Application of a Regenstrief RELMA V.6.6 to Map Russian Laboratory Terms to LOINC

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Keywords
LOINC, laboratory information system, hospital information system, semantics

Summary
Background: Manual mapping of laboratory data to Logical Observation Identifiers Names and Codes (LOINC) requires a major effort. Application of the LOINC mapping assistant RELMA V.6.6 can reduce the effort required for mapping. The goal of the paper is to perform a semi-automated mapping of Russian laboratory terms to LOINC.

Methods: A semi-automated mapping of the 2563 terms from two clinics in Russia was performed. The first step was automatic mapping using RELMA V.6.6 and LOINC V.2.48 Russian translation by Yaroslavl state medical academy. The second step was a manual expert mapping. To evaluate the correctness of mapping all the mapped terms were reviewed by two experts.

Results: The paper presents the results of semi-automated mapping of Russian laboratory terms to LOINC. Two clinics (A and B) and a laboratory service participated in the project. The following results were achieved: mapping of 86% terms from Clinic A and 87% from Clinic B. It has to be mentioned that 99% of terms used in 2014 were mapped. In total 2398 out of 2563 were mapped.

Discussion: The required effort was reasonable and the price of mapping and maintenance was considered as relatively low in comparison to manual methods.

Conclusion: RELMA V.6.6 and LOINC V.2.48 offer the opportunity of a low effort LOINC mapping even for non-English languages. The study proved that the mapping effort is acceptable and mapping results are on the same level as the manual mapping.

1. Introduction

The integration of laboratory information systems (LIS) and hospital information systems (HIS) is growing fast [1]. The data exchange process usually consists of the following steps: HIS defines a task for laboratory tests, the task is exported to a LIS, a LIS exports the results back to a HIS [2, 3]. Laboratory analysis results are usually well-structured and defined data elements that are automatically generated and stored [4]. As electronic health records (EHR) become more widespread, clinical laboratories are increasingly delivering reports electronically in a form that can be directly stored in the client’s EHR. However, the content of EHR, is often coded using locally developed schemes [5]. Integration with each HIS requires that individual laboratory terms are carefully inspected and mapped to a common set of concepts that are in use in the laboratory. Every laboratory introduces new tests on a constant basis. This requires that the mapping is maintained and the mapping scheme should be kept up to date, which is highly resource consuming work. The choice of a coding system in Russia is usually left to laboratory service. Usually local idiosyncratic codes are used and no universal coding scheme has yet gained a widespread acceptance. This situation is particularly of current interest in Russia, where international identifiers and coding schemes face a problem of translation. The Logical Observation Identifiers Names and Codes (LOINC) terminology [6–8] has been reported to be a very efficient tool for being a basis for definition and exchange of laboratory data. It provides a large, structured and multiaxial coding system for clinical observations with a major focus on laboratory data. LOINC terminology covers at least 98% of the average laboratory’s tests [9]. During its development, researchers already used the logical structure of LOINC terms as a way to translate local terms into LOINC for the purpose of sharing patient data [10]. However, its application in Russia is very limited and it is not used by laboratories in their routine work.

Since LOINC was introduced in 1996, it has been cited in more than 140 peer-reviewed publications addressing its use for coding EHR data, mapping between terminologies and other topics. However, the application of LOINC for routine use in clinical laboratories has been limited. Published LOINC mapping projects indicate that the availability of efficient tools and the effort to define and maintain full coverage of lab-

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oratory observations are important factors influencing the decision to employ LOINC as a coding system [6, 8, 11–17]. In addition to the LOINC database, Regenstrief has developed a free software program called RELMA (the Regenstrief LOINC Mapping Assistant). RELMA facilitates searching the LOINC database, viewing detailed information about the terms, and facilitates mapping local terminology to LOINC. RELMA provides multilingual searching capabilities using language indexes. As an automatic mapping tool RELMA processes local terms files and creates mapping to LOINC indexes [10].

