CREWS - l'Ecritoire Analysis for the Implementation of a medical image database for mammography

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ABSTRACT

In this paper, we present our approach in order to implement a Medical Image Database (MIDB) for archiving mammograms and their related information in the Department of Radiology of the Necker Hospital (Paris). The aim of such a database is to help breast cancer screening in clinics, research and education.
As implementation of such a MIDB requires the understanding of users' needs, we have analyzed requirements by using the Crews-l'Ecritoire (Cooperative REquirements With Scenarios) approach developed in our laboratory. This approach is based on the "Requirement Engineering" concept. It helps understanding users' needs using a semi-automatic analysis of textual scenarios, i.e. scenarios written in natural language. This approach mixes concepts of goals and of scenarios into the notion of "Requirement Chunk". Authored scenarios and goal discovery are guided by rules, which lead to a structured network of scenarios.
Our analysis resulted in 58 Requirements Chunks gathering 72 authored scenarios and 300 goals which represent MIDB services requested by radiologists in the course of their daily practice.

Keywords: Medical Image Database, Breast Cancer Screening, Requirement Engineering, Mammography.

1. INTRODUCTION

Breast cancer is considered as a major public health problem [1]. Various epidemiological and clinical studies have proven that early diagnosis [2,3] allows for reducing mortality. These studies agree on that only radiological examination (mammography) permits this early diagnosis. Breast cancer screening is based on the association of clinical data and mammographic image interpretation to conclude to the possible presence of abnormalities and their grade (i.e. benign, malignant, suspicious or doubtful).
As above mentioned, all studies advocate one mammography each 2 years after 50 years old [4,5]. Unfortunatly, systematic screening can result in a volume of data which can not be managed by present computer architecture, either in terms of storage capabilities and in terms of exploitation tools.
To overcome these deficiencies, we have designed a mammographic image database (MIDB) based on a model derived from the analysis of digital mammography features, and from users' requirements. Furthermore, we have assigned to this model to be "opened " as far as possible as medical domain image is evolving by nature (e.g., new imaging techniques, improvement in data interpretation).
This database will be interfaced with other medical information systems (PACS, HIS, RIS). It will, thus, allows to reduce data lose (contrarily to the conventional paper-based archiving) and to improve data and report structuring. As a consequence, it will:

- improve patient follow-up;
- make data available and accessible to research teams for various studies (epidemiological, image analysis…), and give them supplementary tool for rationalizing, improving and automating screening data access to facilitate their research;
- capitalize experts' experience.

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We have focused this paper on the part of the model taking into account requirements for microcalcification cluster detection. This model was built using the Crews-l'Ecritoire (Cooperative Requirements With Scenarios) approach, a Requirement Engineering approach developed in our laboratory. It helps understanding the users' needs from a semi-automatic analysis of textual scenarios i.e. scenarios written in natural language. It mixes concepts of goals and scenarios. Authoring scenarios and goal discovery are guided by generic rules which are used to manage any kind of scenarios. As a result, Crews-L'Ecritoire leads to a structured network of scenarios.

2. USERS REQUIREMENTS

The first step of database building is to set up specifications from user requirements. We have defined these specifications from the experience of senologists of the Department of Radiology of the Necker Hospital, department where the mammographic database will be implemented.

2.1 DATABASE USERS

Users belong to three categories [6]. The first category comprises healthcare professionals (HCP) who perform clinical examinations, read and interpretate mammographies. When the result is doubtful, HCPs need complementary examinations such as biopsies. At this moment, HCPs have to face with various kinds of data with their own structure and formats. Using a unified format and structure, both managed by a generic tool such as a MIDB, facilitates HCP tasks. The second category of users is research teams who are working on new solutions to detect and cure breast cancer more efficiently (e.g., computer-assisted diagnosis). Statistical analysis, for example, requires a large amount of cases, and a digital storage would allow access to nationwide data. The third category includes academicals, enrolled for teaching capabilities. Digital atlases, based on MIDB content, allow the training of medical students and are useful during continuing education. Furthermore, MIDB and atlases can help in clarifying difficult cases or in capitalizing expertise and knowledge of experts.

