

Implementing Guideline-Based, Experience-Based, and Case-Based Approaches to Enrich Decision Support for the Management of Breast Cancer Patients in the DESIREE Project

Brigitte SEROUSSI^{a,b,1}, Jean-Baptiste LAMY^a, Naiara MURO^{a,c,d}, Nekane LARBURU^{c,d}, Booma Devi SEKAR^e, Gilles GUÉZENNEC^a and Jacques BOUAUD^{f,a}

^a*Sorbonne Université, Université Paris 13, Sorbonne Paris Cité,*

INSERM, UMR S_1142, LIMICS, Paris, France

^b*AP-HP, Hôpital Tenon, Paris, France*

^c*eHealth and Biomedical Applications, Vicomtech-IK4, Donostia-San Sebastian, Spain*

^d*Biodonostia, Donostia-San Sebastian, Spain*

^e*Computer Science Research Institute, Ulster University, Newtownabbey, United Kingdom*

^f*AP-HP, DRCI, Paris, France*

Abstract. DESIREE is a European-funded project to improve the management of primary breast cancer. We have developed three decision support systems (DSSs), a guideline-based, an experience-based, and a case-based DSSs, resp. GL-DSS, EXP-DSS, and CB-DSS, that operate simultaneously to offer an enriched multi-modal decision support to clinicians. A breast cancer knowledge model has been built to describe within a common ontology the data model and the termino-ontological knowledge used for representing breast cancer patient cases. It allows for rule-based and subsumption-based reasoning in the GL-DSS to provide best patient-centered reconciled care plans. It also allows for using semantic similarity in the retrieval algorithm implemented in the CB-DSS. Rainbow boxes are used to display patient cases similar to a given query patient. This innovative visualization technique translates the question of deciding the most appropriate treatment into a question of deciding the colour dominance among boxes.

Keywords. Decision support systems, Ontology, Clinical practice guidelines, Case-based decision support, Rainbow boxes, Breast cancer

1. Introduction

Breast cancer is the most common cancer in women worldwide, with nearly 1.7 million new cases diagnosed in 2012. In many countries with advanced medical care, the five-year survival rate of early stage breast cancers is 80–90%, falling to 24% for breast

¹ Corresponding Author, Brigitte Séroussi, Hôpital Tenon, Département de Santé Publique, 4 rue de la Chine, 75020 Paris, France; E-mail: Brigitte.seroussi@aphp.fr.

cancers diagnosed at a more advanced stage. Studies have reported that implementing oncology clinical practice guidelines (CPGs) does improve clinical outcomes in both overall and recurrence-free survivals [1]. Multidisciplinary tumor boards (MTBs) have been introduced and endorsed to ensure that decisions made for the management of cancer patients are consistent with the best available evidence. However, concerns have been raised because MTBs discuss a high caseload, and individual cases usually only receive a very limited amount of time for review. Clinical decision support systems (CDSSs) have been developed to help overburdened MTB clinicians improve the compliance of MTB decisions with CPGs (e.g., [2]).

DESIREE is a European-funded project designed as a web-based software ecosystem for the personalized, collaborative, and multidisciplinary management of primary breast cancer. Beyond offering guideline-based decision support (GL-DS), DESIREE offers experience-based and case-based decision support (resp. EXP-DS and CB-DS) during MTBs renamed as Breast Units (BUs). Whereas guideline-based decision support may suffer from the knowledge gaps existing in CPGs, both EXP-DSS and CB-DSS rely on methods that infer from previously solved clinical cases how to make the best decision for a new patient. The principle of EXP-DSS is to model the clinical know-how expressed in non-compliant decisions. The method is to build new EXP-rules from the description of the patient profiles for which BU decisions did not comply with guidelines and the criteria defined in the decision-making process to justify the non-compliance [3].

This paper is focused on the description of GL-DSS and CB-DSS implemented in the DESIREE platform to support the management of breast cancer patients.

2. Decision support in DESIREE

Decision support (DS) is made of three functional modules, i.e. GL-DSS, EXP-DSS, and CB-DSS, as described in Figure 1. Each module exploits patient data stored in the DESIREE Information Management System (DESIMS) in charge of incorporating the data repository and of controlling the user interface.

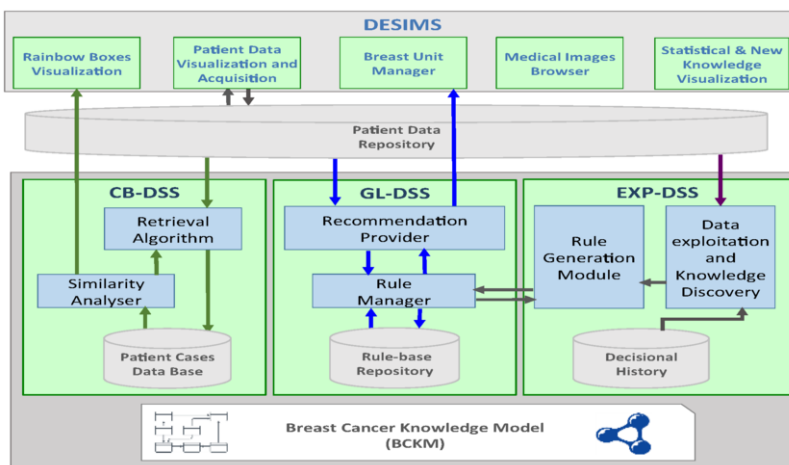


Figure 1. General architecture and information flows among decision support modules.