In this paper, a study on a semi-automated approach to mapping Russian local laboratory terms to LOINC with the Regenstrief LOINC Mapping Assistant (RELMA) is presented [10] and its advantages and disadvantages in comparison with previously reported approaches discuss are discussed. The project focused on the following aspects:

1. Semantic integration between a LIS that uses LOINC as a coding system and hospital information systems by mapping the interface terminologies of HIS to LOINC.
2. Evaluation of the semi-automated mapping approach and comparing it with the methods and results of previously reported LOINC mapping projects.
3. Study the conditions and effort for application and maintenance of LOINC as a coding system.

2. Methods

Helix laboratory is a clinical laboratory located in Saint-Petersburg, Russia. The laboratory uses a self-developed LIS, with a unified LOINC based dictionary. The laboratory receives orders from multiple clinics and sends back results using a proprietary protocol. The necessity to work with different clinics that use different coding systems makes each integration cumbersome and time consuming. At the moment the laboratory is working with more than 100 healthcare providers and health care providers’ chains. Most of them use the coding schema of the laboratory (about 70%) other 20% use another three different coding schemes of three HIS vendors. About ten health care providers use their own coding schemas. Each of them should be mapped and maintained.

Two of the laboratory’s partner clinics (clinic A and clinic B) were employed to participate in the pilot mapping project. These clinics use the same HIS, which facilitate the mapping project. HIS Avorra is a complex archetype based hospital information system that automates most of the clinical processes from appointments to billing [18, 19]. It can natively process XML definitions of ISO 13606 archetypes, so after the mapping has been completed the LOINC codes were added to the ontology sections of the archetypes.

To run semi-automated LOINC mapping, two datasets were exported into excel files, each from one HIS containing Russian language interface terms, including available additional information such as specimen type, rules (e.g., five blood samples each after 30 minutes) and specimen volume where applicable.

Two RELMA local term files were created as Excel sheets from these two HIS datasets. The local terms files were exported to RELMA using “Import local terms from delimited file or Excel spread sheet” functions to start the concept extraction. RELMA V.6.6 and LOINC V.2.48 were used for the project. A linguistic index for the Russian language (Russian translation by Yaroslavl State Medical Academy) was added by the “Set preferred language” function to correctly process the Russian terms. The index contains official LOINC Russian translation of more than 11,000 terms. The data set contained 92% of Russian terms other terms were in English.

A semi-automated mapping of the 2563 terms from Clinic A (1358 terms) and Clinic B (1205 terms) was performed. The first step was automatic mapping using RELMA. This was done using “Lab auto mapper” tool from RELMA followed by the “Choose From” screen. The RELMA Lab auto mapper takes the available local test information and returns the best matches in LOINC. After the mapping has been completed the mapping file was exported to excel.

The second step was a manual expert mapping using RELMA manual search tool. After the automated terms processing by RELMA the results were sorted to the following categories:

1. Fail: No appropriate LOINC code were found
2. Success: Exactly one matching LOINC code were found
3. Several possible codes found

In the second and the third cases a semi-automated mapping process required an additional task when an expert analysed the English LOINC V.2.48 for matching codes (second case) and an expert reviewed all 1:N results to select the right LOINC code (third case).

To evaluate the correctness of mapping made a full validation of all the mapped terms was made. The sample of 2563 terms was sent to two laboratory service physicians for independent expert review. The result of this expert review was used to calculate precision (All terms – Mistakes)/All terms), recall (ratio of true positives to (true positives + false negatives)), and F-measure (2 * recall * precision)/(recall + precision) [20]. All the disagreements between reviewers were settled by consensus. Cohen’s kappa has been calculated to rate the disagreement between experts [21]. Based on all 2563 terms the coverage has been calculated as a fraction of laboratory terms that could be mapped.

To evaluate the sustainability of the mapping a turnover rate of the local terms was calculated. Firstly the mapping success rate has been calculated for the terms that were in use in 2014. On the second step calculated the number of terms that were in use in 2010 has been calculated. Then the number of terms that were added each year since 2010 has been calculated to estimate the required mapping effort.