2.2 CHARACTERISTICS

Users have pointed out that the following characteristics must be taken into account for database modeling: security, identification data, demographic data, radiological data, clinical data, histological data, digital image data and image production characteristics [6,7]. Note that clinical and radiological data can change in the time.

1. *Security characteristics***.** Because of the presence of private and legal information, access to data must be strictly controlled. Access to the database is granted either according to the location of the user: outside the hospital (other hospitals, referring physician who sent the patient…), a department inside the hospital (medical, administration, technical…), and his/her function as HCP.
2. *Identification characteristics.* They serves to associate mammographic records with other clinical data from the hospital patient's record. Among others, they include demographic data.
3. *Clinical characteristics*. They include data about health patient history: screening history, current health status, and previous clinical examination.
4. *Radiological characteristics*. They include information such as those defined by BI-RADS [8].
5. *Histological characteristics.* They grasp information about histological examinations such as type of procedure, reporting source, laterality, histopathology, staging, therapy.
6. *Digital image characteristics.* They include image production characteristics and other technical or administrative information such as those defined by DICOM [9] and information about the used analysis procedure (e.g., CAD system).

3. PRESENTATION OF CREWS-L'ECRITOIRE

Several approaches on Requirement Engineering couple goals and scenarios [10,11,12,13,14,15,16]. These approaches overcome some of the deficiencies and limitations of goal-based and scenarios-based requirement elicitation approaches used in isolation. However, they rarely propose a formal methodological way for discovering requirements. Crews-l'Ecritoire proposes a set of formal methodological guidelines for extracting relevant requirements [17,18,19,20].

Crews-l'Ecritoire takes advantage of a bi-directional coupling between goals and scenarios to support requirement elicitation. When a goal is discovered, the approach proposes to author a scenario (coupling in the forward direction). Then, the approach analyzes every scenario to yield new goals (coupling in the backward direction). Starting from a high-level problem statement, the Crews-l'Ecritoire approach guides the discovery of a complete hierarchy of goals illustrated by scenarios to help writing scenarios in a top-down manner. The approach is based on a set of guidelines. These guidelines consist (1) in automated rules to guide goal discovery and (2) in guidelines to guide linguistic analysis and verification of scenarios

The three first sub-paragraphs are devoted to the presentation of the concepts of Crews-l'Ecritoire. The last sub-paragraph presents l'Ecritoire, the tool developed by the Crews-l'Ecritoire team to support the Crews approach.

3.1 THE CONCEPT OF GOAL

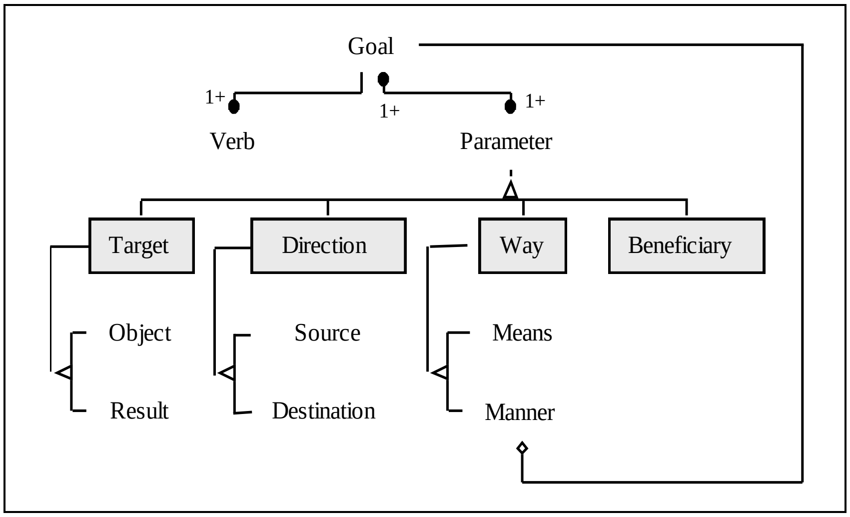

Figure 1. Goal Modeling by Crews (from [18])

