Development of a Medication Reconciliation Tool for Norwegian Primary Care EPR Systems: Experiences from a User-initiated Project

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Abstract. Medication reconciliation is one of the most important priorities of national and international patient safety efforts, due to the numerous deaths and adverse drug reactions caused by inappropriate medication use. One of the main challenges of general practitioners (GPs) is to get an overview of changes in the patients' medications after transitions between healthcare institutions. This paper presents how Natural Language Processing of free text notes such as discharge summaries is used to automatically extract information about medications and how this can be compared to the patient's existing medication list in an electronic patient record (EPR) system. The functionality has been developed in a user initiated project, as a cooperation between four different vendors and with a strong involvement of the end users. The functionality is available for most Norwegian GPs and is seen as a very useful tool in the medication reconciliation process.

Keywords: Medication reconciliation, natural language processing, user centered development

1 Introduction

1.1 Medication Reconciliation

Medication reconciliation is the proposed formal, systematic strategy to overcome medication information communication challenges and reduce unintended medication discrepancies that occur at transitions in care [1]. When conducted as intended, medication reconciliation is a conscientious, patient-centred, interprofessional process that supports optimal medication management [2].

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The lack of medication reconciliation is seen as a significant challenge to patient safety. Several studies have shown that different healthcare professionals, the patient and the relatives do not have the full overview of the patients' prescribed medications, particularly after transitions between different healthcare insitutions. Not having the full overview of medication use is one of several causes of adverse drug reactions [3–5].

Several ongoing initiatives focus on processes where different health care providers such as physicians, nurses, and pharmacists cooperate with patients and their relatives to ensure accurate and consistent medication lists across transitions in care. In Norway, three of eleven focus areas in the Norwegian Patient Safety Programme: In Safe Hands [1] are related to medications: Medical reconciliation, drug review in nursing homes and drug review in home care services. Other programmes have been introduces in other countries. For example, the Institute for Safe Medication Practices in Canada[2] support medication reconciliation at a provincial, national and international level, and the Agency for Healthcare Research and Quality[3] in the US has developed a toolkit for organizations to develop medication reconciliation based on knowledge of best practice.

However, the medication reconciliation process is tedious and time-consuming, and there has been a lack of electronic systems that facilitate the process of comparing and adjusting medication lists from different sources such as discharge summaries from hospitals or nursing homes and the "medications in use" list in the general practitioners (GPs) electronic patient record (EPR) system. In Norway, this has been done by the GPs, who had to print lists of medications on paper from their own EPR system as well as lists received in e.g. discharge letters, and then comparing each medication manually. The result then had to be entered into the EPR system. If the patient uses many medications the comparison process becomes complex and sometimes neglected.

This paper presents how natural language processing of free text notes such as discharge summaries has been used to automatically extract information about medications and how this can be compared to the patient's existing medication list in an EPR system. The functionality has been developed in a user initiated project, as a cooperation between four different vendors and with a strong involvement of representative end users.

1.2 Natural Language Processing

Several studies have shown how information technology and natural language processing (NLP) is used to facilitate the medication reconciliation process [6, 7]. Some of the main challenges are that the medication information is coming from multiple sources, using different controlled terminologies that has to be consolidated.

[1] Norwegian Patient Safety Programme, http://www.pasientsikkerhetsprogrammet.no
[2] Institute for Safe Medication Practices Canada, http://www.ismp-canada.org/medrec/
[3] Agency for Healthcare Research and Quality, http://www.ahrq.gov/qual/match/

Basic lexical approaches, such as keyword matching, may sometimes be appropriate for detecting simple concepts from medical free-text [8, 9]. Problems such as understanding the medical context [10], recognizing negative terms and ending up with too many false positives [11] may, however, be common. To achieve higher accuracy, natural language processing techniques are often employed, at the cost of higher development complexity [12, 13]. The well-defined sub-language of the medical domain is often considered suitable for linguistic processing, given that the vocabulary is more restricted than in general language and sentences can be terse and to the point [14]. On the other hand, this creates its own set of problems when using e.g. parsers trained on typical corpora, such as newspaper texts, in particular related to ungrammatical language, spelling mistakes and non-standard abbreviations.