3. Results

The first task of the project was to map terms from two clinics to LOINC to enable semantic integration of heterogeneous laboratory data. Two thousand five hundred
and sixty-three terms were processed, and 2209 could be automatically mapped to LOINC and 189 were mapped manually. After the automatic mapping the following distribution of terms has been received (Table 1). One-to-many results were caused by several possible specimens for each test. The specimens were not specified in the dataset. NO appropriate LOINC code mapping was mostly resulted by missing the term in the Russian translation. All these terms were processed manually on the next step of the mapping. All one-to-many mappings were later resolved by the experts. 35 mappings that were not found automatically were later mapped manually.

Table 2 presents the results of the automatic mapping. After the manual expert mapping has been finished the terms that were left unmapped were analysed for the reason why they could not be mapped. All the terms that could not be mapped were either service terms that could not be mapped to LOINC or were not in LOINC at the time of the analysis.

Table 3 presents the results of the classification of unmapped terms. They can be classified to three categories: comments (e.g. “hemolytic blood sample” or “clotted blood sample”), service (e.g. blood sampling performed by mobile laboratory service) and internal use codes (e.g. test is made by an outsource lab). This characterizes the quality of the initial data set and these terms are not to be mapped to LOINC.

After the mapping has been finished the second step of the study has been performed: mapping validation.

As described in the methods section a full sample of mapped terms was independently reviewed by two laboratory physicians of the laboratory service. The results of evaluation (e.g. precision, recall and F-measure) for each clinic are presented in Table 4. Cohen's kappa was calculated to check the inter-rater agreement between the two laboratory physicians. The physicians showed disagreement in the case of three terms mapped in the clinic B and one term from the clinic A.

The third goal of the study was to investigate the effort and conditions for maintaining LOINC as a coding system for integration with external HIS. To achieve a sustainable use it is necessary to minimize the effort to map the currently used terms and the effort to map new terms in the future. To check how many of the terms that were in use in the year 2014 both clinics HISes were queried to check how many of the terms used in the year 2014 could be mapped (automatically and semi-automatically). The query showed the coverage of 99% (Table 3) for the most recently used terms.

### 3.1 Turnover Rate

As was mentioned above a sustainable use of LOINC implies that the effort to map newly introduced terms is minimized. A number of new interface terms introduced each year since 2010 has been measured. The results are presented in Figure 1. Only about 4% of terms were introduced since 2010 (about 1% a year).

### 4. Discussion

The majority of more than 2500 Russian laboratory interface terms from two clinics could have been mapped to LOINC with a semi-automated approach using RELMA V.6.6. The evaluation of mappings quality showed that only 13 out of the reviewed 2563 terms were not correct.

The HIS of the Clinics A and B did not provide all the relevant data to perform mapping in every case. Even though many items could be mapped on the basis of the existing structured metadata and additional specifications in most cases analysis methods were required to resolve some cases. The missing information, mostly the analysis methods, was available in standard operating procedures provided by the clinical laboratories or Helix laboratory system.

A high efficiency of mapping was achieved by implementing a semi-automated mapping approach with RELMA.

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**Table 1** Automatic mapping results distribution

<table>
<thead>
<tr>
<th>Clinic</th>
<th>Source terms</th>
<th>Exactly one matching LOINC code</th>
<th>Several possible codes found</th>
<th>No appropriate LOINC code was found</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1358</td>
<td>1163 (86%)</td>
<td>76 (6%)</td>
<td>119 (9%)</td>
</tr>
<tr>
<td>B</td>
<td>1205</td>
<td>1046 (87%)</td>
<td>88 (7%)</td>
<td>71 (6%)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2563</strong></td>
<td><strong>2209 (87%)</strong></td>
<td><strong>164 (6%)</strong></td>
<td><strong>190 (7%)</strong></td>
</tr>
</tbody>
</table>