In the Crews-l'Ecritoire approach, a goal is defined as "*something that some stakeholders hopes to achieve in the future*" [20]. A goal is expressed as a verb with eight optional parameters [21], each parameter playing a different role with respect to the verb (see Fig.1). For instance, the goal of our project can be expressed by the following sentence:

(Use)$_{verb}$ (of the MIDB)$_{target}$ (which supports radiologists mammography-related activity)$_{means}$ **(G3.1)**
(in the Department of Radiology of Necker Hospital)$_{beneficiary.}$

Parameters are:

1. *The target:* which indicates the entity concerned by the goal. Crews distinguishes between an "*object*" which exists before the goal completion and a "*result*" which proceeds from the realization of the goal. For instance in the goal "*validate the biopsy request*", the biopsy request is the target object because it exists before the course of the scenario. At the contrary , "*obtain the agreement of the second radiologist*", the agreement is considered as the target result of the goal.
2. *The direction* which represents an oriented relationship (arc) between two Crews concepts.
3. *The way of goal realization* which is a two-fold conce t including *"Means"* and *"Manner" f*or achieving the goal. The "*Mean*" indicates the support used for achieving the goal whereas the "*Manner*" gives information about the way the goal is accomplished. For example, in the goal "*communicate patient examination results thanks to a vocal record*", vocal record is the support of the goal and it is identified as a *"Mean*" to "*facilitate screening breast cancer with performing mammograph".* The "*Manner*" is expressed by "*with performing mammography"*. A *"mean''* can be formulated as a new goal. In the previous example, after a new formulation of "*with performing mammography",* we obtain a new goal which is "*performing mammography"*.
4. *The beneficiary* concerns the "*agent*" taking advantage of the goal achievement.
5. *The referent* specifies the entity defining the goal. For instance, "*perform a second interpretation for assessing the primary reading*" plays the role of referent.
6. *The quality* qualifies the goal in terms of qualitative features.
7. *The place* locates the goal in space (e.g., in the Department of Radiology of Necker Hospital).
8. *The time* indicates temporal constraints on goal realization or on scenario.

3.2 THE CONCEPT OF SCENARIO

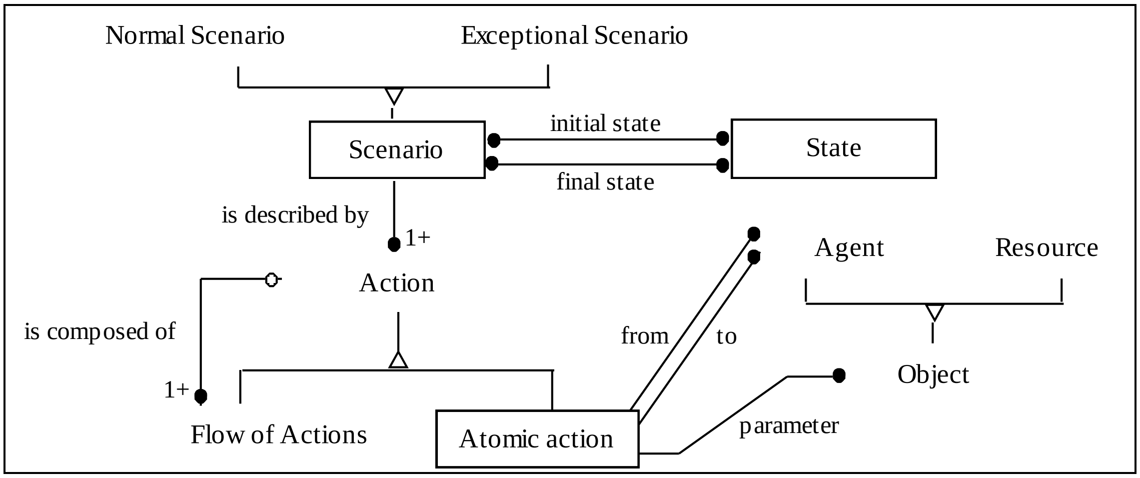

Figure 2. Scenario Modeling by Crews (from [18])

