on-program-software-owl-lite.owl
* action-owl-lite.owl
* agentive-owl-lite.owl
* artefact-owl-lite.owl
* capacity-owl-lite.owl
* collection-owl-lite.owl
* computer-language-expression-owl-lite.owl
* computer-language-owl-lite.owl
* discourse-message-act-owl-lite.owl
* file-owl-lite.owl
* *human-owl-lite.owl*
* iec-owl-lite.owl
* language-owl-lite.owl
* library-software-platform-owl-lite.owl
* linguistic-expression-owl-lite.owl
* number-owl-lite.owl
* participant-role-owl-lite.owl
* particular-owl-lite.owl
* *physical-quality-owl-lite.owl*
* state-owl-lite.owl
* temporal-quality-owl-lite.owl

NeuroLOG domain ontologies

* dataset-owl-lite.owl
* dataset-processing-owl-lite.owl
* medical-image-expression-owl-lite.owl
* medical-image-file-owl-lite.owl
* medical-image-format-owl-lite.owl
* mr-protocol-owl-lite.owl

VIP domain ontologies

* vip-biological-object.owl
* vip-contrast-agent.owl
* vip-foreign-body-object.owl
* vip-model.owl
* vip-pathological-anatomical-object-quality.owl
* vip-pathological-object.owl
* vip-radiopharmaceutical.owl
* vip-simulation.owl

Note: files noted in italics are not used, yet

*Important limitations*

To be completed

# References

[Allen 1983] Allen JF. Maintaining knowledge about temporal intervals. Communications of the ACM (1983) Vol 26, n°11, 832-843.

[FMA 2009] Foundational Model of Anatomy, V3.0, http://sig.biostr.washington.edu/projects/fma/release/index.html

[Kassel 2003] Kassel G. Integration of the DOLCE top-level ontology into the OntoSpec methodology, LaRIA research report 2005-2008, 2003.

[MPATH 2011] Mouse Pathology, http://bioportal.bioontology.org/ontologies/1031

[PATO 2009] Phenotypic quality, http://bioportal.bioontology.org/ontologies/1107

[RadLex 2009] A lexicon for uniform indexing and retrieval of radiology information resources, V3.0, http://bioportal.bioontology.org/ontologies/40885

[Shaw 2011] Shaw M, Detwiler LT, Noy N, Brinkley J, and Suciu D. vSPARQL: A view definition language for the semantic web. Journal of Biomedical Informatics, 44, 102-117, 2011.

# Annex 1

List of terms used to extract a set of relevant anatomical concepts from FMA

|  |  |  |
| --- | --- | --- |
| Adipose\_tissue | Left\_cuboid\_bone | Right\_hamate |
| Adrenal\_gland | Left\_femur | Right\_hip |
| Alimentary\_air | Left\_fibula | Right\_humerus |
| Aorta | Left\_hamate | Right\_leg |
| Artery | Left\_humerus | Right\_lunate |
| Articular\_cartilage | Left\_leg | Right\_ovary |
| Blood\_in\_aorta | Left\_lunate | Right\_patella |
| Body | Left\_lung | Right\_pisiform |
| Bone\_marrow | Left\_patella | Right\_radius |
| Bone\_of\_greater\_trochanter\_of\_femur | Left\_pisiform | Right\_scaphoid |
| Bone\_of\_humerus | Left\_radius | Right\_scapula |
| Bone\_of\_rib | Left\_scaphoid | Right\_talus |
| Bone\_spine | Left\_scapula | Right\_tibia |
| Brain | Left\_talus | Sacrum |
| Breast | Left\_tibia | Set\_of\_central\_veins\_of\_liver |
| C4 | Left\_trapezium | Set\_of\_fingers\_of\_right\_hand |
| Cartilage\_tissue | Left\_trapezoid | Set\_of\_fingers |
| Central\_canal\_of\_spinal\_cord | Left\_triquetral | Set\_of\_toes\_of\_left\_foot |
| Cerebellum | Left\_ulna | Set\_of\_toes\_of\_right\_foot |
| Cerebral\_aqueduct | Left\_ureter | Sinus |
| Cerebrospinal\_fluid | Lens | Skeletal\_muscle\_tissue |
| Clavicle | Lipid | Skin |
| Colon | Liver | Skull |
| Common\_iliac\_lymph\_node | Long\_bone | Small\_intestine |
| Compact\_bone | Lung | Spinal\_cord |
| Cylindrical | Lymph\_node | Spleen |
| Dens\_of\_axis | Lymph | Sternum |
| Diaphragm | Mandible | Stomach |
| Epithelium\_of\_gall\_bladder | Medulla\_oblongata | Testis |
| Esophagus | Muscle\_organ | Thyroid\_gland |
| Eye | Myocardium | Tissue\_fluid |
| Falx\_cerebri | Optic\_nerve | Tongue |
| Fat\_body | Ovary | Tooth |
| Feces | Pancreas | Trachea |
| Femur | Pelvis | Tunica\_adventitia\_of\_artery |
| Fibrous\_tissue | Penis | Tunica\_intima\_of\_artery |
| Gallbladder | Pharynx | Tunica\_media\_of\_artery |
| Gas | Pons | Urethra |
| Gray\_matter\_of\_neuraxis | Portion\_of\_blood | Urinary\_bladder |
| Hard\_palate | Portion\_of\_urine | Uterus |
| Heart | Prostate | Vagina |
| Intestine | Pulmonary\_vein | Vein |
| Jaw | Rectum | Vertebral\_column |
| Kidney | Red\_bone\_marrow | White\_matter\_of\_neuraxis |
| L3 | Rib\_cage | Yellow\_bone\_marrow |
| Lacrimal\_gland | Right\_arm |  |
| Large\_intestine | Right\_calcaneus |  |
| Left\_arm | Right\_capitate |  |
| Left\_calcaneus | Right\_femur |  |
| Left\_capitate | Right\_fibula |  |

# Annex 2

List of terms used to extract a set of relevant anatomical concepts from PATO

|  |  |  |
| --- | --- | --- |
| 1D-extent | distended | increased volume |
| 2D-extent | dwarf-like | increased width |
| 3D-extent | dysplastic | inelastic |
| anterior-posterior diameter | dystrophic | infiltrative |
| area | edematous | inflammatory |
| atrophied | elastic | irregular thickness |
| ballooning | elasticity | length |
| calcified | fatty | molar volume |
| circumference | gigantic | necrotic |
| decreased anterior-posterior diameter | height | neoplastic |
| decreased area | hemorrhagic | neoplastic invasive |
| decreased circumference | hydrocephalic | neoplastic malignant |
| decreased depth | hyperplastic | neoplastic metastatic |
| decreased diameter | hypertrophic | neoplastic non-invasive |
| decreased elasticity | hypoplastic | neoplastic non-malignant |
| decreased height | hypotrophic | nodular |
| decreased length | increased anterior-posterior diameter | ossified |
| decreased perimeter | increased area | perimeter |
| decreased pressure | increased circumference | pressure |
| decreased size | increased depth | specific volume |
| decreased thickness | increased diameter | swollen |
| decreased volume | increased elasticity | thickness |
| decreased water composition | increased height | volume |
| decreased width | increased length | water composition |
| demyelinated | increased perimeter | width |
| depth | increased pressure |  |
| diameter | increased size |  |
| dilated | increased thickness |  |