

Gallbladder description in ultrasound images ontology

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Abstract

The process of ontology elaboration for gallbladder ultrasound images on the base of knowledge enclosed in decision support system SonaRes is described in this article.

1 Introduction

In present paper we present description of the process of ontology construction for gallbladder ultrasound images. This ontology is inspired and based on the knowledge base created and being used for SonaRes – the decision support system for ultrasound diagnostics [1-5]. This system has accumulated the experience of the skillful experts-sonographers in the domain of hepato-pancreato-biliary zone examination. This experience and knowledge is well structured and formalized in this system for gallbladder and pancreas.

On the other hand, there is a powerful and attractive, from the point of view of knowledge portability, tool – ontology, which in computer science is considered as an attempt of comprehensive and detailed formalisation of some knowledge domain with the help of conceptual scheme. The ontology for gallbladder ultrasound images, presented in this paper, is an attempt to make the formalised knowledge from SonaRes system accessible in other environments and to provide interoperability.

2 Ontology Structure

Let's consider the structure of the proposed ontology step-by-step (see Fig. 1).

From a logical point of view there are 5 basic interrelated classes: *Organ*, *Pathology*, *Patient*, *Image* and *Complex.characteristics*. They are at the uppermost level of the ontology.

- Class *Organ* is meant for description of different organs and is related with classes *Pathology* and *Patient*:
 - with class *Pathology* – to reflect, with what pathology the certain description of organ is related;
 - with class *Patient* – to display, what patient from the given database has this pathology.
- Class *Image* is a "container" of all images of concrete patients and is related with class *Patient* to reflect the relation: which patient does the given image belong to.
- Class *Pathology* is meant for the list of pathologies structured by different areas and organs.
- Class *Patient* is a "container" of all patients of the given database. It is related with classes *Pathology* and *Image*:



Figure 1: Class hierarchy.

- with class *Pathology* – to reflect, what pathologies the given patient has;
 - with class *Image* – to reflect, what images belong to the given patient.
- Class *Complex_characteristics* is used for the description of complex organ characteristics. It is related with class *Organ*, and more precisely, with some its subclasses, depending on the organ which is described by respective characteristic. In this article we will speak about gallbladder and its characteristics. Thus, class *Complex_characteristics* contains subclasses that describe characteristics of gallbladder.

2.1 Basic class Organ

Class *Organ* is described by such slots as: *organ_name*, *region*, *pathology*, *image*, *patient*.

Slot *organ_name* serves for the organ name. Slot *region* indicates the area to which the organ belongs. Slot *pathology* is related with the class *Pathology*. Every instance of the concrete organ is related with a certain pathology. Slot *image* is assigned for the image reflecting pathology, indicated in the slot *pathology*. Slot *patient* is related with the class *Patient* and it is assigned for the list of patients which have the pathology specified in the slot *pathology*.

Class *Organ* at present has three subclasses: *Abdominal_zone_organ*, *Cranial_zone_organ*, *Toracic_zone_organ* – depending on the area to which the organ can belong. All these subclasses have the same slots, as class *Organ*, differing only by the allowed values of some slots.

Class *Abdominal_zone_organ* at present has 3 subclasses: *Gallbladder*, *Pancreas*, *Liver*.

2.2 Description of subclass Gallbladder

In subclass *Gallbladder* the relation in slot *pathology* changes. Unlike class *Organ*, the type of slot *pathology* is declared as "Class with superclass *Gallbladder_pathology*".

New slots are added in subclass *Gallbladder* using the knowledge tree as basis (see Fig. 2). This knowledge tree (see Fig. 3) is the representation of knowledge about gallbladder for experts-sonographers in Expert-shell of SonaRes system [6].