**Table 2** Mapping results

<table>
<thead>
<tr>
<th>Clinic</th>
<th>Source terms</th>
<th>Automatically mapped terms</th>
<th>Manually mapped terms</th>
<th>Unmapped terms</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1358</td>
<td>1163 (86%)</td>
<td>95 (7%)</td>
<td>100 (7%)</td>
</tr>
<tr>
<td>B</td>
<td>1205</td>
<td>1046 (87%)</td>
<td>96 (8%)</td>
<td>63 (5%)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2563</strong></td>
<td><strong>2209 (87%)</strong></td>
<td><strong>189 (7%)</strong></td>
<td><strong>165 (6%)</strong></td>
</tr>
</tbody>
</table>

**Table 3** Unmapped terms classification

<table>
<thead>
<tr>
<th>Clinic</th>
<th>Source terms</th>
<th>Unmapped terms</th>
<th>Comments (% from unmapped)</th>
<th>Service (% from unmapped)</th>
<th>Internal use codes (% from unmapped)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1358</td>
<td>100 (7%)</td>
<td>38 (38%)</td>
<td>13 (13%)</td>
<td>49 (49%)</td>
</tr>
<tr>
<td>B</td>
<td>1205</td>
<td>63 (5%)</td>
<td>21 (30%)</td>
<td>10 (19%)</td>
<td>32 (51%)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2563</strong></td>
<td><strong>165 (6%)</strong></td>
<td><strong>59 (36%)</strong></td>
<td><strong>23 (14%)</strong></td>
<td><strong>81 (50%)</strong></td>
</tr>
</tbody>
</table>
V.6.6, followed by manual mapping of items after no terms or multiple terms have been found automatically. The project was limited by the Russian LOINC translation. From the experience it can be assumed that the process of mapping of English terms would have higher efficiency and it would need less manual work to be done.

The manual mapping was performed by an experienced laboratory doctor (with more than 10 years of experience). The has been achieved the average mapping rate 15 terms per hour. The effort can be compared only to the Erlangen University Hospital project as other mapping projects did not report the effort. The efficiency of the project 15 terms per hour is higher than the efficiency of the German project [15]. This can be explained by the difference in the qualification of the experts. The Erlangen University Hospital project reported that the mapping was performed by a third year medical student.

Different validation approached can be applied depending on the planned use of the LOINC codes. A partial validation that was used for example by Zunner et al. [15] is sufficient to check the feasibility of the approach and providing information for decision maker to establish LOINC as a routine coding system. If mapped terms are intended for use in routine clinical care, full validation of all mappings should be mandatory. A full mapping validation has been performed by an independent review of all interface terms by two laboratory doctors to check its correctness.

The project was able to automatically map 86% (Clinic A) and 87% (Clinic B) of laboratory terms using RELMA V.6.6. Other terms were mapped manually to reach 94% mapping rate. In the presented case all the actual laboratory terms were mapped to LOINC. The terms that could not be mapped characterize more a dataset than a mapping method (Table 3 for unmapped terms classification). Lin et al. [17] reported a coverage of 44%, 78% and 79% at three different sites. Khan et al. [22] reported a coverage of 67% with their fully automated mapping tool. Their manual reviews showed that, after automated mapping, there were many unmapped terms remaining for which a precise LOINC existed, but the tool did not find it. Zunner et al. [15] reported 82% and 75% of terms in a semi-automated mapping using RELMA V.5.

So the semi-automated mapping using RELMA V.6.6 was even more efficient than the manual mapping of Lin et al. [17], and a semi-automated method using RELMA V.5 by Zunner et al. [15]. The results of the project were much more efficient than the fully automated mapping of Khan et al. [22], where up to 27% of terms could not be mapped.