Traditional deep-linguistic grammars can be difficult to implement and are prone to producing too many and ambiguous results. A simpler approach is to use partial or shallow parsing [15]. With full parsing, the goal is to produce a complete parse tree of a sentence. A shallow parser will only concern itself with finding the parts of a sentence that are deemed relevant. While building a full parser for natural language will be a difficult task for even restricted medical domains, constructing a shallow parser is a far simpler option. Moreover, in many cases the problem is to identify the parts of a sentence that are of interest. With this in mind, shallow parsing can be a viable approach towards identifying medication administration events.

1.3 Project Overview

The project was initiated in 2011 by the Norwegian College of General Practice (Norsk forening for allmennmedisin - NFA) Reference Group for EPR. The members of the reference group are general practitioner specialists who have a special interest in ICT and EPR systems, and a particular interest in how to obtain improved systems that can function as useful tools for the GPs in their daily work with patients. Developing a tool for medication reconciliation was the top priority of the reference group, and a requirements specification for the solution was developed in cooperation with the Norwegian Centre for Informatics in Health and Social Care. The suggested solution was to develop a module for extracting and comparing medication information from different sources. During the period from September 2011 to September 2012, a project plan was developed and agreed between NFA, Vivit[4], and the three major Norwegian general practice EPR system vendors. Vivit's role in the project was to develop functionality for recognizing and extracting medication information that could be integrated with

[4] Vivit is a small Norwegian company with high competence and experience in the field of health informatics. Vivit focus on user-centered design and development, including empirical methods for user-centered requirements elicitation and analysis, usability testing and evaluation of clinical information systems, and methods for search, de-identification, and secondary use of electronic patient information. The company was founded in 2009 by former health informatics researchers from The Norwegian University of Science and Technology (NTNU).

all the major Norwegian general practice EPR systems. The partners signed the project agreement in September 2012, and the first version of the system was implemented and tested by pilot users in February 2013. In May, 2013, version 1.0 was launched, and from January, 2014, the solution has been available for the majority of Norwegian GPs.

2 Objectives and Main Issues

The main objective of the project was to develop a method for extracting medication information from unstructured text.

Several issues had to be resolved to ensure a successful project outcome: The discharge notes that were to be matched against the medication information in the primary care EPR system were provided as free-text with no semantic or structural markup. Input from several different hospital and elderly care EPRs were to be expected, with no standardized ways of structuring the information. Accordingly, a method for extracting medication information from natural language had to be devised.

A prerequisite for the project was that the new medication reconciliation functionality had to work with three different EPR systems developed by separate, competitive, vendors. Each system had its own approach towards storing medication information, hence a joint interchange format had to be developed.

3 Methods

A set of 100 extracts from discharge notes were collected from various general practice patient records. The source material was discharge notes that were sent via electronic messaging from the hospital where the patient in question had undergone treatment. Since we were only interested in medication information, only the parts of the discharge note that contained such information were used. This also helped ensure that there was no identifying information in the extracted text. To evaluate the system, a gold standard was needed. An annotator was given the task of marking up all relevant medication information (medication name, dosage and frequency) in the 100 training notes. The annotation was done independently from the software development. The annotation was performed by a health informatics researcher. Based on the information available to us, we created a set of EBNF-like [16] grammars that represented various ways of describing medication information. The key part of the grammar were the terminals representing medication names. We made use of the FEST database, which is a national database containing information about all medications available on the Norwegian market. In additional to the medication names, FEST also includes associated ATC (Anatomical Therapeutic Chemical Classification System) codes, information about dosages, frequencies, and various ways of administering each drug. Much of this information could be imported directly as grammar terminals, thus simplifying the grammar building process. The grammars were compiled into a general text matching module, implemented in the