Name	Cardinality	Type	Other Facets
contents_gallbladder	required single	Instance of Contents_Gallbladder	
contour_gallbladder	single	Instance of Contour_Gallbladder	
dimensions	required multi...	Symbol	allowed-values={NORMAL,ENLARGED,DIMINISHED,NOT_DEFINED,ANY_
form_gallbladder	required single	Instance of Form_Gallbladder	
image	single	String	
organ_name	required single	Symbol	allowed-values=GALLBLADDER default=GALLBLADDER
pathology	multiple	Class with superclass Gallbladder_pathology	
patient	multiple	Instance of Patient	inverse-slot=patients_pathologies
region	required single	Symbol	allowed-values=Abdomen
tonicity	required multi...	Symbol	allowed-values={NORMAL,INCREASED_TENSE_ASPECT,DECREASED_A

Figure 2: Respective slots for gallbladder description in current state of ontology.

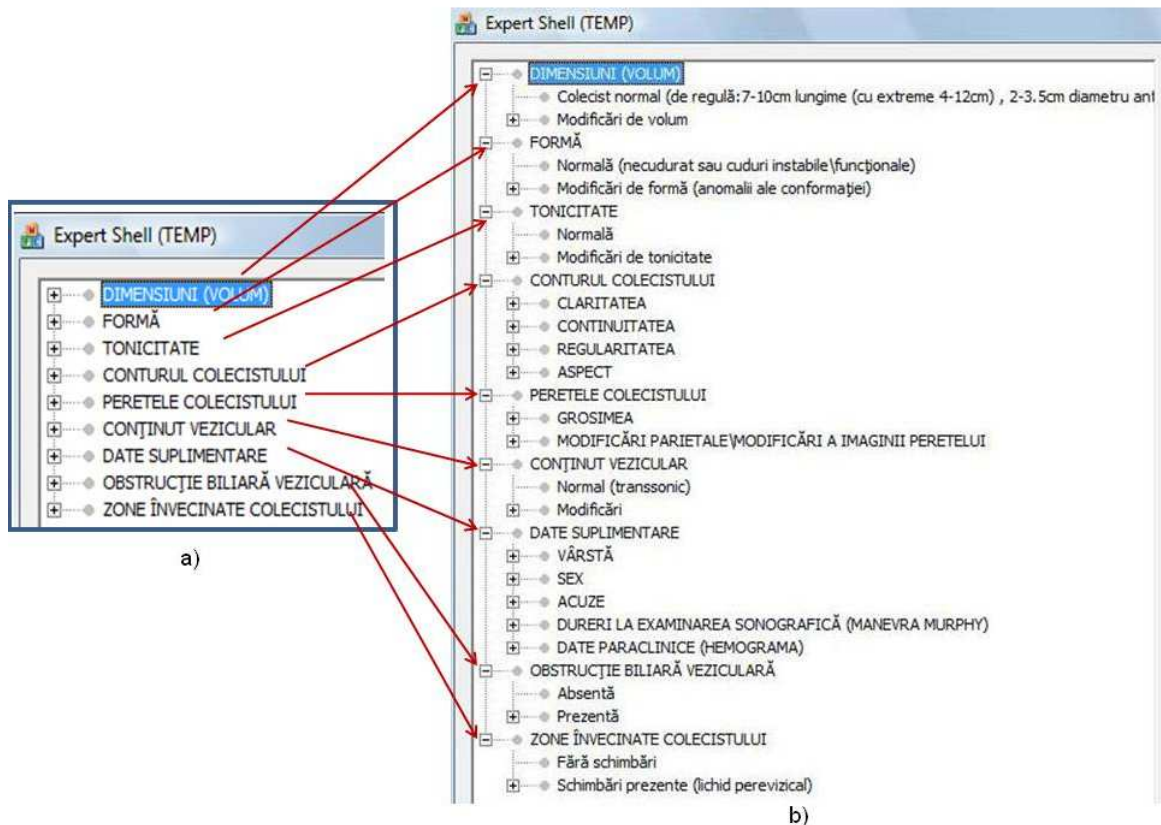


Figure 3: Knowledge tree for gallbladder in Expert-shell: a) collapsed nodes for characteristics; b) partly expanded nodes for characteristics.