As for mapping precision, Lin et al. [17] reported a precision of 0.95, with 40 mistakes in a sample of 884 terms. Khan et al. [22] did report on their mapping precision and error rate. These two projects did not report on their mapping errors. Zunner et al. [15] reported 0.98 precision with mapping errors no more than in one LOINC axes. In the mapping 0.99 precision has been achieved. The validation showed that the mapping errors never concerned more than one LOINC axis (e.g. specimen error “blood venous” instead of “blood cord venous”).

This demonstrates the quality of mapping performed with RELMA is comparable to the quality of manual mapping. Of 163 unmapped terms only 47 concerned actual laboratory findings, with the others being mostly service codes and comments. As the version of RELMA was used in the project has no significant difference in terms of terms processing from the version V.5 that was used by Zunner et al. [15] the better results of the mapping can be explained by the better prepared data set. Unfortunately no data set preparation procedures could be found in the other studies. The typos and the correctness of abbreviation have been carefully checked before the mapping. So it can be recommended to maintain the consistency and quality of a dataset before mapping. It has also to be mentioned that the most problems with automatic mapping were caused by the microbiological tests: 176 out of 189 automatically unmapped laboratory findings were microbiological tests. The reason for this is that the scope of LOINC codes is

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Table 4  Mapping quality

<table>
<thead>
<tr>
<th>Clinic</th>
<th>Terms</th>
<th>Mapped</th>
<th>Unmapped</th>
<th>Mistakes</th>
<th>Precision</th>
<th>Recall</th>
<th>F-measure</th>
<th>Cohen’s kappa</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1358</td>
<td>1258</td>
<td>100</td>
<td>7</td>
<td>0.99</td>
<td>0.99</td>
<td>0.99</td>
<td>0.99</td>
</tr>
<tr>
<td>B</td>
<td>1205</td>
<td>1142</td>
<td>63</td>
<td>6</td>
<td>0.99</td>
<td>0.99</td>
<td>0.99</td>
<td>0.99</td>
</tr>
</tbody>
</table>

Table 5  Mapping results for the terms in use in the year 2014

<table>
<thead>
<tr>
<th>Clinic</th>
<th>Terms used in 2014</th>
<th>Terms mapped</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>685</td>
<td>683 (99%)</td>
</tr>
<tr>
<td>B</td>
<td>754</td>
<td>750 (99%)</td>
</tr>
</tbody>
</table>

Figure 1  Terms turnover rate
intentionally restricted to the names of observations and does not include names for all microorganisms. Event following the recommendations of the previous projects [23, 24] did not guarantee a successful mapping. The manual microbiological terms LOINC mapping required the expert using test result instances rather than just the test names, as the result instances contained test properties such as methods and specimen types. Once the initial mapping has been completed, it appears that only a limited number of new laboratory tests have to be added per year to keep the mapping up to date. With approximately two new terms per laboratory and month, the time required to carry out these additional mappings should be less than an hour per month.

Comparing the presented study with previous non-English mapping projects one can see that the study has almost reached the results of a manual mapping to LOINC project for French, Italian and German languages [16, 25] that provided a 93.1% successful mapping result. The study has reached a better mapping rate in comparison with a semi-automated mapping of German terms by Zunner et al. [15]. The results of an automatic concept mapping using full name and multi-part matching strategies in a number of Taiwanese hospitals achieved as well very good results with average precision (88%), recall (89%) and F-measure (88%) for a fully automatic mapping [12]. These results show that the application of semi-automated approach can significantly reduce the effort and allow adoption of LOINC in non-English environments where one can already observe good results for German, Italian, French, Czech and Chinese local codes mapping [26]. Such mapping methods can advance the use of LOINC also translation with a limited applications for example Korean language [27].

5. Conclusion

The project has shown that a semi-automated approach based on RELMA V.6.6 is efficient for full mapping of Russian (non-English) routine clinical laboratory interface terms to LOINC. This was the first LOINC mapping project in Russia that allowed establishing LOINC as a coding method for two large clinics showing that the required effort is reasonable and the price of mapping and maintenance is relatively low.

References