A scenario is "*a possible behavior limited to set of purposeful interaction taking place among several agents*" [20]. It is composed of one or more actions, an action being defined as an interaction between agents (authors). Crews distinguishes between normal scenarios which achieve the goal and exceptional scenarios to manage failures and exceptions [18,19,20].
A scenario is characterized by an initial state and a final state. An initial state defines conjunctive precondtions for achieving the scenario. A final state defines the state to be reached at the completion of the scenario [22] (see Fig. 2). For instance, from the goal G3.1, we can draw the following scenario:

Initial state: The MIDB is online. The user has grant access to MIDB. The user has to perform examination. 1.Obtain previous patient data from the MIDB. 2.Store radiological interpretation report into the MIDB. 3.Complete archiving of clinical data. 4.Complete images archiving into the MIDB (e.g., from image digitalization). **Final state:** Examination is registered into the MIDB. The MIDB is consistent.	**(SC1)**

3.3 REQUIREMENTS CHUNKS CLASSIFICATION AND ABSTRACTION LEVELS

As a goal is defined in intention and a scenario is operational by nature, a Requirement Chunk (RC) is a possible way for achieving a goal from a given initial state. Therefore a RC is defined by a pair <G, SC> where G is a goal and SC is a scenario allowing to reach the goal (see Fig.3) [18,19,20].

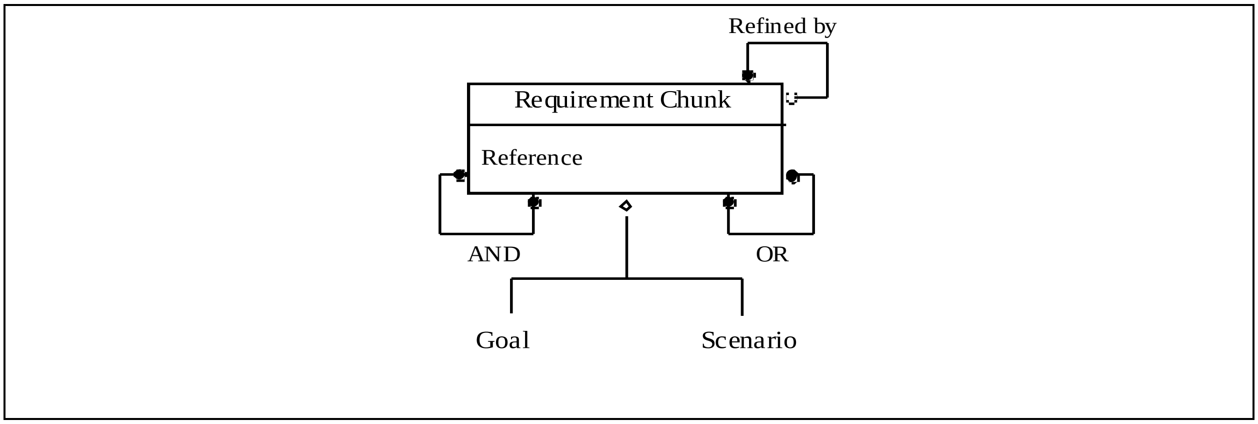

Figure 3. The Requirement Chunk Model (from [18])

Crews introduces three abstraction levels in RCs specifications: contextual, functional and physical.

- The contextual level identifies services to be provided (Contextual level ::= <Design Goal, Service Scenario>).
- The functional level focuses between the system and users to complete the services (Functional level : := <Service Goal, System Interaction Scenario>).
- The physical level deals with the actual performance of the previous level (Physical level : := <System Goal, System Internal Scenario>).

Crews allows to organize RCs according to three strategies in order to construct the RC model, namely: refinement using the (‘‘Refined by’’ connector), complementary (‘‘AND’’ connector) and alternative (‘‘OR’’ connector). This organization is performed thanks to guidelines and rules which allow to map RC defined at a given abstraction level into RCs defined at a lower abstraction level.

3.4 THE TOOL “L’ECRITOIRE”

The tool “l’Ecritoire” [23] was developed by the Crews project team to support the RC notion [20] (see Fig.4), and to guide user in the top-down exploration of a goal-scenario hierarchy. It offers a friendly powerful graphical interface.