At the uppermost level of the tree there are 9 basic characteristics: DIMENSIONS (VOLUME), SHAPE, TONICITY, GALLBLADDER CONTOUR, GALLBLADDER WALL, GALLBLADDER CONTENTS, SUPPLEMENTARY DATA, GALLBLADDER OBSTRUCTION, PERIVESICULAR AREA. They have different degree of complexity. Therefore the slots, corresponding to these characteristics, have different degree of complexity, too.

2.2.1 Slots "dimensions" and "tonicity"

For the description of such a simple characteristic as DIMENSIONS it is enough to simply introduce slot *dimensions* into subclass *Gallbladder*.

Let us give the values and argumentation for some facets for slot *dimensions* (see Fig. 4):

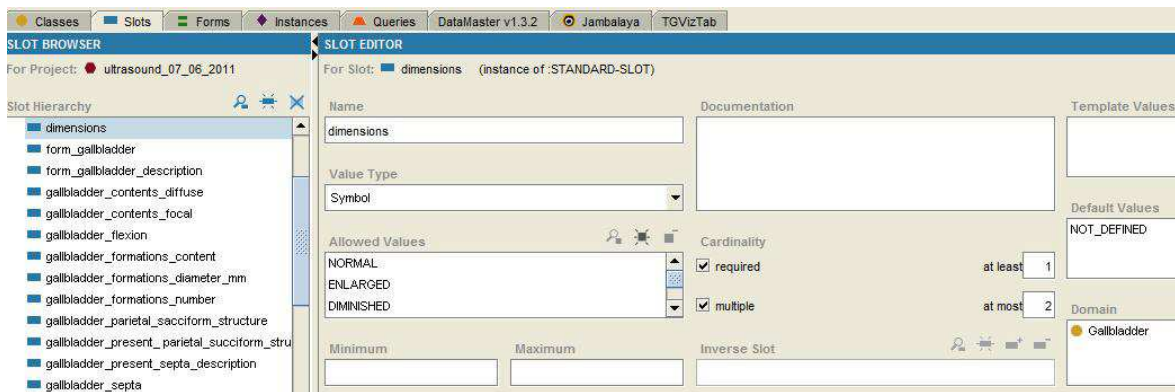


Figure 4: Facets for slot "dimensions".

- Value type = Symbol – then allowed values for this slot can be indicated. In compliance with the knowledge tree, they are the following: NORMAL, ENLARGED, DIMINISHED, NOT_DEFINED, ANY_VALUE. The value NOT_DEFINED is used in the case when the gallbladder dimension is not defined. The value ANY_VALUE is used in the case when the gallbladder dimension doesn't matter for pathology.
- Required – at least 1, since each pathology requires at least 1 value for gallbladder dimension.
- Multiple – at most 2, since, proceeding from the knowledge about gallbladder pathologies, there are pathologies for which two possible values are accepted.

Then, when representing the knowledge on certain gallbladder pathology, it is necessary to select in slot *dimensions* the respective value (one or two) in the respective instance for the class *Gallbladder* (see Fig. 5).

Characteristic of gallbladder TONICITY is as simple as DIMENSIONS. Thus, for its description it is enough to introduce the slot *tonicity*. Slots *tonicity* and *dimensions* have similar structure.

2.2.2 Slot "contour_gallbladder"

Characteristic GALLBLADDER CONTOUR is more complicated. Thus, for its representation it is not enough simply to introduce a slot which gets simple values. For such characteristics the ontology contains the class *Complex_characteristics*. This class contains subclasses *Main_characteristics* and *Additional_characteristics* (see Fig. 6):

- *Main_characteristics* is for characteristics from the highest level of the knowledge tree;
- *Additional_characteristics* is for characteristics which are at lower levels of the knowledge tree and are used for the description of characteristics from higher levels.

