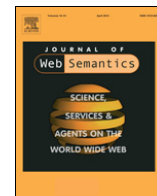




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On the design of a self-medication web application built on linked open data



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ABSTRACT

Open Self-Medication¹ is a Web application that better informs people when treating undiagnosed medical ailments with unprescribed, over the counter drugs, i.e., self-medicating. The application achieves this goal by providing a set of functionalities that ensure safety and efficiency of this practice. The system's most critical operations are processed using a self-medication knowledge base, expressed in OWL, which has been inductively built on medical information obtained from a similar French project. A main characteristic of this application is that almost all the data processed by the system and presented to the end-user comes from a subset of the LOD data sets, namely *DrugBank*, *DailyMed*, *Sider* and *DBPedia*. This paper motivates the design of such an application, provides the design choices, describes some implementation details and presents lessons learned and future work.

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1. Introduction

In OECD (Organization for Economic Co-operation and Development) countries, due to the emergence and wide distribution of the new drugs as well as the aging of populations, the consumption of pharmaceuticals keeps increasing every year. In 2009, the associated bill has been estimated to USD 700 billion, i.e., 19% of the total health spending [1]. On the one hand, this practice comes at an increasing financial cost for the patient and the health system and may also imply some health risks, e.g., contraindications between molecules taken during a given period of time, overdosing a molecule present in different drugs. On the other hand, this rising consumption of drug products is not necessarily correlated with the general public's access to medical information that helps them make more informed decisions. A common practice nowadays is that the general public totally relies on the skills of health care professionals when it comes to the consuming drugs.

Meanwhile, in the same OECD document, it is reported that self-medication (i.e., the act of treating undiagnosed medical ailments with unprescribed drugs) with over-the-counter (OTC) pharmaceutical products typically accounts for approximately 15% of drug spending. This has been exacerbated since 2008, coinciding with the beginning of the financial crisis, with people trying to reduce their health-related spending, e.g., avoiding visits to general prac-

tioners whenever possible. This has contributed to the fact that self-medication is one of the most dynamic drug markets for pharmaceutical companies. Most experts of the domain consider that this practice will accentuate in the coming years. Industrialized countries like France are pushing in this direction by transitioning molecule sets from originally prescribed to OTC, i.e., opening them to self-medication. This political approach can have a disastrous impact on the health of the general public if not guided properly [2].

Due to the increasing practice of self-medication, many government agencies are calling for the development of educational tools targeting the general public on health and medical issues. At the same time, other government agencies, usually in the same countries, are requesting to implement computerized applications based on open data. The Open Self-Medication project aims to satisfy both calls by developing a self-medication Web application fueled on Linked Open Data (henceforth LOD) data sets dedicated to drugs and medicine.

The application presented in this paper achieves this goal by providing a set of functionalities that ensure safety and efficiency of the self-medication practice. With safety, we mean that the system guides the end-user from a set of common mild medical signs to adapted molecules and drug products, but also highlights the risks, e.g., drug interactions, adverse events, of self-prescribing a drug in a given situation. The efficiency argument corresponds to providing a rating, based on a tolerance/efficiency ratio designed by a team of health care professionals, to some identified self-medication molecules. This project leans on the experience of implementing a similar system for the French market. Together

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with Pr. Jean-Paul Giroud (Ph.D., M.D., former pharmacology WHO expert), we have contributed to the practice of a safe and efficient self-medication by releasing several books, recently [3], and Web applications, one of which has been accessible for the last 6 years to over 6 million clients of three major insurance companies in France. This application, named *Les conseils de l'automédication*, is owned by the Santéclair service company and is only granting access to its clients. Recently, an iOS application, namely *Top des médocs*, has been released and is accessible to a larger audience, i.e., those purchasing the application.

Intuitively, the French application, influenced by [4], aims to provide adapted to the general public, objective (i.e., not influenced by pharmaceutical companies), information on drug products sold in France. In just a few interactions, one can select a symptom and obtain information on associated therapeutic classes and drugs. A main feature of this application is the rating of drugs, i.e., a typical French score between 0 and 20, based on an efficiency/tolerance ratio. This ratio depends on the drug's composition, i.e., its set of molecules, as well as its indication. The cornerstone of the system is a drug database which is the result of years of medical and pharmacological research, e.g., translating drug characteristics into chunks of text that are easily understandable by the general public. The back end of the Web application is based on the use of a knowledge base which has been designed and enriched using inductive reasoning over the drug database [5]. The ontology that underpins this knowledge base also serves to ensure the quality of the drug data by performing molecule-oriented inferences [6]. That is reasoning over the properties, e.g., contraindications, of molecules contained in a drug rather than on the properties of a drug. This approach enables us to identify drugs in the scope of self-medication by reasoning over the molecule it is composed of.