Main steps of l’Ecritoire are the following: (1) formulate a goal, (2) analyze a goal to elicit design alternatives, (3) write a scenario to illustrate a goal, (4) verify the written scenario, (5) parse the scenario, (6) analyze the scenario to elicit complementary and alternative goals, (7) analyze the scenario to elicit a refining goal, (8) visualize goal hierarchy and generate the dictionary of terms in the project [23,24].

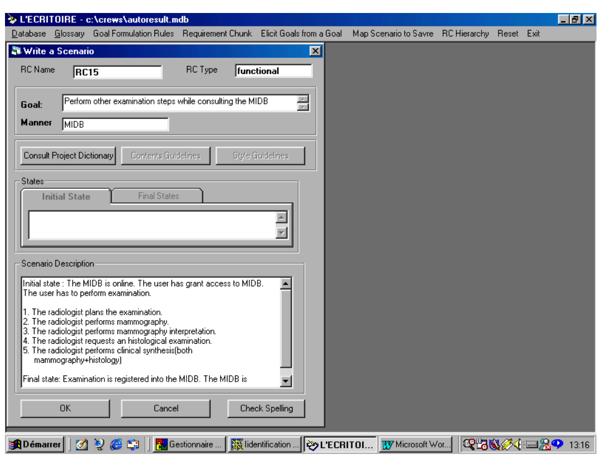

Figure 4. Scenario description as presented by the tool “l’Ecritoire”

4. CONCEPTS UNDERLYING THE MEDICAL IMAGE DATABASE MODEL

This section presents the concepts elicited during our analysis and explains how to translate actions defined at the contextual level into actions defined at the functional level, then into actions defined at the physical level. This translation mainly uses the refinement rule ‘‘Refined by’’ and it results in a structured network of RCs. An example about the use of MIDB is used to illustrate the three previously mentioned strategy of RC organization and to explain how to face with exceptional conditions.

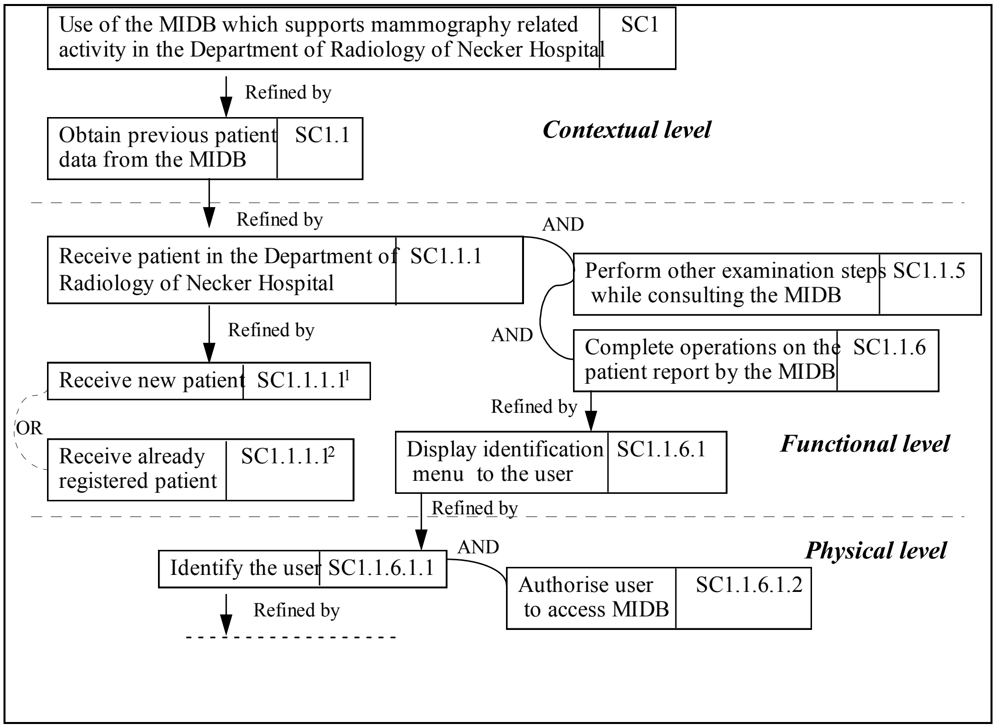

Figure 5. Part of the Requirements Chunks Hierarchy.
SC1 is a sub-goal of the Information System (IS) building. SC1.X... indicates the scenario number.