For all these characteristics, irrespective of the level, it is necessary to indicate the pathology in which they take part. Hence, for all respective classes and subclasses the slot *pathology* is needed. Therefore, such a slot is introduced in the class *Complex_characteristics* – it will be inherited by all its subclasses. But it can be made more exact. Thus, for example, when describing the characteristics regarding the gallbladder, in facets of slot *pathology* it should be indicated "Allowed Superclasses = Gallbladder_pathology".

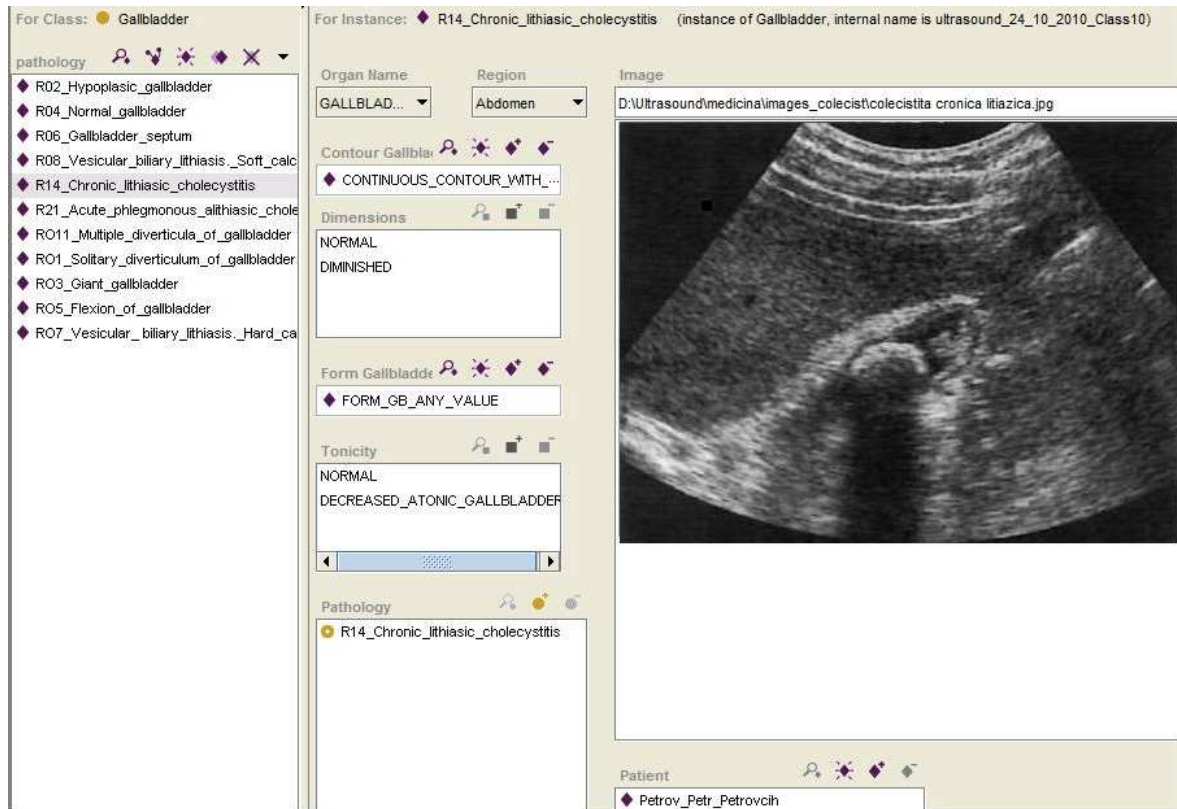


Figure 5: Representation of the knowledge on gallbladder pathology "Chronic lithiasic cholecystitis".