C# language. This module would take two inputs: The unstructured text (e.g. discharge notes) and a structured list of medications from the primary care patient record. The key steps of the processing pipeline were as follows: 1) The text would be split into sentences and tokenized; 2) text matching was applied, returning a list of extracted medications including their location, dosage and frequency; 3) the extracted medications were compared with the known medications, producing a list of matched extracted and known medications. The reconciliation between known and extracted medications was done by doing a combined semantic and syntactic comparison between the two medication sets. For instance, medications would be matched by both name and ATC code, meaning that two medications with different names but the same ATC code were eligible match candidates. Having found a set of possible match pairs, the additional information about dosage and frequency, including possible synonyms, would be included in the comparison. By calculating the Levenshtein string similarity metric [17] between normalized versions of all possible match candidates, the matches that resembled each other the most would be returned as match pairs. The remaining medications where no match was found would be returned as a single medication item with no corresponding match. Due to the use of string similarity measures, the match would be slightly fuzzy by nature, meaning that inexact matches were allowed. In practice, this turned out to be a minor issue, since the user interface could highlight differences between the matches. Also, the output from the extraction module was only intended as a decision support aid. Each suggested medication match would have to be approved manually with a conscious decision of whether or not the match was likely to be correct.

4 Results and Findings

Upon project delivery, the results were evaluated on a sample of 25 notes from the original 100 note test set. Table 1 summarizes the results. To understand the results, note that dosage and/or frequency will never be extracted if an associated medication is not found. If a medication has no dosage, it will still count as a true positive for MD and MDF if no dosage is extracted. Also note that no false positives were found for this evaluation. From user feedback we later learned of (and fixed) false positives, but in practice these are fairly rare.

Table 1. Evaluation Results

Match type	True positives	False negatives	Total	Precision	Recall
Medication (M)	201	10	211	100%	95,2%
Medication and dosage (MD)	175	36	211	100%	82,9%
Medication, dosage and frequency (MDF)	141	70	211	100%	66,8%

4.1 Implementation in EPR Systems

The module has been implemented by the three EPR vendors that participated in the project. Figure 1 shows a part of a screenshot from the Infodoc Plenario EPR system [5].

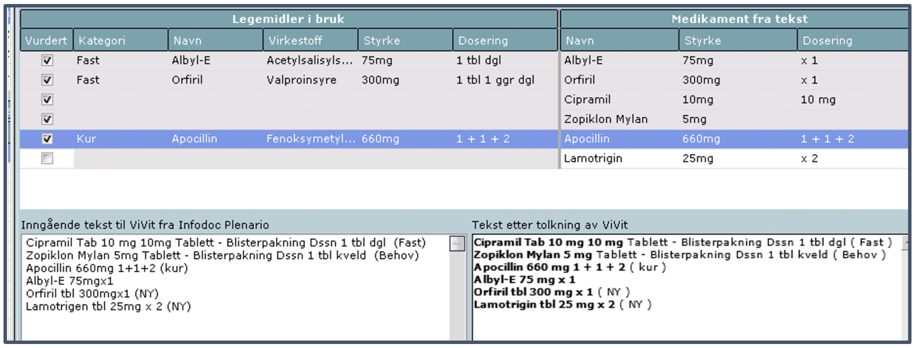

Fig. 1. Screenshot from the Infodoc EPR system

The lower left part of the figure shows the incoming text that has been pasted from a discharge summary. The lower right part of the figure shows the information that has been recognized by the Vivit module in bold text. The upper left part of the figure shows the initial medications in use list, and the upper right part of the figure shows the recognized medications from the discharge summary. The table is sorted in order to match similar medications on corresponding lines.

The physician has to assess every entry in the list in order to accept or reject the suggested changes of the list. New medications can easily be prescribed as the new values are automatically transferred to the prescription user interface.

4.2 The system in Use

All the vendors involved in the project have implemented the solution in their EPR systems, hence the solution is available for practically all Norwegian GPs. However, the vendors have different processes for making the new functionality known to their customers and not all GPs are aware of the functionality. In addition, the vendors have implemented the module in different ways, and the user interface solution may affect how the users perceive the usability of the medication reconciliation solution. A systematic evaluation of the solution is currently being carried out, but the results are not yet ready. However, the responses from many GPs are positive, although there is obviously room for improvement. Some GPs are enthusiastic and state that