Unlike the system we developed previously for the French market, the Open Self-Medication application more heavily uses data originating from the open data initiative. Hence, we believe it will be of practical value to a more general audience of Web users since it enables us to retrieve information from different health systems. To achieve this goal, we had to define correspondences between the molecule identifiers found in our select LOD sets and the ones already present in our Knowledge Base. Our main motivation is to leverage open data, as represented in Semantic Web technologies, and to apply our experience with the French system toward a self-medication application that will better serve an international audience, i.e., support for drug products sold in different countries and providing their description in different languages. Moreover, the goal of using open data amounts to accessing large volumes of data which are hard to obtain in the proprietary pharmacological domain.

2. Related work

The design of a self-medication application is relatively novel and does not currently correspond to any existing work. Nevertheless, related work exists on the topic of exploiting LOD in domain such as life sciences and medicine. As a motivation for our approach, [7] considers that using open data is one of the most efficient ways to collect data and knowledge on the medical domain at large scale. Moreover, as explained in [8], semantic technologies will prove to be amongst the most reliable methods to search into these data sets. In [9], the authors motivate the technical aspects selected during the creation of the Open Pharmacological Space (OPS), a drug discovery platform part of the Open PHACTS project. Although the principal goal of this application differs from ours, i.e., helping in drug discovery versus providing accurate drug information on known products, the approaches share some common aspects such as exploiting data sets of the LOD cloud. We also share opinions on the data quality issue of some of these data sets.

[10] presents the Linking Open Drug Data (LODD) W3C's task force and its project of linking drug related data, some of which have been used in this project. It also proposes best practices for exposing data that could fit efficiently into LOD. Finally, [11] describes an experience in developing a food ontology in the context of the FP6 PIPS (Personalized Information Platform for Health and Life Services) project. The ontology development process did not rely on an inductive approach like Open Self-medication and did not use external knowledge repositories as most recent approaches do.

3. LOD data sets

Some design choices concerning this application were mainly motivated by the results of investigating the LOD data sets relevant to the domain of self-medication. The data sets we formally considered were *DrugBank* [12], *DailyMed*,² *Sider*,³ *DBPedia* [13], *LinkedCT*,⁴ *Diseasome*⁵ and *FreeBase* [14]. We finally retained only the first four since we considered that the others were not adapted to self-medication, e.g., *diseasome* and *LinkedCT*, or were less precise than some selected data sets, e.g., *FreeBase* vs *DBPedia*.

An in-depth study of our selected data sets rapidly emphasized that the central concept of this application's first version would not be the same as in our French system. The central concept in the French application corresponds to a Drug product for the following reasons: (i) a unique identifier, namely the CIP (Club Inter Pharmaceutique) code, is provided to each drug product being sold in France, (ii) information sources are available, although distributed over the several providers, e.g., ANSM (*Agence Nationale de Sécurité du Médicament et des produits de santé*), on these products and (iii) market evolution on these products are also available, i.e., modification, emergence and withdrawal of products. Thus it is possible to maintain an almost exhaustive, up-to-date and accurate drug database for these drugs. Note that (i) and (ii) are characteristics of different national health systems and are not consequences of LOD per se. These three properties also enable us to rate drugs and molecules in a consistent manner. The ability of rating molecules is quite useful in cases of compound drugs containing several molecules with different dosages. For instance, our health experts can use the rating of some molecules to help in defining the rating of a drug composed of several molecules. In the case of drugs found on LOD, we have not found an accurate and consistent list of identified drugs available on the market at a given time. For instance, at the time of developing this application, data sets such as RXNorm are not present on the LOD cloud. For this reason, we have currently decided to only rate molecules and to consider non-compound drugs. Moreover, drug products containing a single molecule generally have better properties, i.e., less drug interactions, contraindications, side-effects, and hence have higher rates and provide a better service to the patient. Nevertheless, we are already working on compound drugs since informing the general public about inefficient or/and dangerous drug products should also be an important feature of our system.

4. Self-medication knowledge base

The issue of selecting the molecules fitting in the field of self-medication is non-trivial. This is partly due to the absence of an explicit 'self-medication' indication in most drug data and knowledge bases. In fact, we consider that being an OTC drug is not a

² <http://dailymed.nlm.nih.gov/dailymed>.

³ <http://sideeffects.embl.de/>.

⁴ <http://linkedct.org/>.

⁵ <http://diseasome.eu/>.

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