In the class *Main_characteristics* we create subclass *Contour_Gallbladder*, and in the class *Gallbladder* we introduce slot *contour_gallbladder*, which is related with class *Contour_Gallbladder* (the slot has the type "instance of *Contour_Gallbladder*"). In the class *Contour_Gallbladder* the following slots are introduced:

- slots which correspond to characteristics from knowledge tree: *aspect*, *clarity*, *continuity*, *regularity*. These slots have allowed values in compliance with the knowledge tree.

- For the slot *aspect*: allowed values= IMAGE_OF_HOMOGENEOUS_BAND, IMAGE_OF_DOUBLE_CONCENTRIC_CONTOUR, ANY_VALUE, NOT_DEFINED.
- For the slot *clarity*: allowed values= CLEAR, UNCLEAR, ANY_VALUE, NOT_DEFINED.
- For the slot *continuity*: allowed values= CONTINUOUS, INTERRUPTED, ANY_VALUE, NOT_DEFINED.
- For the slot *regularity*: allowed values= IRREGULAR, REGULAR, ANY_VALUE, NOT_DEFINED.

- slot *pathology* is related with the class *Gallbladder_pathology*. So, its type is "Class with superclass *Gallbladder_pathology*". Here those pathologies will be introduced, for the description of which the respective combination of slots values in *Contour_Gallbladder* takes part.

- slot *contour_description* is the string, in which per se is written somewhat like the title of the respective contour. For example, *contour_description*= CLEAR_CONTINUOUS_CONTOUR_WITH_IMAGE_OF_HOMOGENEOUS_BAND – for the case when *clarity*= CLEAR, *continuity*= CONTINUOUS, *aspect*= IMAGE_OF_HOMOGENEOUS_BAND, *regularity*= ANY_VALUE.

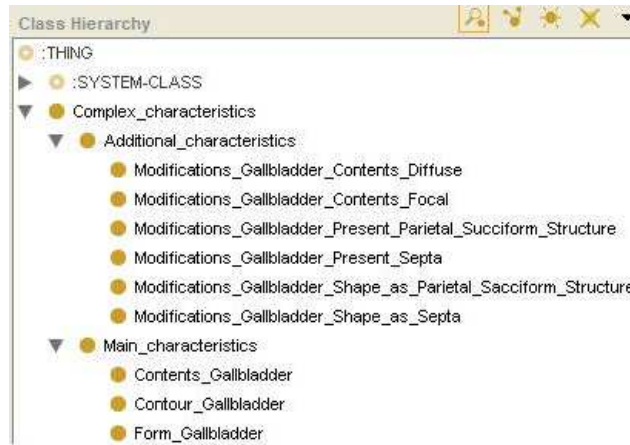


Figure 6: Classes for gallbladder description in current state of ontology.

Thereby, the instance for class *Contour_Gallbladder* is (in terms of knowledge tree) a combination of characteristics values and their relation with respective pathology (or several pathologies). For example:

- instance with the title CLEAR_CONTINUOUS_CONTOUR_WITH_IMAGE_OF_HOMOGENEOUS_BAND is related with the pathology “Normal_gallbladder” since the corresponding combination of values (clarity= CLEAR, continuity= CONTINUOUS, aspect= IMAGE_OF_HOMOGENEOUS_BAND, regularity= ANY_VALUE) takes part in the description of the pathology “Normal_gallbladder”.
- instance with the title CONTINUOUS_CONTOUR_WITH_IMAGE_OF_HOMOGENEOUS_BAND is related with three pathologies (“Hypoplastic_gallbladder”, “Giant_gallbladder”, “Acute_phegmonous_alithiasic_cholecystitis”), since the corresponding combination of values (clarity= ANY_VALUE, continuity= CONTINUOUS, aspect= IMAGE_OF_HOMOGENEOUS_BAND, regularity= ANY_VALUE) takes part in the description of these pathologies (see Fig.7).

Figure 7: Instance for contour with title CONTINUOUS_CONTOUR_WITH_IMAGE_OF_HOMOGENEOUS_BAND.