[5] http://www.infodoc.no/

> *The new tool for synchronizing medication lists is really simplifying the task of comparing and adjusting medication lists between our patient records and the hospitals.* (Specialist General Practitioner, using the module with InfoDoc EPR system)

and

> *The new tool is very useful and makes my daily work easier!* (GP, using the module with WinMed 3.0 EPR system)

Other users find the functionality useful, but miss more information about dosage and frequency, which is important when comparing medications. Further, the module is able to recognize and correct some spelling mistakes, but not all. If this could be improved the usability would have been better. At the moment, medication from unstructured text is better recognized than text in a semi-structured format, which is often used in the Care Sector in the Municipalities. Finally, some GPs would like the functionality to be more automatic, as it still may take considerable time to review the patients medications even with the module. After the different lists are compared, the physician must determine which medications the patient should use or not, and this has to be done for example by clicking on each individual medication.

5 Discussion

The new module does not make the medication reconciliation process automatic, but it offers a tool that can be seen as a decision support system that enables physicians to easily import medication information from various sources into the EPR system. The EPR systems were developed in the same programming language (C#), but they used different versions of C# and .NET. The developed functionality had to work with all systems, so a lowest common denominator approach had to be used when writing the software. This also put some constraints on the use of third-part libraries.

There is no standardised way of denoting medication information. As an example, when denoting medication frequency, the terms x 1 and [1+0+0+0] both mean the same thing (once a day). To some extent the project had to cope with such syntactic differences.

As with almost all clinical text, spelling errors are common in discharge notes. It was a strong requirement that minor spelling mistakes should be handled. We had access to 100 discharge notes as training/example data. This is a fairly small amount of data, which made the use of machine learning methods difficult. Moreover, no gold standard was available, meaning that this had to be developed as part of the project. The annotation was performed by a health informatics researcher with background in computer science. Using more annotators with different backgrounds (e.g. pharmacists, healthcare professionals) could probably have increased the validity of the annotation.

The recall rate for medications is mostly explained by the use of medication names that were not found in the FEST database (typically colloquial terms) and major spelling errors that the module was not able to correct. The lower recall for frequency descriptions can be ascribed to a larger variety of expressions when describing frequencies than what is the case for dosages. The evaluation of the module shows that most medications are recognized, while the recall for dosage and frequency is lower. However, as it is easy to change dosage and frequency values, the users find the functionality very helpful as long as most of the medications are recognized. As more end-users start using the new functionality, feedback and error reports are basis for continuously improvement of the grammar. With partial parsing, the grammar strictly defines the elements that we are able to extract. This means that every false positive requires adding additional rules to the grammar. To make this work, the parser developer must take care so that grammar additions do not break previous functionality. In our experience this calls for a structured, iterative approach to grammar development. Having a full set of unit test cases makes grammar development a lot easier and safer. A positive side-effect is that with this approach the precision is usually very high, at the expense of lower recall. Another problem with shallow parsing approach is that it is not ideal for extracting complex narrative. For simple medication, dosage and frequency extraction we have seen that this is not a big problem due to the usually structured notation. However, building a grammar that e.g. extracts the reasoning behind a prescribed medication will be a lot more difficult, this because reasons usually are given in natural language. A shortcoming with the evaluation was that it was performed on the same material as was used for building the grammars, this due to the relatively small amount of data available to us.

5.1 User Involvement

Experiences from several ICT projects in the health care sector show that a lot of projects do not involve end users in the development. The results are often systems that can be found annoying and time-consuming, failing to meet the needs of the end users. The project presented in this paper was initiated by highly active and engaged users with a real need for improved functionality of their EPR systems. The involvement of the users and their participation in the pilot testing and the approvement of the solution was a clear advantage in order to ensure the success of the project.

6 Conclusions and Further Work

The project presented in this paper has shown how joint efforts and cooperation of end users and vendors have led to the development of new, common functionality that supports the medication reconciliation process.

6.1 Further Work

As part of the project follow-up, the medication reconciliation module will be continuously improved and updated bi-monthly with the latest version of FEST as well as general quality improvement. This will ensure that the module stays up to date.