The output of each DS module is returned to the DESIMS to be displayed to BU clinicians. DS modules are implemented as web services. A central element used by the three DS modules is the Breast Cancer Knowledge Model (BCKM). It describes within a common ontology the data model and the termino-ontological knowledge used for representing breast cancer patient cases [4].

2.1. Guideline-based decision support

We started by the identification of the CPGs to be used by the GL-DSS of DESIREE (NCCN, ESMO, AP-HP, and ONK CPGs). The GL-DSS yields patient-specific recommendations for a given patient case based on the selected CPGs represented as IF-THEN rules. Patient data are transferred from the data repository using FHIR messages. The FHIR bundle is transformed into a triple representation of the patient data (in N3 notation, [5]), consistent with the data model described in the BCKM. Then, rules are matched to the patient representation using a semantic engine (Euler/Eye) that allows for rule-based and subsumption-based reasoning in compliance with the BCKM ontology. Triggered rules infer new patient-derived data and recommendations. Recommendations are mainly made of care procedures, grouped or not into care plans applicable to the patient. In some rules, recommendations are provided as atomic entities that can be combined with additional actions or refined by more specific actions to help the reconciliation of recommendations into care plans performed by the Recommendation Provider. Figure 2 illustrates the GL-DSS output made of three concurrent recommendations: two surgery care plans and a systemic therapy care plan refined by three embedded more specific chemotherapy regimens.

Guideline used: NCCN (exp=false)

1) Mastectomy ^[SHOULD (1)] **1) AxillaryLymphNodeSurgicalProcedure** ^[SHOULD (1)] **1) BreastReconstruction** ^[SHOULD (2A)]
 Rule: R-NCCN-A-inv-I-IIaT3N1M0-M+LN-Surgery+Reconstruction: IF Stage I-II-IIaT3N1M0 THEN Mastectomy AND surgical axillary is recommended (Cat 1) +/-. Breast reconstruction (cat 2A) BINV-2/3.

1) Lumpectomy ^[SHOULD (2A)] **1) AxillaryLymphNodeSurgicalProcedure** ^[SHOULD (GA)]
 Rule: R-NCCN-A-inv-I-II-L+LN-Surgery: IF Stage I-II THEN Lumpectomy AND surgical axillary staging is recommended (Cat 1) BINV-2.

1) BreastCancerSystemicTherapy

> **1) Cyclophosphamide x 4 (14 days)** ^[SHOULD (1)] **1) Doxorubicin x 4 (14 days)** ^[SHOULD (1)] **2) Paclitaxel x 12 (7 days)** ^[SHOULD (1)]
 Rule: R-NCCN-A-inv-NEO-AdJ-HER2-NotT4d-regimens: IF Preoperative systemic therapy is (Possible OR Recommended) AND HER2-negative AND not cT4d THEN ...

> **1) Cyclophosphamide x 4 (14 days)** ^[SHOULD (1)] **1) Doxorubicin x 4 (14 days)** ^[SHOULD (1)] **2) Paclitaxel x 4 (14 days)** ^[SHOULD (1)]
 Rule: R-NCCN-A-inv-NEO-AdJ-HER2-NotT4d-regimens: IF Preoperative systemic therapy is (Possible OR Recommended) AND HER2-negative AND not cT4d THEN ...

> **1) Cyclophosphamide x 4 (14 days)** ^[MAY (1)] **1) Doxorubicin x 4 (14 days)** ^[MAY (1)]
 Rule: R-NCCN-A-inv-NEO-AdJ-HER2-NotT4d-regimens: IF Preoperative systemic therapy is (Possible OR Recommended) AND HER2-negative AND not cT4d THEN ...

^[MAY (2A)]
 Rule: R-NCCN-A-inv-II-IIaT3N1M0-L-Not-CI-except-Tumor-size-NEO-AdJ: IF Stage II or IIaT3N1M0 AND Lumpectomy not contraindicated except for tumor size THEN Preoperative systematic therapy is possible (Cat 2A) BINV-1, BINV-10.

Figure 2. Examples of patient-centered recommendations issued by the GL-DSS.