2.2.3 Slot "form_gallbladder"

Characteristic FORM is even more complicated.

In the class *Main_characteristics* we create subclass *Form_Gallbladder*, and in the class *Gallbladder* we introduce slot *form_gallbladder*, which is related with class *Form_Gallbladder* (the slot has the type "instance of *Form_Gallbladder*").

In compliance with the knowledge tree, in the class *Form_Gallbladder* the slots for the following characteristics are needed: Normal, Flexion, Septa, Parietal succiform structure. These characteristics are of different level of complexity, which is reflected in the way of their description.

The characteristic "Normal" gets the unique value "Normal (without flexion or instable functional flexion)". So it is represented by the slot *normal* with Value Type=Symbol, Allowed Values=NORMAL.WITHOUT.FLEXION.OR.INSTABLE.FUNCTIONAL.FLEXION.

The characteristic "Flexion" can get 5 values. So it is represented by the slot *gallbladder_flexion* with Value Type=Symbol, and Allowed Values= ABSENT, MEDIO-CORPORAL.BILOBATE_GALLBLADDER, DISTAL.FUNDIC.SECTION,PHRYGIAN_CAP, FOLDED_GALLBLADDER.NECKLACE_OF_BEADS, ANNULAR.CLEPSYDRA, ANY_VALUE, NOT_DEFINED.

The characteristic "Septa" unlike the characteristic "Flexion" is complex. Moreover, the characteristic "Flexion" has mutually exclusive values, but values of the characteristic "Septa" are not of such type: values of leaves in subnodes can combine or be absent. Thus, we create the class *Modifications_Gallbladder_Shape_as_Septa* as the subclass of the class *Additional_characteristics*.

In the class *Modifications_Gallbladder_Shape_as_Septa* we create the following slots:

- slot *absent* with Value Type=Symbol, Allowed Values= ABSENT;
- slot *modifications_gallbladder_present_septa* related with the class *Modifications_Gallbladder_Present_Septa*, which is created also as the subclass of the class *Additional_characteristics*;
- slot *gallbladder_shape_as_septa_description* for the title of given combination of values;
- slot *pathology* in this case we make more exact: it has Allowed Superclasses = Gallbladder_pathology.

In the class *Modifications_Gallbladder_Present_Septa* we create the following slots:

- *septum_orientation* with Value Type=Symbol, Allowed Values=Longitudinal, Transversal, ANY_VALUE, NOT_DEFINED
- *number_of_septa* with Value Type=Symbol, Allowed Values=Solitary, Multiple, ANY_VALUE, NOT_DEFINED
- *gallbladder_present_septa_description* for the title of given combination of values;
- *pathology* has Allowed Superclasses = Gallbladder_pathology.

The characteristic "Parietal sacciform structure communicating with vesicular cavity" is also complex and with not mutually exclusive values. Thus, we create the class *Modifications_Gallbladder_Shape_as_Parietal_Sacciform_Structure* as the subclass of the class *Additional_characteristics*.

In the class *Modifications_Gallbladder_Shape_as_Parietal_Sacciform_Structure* we create the following slots:

- slot *absent* with Value Type=Symbol, Allowed Values= ABSENT;
- slot *modifications_gallbladder_present_parietal_succiform_structure* related with the class *Modifications_Gallbladder_Present_Parietal_Succiform_Structure*, which is created also as the subclass of the class *Additional_characteristics*;
- slot *gallbladder_shape_as_formation_description* for the title of given combination of values;
- slot *pathology* has Allowed Superclasses = Gallbladder_pathology.