4.1 THE CONTEXTUAL LEVEL

The contextual level lists services required at the highest level in order to achieve a goal. A contextual RC couples a ‘‘Design Goal’’ to a ‘‘Service Scenario’’.

Let us consider the ‘‘Design Goal’’ associated with the RC ‘‘*use of the MIDB which supports mammography-related activity in the Department of Radiology of Necker Hospital*’’ (see Fig.5). This goal means that the MIDB must provide radiologists with a mean to support their mammography-related activity. In the RC, this goal is coupled with a ‘‘Service Scenario’’ which contains four basic steps: (1) obtain previous patient data from the MIDB, (2) store the radiological interpretation report into the MIDB, (3) complete archiving of clinical data, (4) complete image archiving into the MIDB. These steps are services requested by radiologists in the course of the daily practice and are complementary. They are linked through an “AND"” connector. In the Crews approach, these four steps refine the initial RC. As they also define services, the refinement takes place at the contextual level. This is allowed by Crews when refined scenarios have the same semantics as the initial scenario [25].

4.2 THE FUNCTIONAL LEVEL

The functional level refines services defined at the contextual level when the refinement can be expressed in terms of user-oriented tasks. They lead to ‘‘Service Goals’’ and ‘‘Interaction Scenarios’’.

Let us consider the first refined ‘‘Design Goal’’: “*obtain previous patient data from the MIDB*” (see Fig.5). It includes six steps which correspond to six ‘‘Services Goals’’: (1) receive patient in the Department of Radiology of Necker Hospital, (2) perform clinical examination, (3) verify existence of patient report into the MIDB, (4) save new report into the MIDB, (5) perform other examination steps while consulting the MIDB, (6) complete operations on the patient report by the MIDB. These steps complement one the others and thus are linked through an ‘‘AND’’ connector.

As for contextual level, Crews allows to refine RC belonging to the functional level into new RCs defined at the same level. For instance, the first step *‘‘receive patient in the Department of Radiology of Necker Hospital’’* can be refined in two steps: (1) receive new patient, (2) receive already registered patient’’. As these steps are alternative (i.e. new patient vs. already registered patient), they are connected by an ‘‘OR’’ connector (see Fig. 5). SC4.1 illustrates this refinement process through the refinement of the fifth step (SC.1.1.5) “perform other examination steps while consulting the MIDB” of the SC.1.1. The scenario SC4.1 is defined at the contextual level as follows:

Initial state: The MIDB is online. The user has grant access to MIDB. The user has to perform examination. 1.Receive patient in the Department of Radiology of Necker Hospital. - - - - - 5.Perform other examination steps while consulting the MIDB. 6.Complete operations on the patient report by the MIDB. **Final state:** Examination is registered into the MIDB. The MIDB is consistent.	**SC4.1**

Fifth step is refined at the functional level by:

Initial state: The MIDB is online. The user has grant access to MIDB. The user has to perform examination. 1.The radiologist plans the examination. 2. The radiologist performs mammography. 3. The radiologist performs mammography interpretation. 4. The radiologist requests an histological examination. 5. The radiologist performs clinical synthesis (both mammography+histology). **Final state:** Examination is registered into the MIDB. The MIDB is consistent.	**(SC4.2)**

The step ‘‘complete operations on the patient report using the MIDB’’ is not performed in thisd scenario because our analysis leads to not consider this step as an examination step but as a task performed during the completion of the examination of (scenario SC.1.16,, see Fig. 5).

4.3 THE PHYSICAL LEVEL

The physical level refines the interactions defined at the functional level. This refinement can be expressed in system-oriented tasks. They lead to ‘‘System Goals’’ and ‘‘Internal Scenarios’’.