2.2. Case-based decision support

Case-based Reasoning (CBR) uses previously solved cases stored in the patient cases database to provide a solution to a new query case. In DESIREE, the CB-DSS queries the FHIR server, linked to the DESIMS, for the query case. CB-DSS first parses the query case bundle retrieved from the FHIR server as input attributes to CBR, which includes the similarity analyser and the retrieval algorithm (see Figure 1). The similarity

analyser compares the query case with the patient cases stored in the cases database using various similarity functions, whereas the retrieval algorithm retrieves the most similar patient cases.

The retrieval algorithm is defined using “local” and “global” similarity functions. A patient case is represented as a compound attribute, composed of several simple attributes, including physiological and clinical attributes, such as age, BIRADS, histological type, HER2 receptors, tumour size, etc. Local similarity functions are first applied to compute the distance between simple attributes in the query case against the ones characterizing patient cases in the cases database. In addition to the simple similarity functions like numeric interval, equal, enumerated distance, applicable to compare the simple attributes of integer, string, and enumerated types data type, a semantic similarity function is defined to avail the benefit of the hierarchical placement of concepts in the BCKM. The semantic similarity function computes the distance between the simple attributes of the query patient and those of the patients retrieved from the patient cases database as a degree of taxonomical proximity.

Local similarity measures are first computed for all the patient parameters, then k -Nearest Neighbour (k -NN) is computed as the global similarity function to retrieve the top k similar cases from the patient cases database. The retrieved patient cases are then graphically visualized in the DESIMS using the rainbow boxes visualization technique developed by Lamy et al. [6] (cf. Figure 3).

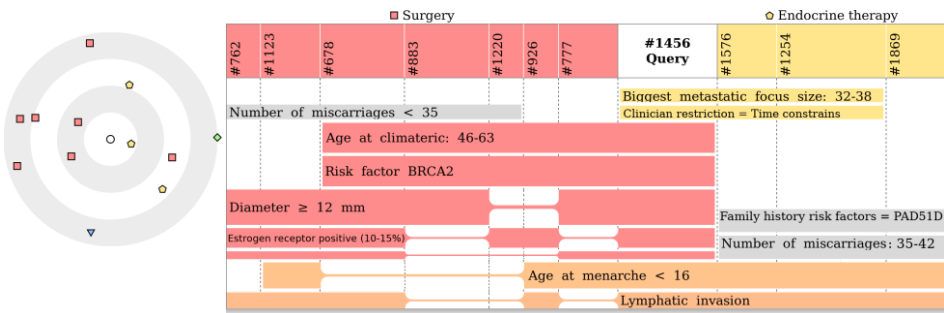


Figure 3. Rainbow boxes visualizing the cases similar to the query case as issued by the CB-DSS.

The left part of the visualization shows an MDS (Multi Dimensional Scaling) scatter plot. The central white circle represents the query case and the other small coloured shapes represent the similar cases. Colours indicate the type of treatment prescribed to the similar cases: red for surgery, yellow for endocrine therapy, green for chemotherapy, blue for radiotherapy. The distance between two shapes corresponds to the dissimilarity between the two cases, and the background target has been added to facilitate the appreciation of the distances involving the query. We can see that seven similar cases received surgery, three received endocrine therapy, one received chemotherapy, and one received radiotherapy.

The right part qualitatively compares the similar cases associated with the two main treatment options. Each case is represented by a column, and columns are grouped by treatment type, with the query case in the middle. Column widths are proportional to the level of similarity with the query. Coloured boxes below column headers represent the characteristics shared by patient cases. Each box covers the columns corresponding to the patients sharing a given characteristic: e.g. patients #1456, #1576, and #1254 have all a “Biggest metastatic focus size between 32 and 38 mm”. Holes may appear in boxes

when patients sharing a given characteristic are not contiguous (e.g., the “Diameter ≥ 12 mm” box) but columns are ordered so as to minimize the number of holes. Boxes that do not cover the query patient are grey. The other boxes are coloured and their colour is the mean value of the colours associated with the columns they cover (weighted by column width). Thus, a box representing a characteristic present only in patients treated by surgery will be red (e.g., “Risk factor BRCA2”), and a box mixing patients with surgery and endocrine therapy will be orange (e.g., “Lymphatic invasion”). In the example displayed in Figure 3, most characteristics of the query patient (i.e. the coloured boxes) are associated with red or reddish colours. Therefore, surgery seems to be the most appropriate type of treatment for the query case.

3. Discussion and conclusion

Three DS modalities have been developed to enrich the decision support proposed to BU clinicians for the management of breast cancer patients. The BCKM formalized as an ontology allows for rule-based and subsumption-based reasoning in the GL-DSS to provide best patient-centered recommended care plans. The BCKM is also used in the CB-DSS to introduce semantics in the similarity function used to retrieve the patient cases similar to a query case. Similar patient cases have been visualized as rainbow boxes. The visualization translates the question of deciding the appropriate treatment into a question of deciding the colour dominance. These DS modalities and their display will be tested within the DESIREE project on simulated patient cases and fake BUs, before being assessed in real-life BUs in various hospitals (in Spain, and France).

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