In the class *Modifications_Gallbladder_Present_Parietal_Succiform_Structure* we create the following slots:

- slot *gallbladder_formation_diameter_mm* with Value Type=Integer to indicate diameter (in millimetres) of formation in gallbladder;

- slot *gallbladder_formation_content* with Value Type=Symbol. Since all the subnodes for respective characteristic are mutually exclusive, and the further expanding of the knowledge tree only precise every higher level, then all the leaves can be simply enumerated (writing the names more extensively by adding the names from lower levels): LIQUID_WITH_TRANSSONIC_ECHOGENICITY, LIQUID_WITH_HOMOGENEOUS_ENHANCED_ECHOGENICITY, LIQUID_WITH_INHOMOGENEOUS_ENHANCED_ECHOGENICITY, LIQUID_AND_SOLID_WITH_REDUCED_MOBILITY, LIQUID_AND_SOLID_IMMOBILE, LIQUID_AND_SOLID_MOBILE, ANY_VALUE, NOT_DEFINED;
- slot *gallbladder_present_parietal_sacciform_structure_description* for the title of given combination of values;
- slot *pathology* has Allowed Superclasses = Gallbladder_pathology.

Thus, the class *Form_Gallbladder* for characteristic "Form" has the following slots:

- *form_gallbladder_description* for the title of given combination of values;
- *gallbladder_flexion* for characteristic "Flexion";
- *gallbladder_parietal_sacciform_structure* related with class *Modifications_Gallbladder_Shape_as_Parietal_Sacciform_Structure* for characteristic "Parietal sacciform structure communicating with vesicular cavity";
- *gallbladder_septa* related with class *Modifications_Gallbladder_Shape_as_Septa* for characteristic "Septa";
- *normal* for characteristic "Normal";
- *pathology* for relation with those pathologies, which have given combination of values.

2.2.4 Instances for classes reflecting complex characteristics

By analogy the other characteristics from the knowledge tree are to be described in the ontology – this is the subject for discussion in future. However, even if all the characteristics from the knowledge tree are described, the knowledge in the ontology will not be full. It is interesting and useful to describe gallbladder pathologies with the help of the elaborated structure.

In this purpose all the subclasses involved in the class *Complex_characteristics* have the slot *pathology*. The instances for all these classes are created. Every instance for each class, corresponding to some characteristic, is the description of some combination of values of characteristics. These combinations may be found in some pathology, and this fact is indicated by the value of the slot *pathology*, which is related to the respective subclass for pathologies.

2.3 What does instance for subclass Gallbladder mean?

Instance for subclass *Gallbladder*, as a matter of fact, is the pathology description.

Every instance for any subclass of class *Organ* (and particularly, instance for the subclass *Gallbladder*) contains a concrete pathology, characteristics which describe this pathology, and the corresponding image. That is the description of the specified pathology (see Fig. 8). Moreover, since class *Organ* (and all its subclasses accordingly) has the slot, related with class *Patient*, then every instance of subclass of class *Organ* specifies which patients have the given pathology.

2.4 Basic class Pathology

Class *Pathology* is meant for the list of all pathologies structured by organs and different areas. It is created as abstract class and divided into the subclasses corresponding to different organs. At the given stage, the subclass *Abdominal_zone_pathology* is created which contains the following 3 subclasses:

- *Gallbladder_pathology* (gallbladder pathologies);
- *Liver_pathology* (liver pathologies);
- *Pancreas_pathology* (pancreas pathologies).

The subclasses with names of corresponding organs pathologies are included into these classes (see Fig. 9). These classes are related with instances of class *Gallbladder* and of all classes which are in the class *Complex_characteristics*.

3 Conclusions

At the first stage of the ontology elaboration its structure differed slightly from the current one [7, 8]. At the uppermost level there were:

- 4 interrelated classes: *Organ*, *Pathology*, *Patient* and *Image*. From a logical point of view they are the basic ones.
- such classes as *Contents_Gallbladder*, *Contour_Gallbladder*, *Form_Gallbladder*, *Modifications_Gallbladder_Contents_Diffuse*, etc. From a logical point of view, they are not basic classes. They were used for the description of complex organ characteristics.