Let us consider the ‘‘Goal Service” ‘‘*display identification menu to the user”* (see Fig.5). It can be refined in two complementary (i.e. connected by an ‘‘AND’’ connector) steps: (1) identify the user, (2) authorize user to access MIDB. Identification means that the user is registered as user by the MIDB, and known by the MIDB. Access authorization is then

granted by the Database Manager System (DBMS) according access rights defined by the administrator. These can be refined into new Internal Scenarios.The following scenario illustrates the procedure by the refinement of the scenario SC1.1.6.1: ‘‘*display identification menu to the user”.*
SC1.1.6.1 is defined at the functional level by:

Initial state: The MIDB is online. The user has got access to MIDB. The user has to perform examination. 1.**Display identification menu to the user**. - - - - - - - - - - - - **Final state:** Examination is registered into the MIDB. The MIDB is consistent.	**(SC4.3)**

It is refined at the physical level as follows:

.**Initial state**: The MIDB is online. The user has grant access to MIDB. The user has to perform examination. 1.The system asks the user to login. 2.The user introduces his login. 3. **If** the code is valid **then** 4. The system continues the login procedure (see SC1.1.1.2.2) **Final state:** Examination is registered into the MIDB. The MIDB is consistent.	**(SC4.4)**

When ‘‘the code is not valid’’, system denies user to access database. This cannot be expressed in a unique scenario as Crews does not allow the use of the ***IF/ELSE/THEN*** structure into a scenario. In order to manage such a structure, Crews offers the concept of exceptional scenario.This scenario is connected to the ‘‘normal scenario’’ with an alternative connector. In our example, the associated connection rule is:

If code is valid ***then*** perform **SC1.1.6.1.1**
else perform **SC1.1.6.1.1**^{1}

Exceptional scenario SC1.1.6.1.1^{1} managing ‘‘not valid code’’ is defined at the physical level as follows:

Initial state: The MIDB is online. The user has grant access to MIDB. The user has to perform examination. 1.**If** the code is not valid **then** 2. The system denies access. 3. The system is consistent. **Final state:** Examination is registered into the MIDB. The MIDB is consistent.	**(SC1.1.6.1.1^{1})**

5. DISCUSSION AND CONCLUSION

In this paper, we have presented an approach in order to implement a Medical Image Database (MIDB) for archiving mammograms and their related information in the Department of Radiology of Necker Hospital. The aim of such a database is to help breast cancer screening in clinics, research and education.
As the MIDB implementation requires understanding users' needs, we have analyzed requirements by using the Crews-l'Ecritoire (Cooperative REquirements with Scenarios) approach developed in our laboratory. This approach is based on the ''Requirement Engineering'' concept and helps understanding users needs using a semi-automatic analysis of textual scenarios, i.e. scenarios written in natural language. Moreover, Crews permits strong control and verification of the extraction process.

Starting from a high-level problem statement, the Crews-l'Ecritoire approach guides the discovery of a complete hierarchy of goals illustrated by scenarios in a top-down manner. The approach is based on a set of guidelines consisting in (1) automated rules to guide goal discovery and (2) guidelines to guide linguistic analysis and verification of scenarios written in natural language. Use of natural language allows radiologists to understand scenario meaning without having expertise in Crews approach and use.

Our analysis results in 58 Requirements Chunks gathering 72 authored scenarios and 300 goals which represent MIDB services required by radiologists in the course of their daily practice. We have checked each RC against daily practice of clinicians involved in this project. RCs feel to be sufficiently fine and pertinent to allow us to plan implementation of a first MIDB demonstrator. This demonstrator will allow to refine our analysis and to test it in comparison with practice of all HCPs of the department.

MIDB implantation cannot be only based on present results as the aim of Crews is not to extract set of classes and objects for the construction of the design scheme but to analyze user requirements. These requirements serve as input of the design modeling of the MIDB, the next phase of MIDB design. We plan the use an object-oriented approach to perform this conceptual modeling [26]. To be compliant with commercial systems for digital mammography and CAD mammography, terminological systems used by the MIDB to describe and index data must be based on DICOM and BI-RADS dictionaries.

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