Semantic-based Decision Support in Healthcare via Radio Frequency Identification

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***Abstract*—RFID technology is widely adopted in healthcare, but pure item identification does not provide benefits in knowledge-intensive medical tasks. The paper proposes an innovative Healthcare Decision Support System (HDSS), based on a semantic enhancement of EPCglobal RFID standard protocols. Annotated descriptions of medications and patient's case history are stored in RFID transponders and used to help caregivers provide the right therapy. The proposed framework includes a lightweight reasoning engine to infer possible treatment incompatibilities and suggest alternatives. The HDSS is independent from back-end infrastructures, enabling full exploitation in ubiquitous healthcare contexts such as first aid, ambulance transport, rehabilitation facilities and home care.**

I. Introduction

Current Radio Frequency IDentification (RFID) solutions [1] enable only elementary item identification applications, relying on a networked database server for the retrieval of item features and properties. If items equipped with RFID transponders (*tags*) could expose to a *reader* not simply a numeric identifier but an articulated description, they might expose themselves directly, without a centralized information repository. Benefits include: (i) reduced latency of item information access; (ii) operativeness even when a networked link to the information server is unavailable; (iii) rich characterization of item properties and capabilities enabling advanced inference procedures over data stored on the tag.

The above features have an undoubted interest in healthcare information systems. RFID technology is increasingly adopted to track and manage patients, staff, equipment and medications within hospitals [2]. Acknowledged benefits include error prevention in identification, tracking and access regulation within and across divisions [3]. Research has also evidenced that Artificial Intelligence can be effective in helping clinicians reduce diagnosis and treatment errors. Ontology-based Knowledge Representation (KR) technologies can enhance current Computerized Physician Order Entry (CPOE) systems, ensuring that only highly relevant information is supplied to physicians and promoting the integration of unobtrusive and context-aware solutions for therapy management. For these reasons, this work presents a ubiquitous Healthcare Decision Support System (HDSS) for innovative medical applications, based on a semantic enhancement [4] of EPCglobal RFID standard protocol [5]. Semantic annotations of both medications and patient's medical profile are compressed and stored on-board of a tag. The main contributions of the proposed framework are: (i) a mobile and pervasive architecture for context-aware decision support; (ii) a knowledge model for patient case history, diseases and treatments amicable to automated inference and extensible to every medical branch; (iii) exploitation of RFID to store semantically annotated descriptions; (iv) semantic matchmaking in healthcare grounded on non-standard inference services.

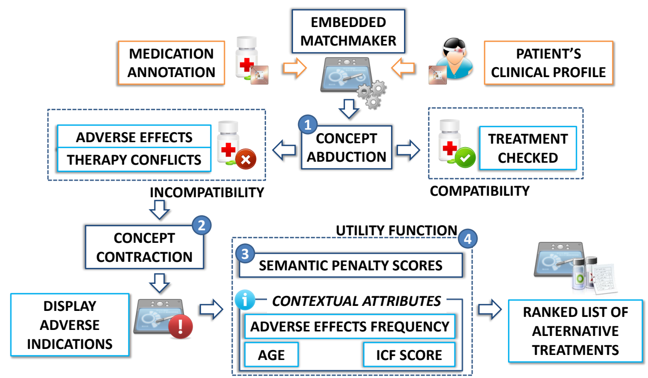

Fig. 1. Diagram of therapy verification process

The next section describes the framework architecture and the matchmaking process at the core of the decision support features, while conclusions and future work close the paper.

II. Proposed Approach

An explanatory scheme of the proposed framework is depicted in Figure 1. The decision support system runs on a mobile computing device equipped with: (i) an RFID reader peripheral for extracting information from tags; (ii) a touchscreen for interaction with the caregiver; (iii) a lightweight embedded reasoning engine [6], providing standard and non-standard inference services. Annotated descriptions stored in RFID tags attached to patients' wristbands, caregivers' badges, pharmaceutical packagings and ward equipment are transmitted to the reader. The $\mathcal{ALN}$ (Attributive Language with unqualified Number restrictions) Description Logic (DL) is the reference formalism underpinning the Web Ontology Language (OWL 2) [7] fragment used for semantic annotation and reasoning[1]. The RFID tag for each instance of patient, caregiver and medication stores a semantic-based annotation in compressed OWL 2 syntax and a set of quantitative attributes. The reference Knowledge Base (KB) models the following main areas of the medical domain.

- Ontology:
  - Anatomy: taxonomy of body structures and systems
  - Taxonomy of treatment classes, related with:
    - general adverse effects
    - interactions (either positive, negative or dangerous ones) with other treatment classes
  - Taxonomy of diseases, related with:
    - affected body structures
    - typical treatment classes
- Instances:
  - Patient's clinical information
    - General information (*e.g.* gender)
    - Disease(s)
    - Current treatment(s)
  - Treatment description
    - Treatment class
    - Specific adverse effects

Non-monotonic inferences in [6] are exploited to discover suitable treatments for a given disease, taking into account the case history of the individual patient. The matchmaker is able to: (i) detect personalized contraindications in a proposed therapy; (ii) arrange best treatment options in relevance order; (iii) explain the matchmaking outcomes. Extra-logical data-oriented attributes –stored within RFID tags– are used to integrate the automated reasoning outcomes, taking context-aware parameters into account in decision support. For patients, attributes consist in age and severity of condition according to guidelines of the International Classification of Functioning, Disability and Health (ICF) framework [8]. For pharmaceuticals, frequency of adverse effects is considered. As shown in Figure 1, Concept Abduction [6] checks whether a given treatment is suitable or not. In particular, treatments and disease descriptions are modeled exploiting disjoint concepts to refer to interested organs and bodily systems. In this way, if a given pharmaceutical presents contraindications for a specific patient, the Concept Abduction check fails due to this incompatibility and Concept Contraction [6] identifies what parts within a therapy annotation cause the incompatibility. A similar approach, based on disjoint concepts, is adopted also to detect interactions between the new treatment to be administered and previous treatments the patient is already taking. The HDSS returns a list of alternative options in a relevance order. By means of *penalty functions* associated to Concept Abduction and Concept Contraction results [6], the system measures the *semantic distance* (hence the affinity level) between each treatment annotation and the description of the patient case history. The semantic distance is then combined with context-specific attributes by means of a *utility function* to obtain the final relevance score and ranking.

[1]The reader is assumed to be familiar with basics of both DLs and semantic matchmaking, and is referred to [6] for examples and wider argumentation.

The proposed framework is independent from centralized back-end infrastructures and is suitable for various ubiquitous healthcare scenarios. Caregivers can use the HDSS on a mobile device for home care and rehabilitation activities; in ambulances, first aid providers can get on-the-fly, in-place decision support. System validation was conducted in a rheumatology case study with *connective tissue disease* (a specific class of rheumatic diseases) patients. By extending the ontology along the adopted patterns, other families of diseases and therapies can be modeled, in order to expand the domain knowledge to further medical fields.

III. Conclusion and Future Work

The paper presented a novel decision support framework for healthcare, based on a semantic enhancement of RFID standard protocol, to help medical personnel in providing correct personalized therapy. A prototype of the proposed system has been built. Further functional and technological evolutions are under investigation including: support for additional communication protocols, *e.g.*, Near Field Communication (NFC), Bluetooth Low Energy (BLE), Physical Semantic Web [9]; alignment of the reference ontology with well-known medical vocabularies (*e.g.*, SNOMED-CT [10]).

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