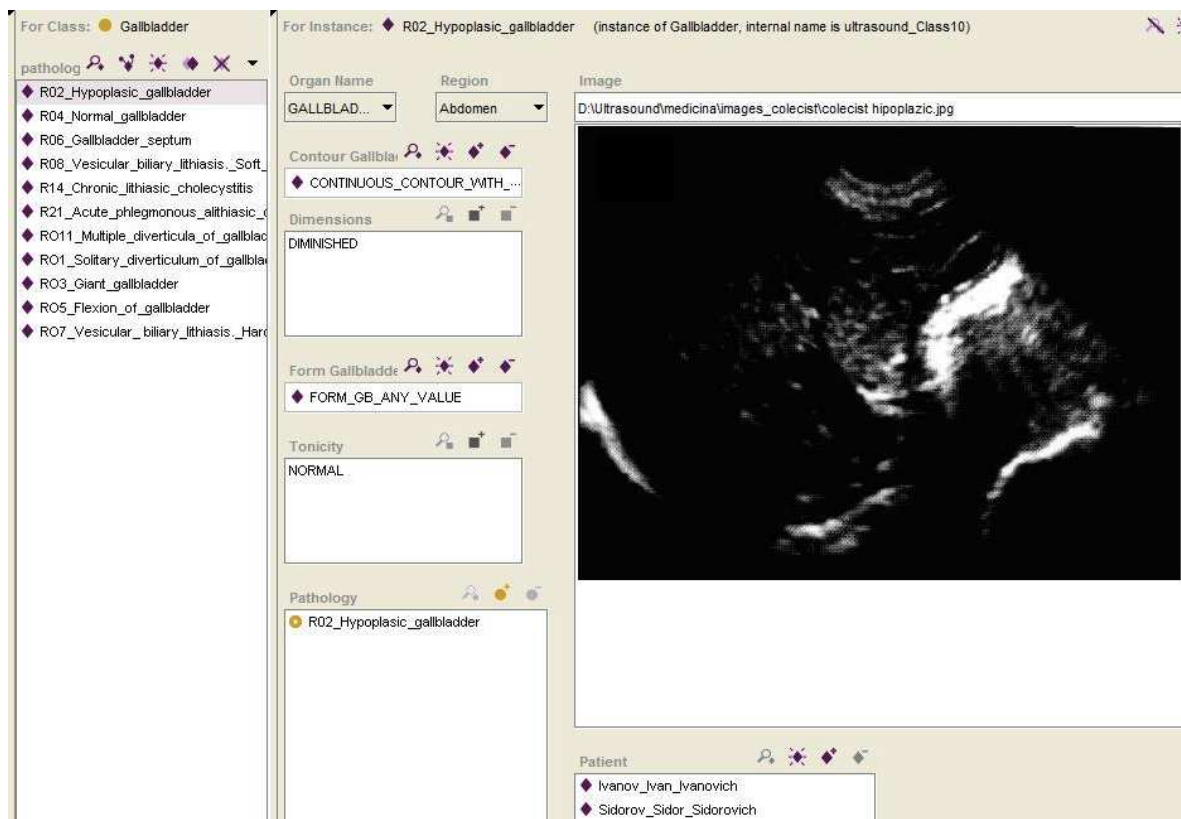


Figure 8: Instance for class *Gallbladder* as the description of the pathology "Hypoplastic-gallbladder".

This structure was ponderous enough and not sufficiently transparent and clear. Thus we decided to introduce at the uppermost level one more basic class *Complex_characteristics* with subclasses *Main_characteristics* and *Additional_characteristics*. So the classes *Contents_Gallbladder*, *Contour_Gallbladder*, *Form_Gallbladder*, *Modifications_Gallbladder_Contents_Diffuse*, etc. were introduced into this structure (see Fig. 1).

These changes in the ontology structure were made rather rapidly and smoothly due to the Protegé [9] flexibility. But the ontology became more transparent. This fact proves once more that the process of ontology elaboration is the iterative one.



Figure 9: Hierarchy of pathologies.

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