Repeating the evaluation on a new set of test data will give a clearer view of real-world precision and recall. Another important aspect is to measure end-user satisfaction with the medication reconciliation tool and how this affects their daily work. For this purpose, a survey is being performed on end users and results are likely to be ready later this year.

To improve recall, making use of machine learning technologies is a viable option. This will, however, require more test data. A benefit of having a hand-crafted extraction module with high precision is that it can probably be used for automated annotation (i.e. applying the module to new test data) so as to make the gold standard creation job much easier.

List of Abbreviations Used in the Paper

ATC	Anatomical Therapeutic Chemical Classification System
EBNF	Extended Backus-Naur Form
EPR/EHR	Electronic Patient Record/Electronic Health Record
FEST	Prescription and expedition support (Norwegian: Forskrivnings- og ekspedisjonsstøtte)
GP	General Practitioner
ICT	Information and Communication Technology
NLP	Natural Language Processing

References

1. Lo, L., Kwan, J., Fernandes, O.A., Shojania, K.G.: Medication reconciliation supported by clinical pharmacists. In: Making Health Care Safer II: An Updated Critical Analysis of the Evidence for Patient Safety Practices. Evidence Reports/Technology Assessments, No. 211. Rockville (MD): Agency for Healthcare Research and Quality (US) (2013)
2. Greenwald, J., Halasyamani, L., Greene, J., LaCivita, C., Stucky, E., Benjamin, B., et al.: "aking inpatient medication reconciliation patient centered, clinically relevant and implementable: A consensus statement on key principles and necessary first steps. Journal of Hospital Medicine **5**(8) (2010) 477–85
3. Mjörndal, T., Boman, M.D., Hägg, S., et al.: Adverse drug reactions as a cause for admissions to a department of internal medicine. Pharmacoepidemiol Drug Saf. **11**(1) (Jan-Feb 2002) 65–72
4. J, E., I, B., J, E., et al: Drug-related deaths in a department of internal medicine. Archives of Internal Medicine **161**(19) (2001) 2317–2323
5. DT, L., JD, K., DB, P., A, L., RG, B.: Hospitalization and death associated with potentially inappropriate medication prescriptions among elderly nursing home residents. Archives of Internal Medicine **165**(1) (2005) 68–74
6. Bassi, J., Lau, F., Bardal, S.: Use of information technology in medication reconciliation: a scoping review. Annals of Pharmacotherapy **44**(5) (2010) 885–897
7. Cimino, J.J., Bright, T.J., Li, J.: Medication reconciliation using natural language processing and controlled terminologies. In: Medinfo 2007: Proceedings of the 12th World Congress on Health (Medical) Informatics; Building Sustainable Health Systems, IOS Press (2007) 679–683
8. Giuse, D.A., Mickish, A.: Increasing the availability of the computerized patient record. Proc AMIA Annu Fall Symp (1996) 633–7
9. Goldman, J.A., et al.: Term domain distribution analysis: a data mining tool for text databases. Methods Inf Med **38**(2) (1996) 96–101
10. Honigman, B., et al.: A computerized method for identifying incidents associated with adverse drug events in outpatients. Int J Med Inform **61**(1) (2001) 21–32
11. Murff, H.J., et al.: Electronically screening discharge summaries for adverse medical events. J Am Med Inform Assoc **10**(4) (2003) 339–50
12. Hripcsak, G., et al.: Unlocking clinical data from narrative reports: A study of natural language processing. Ann Intern Med **122**(9) (1995) 681–688
13. Hripcsak, G., Kuperman, G., Friedman, C.: Extracting findings from narrative reports: software transferability and sources of physician disagreement. Methods of Information in Medicine **37**(1) (1998) 1–7
14. Spyns, P.: Natural language processing in medicine: an overview. Methods Inf Med **35**(4-5) (1996) 285–301
15. Li, X., Roth., D.: Exploring evidence for shallow parsing. Proc of Annual Conference on Computational Natural Language Learning (2001)
16. Scowen, R.S.: Extended bnf – a generic base standard. Software Engineering Standards Symposium (1993)
17. Navarro, G.: A guided tour to approximated string matching. ACM Computing Surveys **33**(1) (2001) 31–88